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LONGER LIFE AND HEALTHY AGING

Edited by
Zeng Yi, Eileen M. Crimmins,
Yves Carrière and
Jean-Marie Robine

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LONGER LIFE AND HEALTHY AGING

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The IUSSP is an international association of researchers, teachers, policy makers and others from diverse disciplines set up to advance the field of demography and promote scientific exchange. It also seeks to foster relations between persons engaged in the study of demography and population trends in all countries of the world and to disseminate knowledge about their determinants and consequences. The members of the IUSSP scientific group responsible for this book were chosen for their scientific expertise. This book was reviewed by a group other than the authors. While the IUSSP endeavors to assure the accuracy and objectivity of its scientific work, the conclusions and interpretations in IUSSP publications are those of the authors.

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Longer Life and Healthy Aging

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PREFACE

ZENG YI
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The International Union for the Scientific Study of Population (IUSSP) Committee on Longevity and Health was formed in 1999. Its initial objectives were to study human longevity, the dynamics of health transitions, the emergence and proliferation of centenarians, and demographic-epidemiological projections, to develop implications for the forecast of future health status.

The IUSSP Committee on Longevity and Health was chaired by Jean-Marie Robine and members included Vaino Kannisto, Shiro Horiuchi, Yves Carriere, Eileen Crimmins, and Zeng Yi. The Committee held three seminars in 2000, 2001, and 2003. The first seminar was held in Montpellier and included two-day meetings, a public symposium and a training session provided by Committee members at INED in Paris. The objectives of the Montpellier seminar were a critical assessment of our knowledge about human longevity, mortality at older ages, and an understanding of the distribution of individual life durations. The two-day meeting of the second seminar took place at Peking University in Beijing, just prior to an international symposium on "Determinants of Healthy Longevity in China" which enabled Committee members to participate in the symposium along with Chinese participants interested in aging populations. Following this, the committee held a two-day training workshop on calculating active life expectancy at Peking University. The main themes of the Beijing seminar were to define healthy aging and its causes, to understand disability patterns and healthy life expectancy, and to further develop an understanding of healthy longevity. The third seminar was a two-day meeting held at Rockefeller University in New York. The objectives included evolution of understanding of the diverse socioeconomic factors that may be linked to greater functional abilities, and that may positively or negatively influence older people's living conditions and quality of life in general. In addition, in 2004 the committee organized an international conference in Beijing on the Demographic Window and Healthy Aging. This conference brought together demographers and population economists from Western and Asian countries, to exchange current scientific knowledge on population dynamics, the change in population age structure, and its impact on economic and social development.

With substantial contributions from the local hosts of the three seminars, the first and second seminars were supported by IUSSP; the international symposium connected to the second seminar was partly supported by the US National Institute on Aging (NIA) grant 7 P01 AG 08761, the third seminar was supported by the NIA Grant R13 AG021466-01, and the 2004 Beijing conference was supported by Asian MetaCentre.

Two books have resulted from these three seminars: *Human Longevity, Individual Life Duration, and the Growth of the Oldest-Old Population* from the Montpellier seminar and this volume, *Longer Life and Healthy Aging*, based on papers presented in Beijing in 2001 and New York in 2003. In addition, an issue of *Genus* contains some of the papers from the New York seminar; the 2004 Beijing conference led to a special issue of *Asian Population Studies.*

The Committee wishes to thank a number of people and institutions for supporting its activities. The IUSSP has provided the initial impetus for our organization; Isabelle Romieu has handled the administrative and editorial tasks for the Committee. We also wish to thank the Centre de Lutte Contre le Cancer (CRLC) and the School of Medicine of the University of Montpellier, the Center for Healthy Aging and Family Studies at Peking University and the Population Research Laboratory at Rockefeller University for their substantial contributions as local hosts of these seminars. The Committee members thank chair Jean-Marie Robine and Isabel Romieu for arranging the Montpellier seminar. We express our gratitude for their contributions to the Beijing seminars to Peng Peiyun who was President of the China Population Association, Wu Changping who was President of the Gerontology Society of China, and committee member Zeng Yi. We also thank the Population Research Laboratory at Rockefeller University, Shiro Horiuchi (the committee member), Joel Cohen, and Kathe Rogerson for coordination and local organization of the New York seminar.

The Committee began with six members but after the Montpellier seminar we were reduced to five with the death of Vaino Kannisto. Vaino's death was a sorrowful loss for the Committee. Kannisto was one of the first demographers to document the aging of the aged and the increases in the older population at progressively older ages. He passed away at 85 years of age. Several times during our committee meetings, he stressed that active life is much more important than long life. His life was exemplarily active, productive, and fruitful. We have all benefited from his empirical observations and methodological advances and we dedicate the products of our Committee, including this volume, to him.

The scientific background, themes, major contents, and structure of this volume are summarized in the following Introduction, and the 20 individual chapters are organized into four parts, dealing with disability and health life expectancy, individual health aging, family and healthy aging, and formal and informal care for the healthy aging, respectively.

INTRODUCTION

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People are living longer and most countries are experiencing unprecedented increases in the number and proportion of their elderly populations. This is true in Europe, Australia, Asia, and North and South America, where both mortality and fertility are relatively low and large cohorts born in the 20th century are becoming elderly. Under the medium mortality assumption, the number of persons aged 65+ in the world will increase from 419 million in 2000 to 956 million and 1.42 billion in 2030 and 2050, respectively. This projection implies an average annual rate of increase of 2.4% in the first half of the 21st century. The world percentage aged 65+ is expected to more than double in the 5 decades from 2000 to 2050 from 7% in 2000 to 16% in 2050. During the same period, the percentage elderly in developed countries (as defined by the UN) will increase from 14% to 26%. World increase in the oldest-old, aged 80 and over, is even faster (3.4% annually). Their numbers are expected to climb from about 69 million in 2000 to 189 million in 2030, and 377 million in 2050 and the proportion of the elderly who are oldest-old will increase from 16% in 2000 to 27% in 2050 (UN 2003).

Such rapid population aging is a result of increasing life expectancy, resulting from declines in infant, child, and late-life mortality, lower-fertility levels, and the baby boom cohorts entering old age. Further population aging and aging of the aged is inevitable. A fundamental issue facing the global community is meeting the challenges of population aging and achieving the goal of living longer with better health and good functional status, that is, achieving healthy or active aging. Improved knowledge of the determinants of healthy survival will help societies develop prevention strategies to preserve health, maintain an active older population, and reduce the number of disabled people. Such strategies may stimulate consumption and investment in goods and services that will improve human

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capital and allow the survival of an economically and socially active elderly population (Cutler and Richardson 1997; Morand 2002; Murray and Lopez 1996; Nordhaus 2002; WHO 2002). Healthy aging is obviously a major goal of all societies facing the challenges of population aging and is the central theme of this book, entitled "Longer Life and Healthy Aging".

Six out of twenty chapters in this book focus on the oldest-old, aged 80 and over. As indicated above, this is the most rapidly increasing elderly sub-population; it is also the sub-population most likely to need assistance in daily living in all countries. Data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which has a prominent focus in a number of chapters in this book, show that the prevalence of disability in activities of daily living (ADL), such as washing, dressing, eating, increases dramatically with age, from less than 5% at ages 65–69, to 20% at ages 80–84, and 40% at 90–94. At ages 100–105, less than 40% are able to perform the basic activities of daily life (ADL) without help or difficulty.

The oldest-old consume services, medical care, and receive transfers at a higher rate than other older persons. Torrey (1992: 382) estimated that in the US, the cost of Medicare for the oldest-old is 77, 60, and 36% higher than that of the elderly aged 65–69, 70–74, and 75–79, respectively. The total cost of long-term care for the oldest-old is 14.4 times as high as that for younger elderly aged 65–74. These facts alone indicate a significant need to study the oldest-old. While the oldest-old consume significant resources, they have made lifelong contributions to current levels of wealth and provided the human capital for significant economic and social development for younger generations. They are not to be characterized solely as a current financial burden; they should also be recognized for the roles they have played as social participants and as parents and grandparents of the rest of the population. This contribution is often forgotten with the focus on the anticipated rising costs associated with the aging of the baby boomers. An important point to remember in projecting costs of an aging population is that age itself may not be the reason why costs rise with age but that age is a proxy for nearness to death. This is one reason that a focus on healthy life is as important as a focus on longer life.

In the US, Canada, Europe, and some Asian and Latin American countries, efforts have been made to attract the attention of academics and policy makers to the concerns of the oldest-old (Baltes and Mayer 1999; Suzman, Willis, and Manton 1992; Vaupel et al. 1998; Zeng et al. 2002). Many countries around the world have collected data from large samples of the old, with over-sampling of the oldest-old. For example, 11 countries in the European Union have developed the Survey of Health and Retirement in Europe (SHARE) surveys and England has collected the English Longitudinal Survey of Aging (ELSA), which are comparable to the American Health and Retirement Survey (HRS). In Japan the Nihon University Japanese Longitudinal Study of Aging (NUJLSOA) has been developed to be comparable to the US Longitudinal Study of Aging (LSOA). A longitudinal survey of healthy longevity with the largest sample size of oldest-old has been ongoing in China since 1998. Longitudinal multiwave studies are also available for Taiwan (SHLSE—Survey of Health and Living Status of the Elderly); Indonesia (The Indonesia Family Life Survey); and Mexico (MHAS—The Mexican Health and Aging Study). Many more studies are now being developed, particularly in developing countries where less is known about the oldest-old. While less is known about the oldest-old, what we do know indicates that they are a group with special needs. For this reason, this book has a significant focus on the oldest-old.

Little is known about why some people live into their 80s, others into their 90s, and a select few to age 100 or more; or why some people survive to very old ages with good health while others suffer severe disability and diseases (Cambois, Robine, and Hayward 2001; Christensen and Vaupel 1996; Crimmins and Saito 2001; Finch 1990; Hayward et al. 2000; Jeune 1995; Robine et al. 2003; Vaupel et al. 1998). We use the term "healthy longevity" to describe survival to the oldest-old ages with reasonably good functional health, while remaining active and independent.

Five chapters of this book explore issues of healthy aging and longevity in China. These studies are useful because the Chinese population is aging at an extraordinarily high rate and it has the largest elderly population in the world. China belongs to a group of countries leading the aging transition in the developing world. Lessons learned from China's experience will be instructive to other countries as they prepare for their own elderly population booms. In 2000, China's population comprised 21% of the world's total population and 21% of the world's population aged 65+. Under the medium mortality assumption, China is projected to have 23% of the world's elderly by the year 2050 (UN 2003). The proportion of persons aged 65+ in China will climb quickly from about 7% in 2000 to 23% in 2050 as the absolute number increases from 87 million elderly persons in 2000 to 334 million elderly in China in 2050 (Zeng and George 2002). There were about 11.5 million oldest-old in China in 2000 and this is expected to climb rapidly to about 114 million in the year 2050 (Zeng and George 2002). By the middle of the 21st century, the proportion of elderly persons in China will be slightly higher than that in the US, with the average annual rate of increase being 2.6 times higher in China than in the United States, resulting from the rigid fertility control policy and large cohorts born in the past now entering old age in China.

In addition to the six chapters focusing on oldest-old and the five chapters dealing with healthy aging and longevity in China, nine other chapters discuss theoretical issues and empirical findings on trends and determinants of healthy aging; the discussions focus on population aging in the United States, France, United Kingdom, Canada, Australia, Denmark, and Netherlands, as well as comparative analyses with other European and Asian countries. Both longitudinal and cross-sectional data from North America, Europe, and Asia are analyzed in different chapters, which include county-specific studies and cross-national comparisons. We organized the twenty chapters into four parts. The first chapter of Part I by Carol Jagger focuses on the definition, components, concepts, measurements, and determinants of healthy aging. Following Jagger's introductory analysis, the other chapters in Part I discuss the trends and patterns of disability and healthy life expectancy at the macrolevel. Part II addresses individual healthy aging, including its biological and sociodemographic aspects. Part III focuses on issues concerning the family and healthy aging, and Part IV explores formal and informal care for healthy aging through governmental policy interventions and community service programs. An introduction to each part outlines the major issues and introduces the chapters in each of the four Parts, respectively.

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Part I

Disability and Healthy Life Expectancy

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Introduction

The fall of mortality among the elderly is thought to lead to a postponement in the age of death and a succession of phases of population morbidity, alternating between phases of expansion and compression of morbidity (Robine and Michel 2004). A clear definition of healthy aging is required to assess change over time and empirical support is needed for the proposed path of change. Empirical information would include chronological series on health and disability, as well as indicators of healthy life expectancy. The first six chapters of this book deal with such topics.

The first chapter asks why we should measure healthy life expectancy and study disability trends? There are at least three major reasons offered by Carol Jagger. The first is to answer whether compression or expansion of morbidity is occurring as life expectancy increases. The second is to uncover sociodemographic and behavioral factors that determine healthy aging and might be amenable to intervention. The third is to compare the prevalence of older people who can be considered to be "aging well" in different countries in order to identify macrolevel factors that affect the aging process. The chapter concludes with a discussion of the necessity to undertake actions at all levels to make healthy aging a reality in the future. According to Jagger, actions should be undertaken in both early and later stages of the life course, especially in the developing countries now facing accelerated aging of their populations. She underscores the idea that in this process we must seriously consider the views of older people themselves on the important components of healthy aging.

In the second chapter, Ming-Cheng Chang and Zachary Zimmer describe disability trends in Taiwan from 1989 to 1999 and compute disability-free life expectancy at multiple points during this time. Taiwan is an interesting example of conditions where the fall of mortality among the elderly may result in an expansion of morbidity. Among the explanations for this expansion proposed by the authors is the recent implementation of a universal health insurance program which may have increased disabilities by providing greater access to medical care and more saved lives. The third chapter, by Yongyi Li and his co-authors, describes disability trends among elderly nursing home residents in the US from 1973 to 1997. The authors show that the nursing home population became more disabled over time

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due to the fact that severely disabled and demented persons became an increasingly larger group in nursing homes. Li et al. also find that functionally independent elderly are less likely to be in nursing homes in the most recent period. This decline in the rate of nursing home use has been observed in several countries and is often considered an indicator of population health improvement without consideration of the characteristics of residents of nursing homes. This chapter helps to qualify such conclusions.

In the fourth chapter Zeng Yi and his co-authors propose technical improvements to the calculation of the disability life expectancy using a multi-state life table approach. They claim that life expectancy with disability is significantly underestimated when the conventional multi-state life table method is applied, because it assumes that no functional status changes occur between the age at the last observations of functional status and the age of death. They propose a method to correct this underestimation and apply it to data from the Chinese Longitudinal Healthy Longevity Survey. Their combined information on ADL disabilities and length of confinement to bed before dying adds to our understanding of the extent of morbidity at the last stage of life as well as gender differentials among the oldest-old. These findings have implications for further evaluation of the compression of morbidity hypothesis.

In the fifth chapter James Laditka and Sarah Laditka investigate differences in life expectancy and in the number of years spent after age 70 with and without disability for individuals with and without diabetes in the United States. They used longitudinal data and compute multi-state life tables with Markov Chain Monte Carlo techniques. They show that people with diabetes live notably shorter, more disabled lives, highlighting this health burden of diabetes for elderly persons. Given the emerging global epidemic of diabetes, these findings have important implications for the development of policies promoting lifestyle changes to postpone and control this disease.

In Chapter 6, Russell Luepker describes the American cardiovascular disease experience during the 20th century and draws conclusions for the future. During the 20th century, cardiovascular disease, specifically coronary heart disease and stroke, became the leading causes of mortality and morbidity as acute infectious diseases declined. Luepker shows how the healthcare system responded to the new epidemiological regime, developing prevention strategies and approaches to care for these chronic conditions. The result was a decline in adult mortality and morbidity and an increase in life expectancy, but cardiovascular diseases were not eliminated but rather postponed to older ages where they remain the leading causes of death. This has led to an expectation that medical technology will provide a long and active life which will result in the healthcare system continuing to develop costly methods to prolong life. Luepker concludes that more emphasis on prevention strategies, which are both low cost and effective, is likely to provide greater benefit to society as a whole.

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CHAPTER 1. CAN WE LIVE LONGER, HEALTHIER LIVES?*

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1. Introduction

The span of life given in Psalm 90 as 70 years, or 80 if we are strong, is on the generous side if we consider the beginning of the last century or, indeed, many developing countries today. In the United Kingdom, male life expectancy at birth in 1900 was around 48 years whilst today this figure is closer to 75 years, a gain of almost 3 years each decade over the century. Women's life expectancy has continued to exceed that of men, making greater gains over the century so that today, female life expectancy at birth in the United Kingdom is close to 80 years.

Improvements in housing, sanitation, and nutrition; the control of infectious diseases and maternal mortality; and the advent of antibiotics have all contributed to these gains (Cassel 2001). But it is not simply life saved at younger ages that accounts for our aging populations. Life expectancy at 65 years of age in the United Kingdom has also shown gains of 4 years for men and 6.5 years for women over the century. Although these seem much less impressive than the gains in life expectancy at birth, in percentage terms they constitute a 50% increase.

But average life expectancy figures hide the tremendous individual variation in lifespan demonstrated by the growth in the number of people reaching extreme ages over the last century. The first centenarians appeared in the United Kingdom around 1800 (Jeune and Vaupel 1995, 1999). By the beginning of the last century they numbered only around 100, though by 1996 numbers had increased to 6000 and by 2036 are estimated to reach 39,000 (Thatcher 1999). In Japan, one of the earliest countries to have a truly national birth registration system and therefore highly reliable data on age at death, there were 13,036 centenarians in September 2000 and the time period for the number of centenarians to double, the centenarian doubling time, has decreased to under 5 years in the last 10 years (Robine, Saito, and Jagger 2003). Moreover, the first super-centenarians (110 years) appeared around 40 years ago and since 1980 their number too has clearly increased (Robine and Vaupel 2001).

Such figures are typical of developed countries but there are interesting variations. Figure 1 shows average life expectancy at birth for both sexes from five European countries over

* Paper presented at the IUSSP Seminar on Longer Life and Healthy Aging held at Peking University, Beijing, China, 22–24 October 2001.

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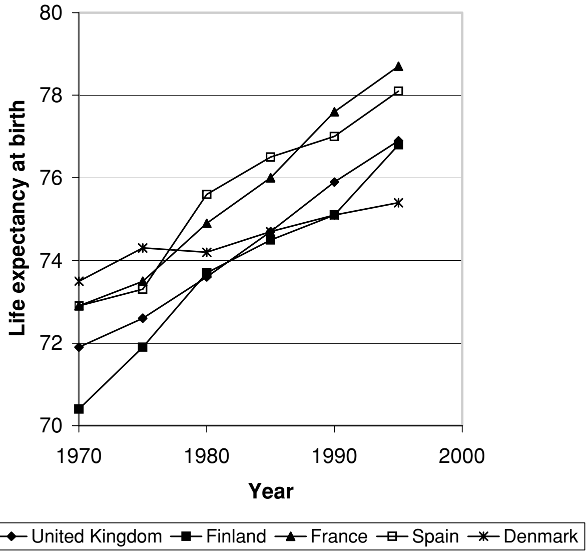

Figure 1. Life expectancy at birth 1970–1995 for five European countries (France, Spain, Denmark, Finland, and the United Kingdom) (HFA Statistical Database, WHO).

the last 30 years. Within these five countries, Finland had the lowest life expectancy at birth in 1970 at 70.4 years but the percentage increase over the 25 years has been greatest at 9%. Denmark, on the other hand, had the highest life expectancy of this group in 1970 (73.5 years) but has showed the lowest percentage increase at 2.6%, in contrast to other European countries (Juel, Bjerregaard, and Madsen 2000). When remaining life at age 65 years is considered, differences between European countries are again apparent and the ranking between these and the values of life expectancy at birth are not constant across countries (Figure 2). Although the life expectancy of women exceeds that of men at all ages in these European countries, in Greece the added years for women at age 65 years is only 2.3 years compared to 4.5 years in France (Robine, Jagger, and Romieu 2002).

There are still disagreements about the maximum length of the human lifespan and whether the falls in mortality and increases in life expectancy can continue in the longer term (Olshansky, Carnes, and Cassel 1990). The changes that have occurred thus far are a triumph for 20th century public health in its widest sense but they hide a darker side when taken alongside low birth rates (e.g., Spain and Italy), resulting in less working population to support an increasingly older population, as well as the greater consumption of health care in the final years of life (Himsworth and Goldacre 1999). The future demand for care, both formal and informal, will greatly depend on the health of the newer cohorts of older people and whether they are aging healthily.

This chapter will debate how we can monitor our potential for healthy aging and how we might live longer, healthier lives in the future. The term “healthy aging” is used freely

Figure 2. Life expectancy at birth and at age 65 years for European member states 1994 (Robine, Jagger and Romieu 2001).

in the gerontology literature, though precise definitions are scarce; so in the first section, the concept of healthy aging and its components will be discussed. The second section will explore the issues around the transition from the concept of healthy aging to its measurement for monitoring both the health of populations and individuals. In the third section, the determinants of healthy aging will be reviewed and finally the potential that exists for manipulating them in the future to live longer, healthier lives.

2. What is Healthy Aging?

2.1. DEFINITION

The gains we have made in life expectancy have been viewed, and in some circles are still viewed, very negatively. As a consequence of this there has been a move to monitor (and enhance) the quality as well as the quantity of life at older ages. This idea that it is not merely sufficient to live a long time can be traced as far back as the Roman writer Martial who wrote in his Epigrammata: "Life is not just being alive, but being well". Much later this concept formed the basis for health expectancy, a population health indicator combining morbidity as well as mortality, to differentiate between the different possible scenarios for future health: the compression of morbidity—where morbidity and disability at older ages are compacted into as short a time as possible before death (Fries 1980, 1989); the expansion of morbidity with increases in survival of those with disease and disability as well as the extension of survival to ages where disease and disability are more likely (Gruenberg 1977; Kramer 1980; Olshansky et al. 1991); and dynamic equilibrium where an increase in overall disability is accompanied with a decrease in the level of severity (Manton 1982).

The key to deciding whether trends indicate if we are experiencing a trade-off between longer life and better health in old age is how we measure health and therefore "healthy aging". For the WHO health is "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (UN 1946). However, as aging is characterized by reduced immunological function and increasing lack of reserves—one definition of frailty (Buchner and Wagner 1992)—perhaps the more dynamic definition of being in good health as also "the ability to fall ill and recover" (Canguilhem 1979) is pertinent. The propensity to concentrate on the negative consequences of aging has meant that descriptions of the other extreme to "healthy aging", for instance "frailty", have been more common (de Jong 2000; Fried et al. 2001), and much of the language of aging is still imbued with negative terms: functional limitations, activity restriction, and impairment. Grant (1996) argues that agism, defined as thinking or believing negatively about the process of becoming old or about old people, is still having a detrimental effect on healthy aging. The WHO definition infers that although health is not merely the absence of disease or infirmity, this is an inherent part of it. But can we possibly expect that "healthy aging" means without disease or infirmity? Would we exclude an otherwise healthy, active older person with well-controlled diabetes, or a 75-year-old woman who had had breast cancer 10 years previously?

Rather than the term "healthy aging", some authors have used "successful aging", notably the MacArthur Studies of Successful Aging (Berkman et al. 1993). Narrow definitions of successful aging with a concentration on physical health include "needing no assistance nor having difficulty on any of 13 activity/mobility measures plus little or no difficulty on five performance measures" (Strawbridge et al. 1996). A much broader model is the selective optimization with compensation (SOC) model of Baltes and Carstensen (1996), which recognizes that successful aging should encompass the ability to minimize losses in function in order to continue to achieve desired goals. Thus older people might proactively restrict tasks or domains and invest more in others, in anticipation of increasing losses (selection). The domains thus no longer selected or given less attention may require delegation to others or less frequent performance (compensation).

A definition that embraces the spirit of the WHO definition of health is that of Rowe and Kahn (1997), who defined successful aging as "the combination of low probability of disease, high functioning and active engagement with life". Their diagrammatic view of successful aging was the intersection of three "states": avoiding disease and disability; high cognitive and physical function; and engagement with life. Avoiding disease and disability was not simply the absence of disease or disability but an absence of potential risk factors. Active engagement was focused on two areas: interpersonal relations and productive activity, the latter being classified as having societal value rather than (necessarily) being reimbursed. We will look at these components in more detail, as well as aspects of the SOC model (Baltes and Carstensen 1996).

2.2. COMPONENTS OF HEALTHY AGING

In terms of the main models of the disablement process, the first two of the three "states" for successful aging—high functioning and avoiding disease and disability—are not independent. In the disablement process, disease and impairment lead subsequently to disability, although it is this term that is not recognized uniformly by the main models (Figure 3). Impairments are defined as anatomical, physiological, intellectual, or emotional abnormalities or losses. Functional limitations comprise three dimensions: physical, emotional, and mental. Disability covers the inability or limitation in the fulfillment of activities and social roles in relation to work, the family and an independent life (Nagi 1991). The International Classification of Impairments, Disabilities and Handicaps (ICIDH) of the WHO (1980), a classification of the consequences of disease essentially developed by Wood (1975) as a supplement to the International Classification of Disease (ICD), provided a further development with four levels: diseases or disorders, impairments, disabilities, and handicaps. For the WHO, impairments followed the same definition as Nagi (1965) but disability corresponded to any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being, whilst handicap or social disadvantage for a given individual resulted from an impairment or a disability that limited or prevented the fulfillment of a normal role (depending on age, sex, and social and cultural factors) (WHO 1980). In his original work, Wood (1975) and other researchers (Verbrugge 1995; Verbrugge and Jette 1994), as well as the new WHO classification (WHO 2001), have differentiated between functional limitation (at the body level) and activity (at the level of the person) within the disability level of the WHO, the resulting five levels being: (1) disease, disorder, or injury; (2) impairment; (3) functional limitation; (4) activity restriction; and (5) handicap. This scheme (Figure 3) is often preferred for

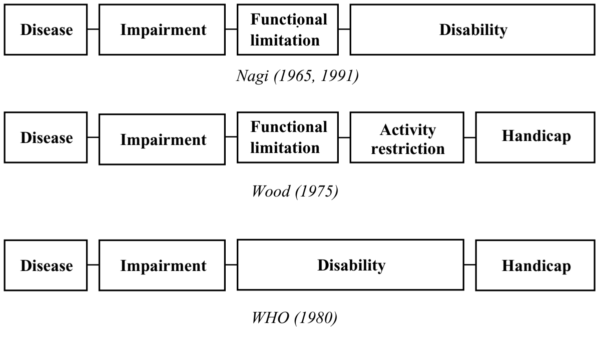

Figure 3. Models of the disablement process.

international comparisons and will be examined in more detail in the next section, as a basis for measuring "healthy aging".

The remaining stage for successful aging was active engagement in life, defined in terms of interpersonal relationships and socially productive activity. Although evidence has emerged about the benefits of social networks for the promotion of good mental and physical health, it suggests that successful aging does not exist without them. Some older people are happy with small networks or solitary lives and despite objective measures classifying them as lonely or isolated, subjectively they are not. This was evident from the trial of an intervention to enhance social contacts with the aim of improving mortality and morbidity. Of those identified as living alone and with low social contact, about half declined several offers of individualized packages of support (Clarke, Clarke, and Jagger 1992). Thus, the issue is not necessarily active engagement in life but of participating in activities we want to do, be they new or longstanding, that most individuals would endorse for "healthy aging". Another emerging area is that of spiritual life or religiosity with differentiation between non-organizational religiosity (beliefs, prayer, practices) as opposed to organizational religiosity, expressed predominantly by attendance at religious services. These two aspects were found to buffer depression differently and were most effective with non-family stressors (Strawbridge et al. 1998). Prayer as a means of "spiritual coping" was also shown to reduce depression and general distress following cardiac surgery (Ai et al. 1998).

The creation of broad definitions of healthy or successful aging, as have been stated above, is relatively easy—the difficult task is how we can measure it and, more specifically, who defines the elements or items essential to assessing healthy aging.

3. From Concepts to Measurement

3.1. MEASURING FUNCTION

At the person rather than the body level, the building blocks for measuring functioning are the well-used personal care activities of daily living (ADLs) such as washing, dressing, getting to and from the toilet, transfer for bed and chair (Katz et al. 1963), and instrumental activities of daily living (IADLs) such as shopping, doing the laundry and cleaning (Lawton and Brody 1969). The latter were first introduced to "tap a level of functioning hereto inadequately represented in attempts to assess everyday functional competence" of older people (Lawton and Brody 1969). The hierarchical nature of the onset of ADLs has been shown through longitudinal studies (Dunlop, Hughes, and Manheim 1997; Jagger et al. 2001) and other studies have also demonstrated a combined ordering for IADL and ADL items together, with IADL items generally preceding ADL items in loss of independence, although there is overlap (Ferrucci et al. 1998; Finch, Kane, and Philip 1995; Kempen and Suurmeijer 1990; Spector and Fleishman 1998). Though historically developed to cover complementary areas of functioning and competence of older people, the placement of IADL items earlier in the disablement process has meant that these items are often included to detect lesser levels of restriction. However, older people themselves do not appear to view the loss of IADLs as being less catastrophic. A comparison of the rankings of ADL and IADL items for importance to perform by experts in long-term care and aging with those made by older people found that older people themselves rated IADLs more highly than experts (Kane et al. 1998; Philp et al. 1998).

Healthy aging would in part seem to be best measured by no restrictions in IADLs or ADLs, so that one is able to perform independently all the necessary tasks for personal and home care. This raises another set of questions: What exactly is meant by no activity restriction? Is ability or capability to perform necessary and sufficient? What are the necessary tasks to sustain life independently in the community? We shall look at each of these in turn.

3.2. HOW DO WE CLASSIFY NO ACTIVITY RESTRICTION?

When first introduced, the focus for ADL and IADL measurement was assessment of the burden on health, social, and informal care that non-performance would bring. Thus restriction was measured by dependence on another person for the task. The advent of greater technical devices, aids and adaptations and the standard use of these in households, such as bath rails, added to the complexity. Should the use of such aids imply disability? Difficulty in performing the task may indicate disability more appropriately, being more a characteristic of the person and less affected by the availability of support or aids and adaptations (Verbrugge 1990). A large discordance between results from "difficulty" scales and "need for human assistance" scales has been found, since these scales do not report on the same kind of disability and also depend on the subject's perception of what is performed with/without help or with/without difficulty (Jette 1994). Specifying the amount of difficulty met or the frequency of help received has also been found to be problematic due to the difficulty in quantifying such notions when self-reporting; clear response proposals (such as "any difficulty met", "any help received" or "any equipment used") appear more efficient and easier to interpret (Rodgers and Miller 1997).

This suggests measuring healthy aging by having no difficulty in performing a task. This may not, however, be sufficient since, for instance, how do we rate someone who has begun to do a task less frequently and therefore now no longer finds it difficult; or someone who has adapted the way they used to do the task to make it easier. These newer measures (Fried et al. 2000) may detect earlier onset of disability but they make it even more difficult to draw the line differentiating "healthy aging" from usual aging.

3.3. PERFORMANCE VERSUS CAPACITY

IADLs are strongly culture and gender-bound and they highlight a particular problem in the ascertainment of activity restriction. Non-performance of a task may not necessarily infer low functioning; for instance, many older men do not undertake food preparation or cooking. We therefore need to differentiate between the capacity to undertake a task (elicited by "Can you . . . .") and actual performance (elicited by "Do you . . . ."), this seemingly subtle difference being termed the "tense" of ADLs (Glass 1998). The original ADL scale of Katz (Katz et al. 1963) questioned performance rather than capacity. Although the hypothetical tense may be more meaningful in hospital settings, healthy aging measures need to be appropriate for older people living independently in the community.

It may be argued that, since these are the most basic personal care tasks, for population estimation there is more interest in actual performance ("Do you . . . ") rather than capacity ("Can you . . . "). However, differentiation between "do" and "can" is less obvious in some languages. Analysis of 15 European health surveys found that that even when following recommended instruments, countries did not adhere exactly in terms of wording, destroying comparability (Robine, Jagger, and The Euro-Reves Group 2003). Such amendments occur during translation but could be successfully overcome if linked back properly to the concepts being measured. Thus, it is less important to have a seemingly exact translation between two instruments than to have translated instruments that both truly reflect the concepts being measured.

Discrepancies between self-reported capacity and performance may arise for a number of reasons. For instance, the reliability of self-reported measures may be problematic in the cognitively impaired, although the inability to perform ADLs as reported by a proxy are often part of the diagnostic procedure for dementia. However, rather than simply being a measurement bias, discrepancies may be informative in measuring stages of the disablement process. As mentioned earlier, there may be underlying capacity but non-performance, especially in the gender-specific household tasks. Indeed, Lawton and Brody (1969) originally created a separate IADL scale for men and women, omitting the three items of food preparation, housekeeping, and laundry from the male version. However, although an elderly man may not undertake meal preparation himself because his wife does so (and therefore if asked about his performance in this domain he would be classified as dependent), he may take over this role if his wife becomes ill (thus having the capacity). Additionally, if IADLs are asked only of households and not separate individuals, or if performance is questioned rather than capacity, there will be no real understanding of the vulnerability or needs of the remaining partner if the composition of the household changes, such as on the death of a spouse. On the other hand, non-performance yet capacity may be a more positive choice of delegation or purchase from others, for instance the task of household cleaning (Rogers et al. 1998). In addition, older people have been found to over-report their capacity to undertake activities, providing further discrepancies between capacity and performance. Finally, when taken alongside measures of functional limitation (at the body level), incapacity yet performance can be observed, representing compensatory strategies.

Newer scales for IADLs have tried to accommodate these issues in different ways. In the assessment of living skills and resources (ALSAR) individuals are rated on two separate ordinal scales, accounting for skill level and utilization of resources (Williams et al. 1991). A resource is defined as a support extrinsic to the person for task accomplishment and may be human or technical, formal or informal. The Canadian Occupational Performance Measure (COPM) gives three scores for each activity: the importance of the activity to the person, performance, and satisfaction with performance (Law et al. 1994). Satisfaction is also an inherent part of other scales (Yerxa et al. 1988). Branch (2000) suggests overcoming these problems by measuring IADLs with a combination of actual performance ("do you . . . ") together with enquiring about the level of satisfaction with the performance and if help is received, a measure of capacity ("could you . . . "). It is here that the need for a measure of process as well as outcome is necessary, as proposed by Baltes and Carstensen

(1996) in the SOC model. Thus, older people may compensate for failing functions, or may optimize their performance to ensure that they still meet their goals. This suggests that careful thought is required in the way we ask ADL and IADL questions and the possible range of responses, to be able to classify those who are aging healthily.

3.4. WHAT TASKS AND FUNCTIONS SHOULD BE INCLUDED?

The original ADL and IADL scales were developed around 40 years ago and, although newer scales have emerged, the major emphasis has been on wording and responses rather than the choice of the actual activities and functions themselves. There appears to have been little research on whether current tasks are still considered by older people themselves as the most important, the activities they *want* to or feel they need to be able to perform as they age. Occupational therapists have taken this on board to some extent in their most recent assessment scale the assessment of motor and process skills (AMPS), where patients choose which tasks they are to be observed performing from a list of culturally relevant and appropriately challenging tasks (Fisher 1995). Indeed, this has overcome some of the gender biases in earlier scales (Duran and Fisher 1996), though the AMPS is not suitable in its present form for use in health surveys.

However, even if the same set of tasks are important, the manner in which they are performed has changed, and will continue to change, over time. This is true in particular for IADLs, since these activities require a higher level of cognitive function than ADLs. Cognitive limitations were classed as the second most common source of difficulty with everyday activities by older people, in particular declarative knowledge which guides initial attempts to perform an unfamiliar task (Rogers et al. 1998). Leisure activities, transportation, and housekeeping were activities most often mentioned and specifically the impact of new technology, for instance videocassette recorders, telephone menus, answering machines, cameras, and credit card scanners. In the disablement model of Wood (1975), functional limitations are the precursors of activity restriction. Rowe and Kahn (1997) also specified high cognitive and physical function as a prerequisite for successful aging. In terms of physical functional limitations, scales have developed to differentiate between lower and upper body function (Simonsick et al. 2001), especially as the latter generate more health services utilization (Guralnik et al. 1995). However, the changing nature of the manner in which IADLs are performed suggests that the future might see a change of emphasis from physical functional abilities to cognitive functional abilities for “healthy aging”. Sensory function has also been much neglected in functional limitation scales, despite being a strong predictor of subsequent disability (Laforge, Spector, and Sternberg 1992; Rudberg et al. 1993; Strawbridge et al. 2000). The assessment of sensory function at the same time as cognitive function is important since lower scores in tests of cognitive function may be a result of failing vision rather than failing cognition (Jagger et al. 1992). Level of education is also a potential confounding factor in many standard cognitive function tests. The greater average level of education in the newer cohorts of older people may provide a greater reserve for failing cognitive abilities but may also mask real effects.

If the issues around the measurement of the functioning appear complex, measuring spiritual life over and above attendance at organized religious events is just as challenging.

Rather than religiosity, organized or non-organizational, a measure of lifetime spiritual experience has been proposed and validated across geographical settings and cultural and age groups (Hays et al. 2001). This could provide some measure of spirituality but one could also argue that a sense of coherence or orientation to life or feelings of being in control of one's life are other important dimensions, and instruments to tap these have been developed.

In this section, the issues around the measurement of the different components of healthy aging have been expounded, concentrating on the difficulty in defining the delineation between healthy and normal aging as well as the changing milieu in which activities are performed. The definitions of successful and healthy aging expounded have been those defined by gerontologists. There is an interesting emerging body of research suggesting that older people themselves define successful aging as encompassing social as well as physical, functional, and psychological health (Phelan et al. 2004), but that older people may rate themselves as aging successfully even in the presence of chronic conditions or less than optimal functioning (Strawbridge, Wallhagen, and Cohen, 2002). In the next section, we examine the prospects for increasing the numbers of older people classified as aging healthily and the length of time this lasts.

4. Determinants of Healthy Aging

To determine how we might intervene to promote healthy aging we need to consider the factors that impact on the disablement process and those that may be amenable to manipulation. Verbrugge and Jette (1994) differentiate between extra- and intra-individual factors that impact on the main pathway to disablement. Factors external to the individual include availability and use of medical care, including drugs, availability of personal assistance and equipment, day and respite care and structural modifications, and access to transport and buildings as well as factors at a community or governmental level such as policies on income, education, transport, and employment. Many of these, particularly in the built environment, have and will continue to improve the gap between capacity and performance. Factors internal to the individual include changes in lifestyle, abilities to cope and adapt, and the way we might accommodate changes in the way activities or functions are undertaken—taking longer, not doing them as often. The role of the latter in monitoring has already been addressed in the measurement of activities.

Over and above declines inherent in the disablement process, that is the effect of functional limitations on subsequent activity restriction, the strongest evidence for increased risk of decline are comorbidity (at the level of pathology), depression (morbidity but may also be a reaction to disease), and poor self-rated health; physical factors such as both high and low body mass index; and lifestyle factors including low physical activity, smoking, and no alcohol use (Stuck et al. 1999). Many of the risk factors impacting on declining function further down the disablement process are also risk factors for specific diseases. Diet, physical activity, alcohol use, and smoking are all potentially modifiable influences and could help maintain health at older ages and current research appears to be focusing on two of these areas, nutrition and exercise, though mainly through slowing the onset of frailty (de Jong 2000; Van Nes et al. 2001).

However, the extent to which preventive measures (in terms of diet modification and exercise regimes) will be or can be taken up by older people is still in question. Southern Europeans, particularly older and less educated individuals, have not only reported lower levels of physical activity but also less belief in the need for exercise compared to their Northern European counterparts, specifically in Finland, where there has been widespread health education and interventions on such benefits, particularly for cardiovascular health (Kafatos et al. 1999). But older people themselves have been reported as having the agism view that participating in vigorous activities is less socially acceptable with increasing age and such views are often reinforced by the rest of society (Darnton-Hill 1995). Even if such views are not held, the decisions by individuals to change lifestyles are made within the context of income, education, and availability of and access to suitable programs.

Another potentially modifiable factor that is important in the disablement process and inferred in the definition of successful aging (Rowe and Kahn 1997) is psychosocial well-being. Social isolation and smaller total social networks have been found to be predictive of ADL dependence (Mendes de Leon et al. 1999; Moritz, Kasl, and Berkman 1995). More recent evidence of the effect of social contact and support on the development of cognitive impairment suggests that an active lifestyle may provide stimulation that maintains cognitive functioning (Fratiglioni et al. 2000). The effect of religiosity as a modifier of the relationship between depression and stressors has already been discussed.

5. Conclusion

There appear to be three major reasons for measuring healthy aging. Firstly, for the comparison of trends over time, to answer whether compression or expansion of morbidity is occurring. Secondly, to uncover those factors—socio-demographic, lifestyle, and behavioral—that are causally associated or that determine "healthy aging" and which may be amenable to manipulation to maintain this state for longer. Thirdly, to compare the proportions of older people who are aging healthily in different countries (or between distinct regions within a country) in order to identify macro-level factors accounting for differences between countries. The last reason is particularly problematic for measurement since different cultures may themselves operationalize the concept of "healthy aging" differently.

This chapter has raised some of the unresolved issues in the definition, measurement, and promotion of healthy aging. It did not aim to cover all potential issues comprehensively—in particular the role of genetics and the biological and physiological mechanisms have not been discussed, though their omission is not a reflection of their potential importance. Instead the chapter aimed at giving a broad epidemiological viewpoint through the definition and measurement of healthy aging.

Action is needed at all levels—as individuals, as researchers, as health care professionals, as countries—if we are to make healthy aging a reality for more older people and for a longer proportion of their life in the future. Individual and societal action needs to be taken early in the life course, especially since recent research indicates that poorer health in childhood increases ill health in later life (Blackwell, Hayward, and Crimmins 2001; Van de Mheen et al. 1998). This is of major importance for the developing countries, now going through the demographic transition more rapidly than developed countries.

Action also needs to be targeted later in the life course. Older people themselves need to maintain or improve their nutrition, lifestyles, and physical capacity. As researchers, we need to develop more appropriate and up-to-date measures of healthy aging. But, more importantly, we must seek the views of older people themselves in this process, to determine not only what they, themselves consider to be the important components of healthy aging, but their understanding of the processes that contribute to its prolongation.

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CHAPTER 2. AGING AND DISABILITY IN TAIWAN: PREVALENCE AND TRANSITIONS FROM A PANEL STUDY

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1. Introduction

Taiwan's net reproduction rate (NRR) fell to 1.0 in 1983, and has been below replacement fertility since 1984. An island-wide family planning program began in 1964, when the total fertility rate was 5.10 and the net reproduction rate was 2.27. But a sustained fertility decline began earlier. In 1955 the total fertility rate was 6.55 and the net reproduction rate was 2.82. Taiwan completed the fertility aspect of the demographic transition during the 20 years after the intensive family planning program was implemented.

Because of the fertility transition in Taiwan, the central concern related to population programs is gradually shifting from high fertility to other issues, especially population aging. As this picture of our demographic future has come into clear focus in recent years, it has stimulated anxiety about long-term health and socio-economic implications. In particular, a central concern of government, professionals, and researchers is the issue of the dependencies of older people and what policies or measures should be formulated in order to meet their needs.

A great deal of concern about the effects of aging stems from disability levels of an increasing older population and the attendant costs. In old age, the incidence and prevalence of chronic disease increases at an accelerating rate (Collins 1988). Chronic health conditions in turn reflect long-term disabilities or functional limitations (Rice and Feldman 1983). Previous studies have found that chronic illness is highly correlated with depression, and subsequent higher disability, poor functioning, and higher morbidity (Cohen and Lazarus 1979). Using a multi-state life table approach, Crimmins, Hayward and Saito (1994) demonstrated that an increase in the proportion of life spent in dependent states of health is a natural outcome of improving mortality. Conversely, Waidmann, Bound, and Schoenbaum (1995) questioned the validity of disability reports amidst a changing health environment, suggesting that the increase in disability rates may be a function of better diagnostic technique and earlier detection of chronic disease.

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More recently, some consistent evidence has appeared supporting declines in functional disability among older populations in the US in the 1980s and 1990s. Manton, Corder, and Stallard (1993), employing the National Long Term Care Surveys, showed decreases in both prevalence and incidence of disability between 1982 and 1989. Crimmins, Saito, and Reynolds (1997), using both the National Health Interview Survey and the Longitudinal Study on Aging, and Manton, Corder, and Stallard (1997) confirmed these trends continuing into the early 1990s. Ofstedal, Madans, and Feldman (1994) examined those aged 70 and older using the Longitudinal Study on Aging and demonstrated that declines in functional limitations have been occurring for this older age group. Freedman and Martin (1998) employed the Survey of Income and Program Participation and demonstrated declining unadjusted and adjusted prevalence rates of functional limitations among several age cohorts of elders, but the declines were particularly strong for the oldest-old.

This empirical work is consequential to policy planning given an important debate in the literature regarding whether increases in life expectancy that are being witnessed in various countries are also leading to more years of life spent disability free or more years spent in morbid states with functional limitations. The debate goes back to Gruenberg's (1977) article on the "Failure of Success" where he postulated that longer life in the present day means removing the lethal sequelae of disease, but lingering on with serious morbidity. This view was countered by Fries (1980) who postulated that individuals would continue to increase the amount of time spend in states of good health and that the time in poor health would be compressed into the last years of life.

Up to 1993, some evidence from Taiwan seemed to support the compression of morbidity. Using the Longitudinal Study on aging in Taiwan, Chang (1997) indicated that the elderly in 1993 seemed to have better health status and functional capacity than those of the corresponding elderly in 1989. Similarly, Zimmer and Lin (2000) and Zimmer et al. (1998) employed the same set of panel data and found that difficulties climbing stairs and walking declined between 1989 and 1993. However, prevalence rates leveled off between 1993 and 1996. The current study examines changes in health between 1989 and 1999, but a particular focus is on changes during the latter part of this period, 1996–1999. This is a particularly interesting period because of the changes in the health infrastructure that took place in the latter part of the decade, that being the introduction of a Universal Health Insurance Program. In this chapter we pull together some results from previous studies using the same data set and we add some original analyses. We use past and new analyses together to come to a conclusion about how health is changing.

2. Data and Methods

2.1. DATA AND SAMPLE

Our study draws on data from the 1989 Survey of Health and Living Status of the Elderly in Taiwan and its follow-up surveys of 1993, 1996, and 1999. The surveys were conducted jointly by the Taiwan Provincial Institute of Family Planning, and both the Population

Studies Center and the Institute of Gerontology at the University of Michigan. Except for a small indigenous population, the sample was representative of the entire elderly population aged 60 years and above as of 1989, including the institutionalized population. It had a response rate of 91.8% (Chang and Hermalin 1989). The Surveys of Health and Living Status of the Elderly have been conducted approximately every 3 years since 1989 (1993, 1996, 1999). Although the original study focused on the elderly population (those aged 60 and above in 1989), the 1996 survey added a "near-elderly" cohort of persons aged 50–66; so in all, the study is now representative of the population aged 50 and above as of 1996. The response rate of follow-up interviews in 1993, 1996, and 1999 ranged from 88.9% to 90.1%. These surveys offer a rich source of information on the characteristics and experience of this population and have been used extensively to study the health, living arrangements, and well-being of the elderly in Taiwan.

2.2. MEASURES

The four waves of the survey all contain detailed health and demographic information. The current study refers to several of these. Self-assessed health status is based on a single item asking individuals to rate their health subjectively as excellent, very good, good, fair, and poor. This indicator correlates well with mortality, functional status, and overall life satisfaction. One activity of daily living (ADL) referred to is difficulty bathing. The bulk of the study involves a number of indicators measuring general functional limitation. These indicate a degree of physical robustness or the ability to conduct basic physical movements that are not necessarily tied to specific daily living activities. Functional capacity items included in this study are reaching over one's head, grasping with fingers, walking 200–300 m, lifting 25 pounds, climbing 2–3 flights of stairs, crouching, and doing heavy work in or around the house.

As far as independent variables are concerned, demographic and socio-economic variables such as age, sex, marital status, ethnicity, and education will be employed. Such sociodemographic characteristics have been consistently shown to relate to health outcomes; therefore they are usually controlled for in models predicting health.

2.3. METHOD

2.3.1. Prevalence

Prevalence is defined as the proportion of the population reporting specific functional task difficulties and at least one difficulty. In order to determine overall changes in prevalence over four time periods, respondents in the same age range of cross-sectional samples for 1989, 1993, 1996, and 1999 will be taken for comparison. In 1993, the elderly who were successfully followed up were aged 64 or above. Accordingly, health and functional status will be examined by comparing the elderly aged 64 or above in 1989 with their counterparts in 1993, 1996, and l999 through the use of cross tabulation.

In addition to determining whether there were significant changes in prevalence in terms of functional limitation over the three periods, cross-sectional samples for 1993, 1996, and 1999 are pooled. Logistic models are fitted for specific difficulties, and having at least one of the six difficulties, that included dummy variables for year of survey, using 1993 as the comparison category and the compositional variables (sex, ethnicity, two education variables, age, and marital status). These regressions take the form:

$$\ln(P/1 - P) = \alpha 0 \text{ year } 1993 + \alpha 1 \text{ year } 1996 + \alpha 2 \text{ Year } 1999 + \alpha 3 \times 3 \ldots \alpha 8 \times 8$$

where $\alpha 3 \times 3 \ldots \alpha 8 \times 8$ represent the six compositional variables. For these, sex, ethnicity, and the two education variables are assumed to not vary and come from the 1993 data. For age and marital status appropriate time-varying values from the individual surveys are entered. Also, an ordinary least squares (OLS) regression approach was employed to predict the total number of limitations across survey years adjusting for population composition.

2.3.2. Transitions

Prevalence rates, which represent the proportion of the population in a particular health or functional state at any one point in time, are the outcome of earlier prevalence rates and the rates of transition in and out of states of health or functional limitation. To summarize the overall situation, health expectancies were calculated with the use of IMACh—a Maximum Likelihood Computer Program using Interpolation of Markov Chains (Lièvre, Brouard, and Heathcote 2003). The program computes Health Life Expectancies from cross-longitudinal data using methodology pioneered by Ladika and Wolf (1998). Within the family of Health Expectancies, disability-free life expectancy is probably the most important index to monitor.

3. Results

3.1. CHANGES IN HEALTH AND FUNCTIONAL STATUS

Table 1 shows the self-assessed health status and difficulties bathing, for the elderly aged 64 and older across survey waves in Taiwan. The proportion that reported fair and poor

Table 1. Self-rated health and bathing difficulties of the elderly 40 and older across survey waves in Taiwan.

Self-rated health and bathing difficulty	1989 (%)	1993 (%)	1996 (%)	1999 (%)
Self-rated health				
Excellent	15.9	18.4	13.2	9.8
Very good	20.2	23.7	19.0	20.6
Good	40.1	34.7	34.9	33.6
Fair	19.4	18.4	27.6	28.1
Poor	4.5	4.6	5.3	7.9
Has difficulty bathing	7.5	6.3	7.3	9.3
N	2861	3147	2291	2475

Table 2. Unadjusted prevalence rates for functional limitations across survey years, for total population, and summary measures by age and sex.

	1993	1996	1999	*p*-Values
% with at least one limitation	49.8	49.2	55.7	0.000
% with problems lifting	39.2	36.9	44.1	0.000
% with problems crouching	32.0	32.0	39.2	0.000
% with problems climbing	24.4	28.9	33.7	0.000
% with problems walking	18.0	19.6	27.1	0.000
% with problems grasping	9.6	8.9	11.3	0.003
% with problems reaching	8.8	8.4	10.1	0.034
Mean number of limitations	1.29	1.33	1.60	0.000

health status was 23.9% in 1989, which decreased to 23.0% in 1993, and then increased to 32.9% in 1996 and to 36.0% in 1999. The proportion that reported difficulty bathing followed a similar pattern, decreasing from 7.5% to 6.3% between 1989 and 1993, then increasing in the following survey years. We will see below that this general trend of better health between 1989 and 1993 and worse health from 1993 on is repeated in measures of general functional capacity.

Functional limitations may be viewed as more "objective" gauges of physical health since they mostly rely on ability to conduct physical movements. The next several tables focus on these limitations and report findings from 1993 onward. Table 2 presents the unadjusted rates of difficulty for these among older adults aged 65 or above in Taiwan in 1993, 1996, and 1999. Older Taiwanese report the greatest difficulties lifting things and the least difficulty reaching. There was some increase in the percentage reporting difficulties between 1993 and 1996, but for most of the items, the rates are fairly level. Looking at the percentage reporting at least one of the functional difficulties, shown in the first row of the table, provides a good example. It was 49.8% in 1993, and almost the same, 49.2%, in 1996. However, between 1996 and 1999, each of six functional difficulties increased significantly. The percentage reporting at least one difficulty increased from 49.2% in 1996 to 55.7% in 1999.

Besides changes to the percentage reporting functional difficulties between 1993 and 1999, the composition of the population changed as well, and it may be that the increase in health problems is a function of changes in composition. Table 3 shows how the composition of older Taiwanese changed over the three survey years. Changes in sex, marital status, and ethnicity, are not significant at the 0.05 level, but changes in age and education are significant. For instance, the percentage of the older population aged 80 and older increased from 11.6% in 1993 to 13.7% in 1996 and further to 15.4% in 1999. The mean age of older Taiwanese increased from 71.8 in 1993 to 73.2 in 1999. Hence, the age distribution of the older population in Taiwan between 1993 and 1999 was becoming more weighted towards the oldest-old. Since older individuals are more likely to report functional limitations, one of the reasons for the leveling of prevalence rates between 1993 and 1996 and for the increase in prevalence rates between 1996 and 1999 would be the further aging of

Table 3. Composition of the 65 and older Taiwanese population across survey waves.

	1993	1996	1999	*p*-Values
Mean age	71.8	72.4	73.2	0.000
Three year age cohorts				
65–67	27.8%	22.5%	19.9%	0.000
68–70	22.1%	23.4%	19.3%	
7–73	17.3%	18.0%	19.7%	
74–76	11.8%	13.5%	14.9%	
77–79	9.3%	8.8%	10.8%	
80 and older	11.6%	13.7%	15.4%	
Sex				
Male	56.7%	56.7%	55.6%	0.104
Female	43.3%	43.3%	45.4%	
Marital status				
Married	61.2%	61.7%	61.5%	0.913
Not married	38.8%	38.3%	38.5%	
Ethnicity				
Mainlander	23.1%	24.7%	22.6%	0.081
Other	76.9%	75.3%	77.4%	
Education				
None	49.3%	44.4%	41.3%	0.000
Primary	31.3%	33.6%	36.7%	
More than primary	19.4%	22.0%	22.0%	
Sample size	3273	3284	3192	

the population. On the other hand, the higher education level of the elderly in 1999 than previously might result in better functional status.

Given these changes to the population, it is necessary to control for compositional variables in order to determine whether there has been a real change in functional abilities of older Taiwanese. Table 4 shows the results of pooled data logistic regression equations for each specific functional difficulty. Positive coefficients for a year indicate an increase in the probability of specific difficulties being reported, while negative coefficients refer a to decline in the probability of specific difficulties.

After controlling compositional variables, there is a decline in the proportion of those having at least one functional limitation between 1993 and 1996. However, the negative coefficient −0.06 is not large enough to reach a statistically significant level, meaning that a leveling of overall prevalence rates between 1993 and 1996 occurred. Between 1993 and 1996 there was, however, a significant increase in difficulties climbing and walking, but a significant decrease in difficulties lifting. Between 1993 and 1999, all regression coefficients including at least one functional limitation and each of six functional difficulties reveal a positive sign, which indicates an increase in any functional difficulty in this period.

Table 4. Logistic regression coefficients predicting functional limitations across survey years adjusted for population composition.

	Has any limitation	Problems lifting	Crouching	Climbing	Walking	Grasping	Reaching
Year							
1993	—	—	—	—	—	—	—
1996	−0.06	−0.12*	+0.02	+0.30**	+0.16*	+0.01	−0.06
1999	+0.24**	+0.16**	+0.31**	+0.50**	+0.56**	+0.20*	+0.20*
Age 65 to 67							
68–70	+0.20**	+0.24**	+0.21**	+0.19**	+0.23**	+0.27*	+0.03
71–73	+0.53**	+0.59**	+0.44**	+0.40**	+0.42**	+0.41**	+0.32**
74–76	+0.78**	+0.84**	+0.64**	+0.61**	+0.70**	+0.59**	+0.51**
77–79	+1.20**	+1.24**	+0.92**	+0.97**	+0.96**	+0.97**	+0.73**
80+	+1.72**	+1.78**	+1.39**	+1.44**	+1.60**	+1.33**	+1.20**
Sex (1 = F)	+1.02**	+1.11**	+0.61**	+0.62**	+0.43**	+0.15	+0.24**
Education							
More than primary	—	—	—	—	—	—	—
Primary	+0.32**	+0.18*	+0.25**	+0.53**	+0.52**	+0.22	+0.09
No education	+0.69**	+0.51**	+0.63**	+0.86**	+0.83**	+0.79**	+0.60**
Ethnicity (1 = Mainlander)	−0.01	−0.03**	−0.01	−0.*15**	−0.31**	−0.11	−0.25*
Marital status (1 = Married)	+0.04	−0.10	+0.05	+0.04	−0.10	−0.13**	−0.19*
Constant	−1.44	−1.84	−1.97	−2.61	−3.04	−3.45	−3.04
−2 LL	11, 747.7	11, 237.0	11, 509.9	10, 571.5	9129.8	551479	5884.3
Δ − 2 LL (Model)	1714.6**	1817.4**	994.7**	1131.9**	1012.0**	368.5**	393.2**

*0.01 > p > 0.05.
**p < 0.01.

Table 5. OLS regression coefficients predicting number of limitations across survey years adjusted for population composition.

	Coefficient	95% Confidence interval
Year		
1993	—	—
1996	+0.05	−0.04 to +0.13
1999	+0.30**	+0.23 to +0.41
Age 65 to 67		
68–70	+0.14*	+0.01 to +0.24
71–73	+0.34**	+0.20 to +0.44
74–76	+0.54**	+0.41 to +0.67
77–79	+0.88**	+0.73 to +1.02
80+	+1.48**	+1.34 to +1.61
Sex (1 = F)	+0.58**	+0.50 to +0.66
Education		
More than primary	—	—
Primary	+0.21**	+0.10 to +0.32
No education	+0.58**	+0.47 to +0.69
Ethnicity (1 = Mainlander)	−0.10*	−0.19 to −0.00
Marital status (1 = Married)	−0.09*	−0.17 to −0.01
Constant	+0.36	+0.21 to +0.51
$F(12, 8670)$	145.3**	
R-SQ	0.17	

*$0.01 > p > 0.05$.
**$p < 0.01$.

Coefficients for the compositional variables are, for the most part, in the expected directions. For instance, older age, being female, and having less education increases the probabilities of reporting difficulties. Being married and being Mainlander generally decrease probabilities, but there is less significance and some mixed results among these compositional variables.

In order to predict the number of functional limitations across surveys adjusted for population composition, an OLS regression approach was employed. As shown in Table 5, between 1993 and 1996 the OLS regression coefficient predicting number of limitations is +0.05, which implies an increase in number of functional difficulties in this period. However, the value is not statistically significant. Hence, it can be said that there is a leveling of prevalence rates in this period. Between 1993 and 1999, the OLS regression coefficient is +0.30 and is also statistically significant. Therefore, it can be said that there is an increase in number of functional limitations during 1993–1999. Although it is not necessarily the fact that number of limitations and the probability of having a limitation go together, in this case we find similarities in the two. That is, the logistic regression showed increases in probabilities while the regression showed increases in number.

3.2. CHANGES IN LIFE EXPECTANCY

We conclude the study with the IMaCh calculations of life and disability-free life expectancy. To make these calculations, we employ three of the items referred to above: ability walking, climbing stairs, and bathing. We combine these three items, and consider an individual as having a disability if they report a difficulty with any one of the three tasks. Limiting our measure of disability to these three items makes the index consistent with previous research that examined transitions in functional limitation in Taiwan and Japan (Liu et al. 1995; Zimmer et al. 1998).

Table 6 shows health expectancies for each period. The results provided here are status-based, that is, they depend upon disability status at the earlier point in time. For instance, looking at the 1989–1993 results, we see that 60 year olds starting healthy in 1989 can expect to live 15.05 years in a healthy (i.e. disability-free) state and 4.51 years in a disability state. Therefore, the total life expectancy for a 60-year-old person starting the period healthy is 19.56 years. Sixty year olds starting the period with a disability can expect to live 13.55 years in a healthy state and 5.25 years in a state of disability, for a total of 18.80. So those originating healthy in 1989 could be expected to live longer and live longer in a disability-free state.

Several observations can be made about Table 6. First, those originating in healthy states can be expected to live longer and more disability-free years. This finding is consistent regardless of the years of data being considered. Second, life expectancies have generally increased. Based on the 1989–1993 data, for instance, a healthy 80-year-old can expect 7.97 more years of life (this total derived by adding the number of healthy and disability years). Based on the 1996–1999 data, a healthy 80-year-old can expect 10.13 more years of life. We also see life expectancy increases for those originating with disability. Third, there appears to be an increase in life expectancy in a disabled state. Taking a 60-year-old as an example, a healthy individual in 1989 could expect 15.05 more healthy years, and this total declines to 14.23 years in 1993, and then stabilizes to 14.60 in 1996. But the number of disabled years for the same person increases from 4.51 in 1989 to 5.86 in 1993 and 7.00 in 1996. In total, then, a healthy 60-year-old is spending a higher proportion of their remaining life in a disabled state. A similar comparison can be made for those that begin the period with a disability. A 60-year-old with a disability in 1989 lives fewer total years than a 60-year -old with a disability in 1996, but the 60-year-old in 1996 lives a greater proportion of life in a disabled state (about 72% for those in 1989 versus about 46% for those in 1996). Finally, comparisons across age result in similar findings. A healthy 80-year-old in 1989 could expect to live 4.63 healthy years, and this number remains fairly similar over time. In contrast, the years that a healthy 80-year-old could expect to live with disability increases from 3.84 in 1989 to 3.87 in 1993 to 5.50 in 1996. Similar comparisons can be made across other age groups. Hence, we conclude that both life expectancy and disabled life expectancy has generally increased in Taiwan from 1989 to 1999.

Table 6. Each two waves healthy life expectancy in Taiwan: status-based analysis.

	Health expectancy: 1989–1993 (IMACH outcome)				Health expectancy: 1993–1996 (IMACH outcome)				Health expectancy: 1996–1999 (IMACH outcome)			
Age	H to H (1–1)	H to D (1–2)	D to H (2–1)	D to D (2–2)	H to H (1–1)	H to D (1–2)	D to H (2–1)	D to D (2–2)	H to H (1–1)	H to D (1–2)	D to H (2–1)	D to D (2–2)
60	15.05	4.51	13.55	5.25	14.23	5.86	8.62	9.02	14.60	7.00	8.84	10.20
65	11.53	4.39	10.08	5.03	10.95	5.45	5.72	8.43	11.27	6.76	5.67	9.87
70	8.58	4.16	7.22	4.67	8.22	4.95	3.61	7.70	8.49	6.43	3.43	9.28
75	6.28	3.79	5.06	4.18	6.07	4.39	2.19	6.89	6.29	6.00	1.98	8.52
80	4.63	3.34	3.52	3.62	4.44	3.80	1.29	6.06	4.63	5.50	1.11	7.66
85	3.50	2.87	2.47	3.07	3.27	3.21	0.75	5.27	3.43	4.97	0.61	6.79
90	2.74	2.44	1.75	2.58	2.47	2.66	0.43	4.55	2.60	4.44	0.34	5.97
95	2.22	2.08	1.25	2.18	1.93	2.17	0.25	3.91	2.04	3.93	0.19	5.22

H: Health; D: Disability; Disability is measured by difficulty of bathing, walking 200–300 m, or climbing 2–3 flights of stairs.

4. Concluding Remarks

A number of important debates in the biodemography of aging center on the future levels of expectation of life and the patterns of mortality at very old ages as overall expectation advances. A related strand centers around the levels of disability that will be associated with increased survival at older ages. Will increased life expectancy be accompanied by longer years of active life or by more years of disability or restricted functioning? The compression of morbidity hypothesis argues that the former scenario is possible and as noted above, some recent US data point to lower levels of disability at older ages in recent years, but the issue is far from resolved.

Evidence from Taiwan turns out to be mixed. Prevalence rates of functional limitations decreased between 1989 and 1993, but increased from 1993 to 1996 and 1996 to 1999. Disability-free life expectancy estimates from IMaCh show longer life over time, but more years lived in states of disability. This seems to suggest a depression of morbidity for the earlier period and an expansion for the latter. Curiously, it was during this latter period that the Universal Health Insurance program was initiated in Taiwan (in 1995), theoretically providing older adults with easier and more frequent access to the medical system. It could be that the better access to the medical system has resulted in saving lives at the expense of rates of disability. This hypothesis is purely speculative and the current results are far from conclusive. Yet the possibility that a change in health infrastructure could influence health outcomes to such a degree should motivate further research. Further study is required in order to determine whether longer-term trends remain the same, whether the Universal Health Insurance program has indeed increased access to health care, and whether health outcomes of older adults are being influenced by changes in health infrastructure.

Regardless of which direction future changes in health and functional status take, the gross number of Taiwanese who will be older will increase dramatically over the next couple of decades. This means that unless very dramatic improvements in functional status occur, the health care needs of this segment of the population will expand, placing a greater burden on society. The current study is not terribly sanguine, but further monitoring of the population in Taiwan is therefore necessary in order to establish whether we are witnessing the beginning of a longer-term trend. Over shorter periods of time, such as the time period covered in this study, there are likely to be sharp changes in health prevalence that flatten when observed for a longer period.

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CHAPTER 3. DISABILITY PATTERNS FOR US ELDERLY NURSING HOME RESIDENTS OVER TWO DECADES: FINDINGS FROM THE 1973 TO 1997 NATIONAL NURSING HOME SURVEYS

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1. Introduction

Older Americans have delayed and decreased nursing home use over the past two decades (Bishop 1999). As a result, the elderly nursing home population has become older and more disabled. According to findings from recent national nursing home surveys (NNHS), the disability characteristics of the nursing home residents (NHR), mainly measured by functional status and primary diagnosis, have changed significantly over the past two decades (Kramarow et al. 1999). However, looking at variables in the surveys individually is unlikely to generate a complete description of the disability changes. This requires a multivariate approach which jointly investigates a range of disease and functional attributes. A good understanding of such changes is essential for health services research and related policymaking.

Previous studies using multivariate approaches (e.g., Corder and Manton 1996; Manton, Cornelius, and Woodbury 1995) were limited to short spans of time, providing little information on changes over time in important aspects of disability. The present study includes information obtained from four waves of the NNHS for years 1973, 1985, 1995, and 1997 to depict longer-term trends in the disability characteristics of elderly NHR: (1) Disease and impairment measures were used to identify impairment groups defining a general hierarchy of disability; (2) Prevalence of each group among residents was calculated for each survey year and compared overtime; and (3) Nursing home use for each level of disability was estimated.

2. Methods

2.1. DATA

All variables used in this study were derived from the NNHS, which are available as public use data files from National Center for Health Statistics. They consist of functional

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assessments, sensory abilities, and primary diagnoses. Four waves of NNHS (1973/1974, 1985, 1995, 1997) were chosen for the analysis, mainly because surveys in these years had similar sampling frames: nursing homes that provided some level of nursing care and were certified by Medicare or Medicaid or licensed by the state as a nursing home facility. The number of survey participants was 16,994 in 1973, 5238 in 1985, 7278 in 1995, and 7331 in 1997. Of the respondents who were age 65 and older at the time of the survey, 36,333 of 36,841 were included in the present study. This sample was both large and nationally representative.

2.2. THE GoM MODEL

The grade-of-membership (GoM) model, developed by Woodbury and Clive (1974); Woodbury, Clive, and Garson (1978); Manton, Woodbury, and Tolley (1994), and colleagues is a multivariate classification technique. It is a way to analyze high-dimensional categorical data based on fuzzy-set mathematics. GoM is utilized in this study to determine the disability groups for the NHR. GoM also provides a more effective way of representing individuals and the probabilities of joint occurrence of variables. The GoM fuzzy-set classification is more realistic than other arbitrary crisp-set categorizations in the sense that each person may have membership in more than one health profile, but to different degrees, just as a patient may have multiple disease symptoms but at different levels.

Nine variables are used to define major disability groups characterizing NHR between 1973 and 1997. Individuals may either resemble one group exclusively or multiple groups to varying extents based on degree of membership in each group. The data set consists of $I = 36{,}222$ persons (indexed by i) who provide information on $J = 9$ categorical variables (indexed by j). L_j denotes the number of categories for each variable. To write the GoM model equations, we specify that K groups (indexed by k) are used to depict the data and allow each person one positive response per variable. The probability of a positive response for each person and variable, i.e., where $x_{iLj} = 1.0$, is predicted using two coefficients. One is the degree of membership of the ith person in the kth group denoted as gik. The other is the probability that a person matching the kth group (i.e., $gik = 1.0$) has the lth response to the jth variable which is denoted as λ_{kLj}. Partial membership of individuals in the groups is represented by constraining the gik to be convex weights that are positive and sum to one for each person, i.e., $0.0 \leq gik \leq 1.0$. The giks represent K latent variables summarizing reliable information on the state of an individual from the J variables. The basic model for each of response variables, x_{iLj}, is,

$$P_{iLj} = P(x_{iLj} = 1.0) = \sum_{k=1}^{k} g_{ik}\lambda_{kLj} \tag{1}$$

Parameters in Equation 1 can be estimated using a conditional multinomial maximum likelihood function,

$$L = \prod_i \prod_j \prod_l \left(\sum_k g_{ik}\lambda_{kLj} \right)^{x_{iLj}} \tag{2}$$

2.3. THE APPLICATION OF GoM IN THIS STUDY

2.3.1. Disability Groups

The appropriate number of disability groups was first identified. The M.L.E. of *gik* membership scores and λ_{kLj} probability parameters was computed three times specifying $K = 3$, 4, and 5 groups. Five groups best represented the data according to the Akaike Information Criterion (1973).

2.3.2. Methods to Capture Trends

Trends in nursing home usage by different disability groups are exemplified in the following ways. (1) Absolute numbers of NHR in each disability group for each survey year are calculated according to age (65–74, 75–84, 85+) and sex as follows: First, each person's *gik* scores are multiplied by survey sampling weights. Second, the weighted scores are summed for each disability group and year according to age and sex. (2) The disability composition among NHR, i.e., relative prevalence or proportion, is calculated for each year according to age and sex by dividing by the total size of the relevant age-sex-year group. Finally, (3) The nursing home use rate for each disability group (per 1000 population) is estimated based on US Census estimates of persons each year in the defined age-sex categories.

3. Results

3.1. THE DISABILITY GROUPS

The disability groups are described in order of increasing functional limitation from I to V (Table 1). The variables used to construct the groups and sample frequencies are shown to the left. The columns labeled I, II, III, IV, and V refer to the set of response probabilities found for each disability group. The probabilities define each disability group and represent persons exactly like the group. In order to clearly demonstrate the hierarchy of functional limitations within the five disability groups, we further separate the five groups into three disability levels according to the response to "help to dress" and "wheelchairbound". The three disability groups are: least disabled (groups I and II) with less than 50% needing help to dress, moderately disabled (III and IV) with 100% needing help to dress, and most disabled (V) with 100% wheelchairbound.

3.1.1. Least Disabled (I and II)—Chronic Conditions

Group I: Circulatory disease, dementia, and muscular diseases

This group is characterized by primary diagnoses of circulatory disease, dementia, and musculoskeletal diseases rather than disability per se, although help is sometimes (43%) needed to dress. Moderate dementia seems likely given that the group is able to ambulate and eat without help.

Group II: Mental and neurologic disorders, diabetes, respiratory diseases

An alternate set of primary diagnoses characterizes group II: diabetes, respiratory disorders, mental illness, and neurologic disorders. Similar to group I in terms of functional level, group II is able to ambulate and eat without help, but sometimes (45%) needs help to dress.

Table 1. Disability groups identified from respondents to the 1973, 1985, 1995, and 1997 National Nursing Home Surveys.

			Disability group				
Variable	**Response**	**Sample (%)**	**I**	**II**	**III**	**IV**	**V**
Group size		36,222	9599.2	6357.4	5401.0	5520.6	9343.8
		100%	27%	18%	15%	15%	26%
Wheelchairbound	Yes	40.2	0	0	0	0	100
Needs help to eat	Yes	39.8	0	0	0	100	100
Incontinent	Bowel bladder	39.4	0	0	0	100	100[a]
	Either	8.7	0	0	100	0	0
	Normal	50.6	100	100	0	0	0
Sight impairment	Blind/severe	11.5	0	0	0	100	0
	Partial	26.8	0	0	100	0	0
	Normal	61.7	100	100	0	0	100
Needs eyeglasses	Yes	66.2	100	100	100	0	100
Hearing	Deaf/severe	6.0	0	0	0	54	0
	Partial	23.6	0	0	100	0	0
	Normal	70.4	100	100	0	47	100
Hearing aids	Yes	7.5	0	0	50	0	0
Help to dress	Yes	78.8	43	45	100	100	100
Primary diagnosis	Stroke	10.6	0	0	0	0	54
	Dementia	14.8	20	0	0	50	19
	Circulatory	26.6	53	0	73	34	0
	Digestive	2.4	0	0	27	0	0
	Muscular	6.2	20	0	0	0	0

	Neoplasms	2.4	6	0	0	6	0
	Blood	0.9	2	0	0	2	0
	Mental	9.4	0	31	0	0	0
	Diabetes	5.4	0	18	0	0	0
	Respiratory	3.4	0	11	0	0	0
Primary diagnosis	Stroke	10.6	0	0	0	0	54
	Dementia	14.8	20	0	0	50	19
	Circulatory	26.6	53	0	73	34	0
	Digestive	2.4	0	0	27	0	0
	Muscular	6.2	20	0	0	0	0
	Neoplasms	2.4	6	0	0	6	0
	Blood	0.9	2	0	0	2	0
	Mental	9.4	0	31	0	0	0
	Diabetes	5.4	0	18	0	0	0
	Respiratory	3.4	0	11	0	0	0
	Neurologic	5.3	0	10	0	8	8
	Infectious	0.3	0	0	0	0	2
	Skin disease	0.7	0	2	0	0	0
	Genitourinary	1.8	0	3	0	0	4
	Other	9.8	0	23	0	0	14

[a] 14% were catheterized.

3.1.2. Moderately Disabled (III and IV)—Sensory Impairments
Group III: Sensory deficits and incontinence
There are problems with sight and hearing. But these problems were at least partially correctable by the use of glasses and hearing aids. The group is either bowel (86%) or bladder (14%) incontinent. The primary diagnoses are circulatory disease (73%) and digestive disorders (27%). Group II can eat without help, but always need help to dress.

Group IV: Loss of sight and hearing; bowel and bladder incontinent
Group IV has more severe losses in sight and hearing compared to group III. Eyeglasses and hearing aids are not used despite noted sensory deficits, suggesting that they are of limited help. This group (IV) is bowel *and* bladder incontinent, rather than bowel *or* bladder incontinent (III). Dementia (50%) and circulatory disease (34%) are the major primary diagnoses. Help is always needed to dress and eat.

3.1.3. Most Disabled (V)—Little Mobility and Highly Dependent on Care
Group V: Wheelchairbound
This group is wheelchairbound, both bowel and bladder incontinent, or catheterized (14%). Stroke (53%) and dementia (19%) are the common diagnoses. Help is always needed to dress and eat.

3.2. DISABILITY TRENDS OVER TIME

Absolute numbers of NHR in each disability group are shown in Figure 1 according to age and sex. Note that different scales are used for men and women since most NHR are female. The number of NHR increased for both men and women in every disability group except group I. For women, the oldest old outnumbered other age groups at each disability level. They also registered the largest increase in number except for group I, in which the number for every age group dropped. This increase may be attributed to the fact that recent cohorts of women enter old age in better health, which delays their entry into nursing homes.

As described above in terms of nursing home composition, there were lower numbers of persons who were able to ambulate and feed themselves, and had a specific set of diagnoses—circulatory diseases, dementia, or muscular diseases (I). Absolute numbers increased for both men and women having another set of diagnoses—diabetes, mental and neurologic disorders (II). For groups III and IV, which were characterized by sensory deficits and incontinence, only oldest old women demonstrated a significant increase, whereas the size of other age-sex groups essentially remained unchanged.

The most striking change was that the number of severely disabled (V) persons in nursing homes increased dramatically from 1973 to 1997: There were threefold increases for women age 85 and older (from 60,000 to 190,000) and for men aged 75 to 84 (from 20,000 to 53,000).

Figure 2 depicts changes in the disability composition of NHR across age and sex groups. Trends for men and women were in general similar. Over time there were fewer relatively independent persons (group I) who had circulatory diseases, dementia, or muscular diseases. For men aged 75 and above, the decrease was from 32% to 18%. Another set of

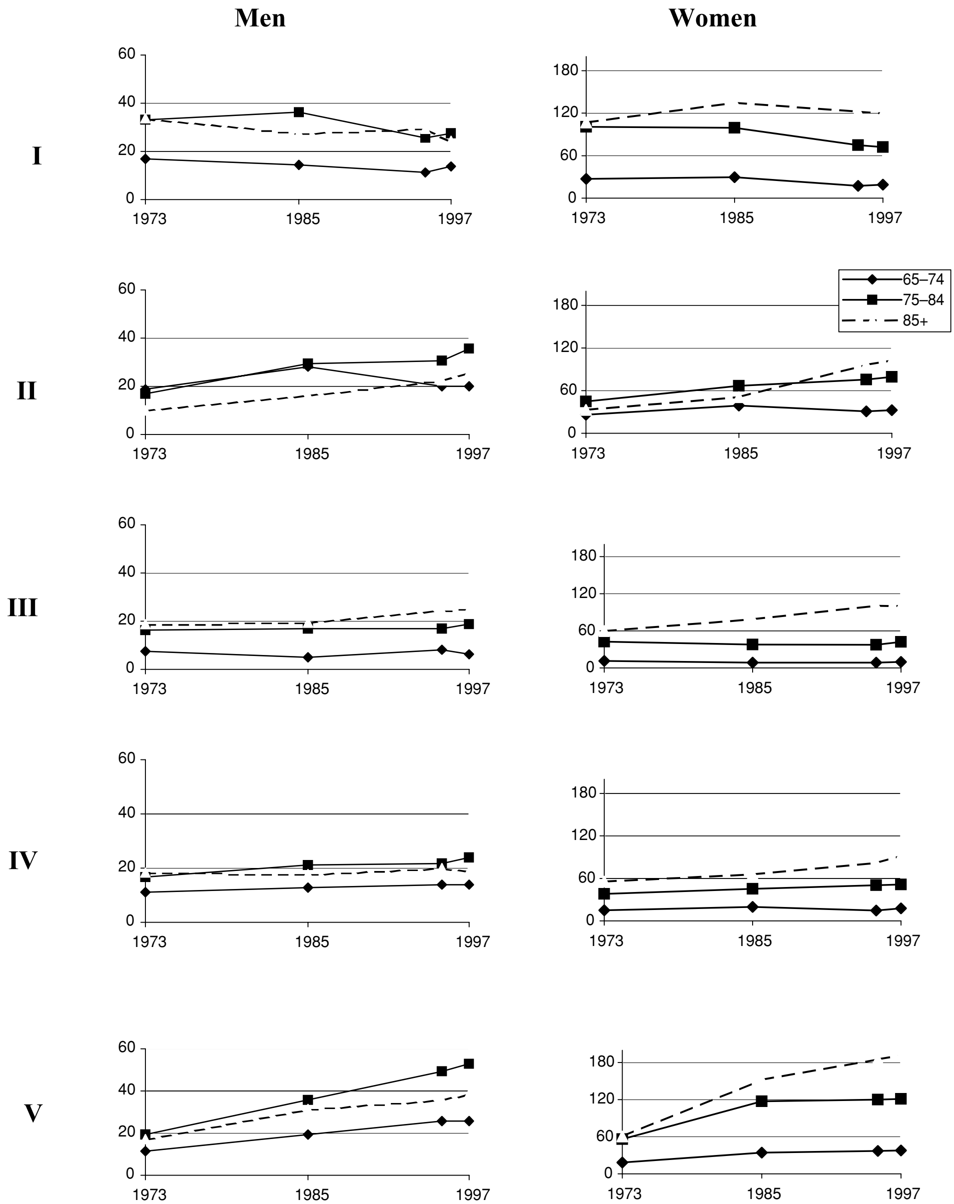

Figure 1. The absolute number of elderly nursing home residents in each disability group (thousands of persons).

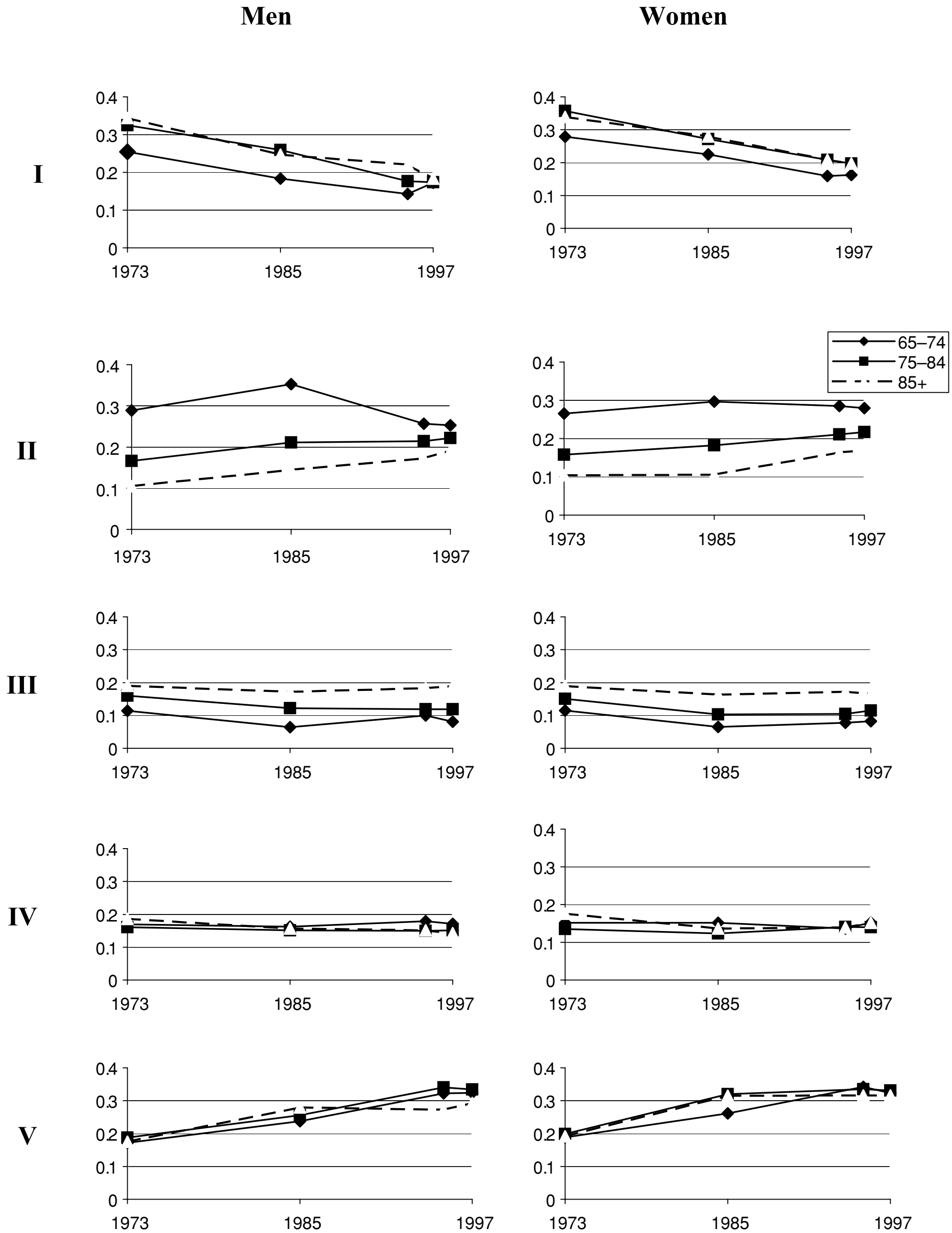

Figure 2. The proportion of elderly nursing home residents in each disability group by age and sex.

primary diagnoses was stable in size or demonstrated small increases among NHR. These were diabetes, mental and neurologic disorders (II). Increases of 5–15 percentage points were found for the two older age groups. For the younger group there was a slight decrease for men and no change for women. Since the proportion decreases of group I is larger than the small increases of group II, overall NHR who can walk and feed themselves showed decreased presence in nursing homes in recent years.

Group III, characterized by less severe incontinence and losses of sight/hearing, became slightly less common over time except for oldest-old men, which remained stable. Group IV, characterized by more severe incontinence and losses of sight/hearing, was stable over time in terms of its proportion among NHR.

The proportion of NHR who were most disabled (group V) had the largest increase, from 20% to more than 30%. Thus, nursing homes have been increasingly occupied by severely disabled elderly over the past three decades.

3.3. US NURSING HOME USE

Figure 3 depicts the changes in the rate of nursing home use per 1000 US population for each disability group according to age and gender. For every disability group, women use nursing homes at a higher rate than men, especially for the oldest old. However, the patterns of change in nursing home usage are similar for men and women: Group I showed dramatic decline, groups III and IV showed significant decline, groups II and V remained stable.

There were major decreases in nursing home use by persons, both men and women, who were able to move around and to feed themselves while having a specific set of primary diagnoses—circulatory disease, dementia, and muscular diseases (I). On a population level these disorders are less likely to require nursing home beds due to better prevention, better medical management to minimize symptoms or progression, and services now available in the community. This appeared to be less true for certain other conditions—mental, neurologic, or respiratory disorders and diabetes (II)—where the rate was stable or even slightly increased (for oldest old women).

Nursing home use rate declined significantly, especially for the oldest old, in subjects who suffered sight and hearing impairment and incontinence (groups III and IV), but were able to walk. In 1973, 52 of every 1000 women aged 85+ were living in a nursing home due to these severe problems (IV) compared to 29 per 1000 in 1997.

Rates of nursing home use for severely disabled group V remained constant. This implies that the use of nursing homes per 1000 for the most severe disability group (being not able to walk, mainly stroke victims, and take care of themselves in daily living) is at the same rate as three decades ago.

4. Discussion

We looked at nationally representative data on NHR in the interval of time from 1973 to 1997 and found that they could be characterized according to five hierarchical disability

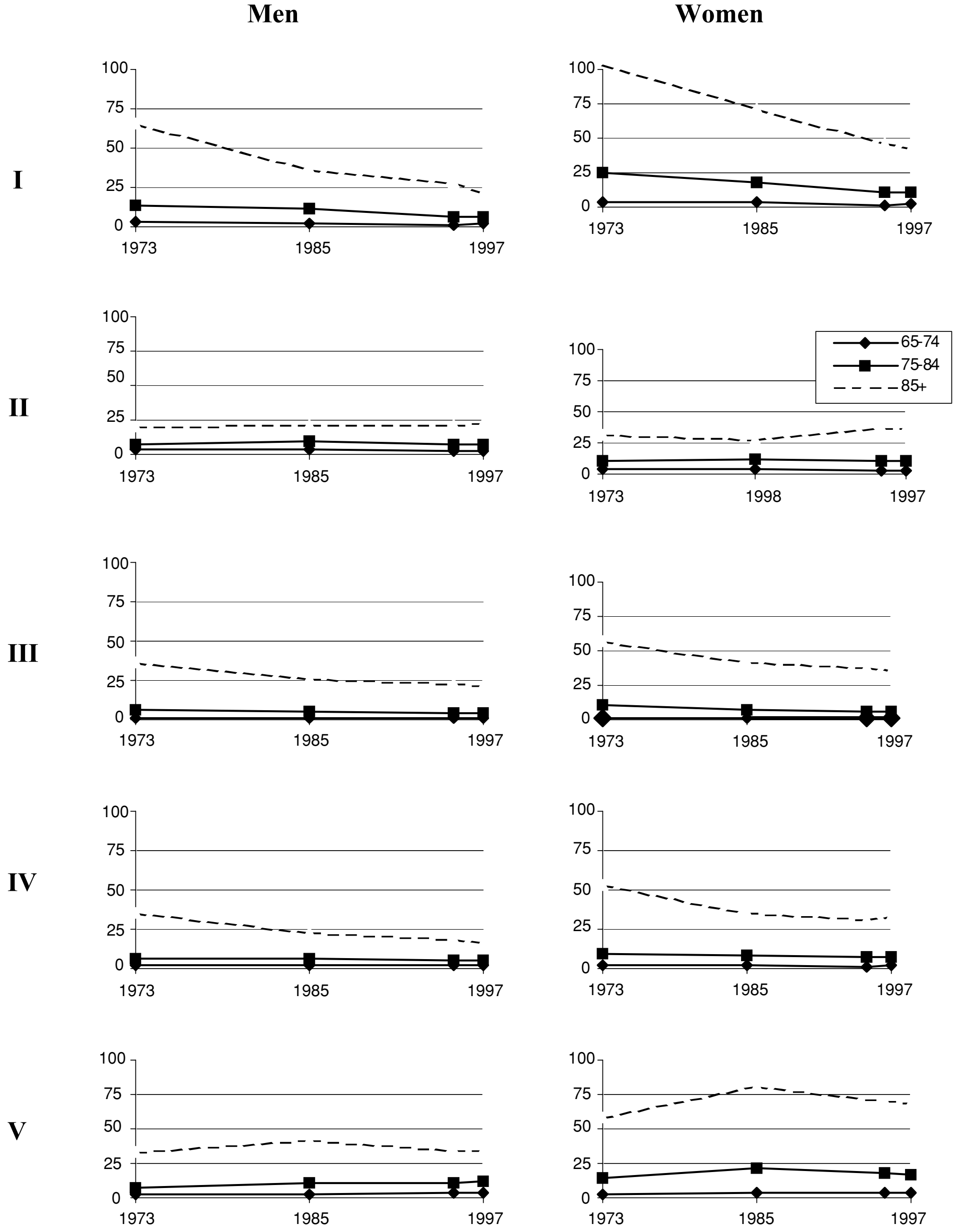

Figure 3. The rate of nursing home use per 1000 for each type of disability according to age and sex.

groups when nine survey items were analyzed using GoM. Individuals matched one group or, more often, resembled multiple groups to varying extents, expressed as a set of membership scores. This common metric allows estimation of changes in the number of NHR over time at each disability level. It also makes it possible to further define demographic trends in relation to age and sex, and to see which diagnoses and limitations were associated with certain trends in nursing home use.

Three secular trends were evident: First, in recent years NHR who have only diagnosed chronic conditions and who can ambulate and feed themselves showed decreased presence in nursing homes. The nursing home use rate for this group declined dramatically (Figure 3). One speculation is that these conditions were better managed in the community by medical treatment and home-based services in recent years. In contrast, another set of diagnoses—diabetes, mental, and neurologic disorders (not stroke or dementia)—did not demonstrate major decreases in nursing home use (group II). This may imply that these disorders have proven to be less avoidable and manageable in the community.

The second trend concerned persons who are moderately disabled and have losses in sight and hearing and incontinence (group III, less severe & group IV, more severe). The rate of nursing home use per 1000 for this disability group decreased dramatically, although the number of residents having these problems increased slightly, and the proportion of residents in this group remained fairly constant. The combination of poor sight and hearing, and incontinence would be more difficult to manage in the community. Thus decreased nursing home use per 1000 for these two disability groups might be due to improved treatments (e.g., cataract surgery, laser treatment for sight losses related to diabetes, and better treatment for initial episodes of stroke), and prevention, (e.g., glaucoma treatment, management of hypertension avoiding strokes, better control of blood sugar levels in diabetics to avoid sight losses). Cataract surgery is particularly important in keeping the elderly from being sight impaired (Javitt et al. 1993). Among 35 million elderly, 2.7 million had a cataract operation in 2003. Over the past decade (1990s), the average number of cataract surgeries conducted each year was over 1.5 million, roughly twice as many as the decade before (1980s).

The third trend was that nursing homes are increasingly populated by more debilitated elderly persons, often stroke victims and demented (group V). This group needed help to dress and eat, was wheelchairbound, and both bowel and bladder incontinent. In more recent years this group became most prevalent among NHR. This was not due to an increase in nursing home use per 1000 for the disability group. The use rate per 1000 population remained quite stable. Instead, the higher proportion and absolute number of severely disabled persons in nursing homes was due to more persons, especially women, reaching ages where stroke and severe dementia related to Alzheimer disease are common, increasingly becoming the major occupants of nursing homes. As a result, the level of disability for NHR as a whole increased dramatically over the past three decades. Furthermore, this group was expectedly the most costly to care for and it drove up the average nursing home cost per person (results not shown).

5. Conclusions

Four pooled waves of NNHS sample data determined the disability group categorization. The goal of this current study was not to establish a disability grouping most appropriate for current NHR or an ideal disability grouping of any time period. Rather, it was to provide a categorization taking into account all the data points in the observation period in order to show major changes on a common metric.

When examining the disability groups, we need to keep in mind that these groups represent the disability distribution of elderly NHR, who are at the high end of the disability spectrum. Thus, these disability groups do not reflect the health status of the elderly population in general.

In summary, three trends emerged concerning the use of nursing homes from 1973 to 1997. Lower nursing home use rates were found for a specific set of diagnoses either avoided or better treated in recent years (circulatory diseases, dementia, musculoskeletal disorders). Other disorders did not demonstrate decreases (diabetes, mental and neurologic disorders [other than stroke and dementia]). Second, there was a lower admission rate for conditions compounded by sensory deficits and incontinence implying that these problems are more avoidable and better treated in recent years. Perhaps most importantly, although rates of admission per 1000 population have been stable, severely disabled demented persons, often stroke victims, became the major disability group in nursing homes in the late 1990s. Thus, the nursing home population became more disabled over the past three decades mainly because functionally independent elderly are less likely to be in nursing homes.

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CHAPTER 4. A METHOD FOR CORRECTING THE UNDERESTIMATION OF DISABLED LIFE EXPECTANCY, WITH AN EMPIRICAL APPLICATION TO OLDEST-OLD IN CHINA

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1. Introduction

At the population level, demographers have used the Sullivan method and multi-state life table models to efficiently summarize information about functional capacity in Activities of Daily Living (ADL) obtained in surveys in the form of estimates of *active* and *disabled life expectancy*. These estimates provide easily understandable indicators of the functional capacity and care-giving needs of the elderly population (Crimmins, Hayward, and Saito 1994, 1996; Crimmins, Saito, and Ingegneri 1997; Robine, Mathers, and Bucquet 1993; Rogers, Rogers, and Belanger 1990; Rogers, Rogers, and Branch 1989). The Sullivan method (Crimmins, Saito, and Ingegneri 1989; Robine et al. 1986) is a useful approach for providing cross-sectional, period-specific, summary measures of disability status when longitudinal data on transitions between functional statuses and mortality differentials among people with different functional statuses are not available. When such longitudinal data are available, the multi-state life table method, which accounts for dynamic changes in functional statuses and the mortality differentials by functional statuses, is preferable (Crimmins et al. 1994, 1996, 1997; Laditka and Hayward 2003; Land, Guralnik, and Blazer 1994; Manton and Land 2000; Rogers et al. 1989, 1990). A recent innovation in the calculation of healthy life expectation is microsimulation, which simulates monthly health status transition probabilities and permits the calculation of the sampling errors attributable to the model's parameters (Laditka and Wolf 1998; Wolf and Laditka 1997).

Extant studies of active/disabled life expectancy based on multi-state life table methods implicitly assume that persons who die between ages x and $x + 1$ (or ages x and $x + n$) do not change their functional status between age x and time of death. Such an unreasonable assumption—due mainly to a lack of data about functional status before dying—causes inherent biases in the estimates of active/disabled life expectancy, with disabled life expectancy particularly significantly underestimated. The main objectives of this chapter are

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to present a new method for correcting this bias and an illustrative application to data on the oldest-old in China. This will be done by extending the conventional multi-state life table method for the estimation of *status-based active/disabled life expectancy* (i.e., active/disabled years of life remaining conditional on health status at certain ages) to include disability information in the period just prior to death collected in the longitudinal survey.

Inclusion of disability information before dying in life table analysis also has its own significance in scientific studies of aging. Based on Medicare data, Lubitz, and Prihoda (1983) showed that 28% of all Medicare costs were incurred by the 6% of enrollees who died within the next 12 months. Another study found substantial increases in several measures of health care utilization with increasing proximity to death (Roos, Montgomery, and Roos 1987). If an individual experiences severe suffering for an extended period before dying, much pain and burden will be brought on the individual, family, and society. Hence, it is important to study both survivors' health and deceased elders' quality of dying.

Demographic studies of active/disabled life expectancy that make estimates conditional on health status before dying are rare due to the lack of such data. One recent study that used estimates of health status before dying is that of Manton and Land (2000). Given a lack of data, Manton and Land estimated heath status changes before death for the deceased elderly by assuming that their probabilities of health status transitions are the same as those for survivors with the same sex, age, health status, and some other characteristics observed in the previous survey. This is better than completely ignoring the health status changes of deceased elders, but the assumption involved is only an approximation, as deceased elders' health status transitions may differ substantially from those of survivors even if they had the same observed conditions and characteristics in the previous interview.[1]

In a recent extensive literature review, George (2002) termed efforts to conceptualize the quality of dying a "young" research field, with many fewer and, consequently, less sophisticated studies than those for quality of life. Steinhauser and colleagues identified six primary domains of quality of dying: symptom and pain, clarity of decision-making, preparation for death, completion, contribution to others, and affirmation of the whole person (Steinhauser et al. 2000). Using a new method which extends the classic multi-state life table model, we will investigate the extent of morbidity before dying, one of the primary domains of quality of dying, due mainly to the lack of data on other domains.

2. Method

The active and disabled life expectancies computed from *multi-state life tables* are average lengths of life in the active and disabled statuses that would be observed if a hypothetical cohort of elders experienced throughout their remaining life the observed age–status-specific rates of death and transition between active and disabled statuses. This is similar to the classic period life expectancy. Although the active and disabled life expectancies are neither reflections of cohort experience nor predictive of active and disabled status into the

[1] Manton and Land (2000: 259) are further investigating linkages to, and the utilization of, Medicare service use data in the prior survey interval among both survivors and deceased elders. This is expected to more accurately describe the dynamics of health status changes.

future, they do provide concise and meaningful summary measures of the current situation in the population under study.

On average, persons who have different ADL statuses at an initial age (denoted as y) are expected to have different active/disabled life expectancies and total life expectancies. The *status-based multi-state model* of active/disabled life expectancy estimates such differentials for those who have different ADL statuses at initial ages (see, e.g., Manton and Land 2000). We decompose the expected length of the remaining life span after initial ages into active and disabled components for those who are active or disabled at the initial age, respectively, and investigate their differentials. The empirical estimates (see below) are given for both the males and females, but we omit the gender dimension in all notation and equations for simplicity of presentation.

2.1. AN EXTENSION OF THE MULTI-STATE LIFE TABLE MODEL

Denote ${}_{iy}l_j(x)$ as the life table number of persons with ADL status i at initial age y, and ADL status j at age $x(y \leq x)$.

$l_j(x)$, the life table total number of persons with ADL status j at age x regardless of ADL status at initial age y;

${}_1p_{kj}(x)$,the probability of surviving and transiting from ADL status k to $j$between age x and $x + 1$ among those who had ADL status k at age x;

${}_1q_i(x)$, the probability of death between age x and $x + 1$ in a *1-year period* for those with ADL status i at age x.

${}_{iy}d_j^{(.)}(x)$, the life table total number of deaths regardless of ADL status before dying between age x and $x + 1$ among those who had ADL status i at initial age y and survive with ADL status j at age x, ${}_{iy}d_j^{(.)}(x) =_{iy} l_j(x) \cdot q_j(x)$;

${}_{iy}d_j^{(k)}(x)$, the life table number of deaths between age x and$x + 1$ with ADL status k before dying and ADL status i at initial age y and ADL status j at age x;

$d_j^{(k)}(x)$, the life table total number of deaths between age x and $x + 1$ with ADL status k before dying and ADL status j at age x regardless of ADL status at initial age y;

${}_nD_j^{(k)}(x)$, the observed number of persons who were aged x and with ADL status j in the first wave, but died with ADL status k before dying prior to the second wave of the survey; the left subscript n represents the average interval (number of years) between the first and the second waves (interviews) of the survey.

We decompose ${}_{iy}d_j^{(.)}(x)$ by ADL status before dying:

$${}_{iy}d_j^{(k)}(x) = {}_{iy}d_j^{(.)}(x) \frac{{}_nD_j^{(k)}(x)}{\sum\limits_{k=1,C} {}_nD_j^{(k)}(x)} \qquad (1)$$

Our decomposition of ${}_{iy}d_j^{(.)}(x)$ expressed in Equation (1) is similar to the decomposition of deaths by causes of deaths for elders who were active or inactive at the beginning of the two-survey observation interval by Hayward, Crimmin, and Saito (1998) in an ALE multi-state life table analysis. It is also similar to the approach employed in the multiple-decrement cause-specific mortality life table (e.g., Namboodiri and Suchindran 1987).

We denote ${}_{iy}S_j^{(k)}(x)$ as the number of persons who were with ADL status i at initial age y, ADL status j at age x and survive to $x+1$ with ADL status k; ${}_{iy}L_j(x)$, person-years lived in ADL status j between ages x and $x+1$ for those with ADL status i at initial age y;

$$ {}_{iy}S_j^{(k)}(x) = {}_{iy}l_j(x) \cdot p_{jk}(x) $$

Assuming a uniform distribution of both deaths and transitions between functional statuses [i.e., assuming piecewise-linear functions for ${}_{iy}l_j(x)$], ${}_{iy}L_j(x)$ can be estimated as follows:

$$ {}_{iy}L_j(x) = \left[{}_{iy}S_j^{(j)}(x) + \frac{1}{2}\sum_{k=1,C}^{k\neq j} {}_{iy}S_j^{(k)}(x) + \frac{1}{2}\sum_{k=1,C}^{j\neq k} {}_{iy}S_k^{(j)}(x) \right] + \frac{1}{2}\left[{}_{iy}d_j^{(j)}(x) + \frac{1}{2}\sum_{k=1,C}^{k\neq j} {}_{iy}d_j^{(k)}(x) + \frac{1}{2}\sum_{k=1,C}^{j\neq k} {}_{iy}d_k^{(j)}(x) \right] \quad (2) $$

Note that the equation for computing ${}_{iy}L_j(x)$ in the conventional piecewise-linear multi-state life table on active/disabled life expectancy is as follows:

$$ \begin{aligned} {}_{iy}L_j(x) &= \frac{1}{2}\left[{}_{iy}l_j(x) + {}_{iy}l_j(x+1)\right] = {}_{iy}l_j(x+y) + \frac{1}{2}\left[{}_{iy}l_j(x) -_{iy} l_j(x+1)\right] \\ &= \left[{}_{iy}l_j(x)p_{jj}(x) + \sum_{k\neq j} {}_{iy}l_k(x)p_{kj}(x) \right] \\ &\quad + \frac{1}{2}\left[{}_{iy}l_j(x) - {}_{iy}l_j(x)p_{jj}(x) - \sum_{k\neq j} {}_{iy}l_k(x)p_{kj}(x) \right] \\ &= {}_{iy}S_j^{(j)}(x) + \frac{1}{2}\sum_{k=1,C}^{k\neq j} {}_{iy}S_k^{(j)}(x) + \frac{1}{2}\sum_{k=1,C}^{k\neq j} {}_{iy}S_j^{(k)}(x) \\ &\quad + \frac{1}{2} {}_{iy}d_j^{(j)}(x) + \frac{1}{2}\sum_{k\neq j} {}_{iy}d_j^{(k)}(x) \end{aligned} \quad (3) $$

The term $(1/2)\sum_{k\neq j} {}_{iy}d_j^k(x)$ in Equation (3) implies that those who were with ADL status j at age x and died between age x and $x+1$ contribute on average half a year of person-years lived in status j. In other words, the conventional multi-state life table method for estimating ${}_{iy}L_j(x)$ assumes that there are no ADL status changes between age x and time of death for those who die between age x and $x+1$. This is an unreasonable assumption, which causes bias in estimating status-based active/disabled life expectancy based on the conventional method, because the health status of those who die between age x and $x + 1$ may change between age x and death, more likely becoming worse before dying.

In contrast, our new method for estimating ${}_{iy}L_j(x)$ expressed in Equation (2) uses follow-up information on observed deaths $({}_nD_j^{(k)}(x))$ classified by ADL status at age x in the previous wave of the survey and ADL status before dying prior to the next wave. We assume a uniform distribution of changes in ADL status between ages x and death among deceased persons. This method removes the unreasonable assumption imposed in the conventional method that there are no ADL status changes between age x and time of death for those who die between age x and $x + 1$. We believe that this is an improvement in active/disabled life expectancy estimation. The bias [i.e., Equation (3) minus Equation (2)] in estimating ${}_{iy}L_j(x)$ based on the conventional multi-state life table method is

$$\left[\frac{1}{4}\sum_{k\neq j} {}_{iy}d_j^{(k)}(x) - \frac{1}{4}\sum_{k\neq j} {}_{iy}d_k^{(j)}(x)\right]$$

and the bias in estimating ${}_{iy}e_j(y)$ is:

$$\frac{1}{4_{iy}l_i(y)}\sum_{t=y}^{\omega}\left[\sum_{k=j} {}_{iy}d_j^{(k)}(t) - \sum_{k\neq j} {}_{iy}d_k^{(j)}(t)\right] \tag{4}$$

The bias in estimating $e_j(y)$, regardless of functional status at initial age y, is:

$$\frac{1}{4l_i(y)}\sum_{t=y}^{\omega}\left[\sum_{k\neq j} d_j^{(k)}(t) - \sum_{k\neq j} d_k^{(j)}(t)\right] \tag{5}$$

We will discuss the direction and magnitude of the bias below in the illustrative numerical application of our extended multi-state life table method for estimating active/disabled life expectancies using the Chinese data.

Similar to the approach for decomposing the total number of deaths into cause-specific deaths in the multi-state life table of ALE analysis (Hayward et al. 1998) and in the multiple-decrement cause-specific mortality life table (e.g., Namboodiri and Suchindran 1987), we estimate ${}_{iy}d_j^{(k)}(x)$ through decomposing ${}_{iy}d_j^{(.)}(x)$ by morbidity status before dying [as shown in Equation (1)], based on the observed data. Note that ${}_{iy}l_i(y) = \sum_{t=y}^{\omega}\sum_{j=1}^{C}\sum_{k=1}^{C} {}_{iy}d_j^{(k)}(t)$. Hence, the *proportion of deaths with morbidity status k before dying* (i.e., extent of morbidity) after age y among those with ADL status i at age y, denoted as ${}_{iy}G_i^{(k)}(y)$, is

$${}_{iy}G_i^{(k)}(y) = \frac{\displaystyle\sum_{t=y}^{\omega}\sum_{j=1}^{C} {}_{iy}d_j^{(k)}(t)}{{}_{iy}l_i(y)} \tag{6}$$

Note that Equations (1)–(6) represent our extension of the standard model of multi-state life tables to include functional status information before dying, and are discussed intensively in this chapter.[2] All of the other equations concerning status-based multi-state life tables construction and their theoretical assumptions (e.g., the Markovian assumption) and justifications used herein can be accessed in standard textbooks (e.g., Palloni 2001; Rogers 1975; Schoen 1988).

2.2. PROCEDURES FOR ESTIMATING ${}_1q_i(x)$ AND ${}_1p_{kj}(x)$

As defined and discussed earlier, ${}_1q_i(x)$ (single-year age and ADL status specific death probabilities) and ${}_1p_{kj}(x)$ (single-year age-specific ADL status transition probabilities) are quantities needed for constructing the multi-state life tables to estimate the active/disabled life expectancies. We cannot estimate ${}_1q_i(x)$ and ${}_1p_{kj}(x)$ directly from longitudinal survey data collected in intervals more than 1 year apart [e.g., the 1998–2000 Chinese Longitudinal Healthy Longevity Survey (CLHLS) data used in this chapter were collected in intervals of approximately 2 years], whereas ${}_1q_i(x)$ and ${}_1p_{kj}(x)$ refer to single-age and 1-year period. Furthermore, working directly with single-year age intervals (and a 2-year period) would cause the serious problem of random fluctuations due to small sub-sample sizes at each single age for each sex. We therefore first estimate ${}_np_{kj}(x, x+4)$, the probability of surviving and transitioning from age group $(x, x+4)$ with status k in the first wave to $(x+n, x+4+n)$ with status j in the second wave; where x refers, for example, to ages 80, 85, 90, 95, and 100 in our illustrative application;[3] n is the average interval (exact years with decimal point) between the first and the second interview (which is approximately 2.2 years, for example, in the Chinese healthy longevity survey).

$$ {}_np_{kj}(x, x+4) = \frac{{}_nM_{kj}(x, x+4)}{N_k(x, x+4)} \tag{7} $$

Here ${}_nM_{kj}(x, x+4)$ is the observed number of persons who were of ADL status k at age $(x, x+4)$ in the 1st wave of the survey interview, and were of ADL status j at age $(x+n, x+4+n)$ in the second wave of the survey interview. $N_k(x, x+4)$ is the number of persons who were aged $(x, x+4)$ and interviewed with ADL status k in the first wave and who may have been re-interviewed in the second wave or may have died before the second wave; we exclude those who were untraceable.

$$ {}_np_{i.}(x, x+4) = e^{-n\,{}_1\mu_i(x+(n/2), x+4+(n/2))} \tag{8} $$

where ${}_np_{i.}(x, x+4)$ is the overall average survival probability from age $(x, x+4)$, to $(x+n, x+4+n)$ *in n-year period* for those aged $(x, x+4)$, with ADL status i in the first wave of the survey; ${}_np_{i.}(x, x+4) = \sum_{k=1,C} {}_np_{ik}(x, x+4)$; ${}_1\mu_i(x+(n/2), x+4+(n/2))$ represents the overall average death rates between ages $(x, x+4)$ and $(x+n, x+4+n)$ over the *n-year period* for those with ADL status i at age $(x, x+4)$ in the first wave; and ${}_1\mu_i(x+(n/2), x+4+(n/2))$ is assumed to be constant over the n-year

[2] Equations (1)–(6) are also applicable in estimating active/disabled life expectancies regardless of functional status at initial age y, and in that case the left-side subscript "$_{iy}$" should be deleted.

[3] When the age x is equal to 100, we deal with age group $(x, x+5)$, i.e., age groups (100, 105) and $(100+n, 105+n)$, since we conduct our data analysis among the oldest-olds up to age 105 in 1998.

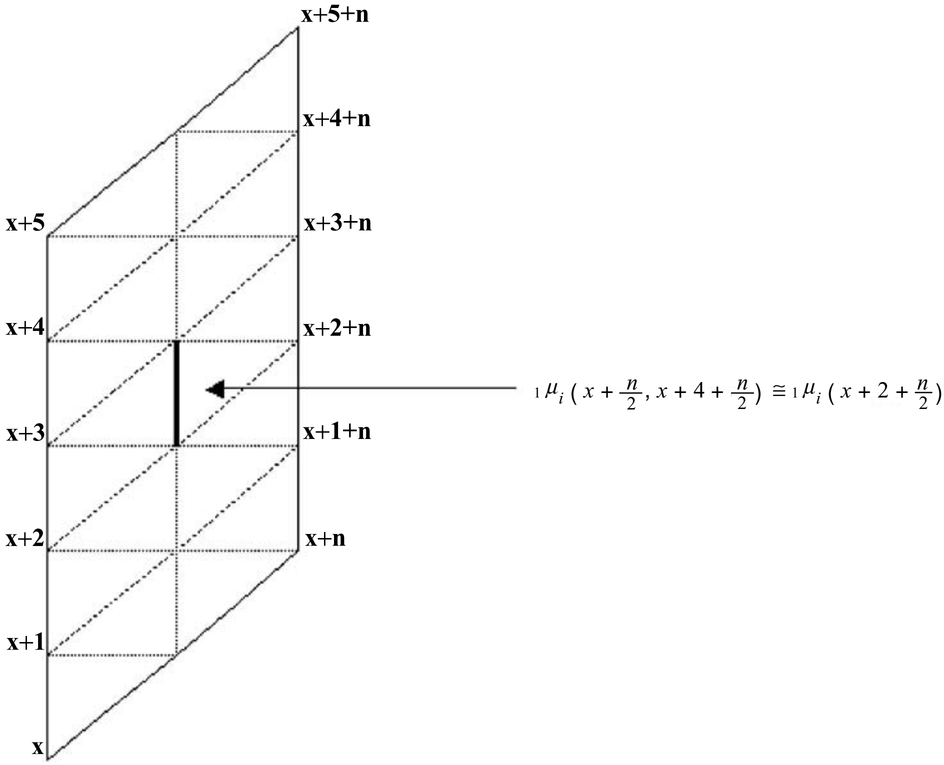

Figure 1. Five-year age group longitudinal data with *n*-year interval between two waves of the survey.

period. Assuming a uniform distribution of the deaths within the 5-year age group and between the two waves of the survey, the average rate ${}_1\mu_i(x + (n/2), x + 4 + (n/2))$ can be considered as the death rate at age $x + 2 + (n/2)$ in the middle of the n-year inter-survey period (denoted as ${}_1\mu_i(x + 2 + (n/2)$, see Figure 1 for illustration). Thus,

$$ {}_1\mu_i\left(x + \frac{n}{2}, x + 4 + \frac{n}{2}\right) = {}_1\mu_i\left(x + 2 + \frac{n}{2}\right) = -\frac{\ln[{}_n p_{i.}(x, x + 4)]}{n} \tag{9} $$

For example, in our illustrative application of Equation (9), x refers to ages 80, 85, 90, 95, 100, and $(n/2)$ is approximately equal to one. We thus estimated ${}_1\mu_i(83)$, ${}_1\mu_i(88)$, ${}_1\mu_i(93)$, ${}_1\mu_i(98)$, and ${}_1\mu_i(103)$, representing the average 5-year age and ADL specific death rates for age groups 81–85, 86–90, 91–95, 96–100, and 101–105 over the period of 1998–2000. We evaluated the fits of various models, such as the Gompertz, Weibull, Quadratic, Logistic, and Simplified Logistic models,[4] to the 5-year age-specific

[4] See Thatcher, Kannisto, and Vaupel (1998: 14–18) for a detailed mathematical description and discussions of these models.

data of ${}_1\mu_i(x + (n/2), x + 4 + (n/2))$.[5] The logistic model[6] fits the data very well. It performs better than the other models we tried. The observed and the fitted curves of the death rates among active and disabled oldest-old men and women aged 80–105 based on the logistic model are remarkably close to each other (see Figure 2 in Zeng et al. 2004). Note that the logistic model also fits remarkably well the overall age-specific death rates without distinguishing active and disabled status of the oldest-old aged 80 and above for 12 European countries and Japan, all of which have high quality data (Thatcher, Kannisto, and Vaupel, 1998). Zeng and Vaupel (2002) previously demonstrated that the logistic model (and its simplified form) describes the age trajectory of overall age-specific death rates disregarding active and disabled status among the Chinese oldest-old aged 80+, based on the 1990 census data.

Using the parameters of the logistic model estimated based on the data of the 5-year age-specific death rates, ${}_1\mu_i(x + (n/2), x + 4 + (n/2))$, we estimated single-year age-specific death rates (${}_1\mu_i(x)$) among active and disabled men and women. We then estimate:

$$ {}_1q_i(x) = 1 - \mathrm{e}^{-\mu_i(x)} \tag{10}$$

${}_1q_i(x)$ are needed for constructing the multi-state life tables to estimate the status-based active life expectancy.

Note that we distinguished two statuses, "active ($i = 1$)" and "disabled ($i = 2$)", in our status-based multi-state life table analysis. We estimated ${}_np_{kj}(x, x + 4)$, the 5-year age-specific transition probabilities between active and disabled statuses for the n-year period, based on the follow-up survey observations [see Equation (7)]. In our illustrative application, we evaluated the fit of various functional forms to the data of ${}_np_{kj}(x, x + 4)$. We found that a specification of an exponential decline[7] fits remarkably well the data on ${}_np_{11}(x, x + 4)$ (probabilities of remaining active), and ${}_np_{21}(x, x + 4)$ (probabilities of transitioning from disabled to active). The fitted and the observed curves are fairly close to each other (see Figure 3 in Zeng et al. 2004).

We then applied the best-fitting parametric model (exponential decline) for the 5-year age group data of ${}_np_{kj}(x, x + 4)$ to estimate the single-year age-specific ${}_np_{11}(x)$ and ${}_np_{21}(x)$ in n-year period. ${}_np_{11}(x)$ is the probability of surviving to age $x + n$ in active status in the second wave among those who were active and aged x in the first wave; ${}_np_{21}(x)$

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[5] We compare ${}_1\mu_i(x + (n/2), x + 4 + (n/2))$ estimated from the Chinese 1998–2000 longitudinal healthy longevity survey data to those death rates at oldest-old ages derived from the 2000 census (mortality data within 12 months prior to the census standard time were collected). We found that Chinese healthy longevity survey death rates at ages 90 and over are fairly accurate, but the death rates at ages 80–89 were somewhat underestimated (−9.4% and −8.7% at ages 80–84 and 85–89 for males; −13.1% and −6.1% at ages 80–84 and 85–89 for females). We therefore adjusted the survey death rates at ages 80–89 based on the 2000 census data of the 22 provinces.

[6] In the logistic model, the function of the hazard rate $\mu(x)$ is defined as: $\mu(x) = c + (a\ \mathrm{e}^{bx}/(1 + \alpha^{bx}))$ (Thatcher, Kannisto, and Vaupel, 1998: 15).

[7] The exponential decline model is defined as: ${}_np_{i1}(x) = a_i + b_i\mathrm{e}^{-c_jx}$.

is the probability of surviving to age $x + n$ in active status in the second wave among those who were disabled and aged x in the first wave.

$$_{n}p_{11}(x) = {}_{n}p_{1.}(x) - {}_{n}\, p_{12}(x) \tag{11}$$

$$_{n}p_{22}(x) = {}_{n}p_{2.}(x) - {}_{n}\, p_{21}(x) \tag{12}$$

Let $\mu_i^-(\overline{x})$ denote the average rate of exits from status i between ages x and $x + n$; $\mu_i^+(\overline{x})$, the average rate of accessions between ages x and $x + n$. The exits include death and transitions from status i to other statuses. The accessions include returning transition from another ADL status back to status i. The rates of exits and accessions between ages x and $x + n$ are the instantaneous rates, and are assumed to be constant within the age interval $(x, x + n)$. According to the principle of the relationship between survival and the instantaneous rates of exits and accessions proposed by Preston and Coale (1982: 225), we have:

$$_{n}p_{ii}(x) = \mathrm{e}^{-\int_x^{x+n}[\mu_i^-(t)-\mu_i^+(t)]\mathrm{d}t} \tag{13}$$

For example, the interval between the two waves of the survey in our application is approximately equal to 2 years; we therefore assume that the average rates of exits and accessions between ages x and $x + 2$ are approximately equal to the single-year age-specific rates of exits and accessions at age $x + 1$, namely, $\mu_i^-(x + 1)$ and $\mu_i^+(x + 1)$. Thus,

$$_{n}p_{ii}(x) \cong \mathrm{e}^{-n[\mu_i^-(x+1)-\mu_i^+(x+1)]} \tag{14}$$

From Equation (14), we have: $[\mu_i^-(x + 1) - \mu_i^+(x + 1)] \cong -(1/n)\ \ln({}_{n}p_{ii}(x))$

So that,

$$_{1}p_{ii}(x + 1) = \mathrm{e}^{-[\mu_i^-(x+1)-\mu_i^+(x+1)]} = \mathrm{e}^{(1/n)\ln({}_{n}p_{ii}(x))} \tag{15}$$

$$_{1}p_{12}(x + 1) = {}_{1}p_{1.}(x + 1) - {}_{1}\, p_{11}(x + 1) \tag{16}$$

$$_{1}p_{21}(x + 1) = {}_{1}p_{2.}(x + 1) - {}_{1}\, p_{22}(x + 1) \tag{17}$$

Based on Equations (15)–(17), we have estimates of ${}_{1}p_{11}(x + 1)$, ${}_{1}p_{12}(x + 1)$, ${}_{1}p_{22}(x + 1)$, and ${}_{1}p_{21}(x + 1)$, and we can then construct the status-based multi-state life table of active/disabled life expectancies. We do not need to have the estimates of $\mu_i^-(x + 1)$ and $\mu_i^+(x + 1)$, which are impossible to derive since we do not have data of returning transitions back to status i (i.e., out of status i first and back to status i again) between the two waves of the survey.

3. Illustrative Application

3.1. DATA AND MEASUREMENTS

The data used in the illustrative application were derived from the first two waves of the CLHLS conducted in a randomly selected sample of about half of the counties and cities in 22 provinces (out of 31 provinces) in 1998 and 2000, covering about 85% of the total population of China. Among the 8805 voluntary participants aged 80–105 interviewed in the baseline survey in 1998, there are 463 and 1811 male and female centenarians aged 100–105, 1316 and 1719 male and female nonagenarians aged 90–99, and 1768 and 1728 male and female octogenarians aged 80–89. In the second wave in 2000, out of 8805 original interviewees, 4691 (53.3%) survived; 3270 (37.1%) were dead; 844 (9.6%) were untraceable. This is the working sample used for the illustrative application presented in this chapter.

In addition to the extensive questionnaire data collected from surviving interviewees including socioeconomic status, health status, life style, diet, etc., follow-up information about ADL, length of being bedridden, and other health and socioeconomic status before dying was obtained concerning 3270 oldest-old who had been interviewed in 1998 but had died before the 2000 survey by interviewing a close family member of these deceased interviewees. As reviewed by George (2002), the use of surrogate or proxy responses from family members is appropriate in quality of dying research (Magaziner et al. 1988; Parker et al. 1996). The sampling design, contents of the questionnaires for the survived and deceased interviewees, and an assessment of data quality, especially the age reporting, etc., are presented in the chapter by Zeng, Liu, and George in this volume and are thus not repeated here.

The elders' status of independence in daily living used in estimating the status-based active/disabled life expectancy with consideration of ADL before dying is measured by the functional statuses of eating, dressing, transferring, using the toilet, bathing, and continence.[8] To avoid problems of small sub-sample sizes in estimating sex–age-specific ADL status transition probabilities for the multi-state life table construction, we simply dichotomized the ADL functional capacity into "active" and "disabled". This is the same as in most of the previous studies of active/disabled life expectancy following the multi-state life table approach (e.g., Crimmins et al. 1997; Land et al. 1994; Rogers et al. 1989).[9] If none of the six ADL activities is impaired, the elder is classified as "active"; if one or more activities are impaired, the elder is classified as "disabled". The dichotomized ADL

[8] The ADL questions are based on the international standard of Katz' ADL index (Katz et al. 1963) adopted to the Chinese cultural/social context and carefully tested by pilot studies/interviews. Six questions about ADL functional statuses (can do it, can do it but need assistance, or cannot do it) were addressed to the oldest-old or a close family member if the elder was not able to answer. "Eating" refers to feeding oneself. "Dressing" refers to getting clothes and getting dressed, including tying shoes. "Transferring" refers to getting in and out of bed as well as in and out of a chair. "Using the toilet" refers to going to the toilet and cleaning afterward. "Bathing" refers to a sponge bath, shower, tub bath, or washing the body with a wet towel. "Continence" refers to control of urination and bowel movement.

[9] We did not use hazards models or other kinds of regression models to estimate the age–sex-specific transition probabilities among multiple (more than two) ADL statuses for two main reasons. First, the estimate of the coefficient of the age covariate in the regression model may not accurately represent the age trajectory, unless the age trajectory precisely follows linear or log-linear or another kind of analytical distribution, which is unlikely to be true. Secondly, the approach using regression models to estimate the age-specific ADL status transition probabilities presume that all sources of individual-level variations are explained by the covariates which enter the regressions. This specification is almost surely not true empirically, especially for extended periods of more than one year (Land et al. 1994: 304).

statuses of "active" and "disabled" are used in computing dynamics of ADL statuses of both survivors and deceased elders to estimate the *status-based active/disabled life expectancy with consideration of changes in ADL between the last interview and death*, using our proposed new method expressed in formulas (1) and (2).

The extent of morbidity is approximately measured by a combination of ADL status and the number of days of being bedridden before dying. Table A1 in the Appendix of Zeng et al. (2004) presents the relatively detailed frequency distributions of ADL active/disabled and days of being bedridden before dying. These and the other relevant data on the dynamics of ADL statuses of both survivors and deceased elders plus the ADL-specific mortality rates were used to estimate the *proportions of deaths with different extents of morbidity before dying* after age y among those who were ADL active or disabled at age y, using formulas (1), (2), and (6).

3.2. UNDERESTIMATION OF DISABLED LIFE EXPECTANCIES BASED ON THE CONVENTIONAL METHODS

As shown mathematically in the Section 2, conventional multi-state methods for estimating ${}_{iy}L_j(x)$, person-years lived in ADL status j between age x and $x + 1$, assumes that there are no ADL status changes between age x and time of death for those who die between age x and $x + 1$. This causes bias in estimating status-based active/disabled life expectancy. Our illustrative application presents the estimates of such biases based on a comparison between active/disabled life expectancies derived by the conventional method and by our extended method, which takes into account ADL changes between age x and death. The relative biases are sizable in most cases. For example, the expected remaining years of life spent in the disabled status for males who are active at ages 80, 90, and 100 are underestimated by 12.3%, 8.5%, and 10.3%, which are statistically significant.[10] Their active life expectancies are overestimated by 1.4%, 2.1%, and 1.4% (not statistically significant), respectively (see Table 1 in Zeng et al. 2004 for details). The relative biases in the underestimation of disabled life expectancy for the female oldest-old who are active at ages 80, 90, and 100

[10] Molla, Wagener, and Madans (2001) show how differences in estimates of Healthy Life Expectancy (HLE) between two subgroups can be tested for statistical significance by application of the conventional statistical method used for testing difference between two means. The estimated HLE is a mean of random variables assumed to be independent of each other and with normal distribution (Jagger, Hauet, and Brouard 1997). Hence, a z-score test can be constructed using the estimated HLE's of the two subgroups (the z-score is a standard normal variable estimated by transforming a nonstandard normal variable). Based on the z-score test and the relevant procedures for calculating the standard errors used by Chiang (1960) and Keyfitz (1968), Molla et al. (2001) conducted statistical tests for difference of HLE between American white males and females. Using the basic method of Molla et al. (2001) with some extension, we statistically tested the difference between the active and disabled life expectancies calculated by our method including ADL status before dying and those calculated by the conventional method assuming no changes in ADL from age x to death if a person dies in the age interval $(x, x + n)$. The extension is necessary because our study on status-based active/disabled life expectancy differs from the study by Molla et al. (2001) in which healthy life expectancies were not conditional on health status at initial ages. The procedures of the statistical test based on the method of Molla et al. (2001) with some extension are not presented in our chapter due to space limitation but are available upon request.

are 6.8%, 6.3%, and 9.2%, respectively, which are statistically significant; their active life expectancies are overestimated by 1.3%, 2.2%, and 2.5% (not statistically significant).

For the male oldest-old who were disabled at age 85, 90, and 100, their active life expectancies were underestimated by 1.5%, 6.5%, and 15.4% (mostly statistically significant) and their disabled life expectancies were overestimated by 1.1%, 2.9%, and 4.5% (not statistically significant), respectively, using the conventional method. A similar pattern of biases was also found among the female disabled oldest-old (see Table 1 in Zeng et al. 2004 for details).

The conventional method and lack of ADL data before dying have caused the percentage of remaining life in disabled status among the male and female oldest-old who are aged 80 (disregarding functional status at ages 80) to be significantly underestimated by 9.5% and 5.5%, respectively. Based on our new method and the observed data, it seems clear that among the oldest-old, the lower the age, the larger the underestimation of total disabled life expectancy (regardless of ADL status at the initial ages), due to cumulative effects (see Figure 2). The underestimation of the disabled life expectancy for male oldest-old is substantially larger than that for their female counterparts (see Figure 2). This is because the time spent in disabled status for those who were active at age x and died between age x and $x + 1$ is more likely underestimated by the conventional method than that for those who were disabled at age x and died in the age interval [see Equations (4) and (5)]; and the male oldest-old who died between age x and $x + 1$ were more likely active at age x than their female counterparts.

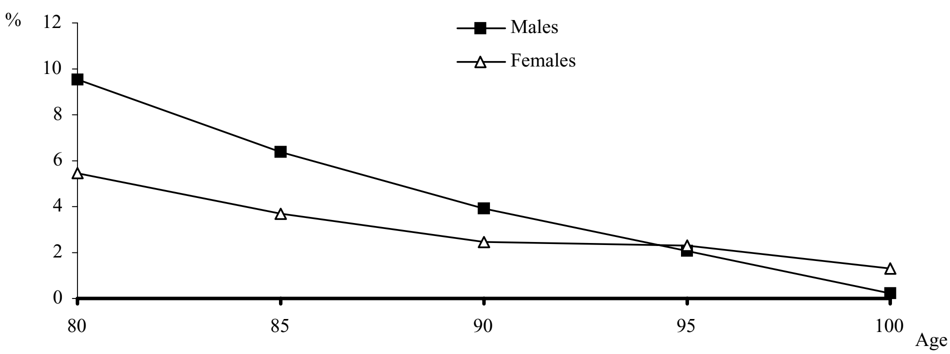


Figure 2. Age-specific distributions of the extent of underestimation of disabled life expectancies (disregarding ADL status at initial ages) based on conventional multi-state life table methods.

Using the new method and extrapolated data at ages 65–79, we also found that the underestimation of the total disabled life expectancy increases from 9.5% at age 80 to 12.0% at age 65 for males. The underestimates of the female total disabled life expectancy at ages 65, 70, and 75 are around 5.5%–6.5%, which do not differ substantially from that at age 80. The underestimates of total disabled life expectancy at ages 65, 70, and 75 for both males and females are all statistically significant at a level of $p < 0.001$. Such simulated results for ages 65–79 can be mathematically interpreted from Equation (5), but they are premature; a more in-depth understanding will have to be based on future research when the longitudinal data including ADL status of survivors and ADL status before dying of deceased interviewees are available for the younger elderly aged 65–79.

In summary, the underestimates of disabled life expectancy using the conventional method due to the unreasonable assumption of no functional status changes between age x and death are sizable and statistically significant. The extended method and data employed in this chapter improve the estimates of disabled life expectancies, as compared to the conventional method, since it removes an unreasonable assumption. The biases in estimating expected years in the active status are mostly not statistically significant; biases in estimating the overall life expectancy (i.e., active and disabled life expectancy combined, see last column of Table 1 in Zeng et al. 2004) based on the conventional method are, however, negligible due to the counteracting effects of overestimates and underestimates of the active and disabled life expectancy.

3.3. GENDER AND AGE DIFFERENTIALS OF STATUS-BASED ACTIVE/DISABLED LIFE EXPECTANCIES

Several interesting observations can be drawn from the estimates of status-based active/disabled life expectancies based on our extended method, which includes information of ADL changes between age x and death and thus corrects the underestimation of disabled life expectancy. First, the percentage of remaining life spent in the active status differs tremendously between those oldest-old who were active and those who were disabled at the initial ages. For example, a man who was active at ages 80, 90, and 100 would expect to spend about 90%, 80%, and 78% of his remaining life in the active status, in contrast to 67%, 31%, and 26% for a man who was disabled at ages 80, 90, and 100. The same pattern of extremely large differences in active/disabled life expectancies between the female oldest-old who were active and the female oldest-old who were disabled was also found (see Figure 3).

Second, gender differentials in active/disabled life expectancies among the Chinese oldest-old who were active at the initial ages are rather large with an obvious female disadvantage; such gender differentials tend to increase with advancing age. For example, the portions of remaining life in the active status of the male oldest-old who were active at ages 80, 90, and 100 were 7%, 8%, 17% higher than those of their female counterparts, respectively (see Figure 3). There is, however, no clear pattern of gender differentials in active/disabled life expectancies among the Chinese oldest-old who were disabled at the initial ages: the male and female curves cross over each other and the differences are mostly small (see Figure 3).

Third, the percentage of active life expectancy among those male and female oldest-old who were active at the initial age declines slightly from age 80 to 105, especially after age 90. The percentage of active life expectancy among the oldest-old men and women who were disabled at the initial age declines very quickly from age 80 to 90 and declines moderately from age 90 to 95. This percentage remains unchanged after age 95 among males, but continues to decline substantially after age 95 among females (see Figure 3).

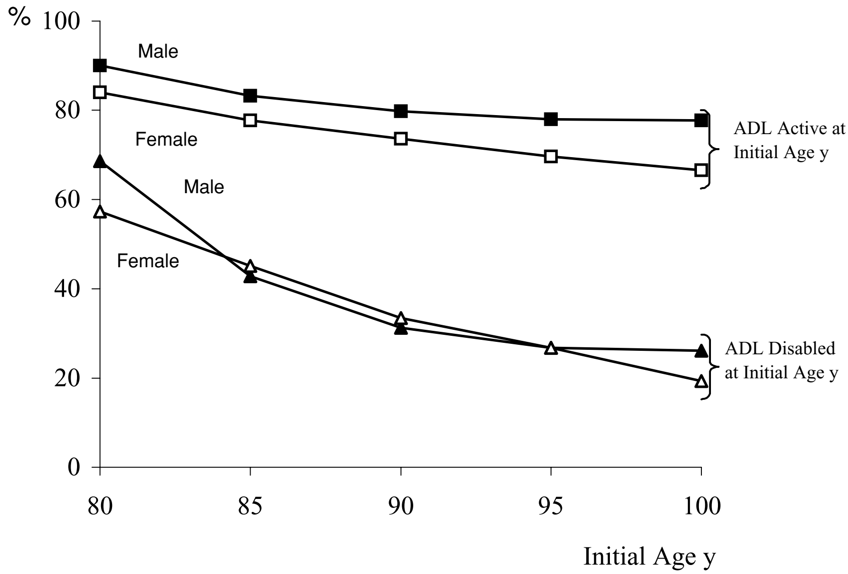


Figure 3. Percentage of remaining life spent in active status among Chinese oldest-old men and women who are active or disabled at initial ages.

3.4. LIFE TABLE PROPORTIONS OF THE EXTENT OF MORBIDITY BEFORE DYING AMONG THE OLDEST-OLD WHO ARE ACTIVE OR DISABLED AT INITIAL AGES

As discussed earlier, data on ADL status before dying among the deceased oldest-old were collected in the Chinese healthy longevity survey and employed to improve the estimation of disabled and active life expectancy—as an easily understandable summary indicator of functional capacity. We, however, believe that ADL status alone is not sufficient for measuring the extent of morbidity before dying. Therefore, we combined data on ADL status and days of being bedridden before dying to estimate the life table proportion of the extent of morbidity before dying among the oldest-old who are active or disabled at initial ages, using the formula expressed in Equation (6).

We grouped the relatively detailed data in Table A1 of the Appendix in Zeng et al. (2004) into four profiles to express the extent of morbidity before dying: slight morbidity, moderate morbidity, severe morbidity, and long-term severe morbidity. Each profile was named by its main characteristics. The *slight morbidity profile* refers to those who were ADL active and bedridden for <5 days (including not bedridden). The *moderate morbidity profile* refers to those who were ADL active and bedridden for $\geq$5 days or ADL disabled and bedridden for <5 days. *Severe morbidity* refers to those who were ADL disabled and bedridden for 5–59 days. The *long-term severe morbidity profile* refers to those who were ADL disabled and bedridden for $\geq$60 days. The cutoffs of the bedridden days in defining the four profiles are arbitrary to some extent, mainly based on common sense about morbidity and suffering plus consideration for a more or less even percentage distribution across the four profiles.

As shown in Figure 4A and B, the oldest-old who were active at the initial age had a substantially higher chance of experiencing a slight morbidity death and a substantially lower chance of experiencing a long-term severe death than those oldest-old who were disabled at the initial age. ADL status at oldest-old ages is a powerful predictor of slight morbidity or long-term severe morbidity death. In general, the male oldest-old had a substantially higher percentage of slight morbidity deaths and a substantially lower percentage of long-term severe morbidity than their female counterparts. The gender differentials with female disadvantages in slight morbidity death and long-term severe morbidity death are remarkable, statistically significant at almost every age regardless of ADL status at initial ages.[11] As compared to their male counterparts, Chinese oldest-old women not only survive in a more likely disabled status, but also suffer more before dying.

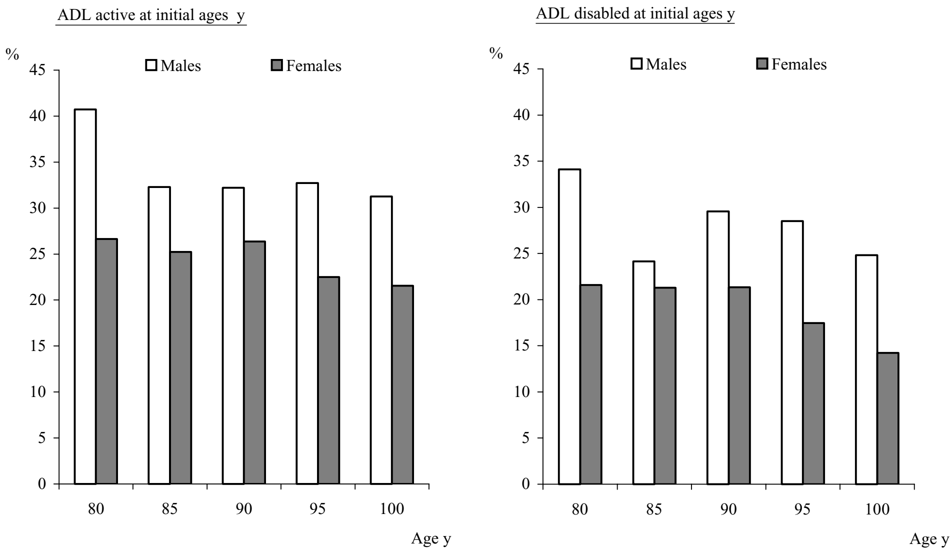
Our empirical results show that the life table proportions of slight morbidity death over initial age y do not decline with an increase of age y, except for males from over age 80 to over age 85 and females from over age 90 to over age 100 (see Figure 4A). The life table proportions of long-term severe morbidity death over initial ages y are rather stable (with few fluctuations) from over age 80 to over age 100 for both males and females regardless of ADL status at initial ages (see Figure 4B). This is generally consistent with previous similar studies and provides additional evidence concerning debates on the hypothesis about compression of morbidity. We will discuss this interesting finding in the following section.

4. Concluding Remarks

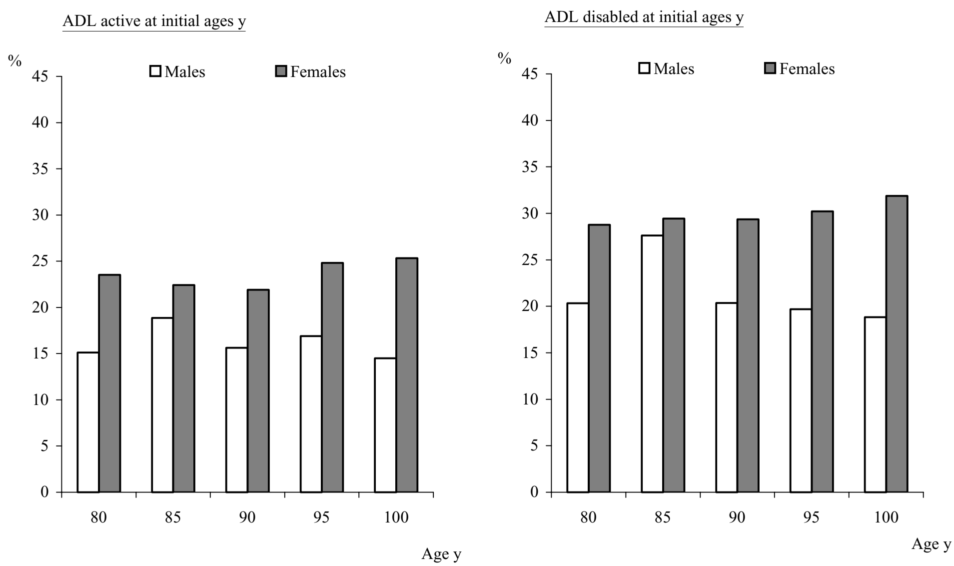
Conventional multi-state life table methods implicitly assume that there are no changes in functional status from age x to death if a person dies in the age interval $(x, x+n)$ due to a lack of data on the functional status before dying. This unreasonable assumption causes statistically significant underestimates of disabled life expectancies and overestimates of active life expectancies which are mostly not statistically significant. Our proposed new method plus the data on ADL status before dying have resulted in higher and more accurate estimates of disabled life expectancy than the conventional method would produce.

Previous research has indicated that the underestimation of disability is one of the major problems in research on population aging (Gill, Hardy, and Williams 2002; Guralnik and Ferrucci 2002). Based on monthly telephone interview data, Gill et al. (2002) demonstrated that estimates of disability based on the proportions of disabled persons (i.e., the prevalence rates) at different waves with longer intervals between waves (e.g., 1–5 years) could be substantially underestimated because multiple transitions from active to disabled between the waves are not captured (Guralnik and Ferrucci 2002). Gill et al. (2002) also noted

[11] The statistical test procedure is based on the method of Molla et al. (2001) with some extension; see note 10 for more details.



(A)



(B)

Figure 4. Life table proportions of slight morbidity before dying by ADL status at initial ages (A). Life table proportions of long-term severe morbidity before dying by ADL status at initial ages (B).

that failure to count the likely transition from active to disabled statuses before dying also markedly increases the underestimation of disability, which is consistent with our findings in this study. Gill and colleagues proposed to substantially reduce the length of the observation intervals between interviews (which will also largely increase the costs) to reduce the underestimation of disability.

This study may be considered an extension of the empirical research findings of Gill et al. (2002) in three respects. First, we have developed a new method and reported new data on functional status changes before dying to correct the bias in estimating disabled life expectancy by conventional multi-state life table methods, which unreasonably assumes no functional status changes between age x and death—Gill et al. (2002) noticed the problem but did not propose a solution to correct the underestimates of disabled life expectancy. Disabled life expectancy based on data collected through monthly interviews (as Gill et al. collected) and using conventional multi-state life table methods is also underestimated. This is because those elderly who are active at the beginning of month x and die within the month may more likely become disabled between the beginning of the month and death, but the conventional methods assume that these deceased elderly remained active until death. Second, the single-year, age-specific probabilities of transitions between the active and disabled statuses employed to construct the multi-state life table in this study are based on single-year age-specific occurrence/exposure (o/e) rates of transitions between active and disabled statuses. These o/e rates are estimated using a formula that represents the analytical relationship between the observed probability of "survival" to a status (i.e., survival to active or disabled status in 2-year interval in our illustrative application) and the instantaneous rates of exits and accessions (i.e., transitions between active and disabled statuses and death in our case) proposed by Preston and Coale (1982: 225). This counting of the multiple transitions between active and disabled statuses during the single-year age interval eliminates or at least minimizes the bias from using prevalence rates which entirely ignore the multiple events, as indicated by Gill et al. (2002). Third, Gill et al. (2002) did not present and analyze gender differentials of the underestimation of disability. Our study has found that, while the underestimation of disability is significant for both sexes, the bias for males is substantially larger than that for females, because the male oldest-old who died between age x and $x + 1$ were more likely active at age x and became disabled before dying, but the females were more likely disabled at age x and remained so until death (Guralnik et al. 1991; Liao et al. 2000).

Thus, as compared to the underestimated disabled life expectancy using conventional multi-state life tables, our extended multi-state life table method and additional data collection on ADL and morbidity status before dying is a useful contribution from a public health point of view. It also indicates practical needs for collecting data on health status before dying in future longitudinal surveys.

Based on our extended method plus the data on ADL and the number of bedridden days before dying collected in the CLHLS study, we found that, as compared with men, women not only spend a relatively larger proportion of their remaining life in the disabled status but also more likely suffer long-term severe morbidity before dying. The male oldest-old had a substantially higher chance of experiencing a slight morbidity death than did their female counterparts; the male life table proportions of experiencing long-term severe morbidity before dying are substantially lower than those of their female counterparts. The gender differentials in the extent of morbidity before dying are remarkable and statistically significant. Similarly, several previous studies (which did not follow an active/disabled life expectancy approach) found that the female elderly had a worse health status than the male elderly in the last days of life in terms of disability and cognitive function (e.g., Guralnik et al. 1991; Latwon, Moss, and Glicksman 1990; Losonczy, White, and Brock 1998; Seeman 1992). The results from our analysis also show that interviewees' ADL status (enquired in the survey) is a powerful predictor of the extent of morbidity before dying for both male and female oldest-old.

This study demonstrates that the age differences in life table proportions of the extent of morbidity before dying among the oldest-old are not substantial. The proportion of long-term severe morbidity before dying among centenarians is not substantially different from that of octogenarians and nonagenarians for both males and females. Such results suggest that a period of morbidity before death (measured by ADL and days of being bedridden in this study) of those exceptionally long-lived individuals could be compressed into a relatively short duration as compared to their largely prolonged life. Our results are consistent with some previous similar studies. For example, Guralnik et al. (1991) demonstrated that a large proportion of the total years spent in the disabled status was contributed by the years just prior to death irrespective of the age at which an older individual dies. Evert et al. (2003) found that the Escapers who have onset of a disease at 100 or higher or have not yet been diagnosed with any disease except osteroarthritis made up nearly 20% of the centenarian sample.

Our findings on the extent of morbidity before dying may support the *hypothesis of morbidity compression* initially proposed by Fries (Fires 1980; Fries and Crapo 1981), although no evidence from our study supports Fries' hypothesis about the natural limit of human life expectancy. Our study also may support the *dynamic equilibrium hypothesis* introduced by Manton (1982): slowing down in the pace of progression of morbidity leads to an increase in the prevalence of light and moderate (but not severe) disability as mortality falls among the oldest-old. Further analysis with more data to be collected is needed to determine whether Fries' hypothesis of morbidity compression or Manton's hypothesis of dynamic equilibrium is fully supported by the Chinese healthy longevity survey study. This study may reject the *hypothesis of a pandemic of disability* which says that a decrease in the fatality rate at oldest-old ages leads to a significant increase in the prevalence of morbidity (Gruenberg 1977; Kramer 1980). Given the concerns of selections and the data limitations, however, it would be injudicious to draw strong conclusions about the compression of morbidity from our available data, but the present study does provide useful information to the debate on the subject.

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CHAPTER 5. EFFECTS OF DIABETES ON HEALTHY LIFE EXPECTANCY: SHORTER LIVES WITH MORE DISABILITY FOR BOTH WOMEN AND MEN

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1. Introduction

Given the unprecedented growth of older populations throughout the world, both in absolute numbers and as percentages of their respective populations, our societies will be challenged to provide accessible health care and other services of adequate quality at acceptable costs. Although mortality rates have declined for several major fatal diseases, such as heart disease and stroke, there has been a large increase in the prevalence of many chronic diseases. Diabetes ranks among the most serious chronic diseases. Its incidence and prevalence in many developed and developing countries have risen dramatically during the past several decades (Burke et al. 1999; King, Aubert, and Herman 1998; Mokdad et al. 2000). Researchers project that diabetes will reach epidemic proportions in many developing and developed countries by 2025, estimating that the largest number of people with diabetes will reside in China, India, and the United States (King et al. 1998). Among older people, health care utilization and costs are notably higher for those with diabetes than for those without the disease (Olsson et al. 1994). Even at younger ages, when the cumulative burden of diabetes has yet to take its full toll on health and functional ability, people with diabetes use substantially more hospital, outpatient, physician, and ancillary health care services (Laditka, Mastanduno, and Laditka 2001). Individuals with diabetes have a shorter total life expectancy (TLE) than those without the disease (Gu, Cowie, and Harris 1998). Yet active life expectancy researchers have only recently begun to specifically examine life course effects of diabetes (Bélanger et al. 2002; Jagger et al. 2003).

The purpose of our study is to develop an expanded model of healthy life expectancy. We identify differences in life expectancy for people with and without diabetes. We also identify differences in the number of years that individuals with and without diabetes can expect to live either with or without disability. The number of years with disability is commonly called inactive life expectancy, or disabled life expectancy. The number of years

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without disability is commonly called active life expectancy, or healthy life expectancy. Diabetes was selected for study because of its high and rapidly growing prevalence, its serious impacts on health throughout the life course, and its amenability to prevention and control. Importantly, recent large-scale controlled clinical research has demonstrated that the incidence of diabetes can be dramatically reduced at any stage in the life course, with either relatively modest lifestyle changes or pharmacotherapy (National Institute of Diabetes and Digestive and Kidney Diseases 2001). To allow sound policy making, it is especially useful for governments to understand the full impacts of diabetes on health and life expectancy. It is also important that individuals, presented with the possibility of themselves delaying or preventing the onset of diabetes through personal action, understand the considerable risks of declining function and shorter life that can be reduced by modest sustained individual effort. With better knowledge of the human costs of this disease, policy makers and individuals alike will be in a better position to weigh the relative costs and benefits of the lifestyle changes or treatments necessary to reduce the likelihood of diabetes onset (Laditka and Laditka 2000).

We develop estimates of total, active, and inactive life expectancy for a nationally representative sample of older women and men in the United States, using data from the 1984–1990 Longitudinal Study of Aging (LSOA). We model functional status transitions as discrete-time Markov chains, and use microsimulation to calculate summary indicators of health expectancy (Laditka and Wolf 1998). Estimates are calculated separately for groups defined by sex, race, education, and the presence or absence of diabetes at age 70, accounting for the initial distribution of disability in each group. Our approach allows us to identify the differential effects of diabetes among these groups over the course of older life. In addition, researchers have highlighted the usefulness of identifying complete distributions of life expectancies, and of analyzing the within- and between-group variability of expectancy estimates (Laditka and Hayward 2003; Wolf and Laditka 1997; Wolf, Laditka, and Laditka 2002). By within-group differences, we mean differences associated with the presence or absence of diabetes within a group of individuals with the same general characteristics, such as gender, race, and education. By between-group differences, we refer to differences among individuals in various groups, such as life expectancy differences among those with diabetes, comparing women with more education to men with more education. We contribute to the body of active life expectancy research by investigating full distributions of total, active, and inactive life expectancy, and by showing how these indicators vary both within and between population groups, with special emphasis on groups defined by the presence or absence of diabetes.

2. Background

2.1. DISEASE-SPECIFIC ACTIVE LIFE EXPECTANCY RESEARCH

A growing number of studies have examined cause-specific mortality and/or morbidity rates, and their effects on active life expectancy. Cause-specific mortality and morbidity calculations have been made using data from Australia, Canada, the Netherlands, the United Kingdom, and the United States (Robine, Romieu, and Cambois 1997). Bone, Bebbington, and Nicolaas (1998) reviewed findings from Australia, Britain, and the Netherlands. They focused on three major disease categories, cancer, circulatory disease, and musculoskeletal conditions, finding that eliminating circulatory diseases had the largest positive effect on longevity. Eliminating chronic nonfatal diseases, such as musculoskeletal conditions, had almost no effect on life expectancy, but brought the largest gain in the proportion of active life for most people studied (Bone et al. 1998). Hayward, Crimmins, and Saito (1998), using data from the United States, estimated models in which several major causes of death were separately eliminated for women and men, finding substantial gender differences in disease-specific effects. For both women and men, eliminating heart disease brought the greatest life expectancy gains. For men, additional years from the elimination of heart disease were primarily active ones. For women, however, years gained were inactive.

Two recent studies of disease-specific effects examined the influence of diabetes on healthy life expectancy. With data from Canada, Bélanger et al. (2002) used multi-state life table methods to examine effects of several chronic diseases and other risk factors on healthy life expectancy for women and men aged 45 and older. Risk factors examined included education, income, smoking, body mass index, physical inactivity, arthritis, diabetes, and cancer. Bélanger et al. found that diabetes presented the greatest threat to health and longevity of all diseases and lifestyle risks studied, reducing life expectancy for women even more than cancer or smoking, two other factors with large impacts on mortality. Bélanger et al. suggested that this effect may in part result from associations between diabetes and heart disease. The impact of diabetes on life expectancy was less for men than for women, though still substantial. For men, only cancer, smoking, and low education were greater risk factors for reduced life expectancy. Diabetes was also found to be responsible for large reductions in disability-free life expectancy. The reduction for women was almost 15 years of disability-free life, while men with diabetes lost 11.5 years. Among individuals with diabetes, the proportion of life expected to be lived free of disability was only 33% for women, 41% for men. These proportions compare to 59.9% for the total population of women, 67.5% for the total population of men. Moreover, for both women and men, the impact of diabetes on the proportion of life expected to be lived free of disability was greater than the impact of any other disease or lifestyle factor.

Crimmins, Kim, and Hagedorn (2002) provide another perspective on disease-specific effects, showing how disease factors combine to yield healthy and diseased life expectancy. Using the Sullivan method, Crimmins et al. found that, beginning at birth, the expected number of years to be lived with diabetes is 3.4 for women, 2.7 for men. The expected number of years to be lived with diabetes beginning at age 65 is 2.1 for women, 1.7 for men. These expected years to be lived with diabetes are averages across entire populations; the number of years lived with diabetes for those who incur the disease is many more than these population averages.

Our study incorporates disease-specific information about diabetes into models predicting estimates of total, active, and inactive life expectancy for populations defined, in part, by the presence (or absence) of diabetes at age 70. The estimates of total, active, and inactive life for people with and without diabetes provide an additional measure of how disease-specific differences in health accumulate over the older life course. Information about the burden of chronic disease is useful for health planners in targeting resources for disease research, and for estimating health care resource needs. In addition, our study provides information that may help policy makers perform cost–benefit analyses for diabetes treatment and prevention.

2.2. DIABETES-RELATED DISABILITY PATHWAYS

Diabetes can lead to impairment and disability through several pathology processes associated with long-term complications of the disease. These processes include peripheral vascular disease, coronary artery disease, cerebrovascular disease, vision disorders, and kidney disease. Peripheral vascular disease is characterized by decreased arterial perfusion of the lower extremities, and is also often referred to as lower extremity arterial disease (LEAD). It has been well documented that the incidence of LEAD is significantly higher among individuals with diabetes than it is among those without the disease (Palumbo and Melton 2001). Frequent complications of LEAD are the development of infections in the lower extremities and foot ulcers. Foot ulcers are common among people with diabetes, affecting about 15% of those with the disease at some time in their lives (Reiber, Boyko, and Smith 2001). Complications due to LEAD, such as foot ulcers that become infected, are a common cause of lower extremity amputations (LEA). An analysis based on 1989–1991 US hospital discharge data with a LEA, for example, revealed that about half of the discharges included a comorbidity of diabetes (Reiber et al. 2001). LEA rates increase with age, and are higher for men and for blacks (Reiber et al. 2001).

Coronary heart disease is the most common cause of death for people with diabetes (Wingard and Barrett-Connor 2001). Heart disease occurs earlier in life for individuals with diabetes. In contrast to generally lower rates of heart disease for premenopausal women than for men, women with diabetes are as likely to have heart disease as men. Heart disease is more likely to be fatal for individuals with diabetes (Wingard and Barrett-Connor 2001). Consistent with substantially higher incidence of heart disease, the prevalence of congestive heart failure is twice as high among individuals with diabetes (Wingard and Barrett-Connor 2001); congestive heart disease is a major cause of mortality and disability for older people (Rich 1997). Diabetes is also clearly linked to significantly higher rates of stroke, particularly for blacks (Kuller 2001). Further, after suffering a stroke, individuals with diabetes have a notably worse prognosis than those without the disease (Kuller 2001). Although deaths from strokes have decreased dramatically in the United States and many other countries since the early 1990s, the incidence of stroke has increased—although some of this increase may be accounted for by improved diagnosis (Kuller 2001). Diabetes has also been associated with increased risks of both Alzheimer's disease and vascular dementia (Leibson et al. 1997; Ott et al. 1999). In the area of vision loss, diabetic retinopathy, caused by hyperglycemia, is the major cause of new cases of blindness in the United States (Harris 2001). Cataracts and glaucoma are also long-term complications of diabetes that can lead to vision loss (Harris 2001). As for kidney disease, diabetes accounts for more than 35% of end-stage renal disease (ESRD). Among those requiring renal dialysis and kidney transplants, individuals with diabetes make up the fastest growing group (Nelson et al. 2001).

Collectively, the major pathologies just described, which characterize long-term complications of diabetes, often result in lower limb amputations, heart disease, stroke, dementia, poor vision, and ESRD, combining to produce significantly higher disability rates for individuals with diabetes than those without the disease (Songer 2001). A number of studies have shown that disability rates for people with diabetes are significantly higher than those for people without the disease (Harris 2001). Results from the 1989 National Health Interview Survey (NHIS), for example, show that activity limitations are two to three times more common for people with diabetes (Songer 2001). The same study also found diabetes to be the 11th most commonly cited main cause of activity limitation, such as difficulty performing an activity of daily living (ADL) (Songer 2001). Researchers have identified several individual characteristics of people with diabetes that are associated with significantly higher rates of disability: being older, being female, and being black (Songer 2001). But results show that the strongest disability risk factor associated with diabetes is the presence of a long-term complication of the disease (e.g., retinopathy, stroke, amputation, and heart problems) (Songer 2001). These findings reinforce the strong causal link between the underlying pathology of diabetes and disability.

3. Methods

3.1. DATA

Our study uses data from the 1984, 1986, 1988, and 1990 waves of the LSOA. One of the primary objectives of the LSOA was to evaluate changes in functional ability among older individuals in the United States over time. The baseline 1984 LSOA survey was administered to 7527 non-institutionalized individuals aged 70 or older. The survey was designed to provide nationally representative estimates of such individuals. Those who subsequently entered nursing homes were included in the follow-up interviews. Kovar, Fitti, and Chyba (1992) provide details about the LSOA. The sample used in this study is restricted to LSOA respondents whose records contained the information required for our modeling. Among the observations omitted from this analysis because of missing data, losses occurred disproportionately among nonwhites. For this reason, we have greater confidence in our findings for whites than for nonwhites. In our analysis, the sample of women, $n = 4281$, provided 9489 instances of functional status transition, from which parameters representing transition probabilities were calculated. Our sample of men, $n = 2640$, provided 5551 instances of functional status transition. Details of the LSOA sample selection criteria are provided by Laditka and Wolf (1998).

Consistent with previous studies of active life expectancy, an individual's functional status assignment in this study reflects the presence or absence of impairment in the following ADLs: bathing, eating, dressing, transferring, and using the toilet (Katz et al. 1963). Individuals were defined as impaired if they reported any difficulty performing one or more of these activities, or if they reported receiving any help carrying out the activity. Our models include several covariates representing other factors that have been shown by previous research to be associated with functional status dynamics: age, race, and education (Hayward and Heron 1999; Laditka and Laditka 2002; Land, Guralnik, and Blazer 1994). Consistent with prior research showing substantial gender differences in mortality and morbidity (Crimmins, Hayward, and Saito 1996), separate models were estimated for women and men. We also included a covariate indicating the presence or absence of diabetes at the age 70 baseline.

Unweighted and weighted sample means and proportions were similar for all variables used in the analysis; unweighted results are presented. Age is measured in years. The mean age of the women in the LSOA sample used for this analysis was 77.1 (SD = 5.6). Mean age of the men in the sample was 76.3 (SD = 5.3). Nonwhites were 8.6% of the unweighted sample of women, of which 90% were blacks. Nonwhites were 7.7% of the sample of men, of which 84.2% were blacks. Low Education, a dichotomous variable, identifies individuals who completed less than 12 years of school (54.7% of women; 59% of men). The presence or absence of diabetes was identified in the 1984 baseline survey with the question: "During the past 12 months, did you have diabetes?" Of women in the sample, 10.1% responded affirmatively to this question, of men, 9.7% did so.

3.2. ANALYTICAL APPROACH

We used a multinomial logistic regression model in which the dependent variable is multichotomous, representing three states: unimpaired (having no ADL limitations), impaired (having one to five ADL limitations), and dead. Previous research provides strong evidence that impairment processes differ notably between whites and nonwhites; in this instance, however, likelihood-ratio tests did not confirm statistically significantly different model parameters by race. Thus, we estimated a single model each for women and men, incorporating nonwhite as a covariate in each of the models. The multinomial estimation procedure produced parameters of functional status transition. In addition to four constants, one corresponding to each transition type, 16 parameters were estimated. One parameter was estimated for each independent variable (age, race, education, and baseline diabetes status) for each of four functional status transitions, such as unimpaired to impaired. Coefficients corresponding to the two transitions to being unimpaired (i.e., the transitions from unimpaired to unimpaired, and from impaired to unimpaired) were normalized to zero. Probabilities for all possible transitions in the three-state model were derived from the estimated coefficients. Thus, from the lived experience of individuals surveyed in the LSOA, these procedures calculated the probability of each possible transition in the model. Although respondents to the LSOA were surveyed over intervals of years, these procedures calculated the probability of each possible transition from one month to the next, providing the basis for the simulation. These procedures were conducted using specialized software designed for this purpose written in the SAS IML™ programing language.

With the parameters of the multinomial logistic regression models, we used microsimulation methods to produce full distributions of TLE, active life expectancy, and inactive life expectancy, and to calculate summary indices of these distributions. The parameters of functional status transition provided the basis for simulating each individual's functional status and survivorship, month by month, from age 70 until death. For example, for an individual with an ADL status of unimpaired in the first month of the simulation, the microsimulation procedure used the parameters of functional status to generate three transition probabilities. Each probability corresponds to a possible functional status state the following month (unimpaired, impaired, or dead) given the individual's sex, age, race, diabetes status at baseline, and his or her functional status in the current month. These three monthly transition probabilities were mapped into subsets of the 0–1 interval. Then a computer-generated random number was drawn from the 0,1 distribution. Based on the subset of the 0–1 interval into which the random number fell, a value for the individual's functional status for the next month was assigned. For each individual, this process was repeated for each successive month until the monthly transition probabilities, interacting with the stochastic process, produced a transition to death. These microsimulations generated sets of functional status histories for older women and men.

For this analysis, individual monthly functional status histories were created for several simulated populations, each of 100,000 individuals. One such population was simulated for each of eight groups of women and eight groups of men, defined by race category, educational attainment level, and baseline diabetes status. The profile of disability characterizing the starting population for each microsimulation matched the disability profile of actual populations at ages 70–75 living in the community with the same combination of sex, race, education, and diabetes status. Actual population profiles were identified through weighted analysis of the 1984 LSOA. Thus, for example, the older life course experience of disability was simulated for two populations of 100,000 white women with a low level of education. One of these simulations identified life and health expectancies for a population *without* diabetes. In this instance 14.9% of the simulated population began the simulation disabled, matching the weighted proportion of the corresponding actual population identified from the LSOA. The second of these two simulations was for a population *with* diabetes at baseline, 24% of which began the simulation disabled. Analogous simulated populations were created for each group of women and men.

The data produced by the microsimulation procedure are treated as longitudinal survey data, analyzed using standard statistical methods. For example, TLE within the simulated population is simply the average age at death. We investigate the degree of variability in the length of active and inactive life by producing a frequency distribution of the number of years spent in each functional status (Wolf and Laditka 1997; Wolf, Laditka and Laditka 2002). We then summarize this variability using conventional summary statistics, such as histograms and standard deviations. Details about the model of functional status, the procedure for estimating transition probabilities, and the microsimulation procedure used in this study have been published (Laditka and Laditka 2001; Laditka and Wolf 1998; Wolf et al. 2002).

4. Results

4.1. MODEL OF FUNCTIONAL STATUS TRANSITIONS

Table 1 shows the estimated coefficients for our model of functional status transitions for women and men. Each block of entries displays coefficients associated with covariates in our model, coefficients which together determine probabilities of transitioning from an origin status to a destination status. Origin statuses are U = unimpaired and I = impaired. Destination statuses include U, I, and D = dead. For each possible transition, Table 1 presents a constant value and four coefficients each representing effects of age, race, education, and diabetes. The estimates for women are shown in the first data column of Table 1. For women, all of the coefficients for the transition from unimpaired to impaired are positively signed and highly statistically significant ($p < 0.001$), indicating that women who are older, nonwhite, have less education, or have diabetes are more likely to become

Table 1. Parameters of multinomial logit models of functional status transitions.

	Estimate (SE)[a]	
	Women	**Men**
Origin = U; Destination = I[b]		
Constant	−5.829 (0.089)***	−5.647 (0.125)***
Age	0.085 (0.006)***	0.066 (0.009)***
Nonwhite	0.374 (0.104)***	0.204 (0.143)
Low education	0.255 (0.065)***	0.269 (0.096)**
Diabetes	0.561 (0.105)***	0.588 (0.140)***
Origin = U; Destination = D[b]		
Constant	−6.719 (0.139)***	−5.915 (0.120)***
Age	0.069 (0.010)***	0.049 (0.009)***
Nonwhite	−0.227 (0.252)	−0.283 (0.185)
Low education	−0.070 (0.108)	0.364 (0.097)***
Diabetes	0.668 (0.172)***	0.390 (0.152)**
Origin = I; Destination = I[b]		
Constant	3.780 (0.142)***	3.411 (0.200)***
Age	0.033 (0.009)***	0.050 (0.014)***
Nonwhite	0.142 (0.172)	0.156 (0.278)
Low education	−0.004 (0.102)	0.113 (0.158)
Diabetes	0.099 (0.161)	0.182 (0.250)
Origin = I; Destination = D[b]		
Constant	−1.521 (0.186)***	−1.197 (0.243)***
Age	0.088 (0.011)***	0.100 (0.016)***
Nonwhite	0.249 (0.214)	0.071 (0.330)
Low education	0.068 (0.132)	−0.026 (0.191)
Diabetes	0.359 (0.195)	0.415 (0.290)
n, respondents	4281	2640
n, functional status transitions	9489	5551

Source: 1984–1990 Longitudinal Study of Aging.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.
[a]SE = standard error.
[b]U = unimpaired; I = impaired; D = dead.

impaired than those who are, respectively, younger, white, more highly educated, or without diabetes. For the transition from unimpaired to dead, the coefficients for age and diabetes are positively signed and highly statistically significant, indicating that both increasing age and having diabetes increase the likelihood of dying in a given month from the unimpaired state. Only age and the constant term are statistically significant for remaining impaired from one month to the next, or for dying from an impaired state in the same interval. Positive signs on most remaining coefficients for these transitions are consistent with greater risks for remaining impaired or dying from the impaired state for nonwhites, those with low education, and those with diabetes. A similar pattern of coefficient signs, magnitudes, and statistical significance is depicted in the second data column of Table 1, which shows coefficients and standard errors corresponding to monthly transition probabilities for men.

4.2. OLDER LIFE CYCLE PATTERNS OF ACTIVE LIFE EXPECTANCY

Tables 2 and 3 and Figures 1 and 2 illustrate the main results of our microsimulation analyses, all of which begin with simulated populations at age 70 with fixed characteristics of race category, educational attainment level, and diabetes status.

Table 2 shows average years of remaining life (TLE), average remaining years of unimpaired life (unimpaired life expectancy, ULE), and average remaining years of impaired life (impaired life expectancy or ILE), all at age 70 for the eight groups of women and eight groups of men studied. Table 2 also shows the standard deviations of these averages, quantifying within-group differences. Within each group defined by sex, race, and education, there are notable differences between those with diabetes and those without the disease. White women with high education without diabetes live over 4 years longer than white women with high education with diabetes. Further, as indicated by the Table 2 column headed "ULE % of TLE", of these two groups, those without diabetes live a substantially greater percentage (72%) of their older lives in good health than those with the disease (61%). Analogous findings are true for all pairings of women.

In groups paired across race categories with the same educational attainment level and diabetes status, TLE for white women exceeds that of nonwhite women. Nonwhite women can also expect to spend a smaller proportion of their lives unimpaired than white women. For example, a nonwhite woman with low education without diabetes can expect to live about 60% of her remaining life unimpaired; the analogous figure for a white woman with the same characteristics is 68%. More education is generally associated with a longer life and a smaller proportion of impaired life for both white and nonwhite women and for both diabetes status groups, but this protective effect of education is small. Importantly, the presence (or absence) of diabetes exerts a much stronger effect on total and healthy life expectancy than either race or education.

Averages (and standard deviations) of remaining years of TLE, ULE, and ILE for men are also reported in Table 2. TLE is, as expected, substantially shorter for men than for women in most groups defined by race category, education, and diabetes status. White men with high education without diabetes at age 70, for example, have a TLE at age 70 of 10.5 years. This expectancy for the corresponding group of women is 13.9 years, 32% longer. For men, as for women, the presence (or absence) of diabetes exerts a powerful effect within all paired subgroups. White men with low education without diabetes live 2.3 years longer than men with the same characteristics with diabetes; this amounts to a 35% greater TLE at age 70. Those without diabetes also live a substantially larger percentage of their lives without impairment than those with diabetes. White men with low education without diabetes at baseline live about 75% of their lives after age 70 without impairment. The corresponding group of men with diabetes live only about 65% of their remaining lives without impairment. Analogous findings appear in all paired groups of men. Education has a more powerful effect for men than for women for both whites and nonwhites. Among nonwhite men without diabetes, for example, those with more

Table 2. Average remaining years of unimpaired, impaired, and total life for women and men, by race, education, and diabetes status at age 70.

	Women						Men					
Group	Age 70 imp[a]	TLE (SD)	ULE (SD)	ULE % of TLE	ILE (SD)	ILE % of TLE	Age 70 imp[a]	TLE (SD)	ULE (SD)	ULE % of TLE	ILE (SD)	ILE % of TLE
White, high education												
Without diabetes	9.7	13.9 (7.8)	10.0 (6.2)	72.1	3.9 (4.3)	27.9	8.6	10.5 (6.9)	8.5 (6.1)	81.0	2.0 (2.7)	19.1
With diabetes	28.6	9.8 (6.5)	6.0 (4.8)	60.9	3.8 (4.1)	39.2	8.6[b]	7.7 (5.4)	5.7 (4.5)	73.7	2.0 (2.6)	26.5
White, low education												
Without diabetes	14.9	13.2 (7.5)	9.0 (5.8)	67.9	4.4 (4.4)	33.0	10.4	8.9 (6.3)	6.7 (5.1)	74.9	2.3 (3.1)	25.3
With diabetes	24.0	9.5 (6.2)	5.5 (4.3)	58.2	4.0 (4.1)	42.0	15.1	6.6 (5.0)	4.3 (3.7)	64.8	2.4 (3.0)	35.5
Nonwhite, high education												
Without diabetes	9.7	12.3 (6.9)	7.6 (5.0)	61.9	4.7 (4.4)	38.2	8.5[c]	11.1 (7.0)	8.4 (6.0)	75.9	2.7 (3.2)	24.3
With diabetes	24.9	8.9 (5.8)	4.5 (3.7)	50.6	4.4 (4.1)	49.8	9.2[c]	8.2 (5.5)	5.5 (4.3)	67.6	2.7 (3.0)	32.7
Nonwhite, low education												
Without diabetes	17.2	12.2 (7.0)	7.3 (5.1)	60.3	4.9 (4.5)	39.9	9.8[c]	9.8 (6.5)	6.8 (5.0)	69.1	3.1 (3.7)	31.2
With diabetes	22.5	8.9 (5.7)	4.5 (3.7)	51.1	4.4 (4.1)	49.2	15.6[c]	7.3 (5.2)	4.2 (3.6)	57.8	3.1 (3.5)	42.5

Source: 1984–1990 Longitudinal Study of Aging.

TLE = total life expectancy; ULE = unimpaired life expectancy; ILE = impaired life expectancy; SD = standard deviation. ULE and ILE may not add to TLE due to rounding.

[a] Weighted percentage of subgroup at ages 70–75 impaired in 1984 LSOA (percentage entering microsimulation impaired).

[b] Unweighted LSOA sample size = 64.

[c] Due to small LSOA samples, assigned weighted impairment of all men at the same education level, regardless of race.

Table 3. Differences in life expectancies for women and men at age 70, by expectancy type, years, and percentage.

	Difference in expectancy by type					
	TLE		ULE		ILE	
	Years	%	Years	%	Years	%
Difference between individuals without diabetes and with diabetes						
Women						
White, high education	−4.1	−29.5	−4.0	−40.0	−0.1	−2.6
White, low education	−3.7	−28.0	−3.5	−38.9	−0.4	−9.1
Nonwhite, high education	−3.4	−27.6	−3.1	−40.8	−0.3	−6.4
Nonwhite, low education	−3.3	−27.0	−2.8	−38.4	−0.5	−10.2
Men						
White, high education	−2.8	−26.7	−2.8	−32.9	0	0
White, low education	−2.3	−25.8	−2.4	−35.8	0.1	4.3
Nonwhite, high education	−2.9	−26.1	−2.9	−34.5	0	0
Nonwhite, low education	−2.5	−25.5	−2.6	−38.2	0	0
Difference between women and men						
White						
High education, without diabetes	−3.4	−24.5	−1.5	−15.0	−1.9	−48.7
High education, with diabetes	−2.1	−21.4	−0.3	−5.0	−1.8	−47.4
Low education, without diabetes	−4.3	−32.6	−2.3	−25.6	−2.1	−47.7
Low education, with diabetes	−2.9	−30.5	−1.2	−21.8	−1.6	−40.0
Nonwhite						
High education, without diabetes	−1.2	−9.8	0.8	10.5	−2.0	−42.6
High education, with diabetes	−0.7	−7.9	1.0	22.2	−1.7	−38.6
Low education, without diabetes	−2.4	−19.7	−0.5	−6.8	−1.8	−36.7
Low education, with diabetes	−1.6	−18.0	1.0	22.2	−1.3	−29.5

Source: 1984–1990 Longitudinal Study of Aging.
TLE = total life expectancy; ULE = unimpaired life expectancy; ILE = impaired life expectancy; SD = standard deviation; ULE difference and ILE difference may not sum to TLE difference due to rounding.

education live longer, healthier lives than those with less education. Nonwhite men with high education with diabetes can expect to spend about 68% of their remaining years without impairment. The corresponding group of men with low education can expect to spend only about 58% of their remaining years without impairment. The rightmost data column for both women and men shows the percentage of total remaining life at age 70 spent impaired. Consistent with fewer years of chronic disease and disability, men in every group have a lower percentage of older life spent impaired than women in corresponding groups.

Also shown in Table 2, in the first data column for both women and men, is the proportion of both the actual and simulated populations disabled in at least one ADL at baseline. Among white highly educated women, for example, 9.7% of those without diabetes have at least one such impairment at baseline, compared with 28.6% of the same group with diabetes.

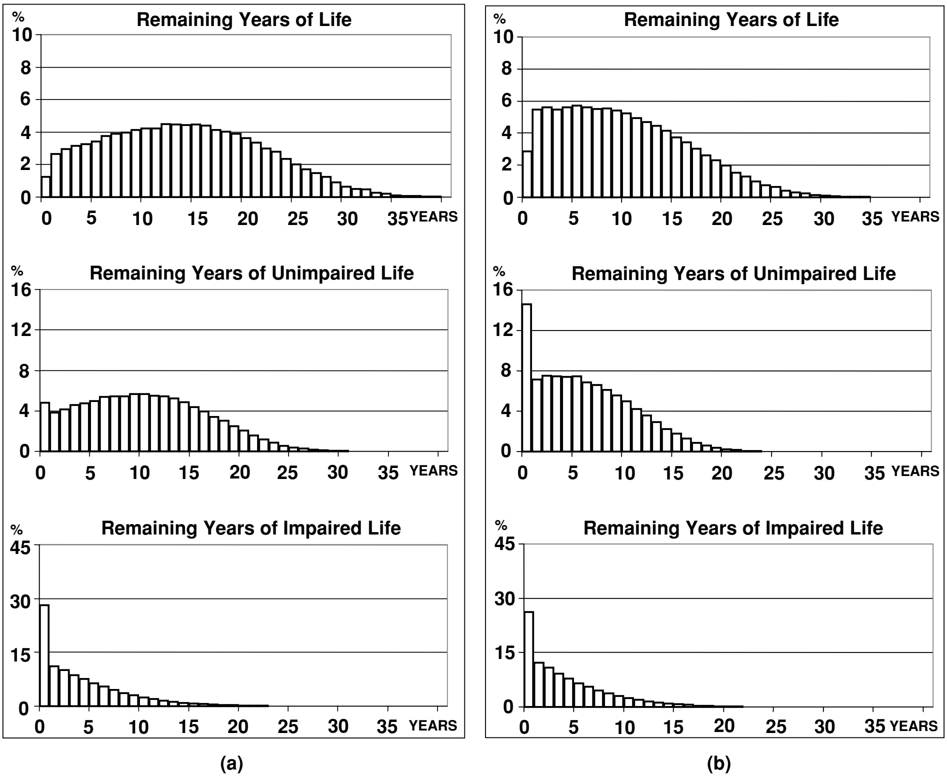

Figure 1. (a) Remaining years of unimpaired, impaired, and total life. White women, high education, without diabetes at age 70, $n = 100{,}000$. (b) Remaining years of unimpaired, impaired, and total life. White women, high education, with diabetes at age 70, $n = 100{,}000$.

It should be noted that the life expectancy measures calculated from the microsimulations and depicted in Table 2 are not highly sensitive to even substantially altered baseline disability profiles. Thus, for example, the baseline proportions of the actual and simulated populations of white men with high education with impairment are equal for both those with diabetes and those without the disease, at 8.6%. (In this instance, Table 2 notes that the proportion of those with diabetes computed from the LSOA relies on a relatively small unweighted sample size of 64.) Nonetheless, the disability dynamics represented by the Table 1 parameters of functional status transition, which are the basis of microsimulation, produce substantially different Table 2 mean estimates of TLE, ULE, and ILE for those with and without diabetes in this group pair. We conducted additional analyses of the sensitivity of other Table 2 results to initial conditions (not shown). These analyses confirmed that the estimates shown in Table 2 are not highly sensitive to altered initial disability distributions.

Turning to within-group differences in life expectancy, we focus on the standard deviations of years remaining in total, unimpaired and impaired life displayed in Table 2. For all

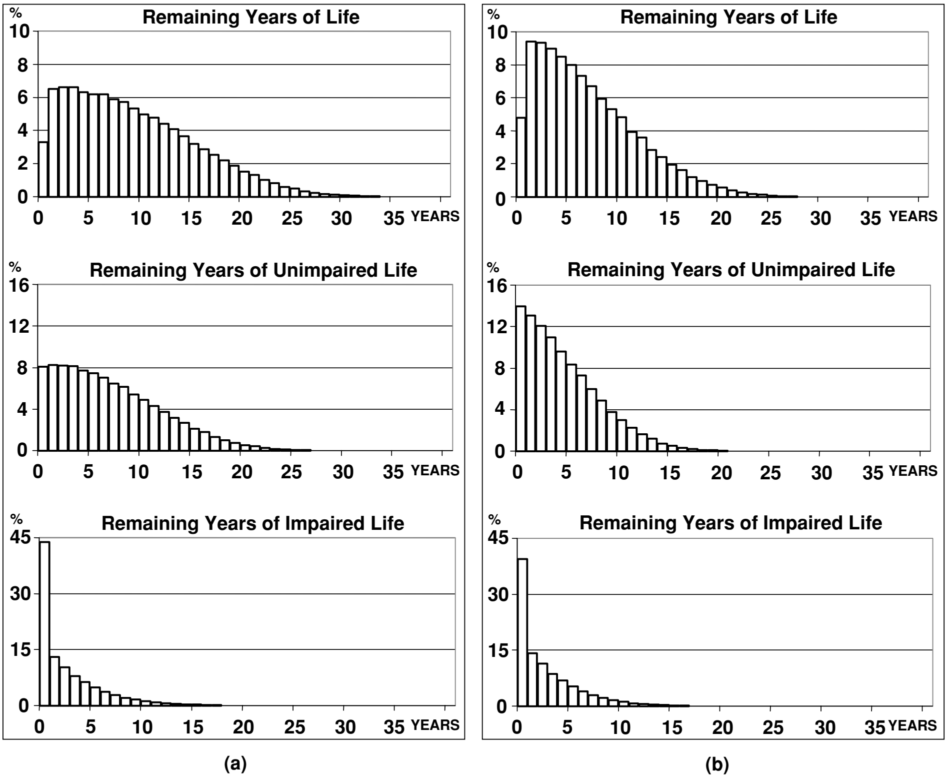

Figure 2. (a) Remaining years of unimpaired, impaired, and total life. White men, low education, without diabetes at age 70, $n = 100{,}000$. (b) Remaining years of unimpaired, impaired, and total life. White men, low education, with diabetes at age 70, $n = 100{,}000$.

groups, the magnitude of standard deviation relative to the mean of TLE and ULE, which indicates relative variability, is considerable. For all groups, the relative variability is larger for impaired life than for total life or unimpaired life. In all instances for men, and in most instances for women, the standard deviation of impaired life is greater than its mean. These results indicate that variability in remaining years of total, active and inactive life is quantitatively substantial.

Table 3 focuses more specifically on differences in life expectancies between groups, with particular regard to differences between populations with and without diabetes at baseline, and differences between women and men. The top panel of Table 3 focuses on differences between those without and with diabetes at baseline. Of particular interest are the consistently large reductions in TLE associated with diabetes for both women and men, where even the smallest TLE percentage reduction associated with diabetes is over 25. The average reduction in life expectancy across groups of women is 28.1%. The average reduction for men is 26.8%. Even more dramatic are the reduced ULEs associated with diabetes for both women and men. For women, the average reduction in ULE across groups is 39.5% (average reduction results are not shown in Table 3). For men, the average reduction is 35.4%.

Table 3 also quantifies differences in total, active, and inactive life expectancy between women and men, depicted in the lower panel. In all groups defined by race category, education, and baseline diabetes status, men at age 70 have substantially lower TLE, and also a substantially smaller proportion of remaining life spent impaired (ILE). Differences between women and men in TLE and ILE are notably less pronounced, though still substantial, for nonwhites than for whites. Within each group defined by race and education, such differences are also generally less pronounced for those with diabetes than for those without the disease. Among whites with high education, for example, the TLE difference between women and men without diabetes is −24.5%, while the corresponding difference between women and men with diabetes is −21.4%.

Figures 1 and 2 present frequency distributions for remaining years of life, remaining years of unimpaired life, and remaining years of impaired life, for four of the simulated populations—one population of women without diabetes and one with the disease (Figures 1a and b), and a similar pair of male populations (Figures 2a and b). These frequency distributions illustrate both within-group variability in these measures, and the between-group impacts of diabetes. We focus our discussion primarily on differences between groups with the same characteristics of sex, race, and education, but differentiated by the presence or absence of diabetes at baseline.

Our microsimulation calculated that women represented by Figure 1a, white women with a high level of education *without* diabetes at baseline, have an average life expectancy at age 70 of 13.9 years. They can expect to live 10.0 of these years without impairment, the remainder with impairment. The histograms of Figure 1a show the variability around these point estimates, as well as the distribution of this variability. For remaining years of life and remaining years of unimpaired life, the histograms of Figure 1a show relatively normal distributions. The histogram for remaining years of impaired life (lower panel) is highly skewed, with a substantial percentage (28.1) of women simulated to have zero full years of impairment, and only small percentages living many additional years impaired. Thus, the within-group differences illustrated by these figures show that the average number of remaining years and years spent unimpaired, and particularly the average number of years spent impaired, are poor descriptions of "typical" life experiences for older women with these characteristics.

Figure 1b shows distributions of the total, active, and inactive life expectancy for a corresponding simulated population of women *with* diabetes at baseline. The distribution of total remaining years is substantially skewed toward fewer remaining years. Approximately 24.8% of the simulated population without baseline diabetes illustrated in Figure 1a lived 20 or more years after age 70, for example, compared with only about 8.6% of the Figure 1b population with baseline diabetes. The middle panels of Figures 1a and b tell a similar story. A total of 24.4% of the population without diabetes (Figure 1a) lived 15 or more years without impairment, compared with only 5.4% of the population with the disease (Figure 1b). The lower panels of Figures 1a and b illustrate the relationship between diabetes and ILE. Of those without the disease in this category of women with high educational attainment, 28.1% can expect *no* full years of disability beginning at age 70. Of those with diabetes, 26.1% can expect no full years of disability. In general, however, the distribution of ILE across the two represented populations is quite similar—as were the estimates of ILE for these groups presented in Table 2 (3.9 years without diabetes, 3.8 years with diabetes). Thus, the more dramatic impact of diabetes does not appear in the absolute ILE estimates, nor even substantially in the distributions of impaired life in each of these populations, but rather in the proportion of those estimates and distributions to the corresponding measures of total life. In that regard, populations with diabetes are considerably less favored than those without the disease. Analogous distributions for all other groups of women studied display similar shapes and relationships to those presented in Figures 1a and b. In all of these instances, the proportions of life spent unimpaired and impaired vary considerably within otherwise homogeneous groups.

Figures 2a and b display the same information for samples of 100,000 white men with low education, and are characteristic of the analogous figures for the other populations of men, which are not shown. The frequency distributions shown in Figure 2 also illustrate substantial within-group differences: there is notable variability within each population in the estimates for remaining years, remaining unimpaired years, and remaining impaired years. A comparison of Figures 2a and b provides a further illustration of between-group differences in total, active, and inactive life expectancies for men without and with diabetes. The histogram for remaining years of life in the upper panel of Figure 2b is quite skewed, far more so than the corresponding distribution in the upper panel of Figure 2a. Men living 15 or more years in the simulated population represented by the upper panel of Figure 2a constitute 19.5% of the population; only 8.1% of the corresponding population with diabetes lived 15 or more years. A comparison of the middle panels of Figures 2a and b shows that a substantially larger proportion of men with baseline diabetes have fewer years of unimpaired life. Indeed, 52.2% of men with low educational attainment without diabetes can expect more than 5 years without impairment, starting at age 70. The corresponding percentage for those with diabetes is only 32.0. Finally, comparing the lower panels of Figures 2a and b again suggests that differences in the absolute number of expected years with impairment are not great between those with and without diabetes; again, however, these differences as a proportion of TLE are substantial. As was true for women, analogous distributions for all other groups of men studied display similar shapes and relationships to those presented in Figures 2a and b.

A comparison of corresponding panels in Figures 1 and 2 illustrates striking gender differences in mortality and morbidity. Comparing the top panels shows that in all instances the distributions for remaining years of life are notably more skewed for men than for women, highlighting that a larger percentage of women live substantially longer than men. Similarly, comparisons of the middle panels show that the distributions of unimpaired life are notably more skewed for men than for women. Comparing the lower panels reveals a substantially higher spike at zero full years of impaired life for men than for women, illustrating that a dramatically smaller percentage of men than women live any remaining full years with impairment. These differences between Figures 1 and 2 are generally characteristic of differences between figures for women and men in other categories of race and education, which are not shown.

5. Discussion

This study used a large representative survey of older Americans and an expanded model of active life expectancy to estimate the older life course impacts of diabetes on estimates of total, active, and disabled life expectancy. Our findings highlight strong links between this chronic disease and active life expectancy. Our results also quantify the heavy toll of diabetes throughout the course of older life, in terms of both life expectancy and the proportion of life with disability. For all groups of women and men, life expectancy was substantially reduced for people with diabetes. White men with more education without diabetes, for example, can expect to live, on average, about 36% longer than the corresponding group of men with diabetes. For all groups, years of disabled life were strikingly more, as a percentage of TLE, for individuals with this disease. For example, white women with more education with diabetes could expect to spend almost 40% more of their remaining lives with a disability than women without diabetes. Our findings in these areas are consistent with those of a recent study that examined the impact of diabetes on healthy life expectancy (Bélanger et al. 2002). Moreover, we found that reductions in TLE and ULE attributable to diabetes are greater for women than for men (Table 3). As other researchers have suggested, this may be due in part to the large toll of heart disease among women with diabetes (Bélanger et al. 2002; Wingard and Barrett-Connor 2001).

Our investigation of between- and within-group variability using information about the full distributions of total, active, and inactive life (Figures 1 and 2), reinforces the heavy health burden of diabetes among all population groups studied. For all population groups, differentiating between the presence (or absence) of diabetes, the histograms for remaining years of life and remaining years of unimpaired life were markedly more skewed for populations with the disease than for those without the disease, illustrating that, in terms of full population distributions as well as averages, people with diabetes live shorter, less healthy lives. The disease-specific health trajectories displayed in these histograms contribute to our knowledge of variability in estimates of total, active, and inactive life (Laditka and Hayward 2003; Wolf et al. 2002). In addition, our results show that, even within populations characterized by a major chronic disease, there is a great deal of variability around standard summary measures of expectancy. This variability was revealed by our histograms (Figures 1 and 2) and in the standard deviations obtained for summary measures of these distributions (Table 2). This finding is consistent with previous research (Wolf and Laditka 1997; Wolf et al. 2002).

Several considerations should be weighed when considering our results. The sample of individuals used for this analysis did not include people living in institutions at the time of the baseline 1984 LSOA survey. The omission of this group likely resulted in a healthier sample of individuals than the full 1984 population of older people in the United States. Thus our results may underestimate the impact of diabetes on active life expectancy. Our findings are also conditional on the individual with (or without) diabetes having lived to at least age 70. On average, those of the same cohort who died prior to age 70 as a result of diabetes likely had a greater disease burden than those who survived to age 70 with the disease. This may particularly affect the sample proportions and diabetes profiles of blacks and people with lower education in our analysis (Songer 2001). Thus, our findings may underestimate the life course impacts of diabetes, particularly for nonwhites and people with less education. Since fewer men than women reach age 70, this process may similarly affect our findings for the relative impact of diabetes in older age for women and men.

Further, it should be noted that the estimates of this study are subject to several sources of unquantified variability (Wolf 2001; Wolf and Laditka 1997). These sources include classical sampling error associated with use of a sample rather than the entire population for the baseline conditions, Monte Carlo errors in the stochastic assignments of the simulation, parameter uncertainty, and specification error. Comorbidities or other individual characteristics not included in our models might play important roles in processes of impairment and death. The estimates depicted in this study should be viewed as suggestive rather than conclusive.

Bélanger et al. (2002) note that the prevalence of diabetes is not currently nearly as great among older populations as smoking, arthritis, low income, physical inactivity, or some other conditions or practices with important impacts on life expectancy and health. In the United States, diabetes prevalence is greatest, at just over 12%, for individuals in their 70s, while heart disease, hypertension, and arthritis reach levels of 30–55% in old age (Crimmins et al. 2002). Thus, when considering health policies at the population level, it is important to recognize that other policy alternatives to promoting diabetes reductions might conceivably produce greater total gains in life expectancy or ULE.

Yet several factors argue in favor of considering the potential for addressing diabetes with more concerted public health efforts. Our findings quantify the heavy health toll of diabetes, and point to the importance of public health policies directed toward reducing its incidence. The vast majority of people with diabetes, about 90%, have type 2 diabetes (National Diabetes Information Clearinghouse 1999). Recent research has demonstrated that the onset of type 2 diabetes can often be delayed, or possibly even prevented, with relatively modest lifestyle changes or pharmacotherapy (National Institute of Diabetes and Digestive and Kidney Diseases 2001). The findings of this large-scale clinical study were particularly notable because the sample was restricted to individuals at risk of the disease, with 45% of participants being black, Hispanic, American Indian, or other minorities. Moreover, the proportion of individuals who delayed or prevented diabetes onset through lifestyle changes or pharmacotherapy was greater at older ages, 71% of those 60 and over. With special regard to the study's applicability to less developed countries, where the costs of drugs in large applications may be prohibitive, the regimen of diet and exercise alone reduced diabetes incidence considerably more (58%) than the drug regimen (31%) (National Institute of Diabetes and Digestive and Kidney Diseases 2001).

In addition to the global epidemic of diabetes that is predicted in the coming two decades (King et al. 1998), the prevalence of adult onset diabetes has risen dramatically among younger populations (Burke et al. 1999). Those who experience diabetes onset earlier in life accrue many more years of cumulative disease burden, resulting in more pronounced levels of morbidity and disability at younger old age (Songer 2001). Public administrators and other health authorities responsible for diabetes reduction programs require little support from highly advanced or expensive technologies. The primary mechanisms of diabetes prevention are modest weight loss and exercise. Promoting these lifestyle changes successfully would provide many collateral health benefits, including reduced rates of hypertension, heart disease, stroke, and dementia. The costs to society and individuals of measures required to delay or prevent diabetes onset are not great, particularly when weighed against the benefits of substantially longer and healthier life.

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CHAPTER 6. INCREASING LONGEVITY: CAUSES, CONSEQUENCES, AND PROSPECTS

CARDIOVASCULAR DISEASE TRENDS

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1. Introduction

Infectious and cardiovascular diseases (CVD) dominated the health patterns of the 20th century. The emergence of an affluent society, where basic needs for shelter, food, and work are met, underlie these trends. Control of infectious diseases through better living conditions, widespread vaccination, and medical treatment resulted in sharp declines in infant mortality and improved outcomes among adults. At the same time, CVD and cancer emerged to become the leading killers of Americans.

Cardiovascular diseases dramatically increased and became common during the first two-thirds of the century. These diseases, particularly heart attack and stroke, limited the life expectancy of middle-aged and older adults. However, in the last third of the century, improved prevention and treatments led to a decline in age-adjusted CVDs and resulting increases in longevity. This decline in mortality, however, has not eliminated these diseases. Instead, they have been pushed into older age groups where they still take an enormous toll on quality of life and life span. In addition, the advanced technologies to detect and treat CVDs have brought enormous medical costs to society.

In the following, CVD patterns including the magnitude of the problem, disease trends and costs will be discussed. The overwhelming burden of CVDs in America and other industrialized nations suggests that any changes in longevity will strongly influence and be influenced by these conditions.

2. Origins of the Epidemic

Cardiovascular diseases were known in early times among the very wealthy as evidenced by data from the ancient Egypt mummies (Hanke, Lenz, and Finking 2001). However, for the following millennia, the dominant issue for most humans was finding adequate food and safe living conditions. The CVD epidemic began in the 20th century in industrialized countries. It is the direct result of the control of infections and a society with widespread affluence. While genetic influences are debated, the emergence of this epidemic over a few generations suggests that genes are not essential to explaining or preventing these diseases.

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The stage for this epidemic was set in the 20th century by the control of infectious diseases. Infectious diseases were the leading killer of both the young and old throughout most of history. In the 20th century, factors such as clean water, clean air, safe food, and widespread vaccinations led directly to dramatic declines in infectious diseases. Diseases such as smallpox were eliminated through vaccination. Similarly, polio, cholera, plague, pertussis, diphtheria, tetanus, and other formerly common infectious diseases are practically unknown in industrialized countries. Broad public health measures had an enormous impact on mortality among infants and children. They also influenced mortality among adults, permitting increased life span. Antibiotics, which were not discovered until the middle of the century, also played a role, particularly in adults. Pneumonia, "the old persons' friend", became treatable and declined as a cause of death. The fall of infectious disease gave rise to expression of chronic diseases as people survived childhood into adulthood and lived to older years.

The environmental factors underlying the CVD epidemic are well known and described (American Heart Association 2002; US Department of Health and Human Services 2002). First and foremost were changes in the food supply. Food became available in surplus and excess grain products allowed intensive farm animal feeding. Higher quality meats and dairy products became widely available and inexpensive. Foods that were once the pervue of only the wealthy or for special occasions (Dickens "Christmas goose") were now available to everyone. These foods also were high in calories and fat leading to increased blood lipids, particularly cholesterol. Increasing blood cholesterol in the population is directly related to the epidemic.

At the same time, high blood pressure or hypertension began to rise. Increased weight and decreasing physical activity along with available salt were all directly related to blood pressure. All became more common during the 20th century. Blood pressure is observed to rise with age and over 50% of Americans 65 and older have hypertension which requires treatment. Hypertension is directly related to heart attacks and stroke.

The third factor implicated is cigarette smoking. The advent of machine-made cigarettes that were cheap and widely available changed the smoking habits of Americans. Throughout the first half of the 20th century, rates of cigarette smoking for both men and women increased dramatically. Widespread distribution of cigarettes to the Armed Services during the Second World War (they were included in Army rations along with a chocolate bar) reinforced this habit as common and usual. Addiction to nicotine resulted in life-long smokers. Cigarette smoking is also related to CVD, both in the development of the disease process and the acute event.

Finally, physical activity declined significantly as laborsaving devices and personal transportation became widespread. Today, few people perform significant physical labor during their workday. Even farmers have an array of hydraulic and electric laborsaving devices to do formerly physically active jobs. Physical activity is now a leisure-time pursuit and rarely at a level formerly seen with jobs with hard labor. Among the outcomes of an increasingly sedentary society are obesity, hypertension, and hyperlipidemia.

The combination of infectious disease control, surplus food, inexpensive cigarettes, and laborsaving devices in an aging population resulted in the cardiovascular epidemic. These characteristics, called risk factors by epidemiologists, are directly related to a prediction of disease outcomes through their role in the pathogenic process. The factors are ubiquitous in American society, which is frequently characterized as a "high-risk" society for CVD.

3. Magnitude of the Problem

Cardiovascular diseases are the leading cause of death in the United States. As shown in data from 2000, 36% of all deaths in the United States were attributable to heart disease and stroke (Table 1). Although in the public eye, widely discussed diseases such as HIV/AIDS as a cause of death is not on the list of the top 10. This pattern, with heart disease as the #1 killer, has persisted for many decades.

Underlying this mortality is a substantial burden of morbidity, with nearly 25% of the US population afflicted by diagnosed CVD (Table 2). Hypertension is present in approximately 50 million people and is among the most common treatable chronic conditions in the United States. The enormous numbers of individuals with cardiovascular conditions have broad implications for medical resources and the cost of care.

Similarly, serious heart ailments requiring hospitalization are quite common with the leading causes being heart attack, stroke, and heart failure (Table 3). While these are predominantly diseases of adults aged 65 and older, they also are common as a cause of death and hospitalization in younger age groups (Table 4).

Table 1. Leading causes of death, US, 2000.

Cause of death	Number
Total	2,404,624
Heart disease[a]	709,894
Cancer	551,833
Cerebrovascular disease (stroke)	166,028
COPD and allied conditions[b]	123,550
Accidents	93,592
Diabetes	68,662
Influenza and pneumonia	67,024
Alzheimer's disease	49,044
Nephritis	37,672
Septicemia	31,613
All other causes of death	505,712

Source: NHLBI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.
[a] Includes 529,659 deaths from coronary heart disease.
[b] Chronic lower respiratory diseases.

Table 2. CVD prevalence, US.

CVD	61,800,000
Hypertension	50,000,000
CHD	12,600,000
Acute myocardial infarction (AMI)	7,500,000
Angina pectoris	6,400,000
Stroke	4,600,000
Heart failure	4,800,000
Congenital heart defects	1,000,000
Atrial fibrillation	2,000,000

Source: NHLBI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

Table 3. CVD incidence and recurrence, US.

Heart attack	1,100,000
First event	650,000
Recurrent event	450,000
Stroke	600,000
First event	500,000
Recurrent event	100,000
Heart failure	550,000
First event	550,000

Source: NHLBI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

Table 4. Leading causes of death by age and rank, US, 2000.

Cause of death	1–24	25–44	45–64	65–84	85+
Heart disease	5	3	2	1	1
Cancer	4	2	1	2	2
Cerebrovascular disease	9	8	4	3	3
Accidents	1	1	3	9	9
COPD and allied conditions[a]	8	—	5	4	6
Influenza and pneumonia	7	10	—	6	4
Diabetes mellitus	—	9	6	5	7
Suicide	3	4	8	—	—
Chronic liver disease	—	7	7	—	—
Nephritis and nephrosis	—	—	10	8	8
Homicide	2	6	—	—	—
Septicemia	—	—	—	10	10
HIV infection	10	5	9	—	—
Congenital anomalies	6	—	—	—	—
Alzheimer's disease	—	—	—	7	5

[a] Chronic lower respiratory diseases.
Source: NHLBI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

In summary, CVDs are the leading causes of death and common causes of morbidity and treatment in the United States today.

4. Mortality Trends

Death rates for the major CVDs have shown dramatic changes during the 20th century with a rise and gradual decline of the epidemic (Figure 1). The peak occurred in the mid- to late-1960s manifest first in California and then spreading throughout the nation. These mortality trends have been the subject of considerable speculation as to cause. The reasons for the rise, as described above, are quite clear. However, the causal factors for the decline are more speculative as shown in Figure 2. Nevertheless, that decline has been steady and substantial for both age-adjusted coronary heart disease and stroke (Figure 1). Other causes of death have declined, but much more modestly. Because of the substantial proportion of mortality due to CVD, the result of declining age-adjusted death rates has resulted in increased life span with little change in the rates of other causes of death.

Unfortunately, age-adjusted rates tell only part of the story. Absolute mortality is a more appropriate depiction of the national disease burden. As shown in Figure 3, absolute mortality has been level for several decades. People are still dying of CVD, but at older ages. Interestingly, this disease, which is commonly thought of as a male condition, has become more common as a cause of death among women (Figure 4).

The declines have also affected gender and ethnic groups differentially. While all groups have seen declines in CVD, the greatest advances have been among white and black men. Women have fared less well (Table 5). It is also apparent that some cardiovascular causes of death have actually increased, such as congestive heart failure (Table 5). This increase

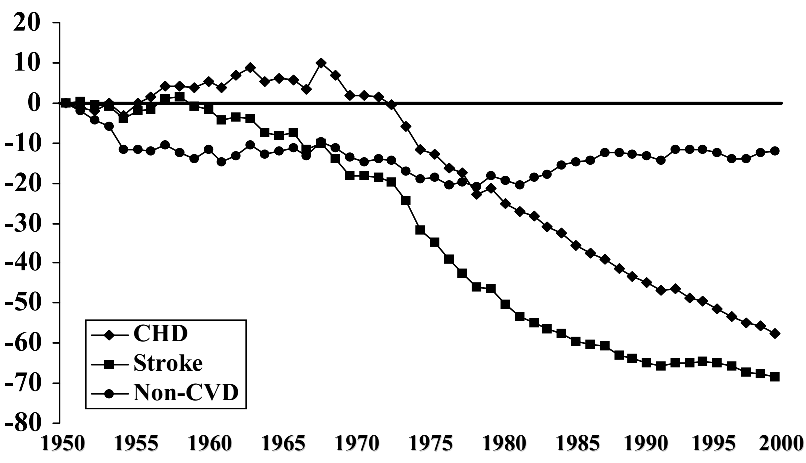

Figure 1. Change in age-adjusted death rates since 1950, US, 1950–2000.
Source: NHLBDI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

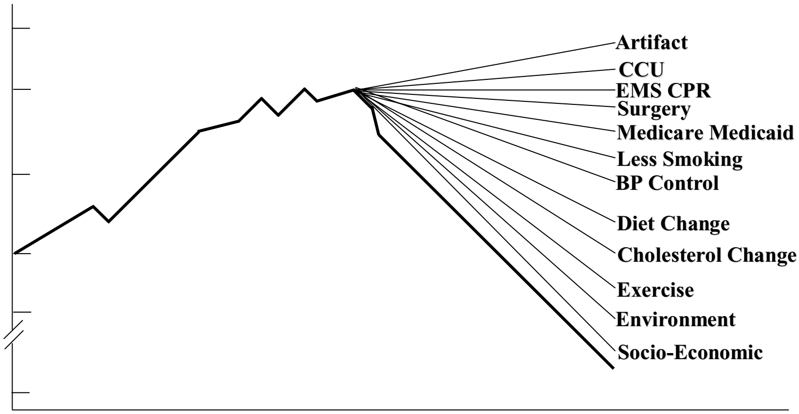

Figure 2. Causes of the decrease in cardiovascular mortality.
Note: Can we identify factors causing the coronary mortality rate decrease and measure their contribution?
BP = blood pressure; CCU = coronary care unit; CPR = cardiopulmonary resuscitation; EMS = emergency medical service.
Source: Levy (1984) *The American Journal of Cardiology*, 54:7C–13C.

is generally attributed to improved survival of people with heart attacks. They continue with a scarred damaged myocardial muscle which leads to inadequate muscle function and heart failure.

It is also apparent that different sections of the United States have different burdens. As shown in Figure 5, CVD is more common in the East than the West and is most common in the states bordering the Mississippi and Missouri river valleys. These differences are

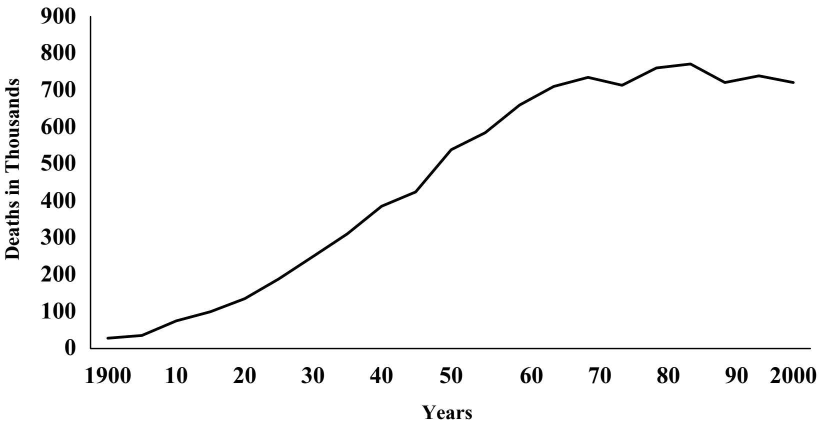

Figure 3. Deaths from diseases of the heart, United States: 1900–1999.
Source: “2002 Heart and stroke statistical update”, American Heart Association.

Table 5. Average annual percent change in age-adjusted death rates for all causes and cardiovascular diseases by race and sex, US, 1990–2000.

Cause of death	Total	White male	White female	Black male	Black female
All causes	−0.7	−1.3	0.0	−2.0	−0.4
CVD	−1.8	−2.4	−1.4	−2.2	−1.2
Heart disease	−2.0	−2.5	−1.6	−2.4	−1.5
Coronary	−2.8	−3.2	−2.6	−2.6	−1.8
CHF[a]	1.4	1.0	2.0	0.1	0.7
Stroke	−1.1	−1.5	−0.7	−2.2	−1.3
Non-CVD	0.1	−0.6	1.0	−1.8	0.3

Source: NHLBI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.
[a] 1990–1999.

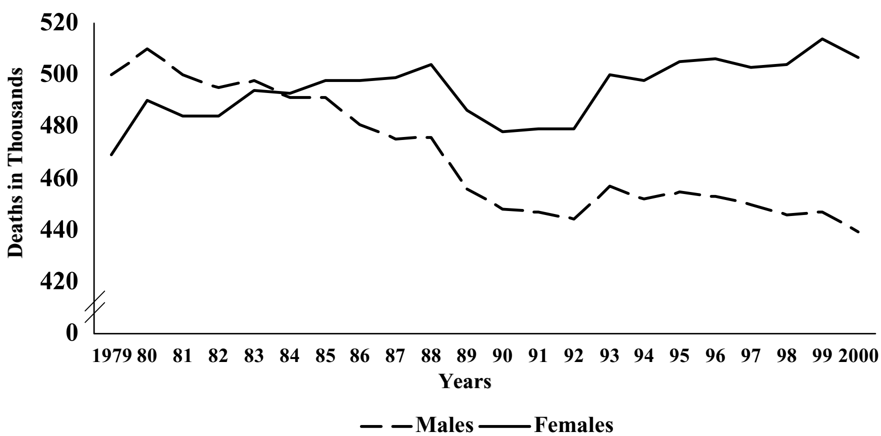

Figure 4. Cardiovascular disease mortality trends for males and females, United States: 1979–1999.
Source: "2002 Heart and stroke statistical update", American Heart Association.

partly a result of ethnic disparities, with blacks having significantly higher disease rates than whites. However, even among Caucasians, the age-adjusted death rates are also highest in the Southeastern states.

5. Morbidity Trends

Prevalent CVDs afflict almost 25% of the US population (Table 2). This is manifest in a number of ways including hospitalizations which have risen steadily since 1970 (Figure 6). There are now over 6 million hospitalizations per year for CVDs and it is a major source of inpatient admissions. Much of this is due to an aging of the population as shown in Figure 7. Here, hospitalization rates for those 65 and over have steadily risen, while they

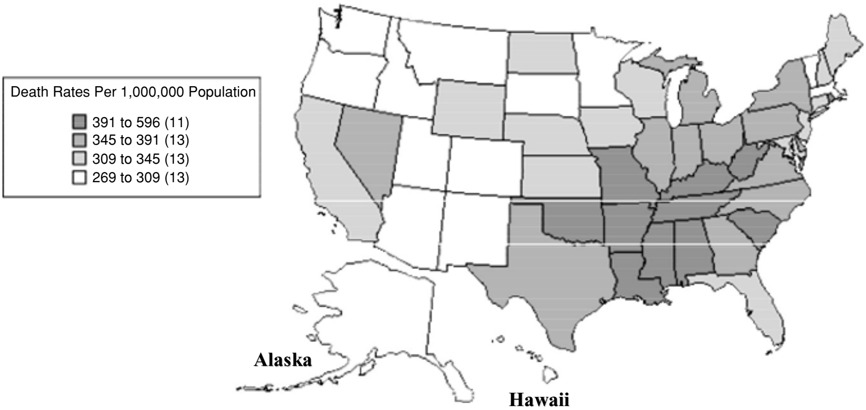

Figure 5. 1996–1998 Total cardiovascular disease age-adjusted death rates by state.
Source: "Heart disease and stroke statistics—2003 update", American Heart Association.

have remained relatively stable for the 45–64 age category. Excluded from this figure is a growing but undocumented trend for major cardiovascular procedures done as outpatients without hospitalization. Such procedures include cardiac catherization and pacemaker implantation, which formerly required hospitalizations. The hospitalization rates shown here may be an underestimation of the disease trends.

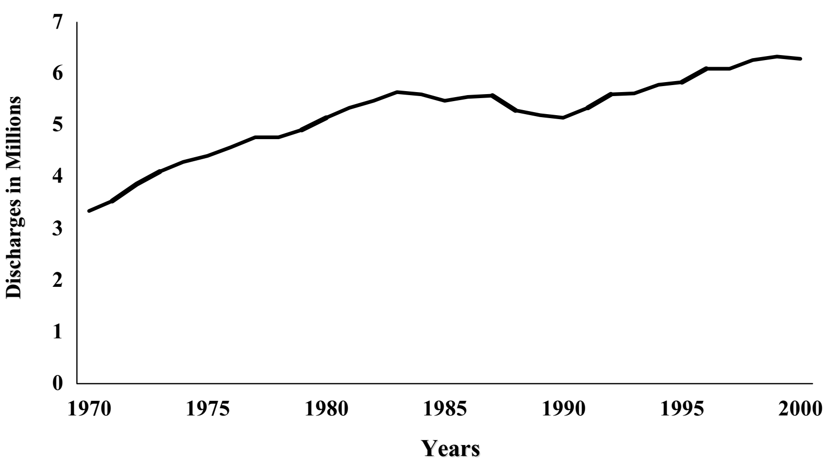

Figure 6. Hospital discharges for cardiovascular diseases, United States: 1970–2000.
Source: "Heart disease and stroke statistics—2003 update", American Heart Association.

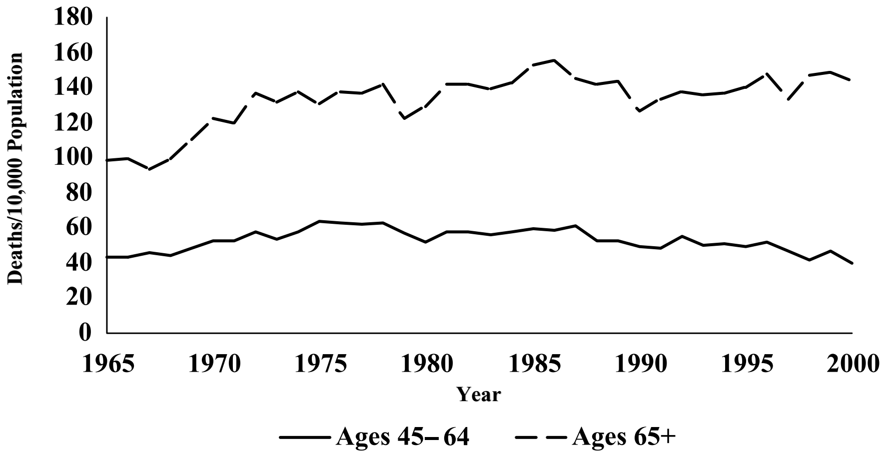

Figure 7. Hospitalization rates for acute myocardial infarction ages 45–64 and 65+, US, 1965–2000.
Source: NHLBDI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

Within CVDs are many categories. As noted above, congestive heart failure is an increasing cause of morbidity. Diagnosis and hospitalization for congestive heart failure has risen steadily from 1971 and constitutes an important portion of overall CVD hospitalizations (Figure 8). It is rising in all age groups. At the same time, while rates of hospitalization are

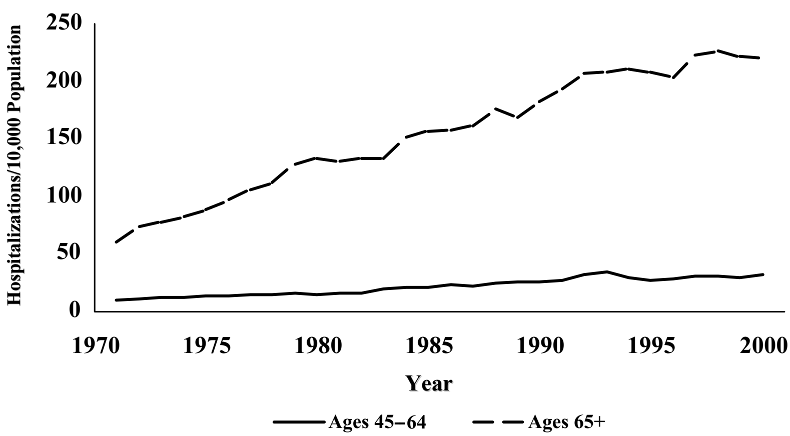

Figure 8. Hospitalization rates for congestive heart failure ages 45–64 and 65+, US, 1971–2000.
Source: NHLBDI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

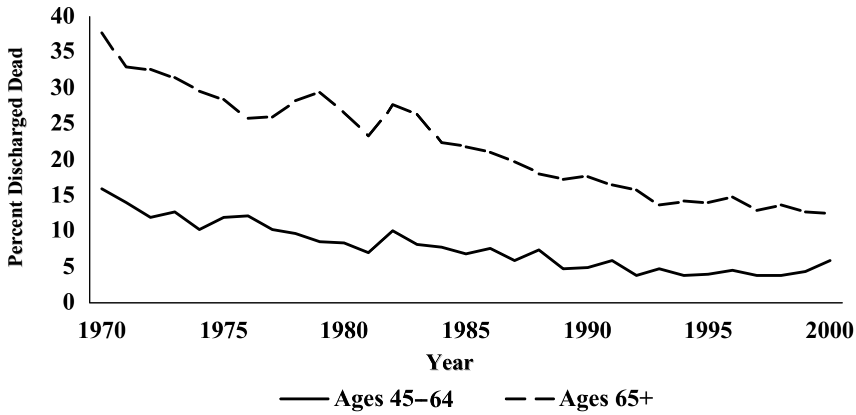

Figure 9. Hospital case-fatality rates for acute myocardial infarction ages 45–64 and 65+, US, 1970–2000.
Source: NHLBDI morbidity and mortality 2002 chart book on cardiovascular, lung, and blood diseases.

steadily rising, the length of an average stay is falling. Individuals are discharged quickly, when at all possible. Fortunately, earlier discharge has not been reflected in greater case fatality for acute myocardial infarction, which has also steadily fallen associated with dramatic improvements in methods of care (Figure 9).

In summary, the prevalence of CVD in the US population is rising with an aging population and increased prevalence of CVD morbidity. Some categories are rising more rapidly than others, but the net is increasing hospitalization rates.

6. Risk Factor Trends

The rise in cardiovascular risk factors in the first half of the 20th century is directly associated with the rise in CVDs. The principal risk factors are high blood pressure or hypertension, hyperlipidemia, particularly elevation of blood cholesterol, and cigarette smoking. Widespread observational data and clinical trials find that all three are causally related to atheroscleroticcardiovascular disease.

Hypertension or high blood pressure is very common in the American population as shown in Figure 10. It is significantly higher in black men and women through age 74. By age 65, all race and gender groups have a prevalence of high blood pressure greater than 50% in the general population. Awareness, treatment, and control of high blood pressure has gradually improved over the past three decades. The majority of Americans regularly have their blood pressure measured and are aware of their hypertensive status. A substantial proportion of them have blood pressure normalized or controlled by antihypertensive drug treatment.

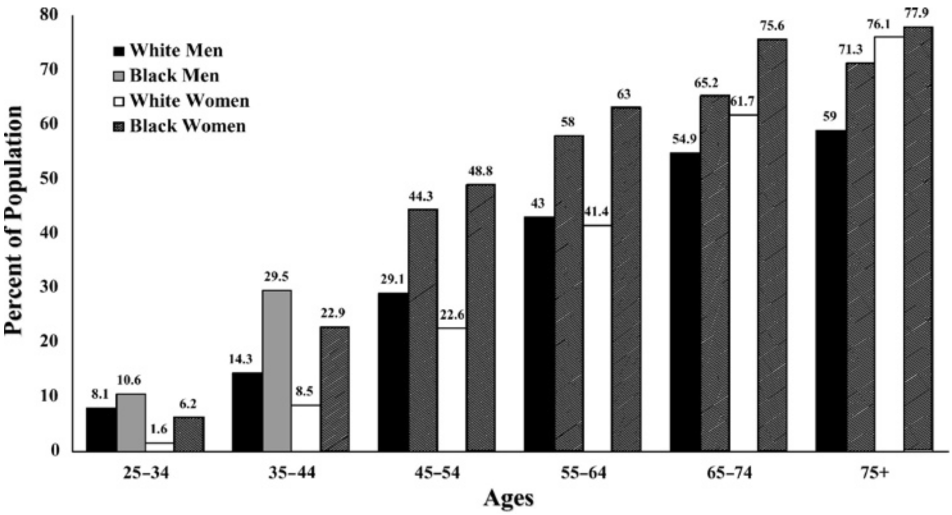

Figure 10. Prevalence of high blood pressure in Americans age 25 and older by age, sex, and race, United States: 1988–1994.
Source: "Heart disease and stroke statistics—2003 update", American Heart Association.

In addition to hypertension, elevated blood lipids are extremely common in the United States as shown in Figure 11. This applies to both men and women in all major ethnic groups (Figure 11). Elevated LDL cholesterol (the fraction causing CHD) is present in nearly 50% of Americans aged 20 and above. It is another cause of the epidemic.

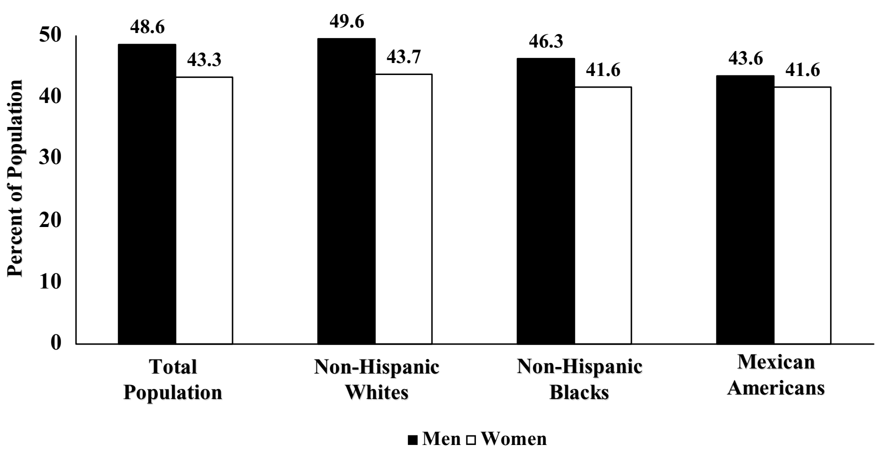

Figure 11. Age-adjusted prevalence of Americans age 20 and older with LDL cholesterol of 130 mg/dL or higher by race/ethnicity and sex, United States: 1988–1994.
Source: "Heart disease and stroke statistics—2003 update", American Heart Association.

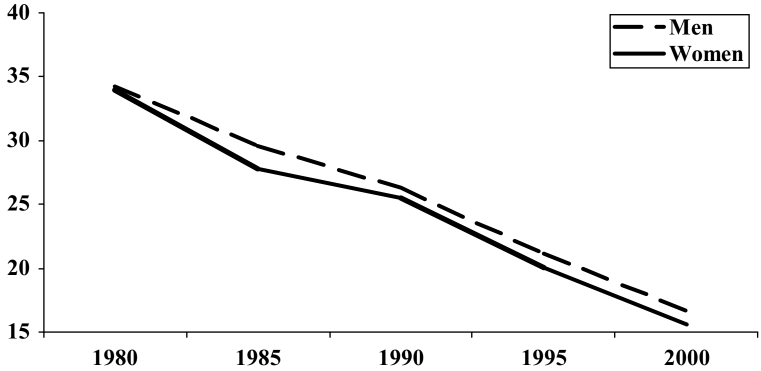

Figure 12. Trends in current smoking.

In recent years, hypercholesterolemia, like hypertension, has become an increasing focus of pharmacologic therapy. In some areas, 5–10% of all adults are taking effective cholesterol-lowering medication on a daily basis. They will need to continue this treatment throughout their lives.

Cigarette smoking, commonly associated with lung cancer and emphysema, is a major risk factor for heart attack and stroke. Fortunately, in recent years cigarette smoking has steadily declined in the population. As shown in Figure 12 from a population survey in Minnesota, cigarette smoking is now in the range of 16% for both men and women. Similar rates are observed in other areas of the country, although smoking remains stubbornly high, particularly in the Southeast United States.

The improved control of the classical risk factors in the American population has played a major role in the prevention of first events of heart attack and stroke and recurrent events among those already stricken. Much of this advance is the result of life-long pharmacologic therapy of expensive medications. In addition, cigarette smoking has declined substantially in association with bans on indoor smoking, increased taxation on cigarettes, and a widespread desire to quit the habit. Other risk factors exist which should be considered. They include sedentary lifestyles, the growing obesity epidemic, and increasing adult onset diabetes. These factors have undoubtedly modified the beneficial effects of improvement in the other risk characteristics.

7. Medical Care and Costs

In addition, prevention of CVD, medical and surgical therapy for these diseases has attained an extraordinary level of sophistication and effectiveness. Over the past 50 years, the development of cardiac pacemakers, open heart surgery, valve replacement, heart transplantation, and angioplasty comprise just a brief list of the technological approaches now available for the diagnosis and treatment of CVDs. There is, perhaps, no other field in medicine that has attained such a broad level of sophisticated and effective therapeutic

Table 6. Estimated inpatient cardiovascular operations, procedures, and patient data by age, US, 1999 (in thousands).

Operations/procedures/patients (ICD/9 code)		Age 15–44	45–64	65+
Angioplasty (36.0)	Procedures	62	437	524
PTCA (36.01, 36.02, 36.05)	Procedures	30	236	283
	Patients	33	234	279
Stenting (36.06)	Procedures	28	195	233
Cardiac revascularization (bypass) (36.1–36.3)	Procedures	17	216	286
	Patients	10	127	177
Diagnostic cardiac catheterizations (37.2)	Procedures	113	550	646
Endarterectomy (38.12)	Procedures	—	32	91
Implantable defibrillators (37.94–37.99)	Procedures	—	10	22
Open heart surgery	Procedures	38	258	357
Pacemakers (37.8)	Procedures	—	20	129
Valves (35.1, 35.2, 35.99)	Procedures	7	23	49
Total vascular and cardiac surgery and procedures (35–39)		569	2170	3215

Source: Heart disease and stroke statistics—2003 update, American Heart Association.

options. In addition, these procedures, which were formerly available to only a few, are now widespread in their application to the adult and older adult population (Table 6). There are few Americans, particularly older Americans, that do not have access to a high level of care. For example, in the year 2000, well over 1 million cardiac catherizations were performed. The costs of high technology procedures and treatments are substantial. Ranging from cardiac transplants, which can cost several hundred thousand dollars, to life-long medications from CVD, direct costs for cardiovascular care are currently several hundred billion dollars per year (Figure 13). The advent of the intracardiac defibrillator (ICD), a device which prevents sudden death by delivering an electrical charge to the heart, is an example of this technology. Diagnostic procedures, purchase, and implantation of this device can easily cost over $50,000 in a single patient. The indications for this device are broad and the effects potentially life-saving. Already, Medicare has projected many billions of dollars spent per year for implantation of ICDs in the 65 and older population.

The implications of costly but effective high technology procedures for healthcare in the United States are many. In a disease that predominantly affects older adults, a growing population of elderly has resulted in skyrocketing Medicare costs and projected deficits. In a society where technological solutions are favored and made available through private enterprise, the term "life-saving treatment" has powerful and unarguable implications. Cost containment strategies to limit individual and tax payer liability have largely failed and the nation faces a serious healthcare cost crisis due in large part to CVD diagnosis and treatment.

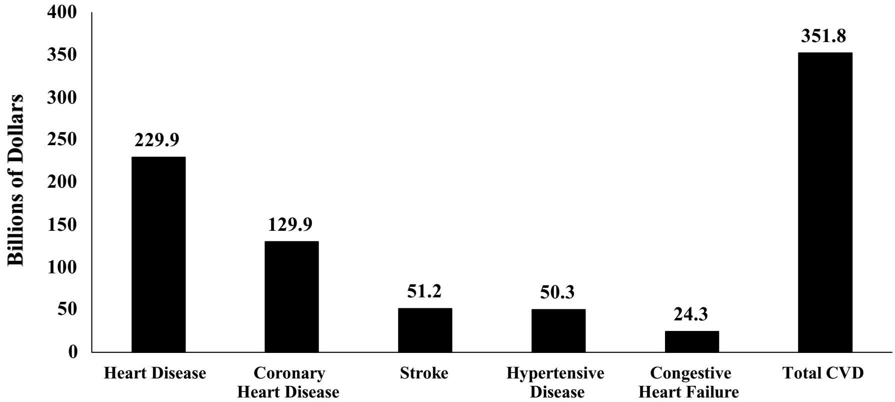

Figure 13. Estimated direct and indirect costs (in billions of dollars) of cardiovascular diseases and stroke, United States: 2003.
Source: "Heart disease and stroke statistics—2003 update", American Heart Association.

8. International Trends

The United States was among the highest countries in CVD mortality in the 1950s. This was true for both men and women. However, the age-adjusted decline in the United States and Western Europe has resulted in these countries being mid-range in rates (Figure 14). The former Socialist countries, including the Russian Federation, have significantly higher rates as they have entered a period of greater affluence while lagging in modern medical care. For example, rates of CVD in Russia have risen to a level where life expectancy among men fell in the 1990s (Men et al. 2003).

There are similar concerns in the developing world where a "epidemiologic transition" is underway. As infectious diseases are conquered, infant mortality declines and chronic diseases emerge. Found initially in the most affluent classes, they are increasingly observed in the middle classes. There is evidence that this epidemic in developing countries will reach the same proportions as observed in the middle of the 20th century in the United States and Western Europe. In that context, CVD is on a course to become the leading killer worldwide.

9. Summary

The 20th century experienced a major shift from the acute infectious diseases to chronic diseases as the leading causes of mortality and morbidity in populations. Among those chronic diseases, CVD, specifically coronary heart disease and stroke, reached epidemic rates. The healthcare system responded with prevention strategies and sophisticated modern care which has resulted in a decline in age-adjusted mortality and morbidity. An increasing

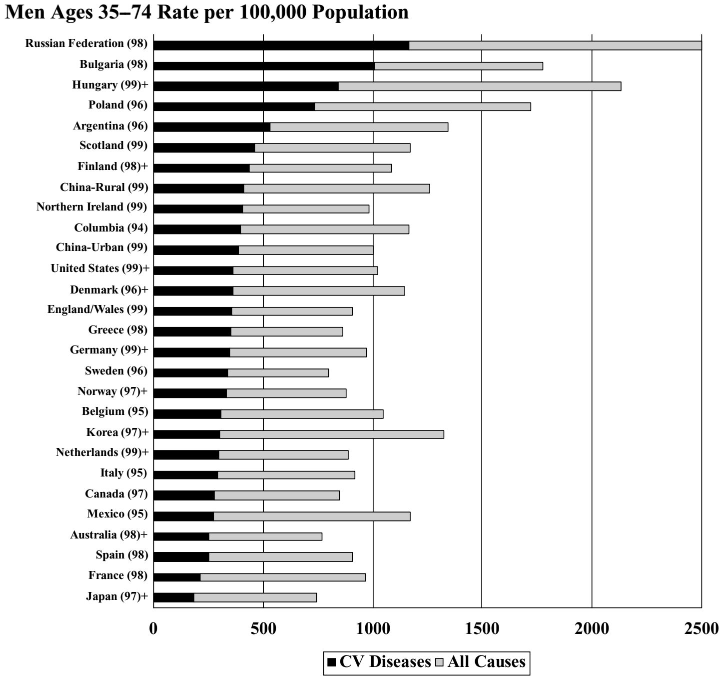

Figure 14. Death rates for total cardiovascular disease, coronary heart disease, stroke and total deaths in selected countries (most recent year available).
Source: "2002 Heart and stroke statistical update", American Heart Association.

life span for Americans was one result. However, the epidemic was not eliminated but pushed into older age categories where it still remains the leading killer of Americans.

The development and widespread use of modern medical therapy to treat CVD has brought an unexpected consequence. The older population as well as middle-aged adults expect high technology solutions for their health conditions. These have grown increasingly complex and costly, resulting in a major burden on the healthcare system due to increasing utilization and skyrocketing costs.

These trends have important implications for the future where an aging population expects to live long and active lives. The healthcare system will continue to develop methods to prolong those lives at increasing costs. This trend is unlikely to change. However, many observers suggest that increased emphasis on prevention strategies, which are both low cost and effective, are more likely to benefit society.

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Part II

Individual Healthy Aging

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Introduction

In recent years, models of healthy aging have been increasingly interdisciplinary. Biopsychosocial models have been proposed by a number of researchers focused on health change in old age; an example is provided in Figure 1. These models provide a schematic representation of the risk factors for diverse health outcomes including dementia, disability, functioning loss, cardiovascular disease, and mortality. The fact that recognized risk factors are similar for most common health problems in old age is clarified by the model (Crimmins and Seeman 2005; de la Torre 2002, 2004). In addition, the fact that most health outcomes have risks arising from multiple domains—biological, psychological, social/behavioral, and care related—is portrayed. The heuristic portrayal in the figure is generally time ordered from left to right. None of these circumstances are static so lifecycle conditions are important. While genetic factors are placed on the left indicating that genetic makeup is determined before birth; gene expression may result from environmental exposures and behaviors that interact with genetic makeup. This is not shown in the figure.

Part II of this volume contains chapters that focus on either specific causal mechanisms and/or specific health outcomes. Much research on healthy aging emphasizes one risk factor and one health outcome; others consider multiple domains in one analysis. Both types of work are presented here. Some of the most path-breaking works in healthy aging involve the incorporation of genetic indicators into models predicting healthy aging. Corder and colleagues examine apoliprotein E (APOE) genotype frequency by age and find that mortality selection affects genotype distribution among the oldest-old. They suggest that the ability to survive vascular accidents may be related to APOE genotype and that this may be the mechanism determining differential genotypic frequency distributions found for centenarians and young adults. This part valuable from a demographic perspective in that it clarifies how mortality affects the distribution of risk in the survivors at very old ages as well as how risk factors predict specific health outcomes in old age.

Crimmins and colleagues are interested in how biological risk or physiological frailty changes with age. This cross-sectional study of persons at all adult ages again clarifies how

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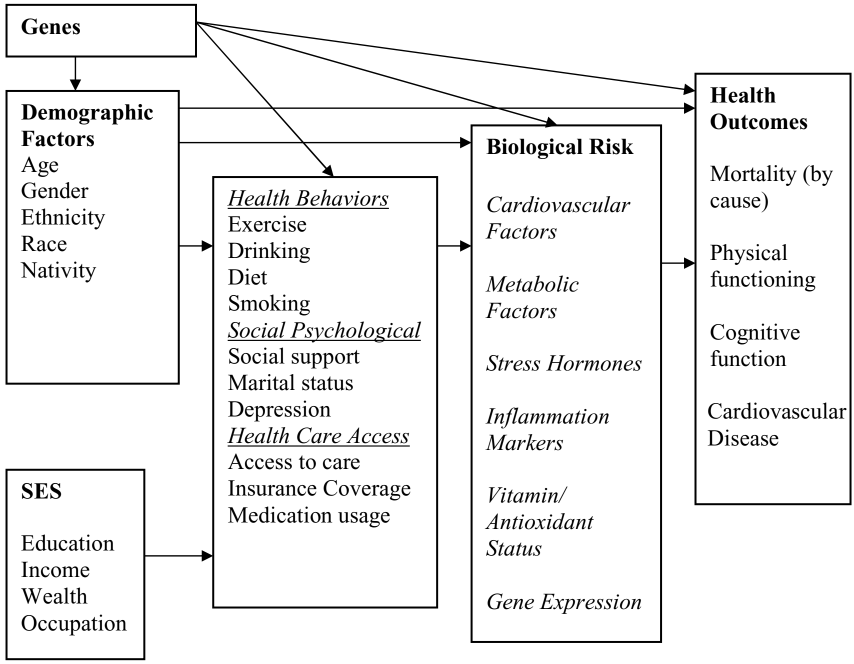

Figure 1. A biopsychosocial model of health outcomes common on old age.
Source: Crimmins, Eileen M. and Teresa Seeman, 2005.

mortality selection affects the characteristics of the surviving old and old-old population. Cumulative biological risk as outlined in Figure 1 increases markedly before old age and then remains relatively constant in very old age. They conclude that persons with high biological risk are those who are selected out of the population through mortality leaving a surviving population that does not continue to decline in this index of physiological frailty. This part demonstrates the need to remember the role of selectivity in producing the oldest old popualation.

Andersen-Ranberg and Bernard Jeune investigate the characteristics of the Danish Longitudinal Centenarian sample. This is a population-based centenarian study that involved an interview, a clinical exam, and a blood test. While centenarians make up only a small group of the original cohort, Andersen-Ranberg and Jeune conclude that they cannot be described as healthy at this very old age as they have a high prevalence of chronic conditions and functional limitations. This study is unique in its comprehensive approach to monitoring an extremely old group.

Two chapters focus on gender differentials in healthy aging in two very different cultural and geographic settings: the United Kingdom and China. Gender differentials are clearly a mix of biological, psychological, and social effects. In the United Kingdom, Emily Grundy reports that older women are poorer and less educated but they live longer and they spend more of their lives with disability. Women are more likely to live alone and to be widowed but also to have stronger family support networks. Grundy also reports that changes in the extent of gender differentiation in more recently born cohorts means future trends are uncertain.

Zeng Yi and colleagues report that many of the same gender differences are found in China as in the UK: older women are disadvantaged socioeconomically across the older ages. They also appear to have lower cognitive ability and worse self-reported health. Functioning differences by gender varies for the younger and older-old. Among the young-old, the differences in ADL functioning and physical performance are small; but among the older-old, women do considerably worse. Zeng Yi and colleagues interpret the lack of gender differences in life satisfaction as a reflection of differing expectations as well as a difference in reality by gender.

Two of the chapters in Part II deal with social and behavioral differences in aging health outcomes. Cambois is interested in the effect of social inequality and social mobility on mortality at the older ages. Using a longitudinal data set, she investigates how earlier moves up or down the occupational ladder delineating social class affect subsequent mortality. As both social status and social mobility affect subsequent mortality, Cambois suggests the presence of life-long occupational effects on mortality in old age. Barberger-Gateau and colleagues are interested in cognitive decline and dementia in older persons. Cognitive decline is also related to social status but they suggest multiple mechanisms for this effect. They test the idea that prevention or delay of cognitive decline occurs through enhancing cognitive stimulation by mental activity or through protection achieved by diet. They conclude that increasing educational level, encouraging regular involvement in social and leisure activities, facilitating equal access to health care, and promoting a diet rich in fish and antioxidants such as fruit, vegetables, and tea could contribute to healthy cognitive aging.

This set of chapters examines multiple aspects of individual aging across a number of cultures and age groups. Each individual piece adds to our understanding of the process.

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CHAPTER 7. AGE DIFFERENCES IN ALLOSTATIC LOAD: AN INDEX OF FRAILTY*

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1. Introduction

Frailty is an emerging concept in the study of health outcomes at older ages (Cohen 2000; Fried et al. 2001; Morley, Perry, and Miller 2002). It is recognized as a downward trajectory in health and ability to perform daily tasks. This downward spiral results from the accumulation of acute and chronic diseases as well as the physiological decline and dysregulation that accompany the onset of diseases and advanced age (Cohen 2000).

This chapter investigates population differences in physiological frailty as evidenced by levels of allostatic load to determine how physiological deterioration occurs in a population as it passes through old age. We are interested in examining age differences in this summary indicator of biological risk—allostatic load—to see how physiological dysregulation in the population differs by age. We examine the age pattern of population increase in physiological frailty across the adult years, as represented by allostatic load. Of particular interest is whether there is any leveling off of average physiological risk as the oldest ages are approached. In addition, we are interested in the population variability in allostatic load as age increases. Our analysis does not provide insight into how frailty changes within an individual lifespan but clarifies how physiological challenge varies in the population at different ages. Because our analysis is cross-sectional we are examining frailty in a population that is comprised of a set of different cohorts, which have experienced differential selectivity because of death and which may have differed in many characteristics in their lifetime.

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2. Background

Measures of allostatic load have been both developed theoretically and related to a variety of health outcomes in a number of recent studies (McEwen 1998; McEwen and Stellar 1993; Seeman et al. 1997, 2001, 2004; Sterling and Eyer 1988). Allostatic load is an indicator of physiological dysregulation in a variety of bodily systems. In the course of normal life experiences, challenge to various physiological systems is met with physiological responses appropriate to eliminating the threat posed by the challenge. Such bodily responses should occur within an optimal range. When the body has received significant challenge over many years, physiological systems may begin to operate less efficiently essentially showing wear and tear. A central feature is that they begin to operate increasingly outside their optimal range or may have difficulty returning to optimal ranges after challenge. The concept of allostatic load takes a multisystems view of these dysregulations, postulating that it is the cumulative burden of dysregulation across multiple systems that predicts subsequent health and longevity (Karlamangla et al. 2002; Seeman et al. 2001). Allostatic load has been linked to mortality as well as other adverse health outcomes such as cardiovascular disease, loss of physical functioning, and cognitive failure (Seeman et al. 2001). Allostatic load can be regarded as a direct indicator of population frailty as it is indicative of the extent to which the body is at risk of adverse health outcomes because of physiologic dysregulation across multiple regulatory systems (Seeman et al. 2001).

A number of studies have examined both age differences and age changes in a variety of indicators of physiological capacity or of physiological reserve (Lipsitz and Goldberger 1992; Manton, Woodbury, and Stallard 1995; Shock et al. 1984). These studies make clear that in many indicators of physiological state there is decline with age in the population average although there is great variability across different biomarkers in the average rate of change and its relationship to age. On an individual level there is also great variability in the rate of decline resulting in increased population variability in physiological state with age.

Frailty is assumed to vary across population members because of both innate characteristics and environmental exposures. While persons are born with different susceptibility to frailty, individual frailty is assumed to increase with physiological changes related to aging, and also as a result of increasing exposure to challenging environmental conditions. As a population ages one assumes that innate characteristics and external circumstances join to operate so that those with greater frailty are more susceptible to the risks of mortality and morbidity (Vaupel, Manton, and Stallard 1979). If mortality continuously selects the most frail from the population, those who survive to the oldest ages may be those who began life with the highest innate resources and/or faced the least challenge (Vaupel et al. 1998). This would lead one to expect an age pattern of frailty that does not increase exponentially with age but slows in its increase with age at the oldest ages.

The demographic approach to frailty emphasizes the role of innate characteristics and genetic influences on frailty (Yashin et al. 1999), while the bio-geriatric approach to frailty emphasizes factors such as inflammatory response, neurological control, aerobic capacity, alterations in immune and endocrine systems, hormone levels, free radicals, antioxidants, and macro/micro nutrients (Cohen 2000; Ferrucci et al. 2002; Markle-Reid and Browne 2003). In contrast to the demographic focus in defining frailty, the bio-geriatric approach to frailty emphasizes the end of life cascade of experiences leading to disability, dependency, and death (Buchner and Wagner 1992; Carlson et al. 1998; De Jong 2000; Fried et al. 2001). Geriatricians emphasize the complex interactions of many physiological systems which when disturbed can lead to greater stress than an organism can tolerate and subsequent poor health outcomes. This approach to frailty corresponds to the idea of frailty or risk of mortality described by Kannisto when he said that deaths were the outcome of "little devils" or potential causes of death that can either work together or individually to harm the organism (Kannisto 1991).

Several researchers have linked individual biological measures of frailty to performance measures of frailty and negative health outcomes such as cardiovascular disease, congestive heart failure, diabetes, and hypertension (Taafe et al. 2000; Walston et al. 2002). Only recently have researchers recognized the cumulative negative effect of multiple risk factors indicating dysregulation in interrelated biological systems in causing poor health and disability. Parameters included in earlier specifications of allostatic load have included profiles of physiologic activity across a wide range of regulatory systems including the hypothalamic pituitary axis, the sympathetic nervous system, the cardiovascular system, the metabolic system, renal function, lung function, and markers of inflammation (Seeman et al. 1997, 2001). Each indicator of risk included has been related to poor health outcomes. These analyses have shown that the summary indicator of allostatic load is a better predictor of poor health outcomes than the individual biomarkers (Karlamangla et al. 2002; McEwen and Seeman 1999; McEwen and Stellar 1993; Seeman et al. 2001, 2004). Other summary indicators of physiological status have been related to both mortality and specific causes of morbidity. For instance, Syndrome X, a combination of cardiovascular and metabolic risk factors, has been related to cardiovascular mortality (McCarty 1995; Reaven 1988; Wannamethee et al. 1998).

Previous analyses of allostatic load have been performed among age-limited samples: the MacArthur Study of Successful Aging (Seemon et al. 2001, 2004), ranging in age from 70 to 79 at the onset of the study, or the Wisconsin Longitudinal Study (Singer and Ryff 1999). The current study is the first to empirically examine allostatic load in a representative population sample, spanning the adult age range.

3. Data and Methods

3.1. NHANES DATA

Data for this study come from the third National Health and Nutrition Examination Survey (NHANES III). Survey information and laboratory and clinical exams were conducted with about 40,000 persons in this nationally representative sample of the US noninstitutional population (National Center for Health Statistics 1994). In this analysis, we use data on the 23,426 sample members 20 years of age and over. Data were collected over a 6-year period from 1988 through 1994.

3.2. MEASUREMENT

3.2.1. Allostatic Load

Data for the frailty measure are derived from the examination and laboratory results. In developing an index of frailty, we follow the lead of other research on allostatic load and construct an index representing the number of physiological indicators that are at least moderately outside the appropriate range for each indicator. Because our sample includes all ages, we use definitions of risk based on clinical practice guidelines where such guidelines exist. Where such guidelines are not available, we empirically derive the risk group aiming to defining those in the top 25% as at risk such as has been done in other operationalizations of allostatic load (Seeman et al. 2001; Singer and Ryff 1999). The 13 allostatic load markers, their definitions and means and SDs are shown in Table 1.

As indicated above, physiological risk factors represent functioning across a number of bodily systems. Indicators of cardiovascular and metabolic functioning include diastolic and systolic blood pressure, high-density lipoprotein (HDL), total cholesterol, triglycerides, body mass index (BMI), and glycated hemoglobin. Three markers of inflammation [albumin and C-reactive protein (CRP) and fibrinogen] are included. Indicators of lung function (peak flow), urinary function (creatinine clearance), and homocysteine (an amino acid that has been shown to be related to a variety of health outcomes) are also included. Our choice of indicators has been guided by both prior research and data availability. For instance, other operational approaches to defining allostatic load have included indicators of sympathetic nervous system functioning that are not available for this analysis (Seeman et al. 1997, 2001, 2004).

Some of the indicators included in our definition of allostatic load were collected in a physical exam (see Appendix A, Table A1). Two measures of cardiovascular health, diastolic and systolic blood pressure, were obtained from the mean value of three sets of blood pressure measurements performed at a mobile examination center and during household interviews. BMI was calculated from weight and standing height using the formula: BMI = weight (kg)/(height (cm)/100)^2). Peak flow was determined by the maximum expiratory flow observed from all acceptable forced vital capacity maneuvers.

Blood samples were used to estimate levels of HDL, total cholesterol, triglycerides, and glycated hemoglobin. A fasting status of greater than 9 hours was used in the measurement of triglycerides. Glycated hemoglobin measurements were obtained from a specific glycohemoglobin test known as HbA1c. Homocysteine, as well as measures of inflammation including albumin, CRP, and fibrinogen were also obtained via blood samples. Urinary samples were used to obtain measures of creatinine clearance.

For 9 of the 13 indicators the percentage in the risk category is between 20 and 32. Diastolic blood pressure, which is based on a widely accepted clinical standard of risk, is the indicator with the smallest number of people at risk, only 6%. The high value—for triglycerides—is also based on a standard clinical practice level for treatment.

Table 1. Allostatic load variables—NHANES (frequencies and means).

Variable name	Total *N*	High risk	Percentage	High-risk group	Mean	SD	Determinant of cut point
Cardiovascular and metabolic factors							
Diastolic blood pressure (mmHg)	22,815	1341	5.9	>90	72.9	13.5	Clinical practice
Systolic blood pressure (mmHg)	22,815	3128	13.7	>140	120.9	22.6	Clinical practice
Glycated hemoglobin (%)	22,666	5826	25.7	≥5.6	5.4	1.1	Empirical
Body mass index	23,403	5096	21.8	>30	26.5	6.7	Clinical practice
Triglycerides (mg/dl)	10,243	3166	30.91	≥150	143.7	143.5	Clinical practice
HDL cholesterol (mg/dl)	22,257	5861	26.3	≤40	50.7	18.2	Clinical practice
Total cholesterol	22,453	3052	13.6	>250	204.4	50.9	Clinical practice
Inflammation markers							
Albumin (g/dl)	22,221	5472	24.6	≤3.9	4.2	0.4	Empirical
CRP (mg/dl)	22,295	5269	23.6	>0.33	0.4	0.8	Empirical
Fibrinogen (mg/dl)	11,877	3239	27.3	>336	305	94.7	Empirical
Peak flow (largest value, ml)	22,232	5361	24.1	<5922	7548.1	2836.3	Empirical
Creatinine clearance (mg/dl)	22,849	3767	23.8	<60	128.9	98.1	Clinical
Homocysteine (μmol/l)	9904	2605	26.3	>10.9	9.8	6.8	Empirical

Allostatic load for each individual indicator is defined as the number of factors out of 13 in the high-risk category. It is created for individuals by counting the number of indicators falling in the high-risk range. Because two of the factors are available for a subset of the sample, i.e., fibrinogen is only determined for those over 40 and homocysteine is only calculated for the half of the sample collected in the latter half of the survey, we compute an indicator based on 11 factors as well as 13. Average allostatic load (based on 13 factors) is 2.67 (SD 2.44) for the entire sample, meaning that an average adult is in the high-risk category for about three factors. The range is from 0 to 11. Using the 11 factors to define allostatic load the mean is 2.39 with an SD of 2.19.

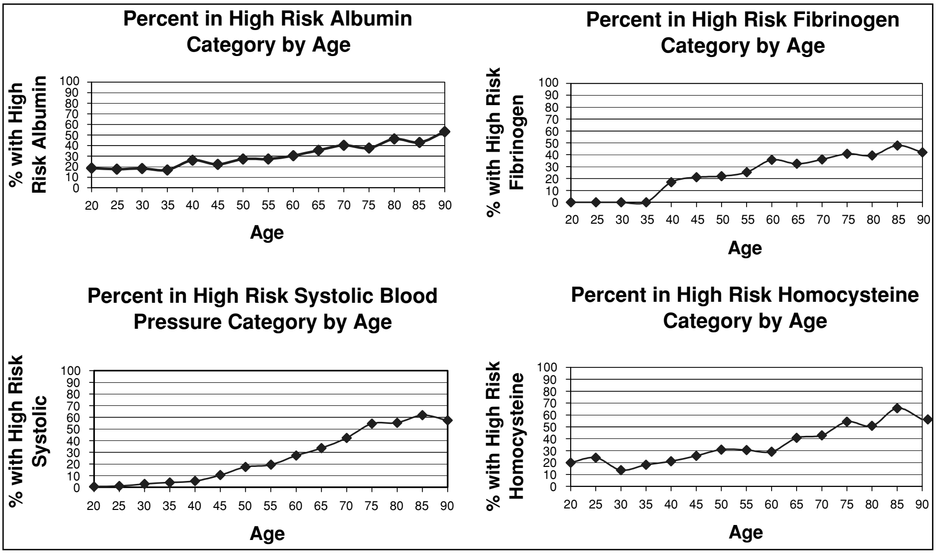
3.2.2. Health Outcomes

In order to validate our use of this measure of frailty we relate our measure to the concurrent presence of poor health outcomes including the presence of cardiovascular disease and levels of physical functioning. Cardiovascular disease was defined as the presence of at least one of the following: heart attack, stroke, congestive heart failure, or angina. Heart attack, stroke, and congestive heart failure were based on self-reports of doctor-diagnosed conditions. Presence of angina was based on self-reported answers to the Rose Angina Questionnaire. A summary measure of physical functioning was based on 12 questions assessing the degree of difficulty engaging in specific tasks including: walking a quarter of a mile, walking 10 steps without rest, stooping/crouching/kneeling, lifting or carrying 10 pounds, doing chores around the house, preparing own meals, managing money, walking room to room, standing on an armless chair, getting in and out of bed, eating, and dressing oneself. Level of difficulty ranged from 1 to 48 with higher levels of functioning characterized by lower levels on the scale. Multivariate analyses linking allostatic load to these outcomes included controls for age, age squared, and gender.

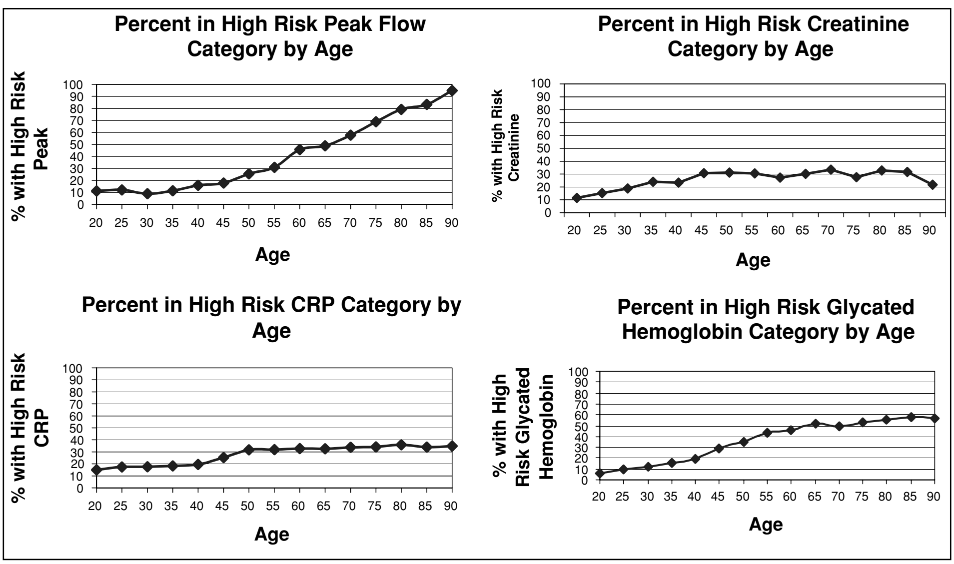
4. Results

Since our interest is in how physiological dysregulation or frailty varies with age, we examine the age distribution of risk for each individual factor in Figure 1. Being in the high-risk group increases regularly with age for the following factors: albumin, homocysteine, systolic blood pressure, fibrinogen, and peak flow. Other risk factors increase in the population up to early old age and then level off in prevalence: CRP, creatinine clearance, and glycated hemoglobin. Some factors have a curvilinear relationship with age such that the proportion of the population at risk is low at both young adult and old ages: BMI, HDL cholesterol, total cholesterol, diastolic blood pressure, and triglycerides (Figure 1). This last list of factors includes many of the most commonly employed clinical markers of physiological status. One hypothesis would be that the stronger the association of the risk factor with death, the more likely the factor will not continue to increase in the population at the older ages.

Our main interest is in the age pattern of our summary measure of physiological challenge as represented by allostatic load. The population level of physiological challenge increases with age up through the 60s and then levels off so that the population has fairly similar average levels of allostatic load during their 60s, 70s, 80s, and 90s (Figures 2A and B).

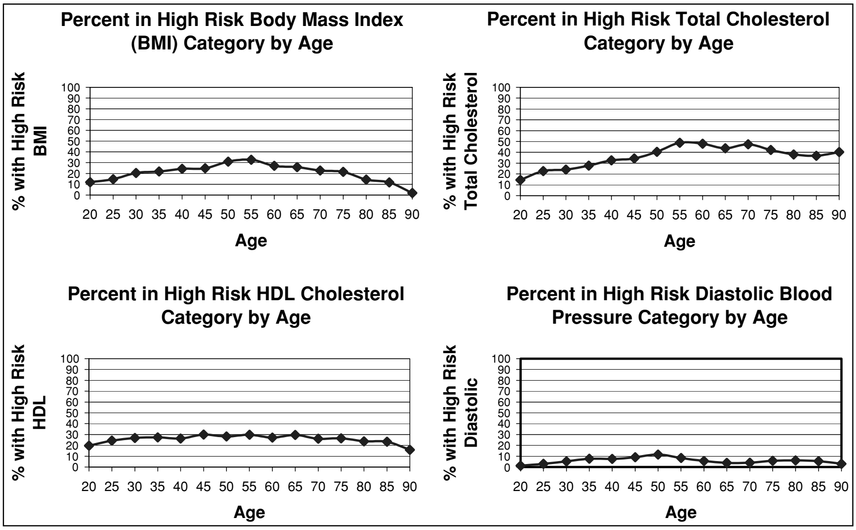


(a)

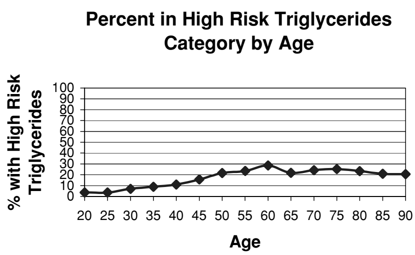


(b)

Figure 1. Percent in high-risk category by age.



(c)



(d)

Figure 1. (*Continued*)

Examination of the ratios of allostatic load of one age group to the preceding age group show the increase in the mean from one age group to the next is between 30% and 40% up to the 50–59 age group, and between 5% and 15% from 60 through 80–89 years of age (Table 2). For those over the age of 90, mean allostatic load levels are 4–6% lower than those aged 80–89 years. This index of physiological frailty indicates how the risk for adverse health outcomes in old age increases rapidly as old age is approached.

Health outcomes may be affected more by the extremes of the allostatic load distribution in the population than by the mean. The proportion of the population with an allostatic load of five or higher and one or lower are also shown in Table 3. While the percentage of the population with the highest allostatic load increases up to age 80–89, the rate of increase is higher between relatively young age groups. Table 3 presents the distribution of allostatic load by age. After age 60 about a third of the population has an allostatic load of five or higher and less than 15% are in the minimal risk category (Table 3). Most of

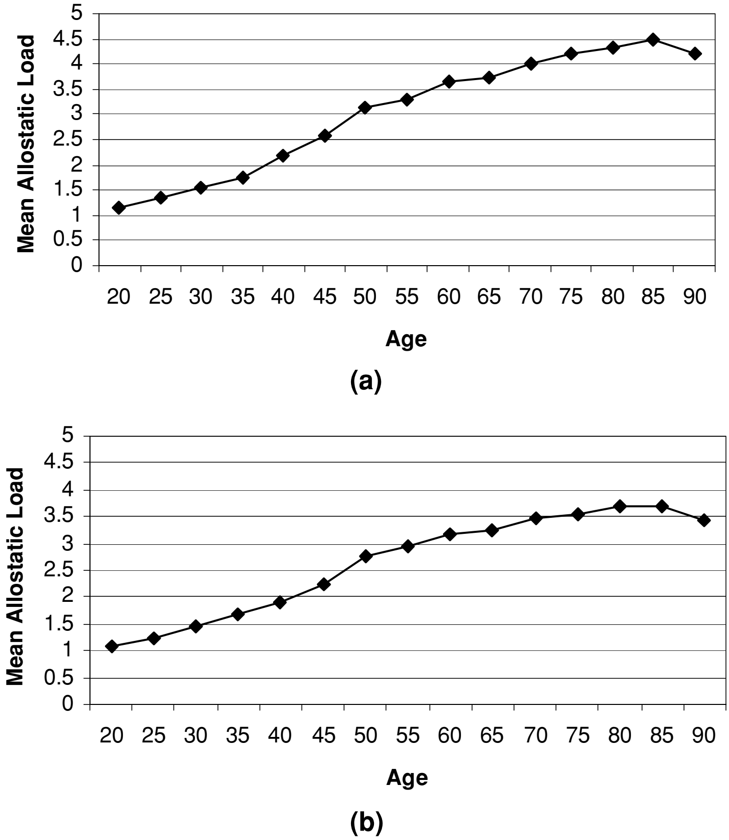


Figure 2. (A) Mean allostatic load (13) by age and (B) Mean allostatic load (11) by age.

Table 2. Mean allostatic load by age.

Age	Allo (13)	Allo (11)	Ratio of each age group to prior age group Allo (13)	Ratio of each age group to prior age group Allo (11)
20–29	1.28	1.17	—	—
30–39	1.65	1.57	1.29	1.34
40–49	2.34	2.05	1.42	1.31
50–59	3.22	2.84	1.38	1.39
60–69	3.69	3.21	1.15	1.13
70–79	4.08	3.50	1.11	1.09
80–89	4.37	3.69	1.07	1.05
90+	4.19	3.45	0.96	0.93

Table 3. Distribution of allostatic load by age (%).

Age	AL ≤1	AL 2–3	AL 4–5	AL 5+
20–29	64.6	28.4	4.9	1.9
30–39	54.1	34.4	6.9	4.6
40–49	38.1	37.1	11.7	13.2
50–59	21.2	35.6	18.5	24.7
60–69	14.1	34.6	18.6	32.8
70–79	7.0	33.9	19.6	39.5
80–89	6.3	28.0	18.3	47.4
90+	6.5	19.2	29.5	44.8

the population change in the distribution of risk takes place before age 70, after that the distribution is relatively stable even up through the ages above 90.

Because each of the indicators is a component of the total allostatic load, regressing individual variables on allostatic load clarifies the relative importance of each of them in determining the total variance in allostatic load within the population. The variance in individual age groups can also be determined in this way. The proportion of variance accounted for by each of the indicators of biological risk is shown in Table 4. Of the 13 factor indicators, fibrinogen accounts for the most variance—22%. Other important variables include BMI (12%), albumin (9%), and total cholesterol (8%). The three most important measures accounting for variance in the 11 factor index are BMI, albumin, and total cholesterol. When the role of individual factors in explaining variance is calculated for three age groups (20–39, 40–59, and 60+), it is very clear that the proportion of variance accounted for by several of the biological indicators varies by age. For example, the role of BMI in accounting for allostatic load is reduced with age from 30% among ages 20–39 to 14% among ages 60+. However, BMI accounts for the greatest variance in allostatic load across all three age groups. Furthermore, glycated hemoglobin, peak flow, and systolic blood pressure are important in the older years compared to the younger years, accounting for 9%, 8%, and 9% of the variance in allostatic load among those over age 60. These differential weights by age give some clue as to how physiological differences across systems affect populations at different ages.

Allostatic load has also been linked to poor health outcomes in previous studies. However, as mentioned earlier, these studies were limited in age and sample range. In order to provide evidence of the validity of our measure of allostatic load, we examine how predictive it is of both cardiovascular disease and physical functioning (when controlling for age and gender) in a national sample, across ages 20–90. Table 5 shows the relationship between allostatic load and physical functioning and cardiovascular disease. Allostatic load ($b = 0.24$, $p < 0.001$) is associated with poorer physical functioning and this relationship remains statistically significant after controlling for age and gender. Similarly, allostatic load is associated with a 1.2 ($p < 0.001$) times greater odds of having cardiovascular disease after controlling for age and gender. These findings serve to validate allostatic load

Table 4. Proportion of variance in allostatic load due to individual biological factors: all ages and three age groups.

	(13 Factors)	(11 Factors)	(11 Factors)	(11 Factors)	(11 Factors)
Biomarker	**All ages $N = 4087$**	**All ages $N = 15,908$**	**Ages: 20–39**	**Ages: 40–59**	**Ages: 60+**
Fibrinogen	0.216	n/a	n/a	n/a	n/a
Total cholesterol	0.084	0.132	0.068	0.104	0.106
Body mass index	0.123	0.213	0.307	0.276	0.144
Albumin	0.093	0.138	0.130	0.108	0.142
HDL cholesterol	0.073	0.089	0.143	0.098	0.077
CRP	0.067	0.093	0.082	0.094	0.119
Homocysteine	0.067	n/a	n/a	n/a	n/a
Creatinine	0.052	0.071	0.069	0.069	0.078
Glycated hemoglobin	0.082	0.095	0.054	0.080	0.094
Peak flow	0.049	0.067	0.050	0.050	0.084
Triglycerides	0.046	0.054	0.064	0.062	0.067
Systolic blood pressure	0.037	0.037	0.019	0.042	0.080
Diastolic blood pressure	0.011	0.013	0.015	0.018	0.009
	1.000	1.000	1.000	1.000	1.000

Table 5. Effect of allostatic load (11 factors) on physical functioning and cardiovascular disease (ages 20+).

	Physical function	Cardiovascular disease
	***b* value**	**Odds ratio (CI)**
Intercept	13.67***	n/a
Age	−0.13***	1.03*** (1.01–1.05)
Age squared	0.001***	1.00 (1.00–1.00)
Allostatic load	0.24***	1.21*** (1.18–1.25)
Gender	0.48***	0.81*** (0.73–0.89)
Total *N*	10,526	15,354

***$p < 0.001$.

as a measure of frailty, and supports previous studies in linking biological risk factors to poor health outcomes.

We also link each individual indicator included in allostatic load to each of the health outcomes in Table 6. It is interesting that the two blood pressure measures, perhaps the most widely recognized indicators of risk in this set, are the least related to the presence of either functioning problems or cardiovascular disease. Creatinine clearance is also not

Table 6. Regression models assessing effects of individual biological component of allostatic load on physical functioning and cardiovascular disease among ages 60+ (NHANES III).

	Physical functioning	Cardiovascular disease
Individual biological factors	***b* values**	**Odds ratios (CI)**
High diastolic blood pressure	0.34	0.92 (0.67–1.26)
High systolic blood pressure	−0.02	1.04 (0.91–1.20)
High glycated hemoglobin	0.57***	1.61*** (1.40–1.85)
High body mass index	1.40***	1.50*** (1.28–1.74)
High fasting triglycerides	0.89***	1.61*** (1.32–1.96)
Low HDL cholesterol	0.84***	1.87*** (1.61–2.18)
High total cholesterol	0.08	1.26** (1.08–1.48)
Low albumin	1.00***	1.20* (1.04–1.38)
High CRP	1.26***	1.63*** (1.42–1.88)
High fibrinogen	1.23***	1.56*** (1.36–1.80)
Low peak flow	1.35***	1.26** (1.06–1.50)
Low creatinine	−0.59***	0.91 (0.78–1.07)
High homocysteine	1.00***	1.35** (1.09–1.67)

Note: Models include age, age squared, gender, and biological factors.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

related as expected. The other indicators are each individually linked to higher levels of at least one of the conditions.

5. Discussion

We have provided evidence for the pattern of population allostatic load by age: increasing rapidly through adulthood until old age and then remaining relatively constant. We believe this pattern is related to the selectivity of the population by death and allostatic load.

While we are looking at a cross-section of the population by age, we are cognizant of the fact that the population in each age group examined is the surviving population from cohorts born years earlier. The selectivity of the population is greater as age increases. Using current mortality rates and the resulting cross-sectional life table indicates that about half of the population will die by age 80 and only about a third of those who reach 80 survive to age 90. For current 80 year olds, a far greater proportion of the cohort has died before age 80 (Crimmins 2001).

The age pattern of allostatic load—increasing markedly before old age and then remaining relatively constant in very old age—must be related to mortality. While we cannot test this in this sample, ample evidence supports this idea. Allostatic load as well as each of these individual indicators has been related to mortality in a study of 70–79 year olds (Seeman et al. 2001). The increase in the relative odds of mortality linked to each individual measure varies across indicators. The strongest relationships are with CRP, peak flow, fibrinogen, and creatinine clearance. Being in the high-risk category for any of these conditions approximately doubles the relative risk of mortality over 7.5 years (Seeman et al. 2001). In this study, the relative risk of mortality over the 7.5-year period increases very regularly with a summary index of allostatic load. Relative mortality (to those with allostatic load from 0 to 2) is about four times higher when allostatic load is three or four and it is about seven times higher when allostatic load is seven or higher (Seeman et al. 2001). Our hypothesis is that the high mortality associated with high allostatic load operates to keep the level of biological risk from increasing exponentially in the older population. Increases in frailty of this population are clearly dampened by mortality, which selects the most frail.

This is a preliminary analysis with a number of limitations. The indicators of biological risk included in our measure of allostatic load do not span as many systems as would be desirable. In other work, we have been able to include indicators of HPA and SNS functioning; these and additional indicators would be desirable (Seeman et al. 2001, 2004). This data set is not linked to subsequent health outcomes as yet; so it is not possible to link allostatic load to death in this data set. Furthermore, persons with chronic diseases such as cardiovascular disease and diabetes were included in the analyses, which could potentially confound some of the results of our study since allostatic load is a measure of preclinical symptoms of some diseases. However, preliminary analyses (not shown) excluding persons with cardiovascular disease and diabetes indicate no change in the age distribution of allostatic load. Also, in future analyses it will be important to consider gender differences as well as age differences.

See Appendix A

Table A1. Definitions, tests, and sample source of biomarkers included in allostatic load (NHANES III).

Disease/health area	Biomarker	Diagnostic test	Sample source	Cut-off point
Cardiovascular	Diastolic blood pressure mmHg	Three sets of blood pressure measurements performed at a mobile examination center or during household interviews	Exam	>90
	Systolic blood pressure mmHg	Three sets of blood pressure measurements performed at a mobile examination center or during household interviews	Exam	>140
	HDL cholesterol mg/dl	Hitachi 737 Analyzer/Boehringer-Mannheim Diagnostics	Blood serum	≤40
	Total cholesterol	Hitachi 737 Analyzer/Boehringer-Mannheim Diagnostics	Blood serum	>250
Metabolic system	Triglycerides mg/dl	Measured by contract labs using reference analytic methods	Blood serum	≥150
	Body mass index	Calculated from weight and standing height using The following formula: BMI = weight (kg)/(height (cm)/100)^2)	Self-report or exam	>30
	Glycated hemoglobin (%)	Diamat Analyzer System Diabetes Diagnostic Laboratory, University of Missouri, Columbia	Blood serum	≥5.6
Inflammation	Albumin g/dl	Hitachi 737 Analyzer/Boehringer-Mannheim Diagnostics	Blood serum	≤3.9
	CRP	ELISA	Blood serum	>0.33
	Fibrinogen (mg/dl)	Coag-A-Mate XC Plus Organon-teknika	Blood plasma	>336
Lung function	Peak flow largest value (ml)	Maximum expiratory flow observed from all acceptable repeated forced vital capacity (FVC) maneuvers	Exam	<5922
Kidney function	Creatinine clearance	Synchon AS/ASTRA Clinical analyzer	Urine sample	≤44.64
Homocysteine	μmol/l	Rasmussen method	Blood serum	>10.9

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CHAPTER 8. AGING WITHOUT DEMENTIA

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1. Introduction

Preservation of intact cognitive functioning is a major component of healthy aging. Cognitive decline and dementia are major determinants of disability and loss of autonomy in older people (Barberger-Gateau and Fabrigoule 1997). The prevalence of dementia increases almost exponentially with age in all countries, from 0.3–0.7 per 100 people under the age of 60, to 12 per 100 in the age group 80–84 years (Fratiglioni, DeRonchi, and AgueroTorres 1999). Estimates for the oldest ages are unstable, given the small sample sizes of most studies in this age group. Incidence figures are very similar in the youngest old in Europe, North America, and Asia (about 1 per 1000 person years in people aged 60–65 years), and they increase dramatically with increasing age to an average of 90 per 1000 person years in people older than 95 (Fratiglioni, DeRonchi, and AgueroTorres 1999). The most frequent cause of dementia is Alzheimer's disease (AD), accounting for about two thirds of the cases, followed by vascular dementia (VD). Mild cognitive impairment (MCI), defined as a memory impairment beyond that expected for age and education but without dementia nor repercussion on activities of daily living (ADL) (Petersen et al. 1999), is a much more frequent feature in older people, although estimates of its prevalence vary considerably across studies, given the general absence of standardized diagnostic criteria (Ritchie and Touchon 2000). MCI has been considered by some authors as a transitional zone between normal function and clinically probable AD (Petersen 2000) although not all these people will evolve toward diagnosable AD. Thus preventing or at least postponing the onset of cognitive decline and dementia could considerably improve the quality of life of many older people and relieve the burden placed on society by this dramatic "silent epidemic" (Larson 1998).

After age, the main risk factor for late-onset or sporadic AD is a genetic one. Individuals carrying the ε4 allele of the apolipoprotein E (apoE4) are at increased risk for AD, but AD may occur in individuals without this risk factor and conversely individuals carrying this risk factor may not develop the disease (Cummings et al. 1998). Thus, this allele is only a predisposition factor. This genetic risk factor is not modifiable, with the current state of knowledge. However, recent studies have suggested that the prevalence of severe

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cognitive impairment (Freedman, Aykan, and Martin 2001, 2002) and dementia (Corder and Manton 2001) might be declining as well as that of chronic disability (Crimmins, Saito, and Reynolds 1997; Freedman, Martin, and Schoeni 2002; Manton and Gu 2001; Schoeni, Freedman, and Wallace 2001) of which dementia is one of the major determinants (Agüero-Torres et al. 1998).

Since decline in a short time period cannot be attributed to a modification of the genetic characteristics of the population, environmental factors must have played a role in this phenomenon. If these data were confirmed, they would be good news, since the identification of modifiable environmental risk factors could open the door to preventive interventions against dementia. These environmental factors include lifestyle (e.g., leisure activities) and eating habits. Lifestyle is partly determined by socioeconomic status, itself strongly related to educational level. Given the cost and moderate efficacy of current symptomatic drugs in AD, and despite the potential hope of a "vaccine" against AD in the future, an environmental approach could be the most cost-effective way to decrease the incidence of dementia and more generally that of cognitive impairment in older people.

The aim of this chapter is to present a summary of epidemiological data regarding preventable risk factors of cognitive decline and dementia in older people, either by enhancing cognitive stimulation, such as education or participation in activities, or by a neuroprotective effect, which could be provided by some nutriments included in food.

2. Methods

The data come from the PAQUID (Personnes Agées QUID) study on cognitive and functional aging whose general methodology has been described elsewhere (Barberger-Gateau et al. 1992; Dartigues et al. 1992). A representative sample of 5554 community dwellers aged 65 and over was randomly drawn from electoral rolls of 75 parishes randomly selected in two administrative areas of South-western France around Bordeaux, Gironde, and Dordogne. Among them, 3777 (68%) gave their written consent to participate. The sample was representative in terms of age and sex of the local community population aged 65 and over.

Each participant was first visited at home in 1988–1989. The data collected by a psychologist included sociodemographic information, living habits, main symptoms, a functional assessment [covering the domains of ADL, instrumental activities of daily living (IADL), and mobility], and a neuropsychological test. General cognitive functioning was assessed by the score on the Mini Mental Status (MMS) examination (Folstein, Folstein, and McHugh 1975). Education was considered in two levels: at least primary school level validated by the French diploma "Certificat d'Etudes Primaires" (CEP) corresponding to about 7 years of education versus no diploma (Letenneur et al. 1999). Height and weight were self-reported and the body mass index (BMI) was computed by the ratio: Weight (kg)/Height^2 (m^2). The concordance of self-assessed weight with actual weight measured at the baseline interview was assessed in a subsample of 585 subjects by the method of Bland and Altman (1986).

If a diagnosis of dementia was suspected by the psychologist according to the criteria for dementia from the Diagnostic and Statistical Manual of Mental Disorders, third revision revised (DSMIII-R) (The American Psychiatric Association 1987), the subject was visited by a neurologist to confirm the diagnosis and ascertain its etiology according to the criteria of the National Institute of Neurological and Communicative Disorders and Stroke and AD and Related Disorders Association (NINCDS–ADRDA) (McKhann et al. 1984).

Then the subjects were followed-up in the same manner 1 (in Gironde only), 3, 5, 8, and 10 years after baseline assessment. All incident cases of dementia were registered following the same procedure: all the subjects declining three points or more on the MMS since a previous examination or suspected of dementia by the psychologist according to DSMIII-R criteria were reviewed by a neurologist.

The 3-year interview included a brief food questionnaire, assessing the frequency of consumption of broad categories of food. In addition to the usual follow-up, a sample of 169 voluntary subjects living in Dordogne participated in a specific project about nutrition named PAQUINUT (PAQUId NUTrition). In these subjects, dietary intake was assessed by a 3-day food record and a dietary history.

A blood sample was obtained in 626 volunteers at 1-year follow-up and frozen. A nested case–control study within the PAQUID cohort was designed to analyze the relationships between plasma levels of antioxidant vitamins A and E, and MDA (Malondialdehyde, a lipoperoxidation catabolite) and incident dementia. Among the 626 subjects with a blood collection at baseline, 46 developed dementia during the seven subsequent years and were considered as cases. Each case was matched (on sex and age at the time of onset of dementia) to three controls.

As cholesterol and some other biological parameters could not be measured retrospectively from frozen samples, another blood collection was conducted at 8-year follow-up, in the subsample of subjects who already had blood collected at 1-year. Among these subjects, 344 (55%) were still alive, and accepted a new collection and the 8-year follow-up visit, but 10 blood samples could not be used because of technical incidents. Thus, this study sample was composed of 334 subjects: 37 demented subjects (including 28 AD) and 297 non-demented controls. Total cholesterol, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were measured in sera after a 10–12 h fast. ApoE genotype was quantified on DNA samples.

Statistical results are expressed in terms of odds ratios (OR) or relative risks (RR) function of the statistical models used. Ninety-five percent confidence intervals (95% CI) are provided.

3. Results

Among the 3777 individuals of the initial sample, 3675 were not demented at baseline, 2133 were (58.0%) women and 1822 (49.6%) individuals aged 75 or above.

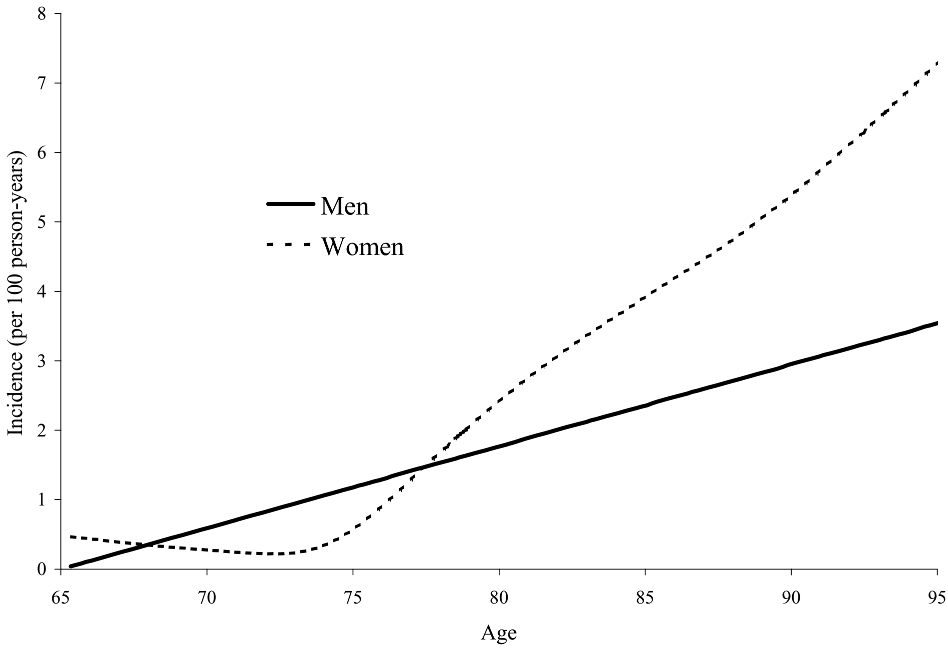

Figure 1. Age and sex incidence of dementia. PAQUID 1987–1995.

3.1. INCIDENCE OF DEMENTIA

During the first 5 years of follow-up there were 190 incident cases of dementia among these subjects, including 140 cases of AD. The incidence rate of dementia was 1.6 per 100 person years and that of AD was 1.2 per 100 person years. The global incidence of dementia was estimated as 1.3 per 100 person years in men and 1.8 per 100 person years in women. As shown in Figure 1, incidence of dementia increased dramatically with age, in particular in women after age 75. The incidence of AD was higher in men than women before 80 years of age, and higher in women than men after 80 years (Letenneur et al. 1999).

3.2. EDUCATION

There was an association between educational level and 5-year risk of incident dementia. Incidence of dementia decreased as educational level increased. However, the most discriminating cut-off was possession of the CEP: subjects with no education or with a primary school level without this diploma had a risk ratio of 1.83 (95% CI [1.37–2.44]) of developing a dementia compared with those obtaining at least the CEP (Letenneur et al. 1999). The association between dementia and gender was not explained by a confounding effect of education, despite the fact that women were in general less educated than men.

3.3. ACTIVITIES

We studied the relationship between the kind and number of social and leisure activities at baseline and the risk of dementia in the three subsequent years in 2040 subjects living in Gironde. People engaged in activities such as traveling (RR = 0.48, 95% CI [0.24–0.94]), gardening (RR = 0.53, 95% CI [0.28–0.99]), doing odd jobs or knitting (RR = 0.48, 95% CI [0.26–0.85]) had a significantly decreased risk of subsequent dementia after adjustment for age and cognitive performance at baseline (Fabrigoule et al. 1995). Moreover, there was a cumulative effect of doing these activities: being engaged in two or three different activities was significantly associated with a lower risk of dementia, the "protective" effect of three activities (RR = 0.20, 95% CI [0.04–0.86] being stronger than that of two activities (RR = 0.41, 95% CI [0.18–0.90]) whereas taking part in a single activity was not significantly associated with a decreased risk of dementia. For sports participation, the relationship reached only borderline statistical significance (RR = 0.33, 95% CI [0.10–1.04]) (Fabrigoule et al. 1995).

3.4. FOOD

The relationship between food and cognitive and functional status was first studied in a cross-sectional way in 1758 subjects who answered the brief food questionnaire at 3-year follow-up. Regarding the specific effect of food rich in polyphenols, which are strong antioxidants, people drinking tea everyday had a significantly decreased risk of scoring <24 on the MMS, in logistic regressions adjusted for age, sex, and education (OR = 0.41, 95% CI [0.23–0.84]). These subjects as well as occasional tea drinkers also had a significantly decreased risk of being IADL dependent (OR = 0.66, 95% CI [0.45–0.97] for daily drinkers). Daily fruit (OR = 0.15, 95% CI [0.05–0.46]) or chocolate (OR = 0.63, 95% CI [0.43–0.92]) consumption was also significantly associated with a decreased risk of IADL dependency. In previous analyses, we showed that IADL dependency was a strong predictor of dementia in the subsequent years (Barberger-Gateau et al. 1999).

However, cross-sectional analyses do not allow us to conclude that these nutritional habits are a cause and not a consequence of better health status. In particular, daily fruit consumers were also less dependent for shopping (OR = 0.65, 95% CI [0.50–0.85]). Thus, they were more able to buy fresh products.

In longitudinal analyses conducted in 1416 non-demented subjects at the 3-year visit followed-up at least once afterward, daily tea consumption was associated with a decreased risk of 7-year incident dementia, which reached borderline significance after adjustment for age and sex (RR = 0.61, 95% CI [0.34–1.10]). This relationship was partly explained by educational level: there were 17.4% daily tea drinkers among subjects achieving the CEP level, versus only 7.6% in the less educated group ($p < 0.001$). Thus, when education was introduced into the model, the RR was slightly higher (0.69) but far from significance with a 95% CI ranging from 0.38 to 1.25.

There was a significant decrease of the risk of incident dementia with increasing frequency of fish or seafood consumption in the same subjects. After adjustment for age and sex, those eating fish or seafood at least once a week had a RR of 0.66 (95% CI [0.47–0.93]) of becoming demented in the seven subsequent years. When education was added into the model, the hazard ratio was almost unchanged (0.73) but the 95% CI [0.52–1.03] slightly overlapped the value 1, indicating that the "protective" effect of weekly fish or seafood consumption was partly explained by higher education of regular consumers. When the analysis was reduced to incident cases of AD, adjusted for age and sex, subjects eating fish or seafood at least once a week had a RR of 0.69 of becoming demented in the seven following years, with borderline significance (95% CI [0.47–1.01]) (Barberger-Gateau et al. 2002). There was no association between meat consumption and risk of dementia. Meat consumption was not associated with education.

Moderate wine consumption was also associated with a decreased risk of developing dementia. Wine was the only alcoholic beverage reported by more than 95% of the 2115 regular drinkers at baseline (56% of the sample). Among the initially not demented 2273 subjects followed at 3 years, the 318 subjects drinking 3–4 glasses per day (between $\frac{1}{4}$ and $\frac{1}{2}$ liter wine per day) had a significantly decreased risk of 3-year incident dementia (crude OR = 0.18, 95% CI [0.06–0.59]) and AD (OR = 0.25, 95% CI [0.08–0.81]) as compared to the 971 non-drinkers. These figures remained almost unchanged after adjustment for age, sex, education, occupation, and baseline MMS. In mild drinkers ($<\frac{1}{4}$ l/day) there was a negative association only with AD, after adjustment (OR = 0.55, 95% CI [0.31–0.99]) (Orgogozo et al. 1997).

The main active components of wine are alcohol and polyphenols, in particular flavonoids which have strong antioxidant effects. Flavonoids are also contained in tea, fruit, and chocolate. The brief 3-year food frequency questionnaire was used to provide an approximate evaluation of the overall flavonoid intake of the 1367 not demented respondents who were seen at least at one of the two following visits. The age-adjusted 5-year RR of incident dementia was 0.55 (95% CI [0.34–0.90]) for the two highest tertiles of flavonoids consumption compared to the lowest. After adjustment for sex, education, weight, and vitamin C intake, the RR was almost unchanged, indicating that the intake of antioxidant flavonoids is inversely related to the risk of incident dementia (Commenges et al. 2000).

3.5. VITAMIN AND MDA PLASMA LEVELS

These results were reinforced by longitudinal biological data obtained in the 626 volunteers who accepted a blood collection at 1-year follow-up. Vitamin E plasma level is not only a reflection of food intake but also an indicator of overall oxidative status of the body. Initial plasma levels of vitamins A and E tended to be lower in the 46 incident cases of dementia than in their healthy age and sex-matched controls (mean values respectively 2.06 and 22.62 μmol/l in cases versus 2.23 and 24.99 in controls). Regarding the marker of lipoperoxidation, MDA was higher in cases than in controls (mean values 1.35 versus 1.23 μmol/l).

Plasmatic values were split in terciles in multivariate logistic regression models. Risk of dementia, adjusted for age, sex, education, and apoE4, was significantly increased for the lowest tercile of vitamin E level, under 21.0 μmol/l (OR = 2.54, 95% CI [1.06–6.10]) as compared with the highest tercile. The same trend was observed for vitamin A but not significant (OR = 2.10, 95% CI [0.88–5.02]). For MDA higher values tended to be associated with a higher risk of dementia, although not significant (for the highest tercile of MDA OR = 2.13, 95% CI [0.89–5.07]). These results suggest that subjects with low levels of vitamin E are at higher risk of developing dementia in the subsequent years.

3.6. CHOLESTEROL

The cross-sectional relationship between serum cholesterol level and the presence of dementia was analyzed in a case-control study conducted at 8-year follow-up in 334 subjects then aged 73 and more (37 demented subjects and 297 non-demented controls).

The following variables were significantly associated with dementia in univariate analyses (p at least < 0.05): age, low HDL-C, presence of apoE4 allele, low educational level, and low wine consumption. Hypolipemic treatment intake was more frequent in non-demented subjects (19.2 versus 2.7%, $p < 0.05$). No significant differences were found between demented subjects and controls for total cholesterol, LDL-C, nor protein plasma level.

For an easier clinical interpretation, HDL-C was split into quartiles. There was no significant difference in the prevalence of dementia between the first three quartiles of HDL-C (12.9%, 13.4%, and 15.3%, respectively), whereas the prevalence (2.4%) was much lower in the highest quartile, corresponding to a HDL-C concentration >1.62 mmol/l. Thus, the HDL-C variable was split into two categories: 1.62 mmol/l or less, and more than 1.62 mmol/l. In multivariate analyses, subjects with a HDL-C rate above 1.62 mmol/l had a strongly decreased risk of being demented compared with those with a lower HDL-C rate (OR = 0.12, 95% CI [0.02–0.57]). Younger age, higher education, and wine consumption also remained significantly associated with a lower risk of dementia in this first model, not taking into account the apoE4 status of the subjects. When apoE4 status was introduced into the regression model, the association between HDL-C and dementia was unchanged. The presence of apoE4 was also associated with an increased risk of dementia (OR = 4.35, 95% CI [1.73–10.9]) whereas wine consumption was no longer significant when adjusting for apoE4 (Bonarek et al. 2000).

3.7. BMI

Non-demented subjects with a BMI lower than 21 at baseline had an increased risk of developing dementia during the 8 years of follow-up as compared with subjects whose BMI was between 23 and 26 (OR = 1.57, 95% CI [1.15–2.15]). However, when individuals who developed dementia early during the follow-up (1 and 3 years) were excluded from the analysis, this relationship was no longer significant (Nourhashemi et al. 2003).

Thus a low BMI does not in itself seem to be a risk factor for dementia in the long term, but rather a sign which occurs early in the infraclinical stages of the disease. However, among the 169 volunteers included in the PAQUINUT project, subjects with a BMI greater than or equal to 23 kg/m^2 had 3.6 times less likelihood of having a cognitive decline in MMS score greater or equal to three points in the five subsequent years, adjusted for age and sex (OR = 0.28, 95% CI [0.09–0.90]). BMI ranging between 23 and 27 was associated with a significantly decreased risk of IADL disability (OR = 0.31, 95% CI [0.10–0.93]). Thus in apparently healthy elderly people a BMI ranging between 23 and 27 is associated with lower risks of functional and cognitive declines in the five subsequent years (Deschamps et al. 2002).

4. Discussion

The data presented above show that a higher educational level, engagement in leisure activities, healthy eating habits including a high consumption of food rich in flavonoids and vitamins such as fish, fruit, vegetables, tea, and chocolate, and moderate wine drinking are associated with a decreased risk of dementia or cognitive decline or as well as IADL dependency. These results come from observational epidemiological data but they have biological plausibility and suggest several possibilities for intervention.

It is hardly plausible that the associations presented here could be explained by a selection bias, in particular by a difference in educational level between participants and non-participants. At baseline participants were representative in terms of age, sex, and occupation of the target population (Dartigues et al. 1991). During follow-up, selection bias could have occurred through selective mortality or drop-outs. Education was not associated with 3-year mortality rate (except for the university level) (Berr, Dartigues, and Alpérovitch 1994) nor with survival in persons with dementia (Helmer et al. 2001). Refusals at follow-up were less educated, which might, on the contrary, result in a loss of power and an underestimation of the number of incident cases of dementia among the low educated (Letenneur et al. 1999).

The effect of education may be explained by the theory of cognitive reserve (Katzman 1993). The cognitive reserve hypothesis supposes that individuals manifest different thresholds for symptom occurrence with brain dysfunction (Cummings et al. 1998). Patients with higher education would have greater brain reserve and thus they would sustain more cerebral lesions before becoming symptomatic and reaching the threshold of diagnosable dementia. Leisure activities could contribute to maintain or even increase cognitive reserve. However, according to this theory patients can have a genetically inherited greater cognitive reserve, which allows them to achieve a higher educational level, or conversely their cognitive reserve could have been developed through education. Both mechanisms probably interact throughout life, as well as deleterious factors such as head trauma.

Another explanation may be that highly educated subjects have better management of risk factors and disease. DelSer et al. (1999) have found no difference in the burden of specific AD neurodegenerative lesions according to educational level, but the less educated subjects had more cerebrovascular lesions that are not specific to AD but may strongly potentiate the dementing effect of the neurodegenerative lesions. Thus, the higher prevalence of dementia among less educated subjects found in other studies could be explained by a higher prevalence of small cerebrovascular lesions in this group. The authors explained their results through better management of risk factors and a greater access to quality health care in highly educated subjects, e.g., a better compliance with treatment for hypertension which is a major risk factor of cerebrovascular disease. Indeed, the SYSTEUR study showed that treatment of hypertension could decrease the overall incidence of dementia by 50%, but also specifically that of AD (Forette et al. 1998). Thus, interventions promoting a better access to health care and reducing socioeconomic inequalities could contribute to decrease the incidence of dementia.

The reduced incidence of dementia associated with regular involvement in social activities could also be explained by the theory of cognitive reserve: regular cognitive stimulation could contribute to maintain optimal brain functioning. An alternative explanation may be that people who are in a preclinical phase of dementia have already given up these cognitively demanding activities. Indeed, we found that slight difficulties in IADL were already present 3–5 years before the clinical diagnosis of dementia could be made (Barberger-Gateau et al. 1999). The efficacy of cognitive stimulation to postpone the onset of dementia could be evaluated in subjects who are already in the MCI stage.

The protective effect of consumption of food or drinks rich in polyphenols or vitamins was also found in other epidemiologic studies, which support the hypothesis of a central role of oxidative stress in brain aging and dementia (Berr 2000; Deschamps et al. 2001). Antioxidant approaches offer a new perspective for the prevention and therapy of AD (Behl 1999; Nourhashemi et al. 2000). Such interventions still have to be evaluated. A prospective clinical trial showed that supplementation of the diet of AD patients with vitamin E reduced significantly, after adjustment for baseline MMS scores, a combined endpoint of mortality, loss of independence and rate of institutionalization (Sano et al. 1997). Our results suggesting that subjects with low levels of vitamin E are at higher risk of developing dementia in the subsequent years, could be of great interest in identifying specific groups of subjects who could be protected by vitamin supplementation.

The lower risk of incident dementia associated with regular consumption of fish or seafood also has biological plausibility and was previously reported in the Rotterdam study (Kalmijn et al. 1997) and replicated in other studies (Kalmijn et al. 2004; Morris et al. 2003). Apart from vascular protection that could be involved in VD and in Alzheimer's-related vascular phenomena, the n-3 fatty acids contained in fish oils could reduce inflammation in the brain and may have a specific role in brain development and regeneration of nerve cells.

However, unmeasured confounding factors may also affect both dietary intake and risk of cognitive impairment, in particular education. We found an association between the educational level and the frequency of fish intake. Daily tea consumption was also more frequent in highly educated subjects. Vitamin E levels were found to be strongly correlated with level of education in other studies (Kilander and Ohrvall 1997). Some studies failed to adjust for education. The impact of education on the relationship between nutrition and cognition is clearly shown in our results on fish and risk of dementia. Highly educated subjects eat fish more often, for socioeconomic reasons (in France fish is expensive) and because they more easily have access to information about healthy food habits. Thus, these subjects would reinforce the "protective" effect of education against dementia by acquiring a healthier lifestyle. Conversely, food habits acquired in childhood and maintained lifelong could have helped them to develop better cognitive abilities (Kretchmer, Beard, and Carlson

1996) and thus to achieve a better educational level. A typology of regular tea or moderate wine drinkers is necessary to identify the psychosocial characteristics associated with these habits, which could also explain their apparently protective effect: circumstances of intake, social environment, pleasure.

There is also probably an interaction of these protective factors with apoE4 (Tol et al. 1999). There is an association between apoE genotype and AD, but also an association between apoE and lipid metabolism. Although introduction of apoE4 status into the regression models did not modify the relationship between HDL-C and dementia in our data, other authors suggested that cholesterol may not directly and independently be related to AD but indirectly through genes such as apoE4 (Chandra and Pandav 1998). However, other studies concluded that altered lipid homeostasis in the brain of AD patients was not related to the presence of apoE4 (Mulder et al. 1998).

There may also be an interaction between apoE4 and the effect of antioxidant nutrients such as wine polyphenols (Ruitenberg et al. 2002). In elderly men stratification by apoE4 status indicated that the protective effect of light drinking was stronger among apoE4 carriers than among noncarriers (Carmelli et al. 1999). Among AD cases, tissues from patients with the ε4 allele of apoE displayed lower activities of catalase and glutathione peroxidase and lower concentration of glutathione than tissues from patients homozygous for the ε3 allele of apoE. These data demonstrate that, in AD, the ε4 allele of apoE is associated with higher oxidative insults (Ramassamy et al. 2000). Prospective studies are needed to determine if individuals at high risk for diseases characterized by oxidative damage and/or who have an apoE ε4 allele might benefit significantly from available antioxidant intervention at a relatively early and asymptomatic age (Dreon and Peroutkal 2001).

5. Conclusion

Aging without dementia is a matter of public health as well as a consequence of individual behaviors. These results suggest that increasing educational level, encouraging regular involvement in social and leisure activities, facilitating equal access to health care, and promoting a diet rich in fish and antioxidants such as fruit, vegetables, and tea could contribute to healthy cognitive aging. The impact of specific interventions still has to be evaluated. Further research is needed to identify groups of subjects who could most effectively benefit from such interventions.

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CHAPTER 9. DOES APOLIPOPROTEIN E POLYMORPHISM DETERMINE THE SURVIVABILITY OF VASCULAR ACCIDENTS AT ADVANCED AGES? IMPLICATIONS FOR MORTALITY DIFFERENTIALS*

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1. Introduction

Two general approaches can be taken to investigate the role of genetics in determining longevity: one involves identifying genomic regions shared more frequently than expected by long-lived relatives, i.e., genetic linkage analysis, eventually narrowing the region of interest to a limited number of genes of interest. The other involves identifying polymorphisms found for candidate genes that change in frequency with age in population samples. This study takes the second approach focusing on apolipoprotein E (APOE) polymorphisms

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and the risk for, and survival following, vascular accidents, i.e., heart disease and stroke, at ages 75 and older.

To place this study into context, population cohorts established in the 1980s to study heart disease measured blood cholesterol levels and motivated molecular characterization of cholesterol transport proteins. Three common isoforms, i.e., variants of the major transport protein APOE were identified (denoted E2, E3, E4). They differ in one or two amino acids at positions 112 and 158 and have different efficiencies in interacting with receptors to allow cholesterol entry into cells. The isoforms influence blood cholesterol levels and the propensity for atherosclerosis (Davignon, Gregg, and Sing 1988). The common use of DNA-based technology in the 1990s shifted emphasis from protein isoforms to polymorphisms in the encoding DNA identifying APOE ε2, ε3, and ε4 alleles. Men in late middle age who carried one or two APOE ε4 alleles have a 40% elevated risk for myocardial infarction (Utermann, Hardewig, and Zimmer 1984). Risk at advanced ages is not well defined.

It was natural to investigate risk for dementia in relation to APOE polymorphism because stroke is associated with atherosclerosis and often results in dementia. Unexpectedly, APOE ε4 was found to multiply risk for the other and major cause of dementia, namely Alzheimer's disease (AD), not stroke—in fact, stroke patients were sometimes used as the control subjects in AD studies. The APOE genotypes vary about 15-fold in risk for AD: ε23 (low risk) < ε33 < ε34 < ε44 (high risk) (Corder et al. 1993, 1994; Kuusisto et al. 1994; Saunders et al. 1993; Strittmatter et al. 1993). The ε22 and ε24 occur infrequently and hence are difficult to evaluate.

The biodemographic relevance of APOE disease associations was indicated by centenarian studies: centenarians carry more ε2, and fewer ε4, alleles compared to young adults (Louhija et al. 1994; Schächter et al. 1994), implying distinct allele-specific mortality curves. We verified the existence of distinct APOE mortality trajectories for the common APOE genotypes ε23, ε33, and ε34: specifically, we compared all-cause mortality for subjects in a population cohort according to genotype. The subjects were identified as persons age 75 and older living in a district of Stockholm in October, 1987 (the Kungsholmen cohort; see Section 2; Corder et al. 1996). The cohort was established to investigate dementia: cognition for study subjects was evaluated during 1987–1989. Midway into the baseline interval it was decided to extract and store DNA for genetic studies. DNA was available for about 60% of the subjects. Mortality from the date that blood was drawn until the end of 1994 was evaluated for the 1077 subjects who carried one of the common APOE genotypes. There was no evidence of selective mortality at ages 75–84. However, the oldest subjects aged 85 and older demonstrated 3-fold variation in risk of death depending on APOE genotype: ε23 < ε33 < ε34. Hence, the selective mortality implied by the centenarian studies was demonstrated to occur at ages 85 and older. If anything, the mortality differentials increased with age.

Despite the wide variation in the risk of AD associated with APOE genotype (at ages 60–75, lesser at advanced ages), AD as a slowly fatal disorder whose clinical progression is only weakly associated with APOE genotype could not account for the selective mortality found at ages 85 and older (Basun et al. 1995; Corder et al. 1995; Dal Forno et al. 1996;

Norrman et al. 1995). Moreover, it was subjects who had good cognition who demonstrated mortality differentials.

On the other hand, vascular disorders are common at advanced ages and can be rapidly fatal. With increasing age, amyloid derived from APP (the amyloid precursor protein) deposits not only in the brain as senile plaque but also in brain vessels as cerebral amyloid angiopathy (CAA) (Kalaria and Premkumar 1995) and in peripheral blood vessels displacing normal smooth muscle cells (Ervin et al. 2004). The rate of deposition is markedly higher for ε4 carriers. This pathology likely alters the integrity of vessels and might determine the APOE-specific trajectories of mortality in late age. In addition, APOE4+ subjects in the Bryan Alzheimer's Disease Research Center brain bank often demonstrate damage to heart valves and to the muscle of the heart, i.e., to actin-containing structures (Corder et al. in preparation) which may be amyloid related.

Kungsholmen cohort members who had a history of myocardial infarction or stroke had marginally lower (not higher) frequency of the ε34 genotype. (MI: 23% versus 28% for women; 21% versus 24% for men; Stroke: 20% versus 24%; Basun et al. 1996). These persons had survived a vascular accident. The implication is that vascular accidents might possibly be less survivable for APOE4+ persons. The possibility that prognosis following vascular accident varies according to APOE genotype is investigated by identifying dates of diagnosis for each vascular ICD-8 code for cohort subjects from computerized diagnostic records for the Stockholm region and then contrasting risk and prognosis according to APOE genotype. We found a 5-fold variation in mortality from 8% to 40% within 3 months of a vascular diagnosis at ages 85 and older depending on APOE genotype.

2. Methods

2.1. STUDY SUBJECTS

The Kungsholmen cohort (Fratiglioni et al. 1991, 1992) consists of 1810 of 2368 residents of a district of Stockholm aged 75-years and over on October 1, 1987. Baseline examinations were completed within the next 2 years. Some subjects died before they could be examined, the major reason for exclusion from the cohort. Mini-mental State Examination (MMSE) score (Folstein, Folstein, and McHugh 1975) was used to divide subjects into cognitively impaired i.e., scores 0–23) and intact (i.e., scores 24–30) groups. The cohort was followed for mortality to December 31, 1994 using vital statistics for the Stockholm region (Corder et al. 1996). Informed consent was obtained for each subject in accordance with protocols approved by the Ethical Committee at the Karolinska Institute.

2.2. ASCERTAINMENT OF CARDIO- AND CEREBROVASCULAR DIAGNOSES

Computerized hospital discharge records and death certificates were accessed for the Stockholm region to identify which subjects had relevant diagnoses and the date of diagnosis. The records contain the date of first occurrence of each ICD-8 code (World Health Organization 1977; as adapted for Sweden) in the range 410–414 (ischemic heart disease), 420–429 (nonischemic heart disorders), and 430–438 (cerebrovascular disease), or equivalent ICD-9 codes (Basun et al. 1996). The records covered the years 1969–1994.

2.3. APOE GENOTYPING

1124 of 1810 subjects were genotyped for APOE. DNA was extracted from peripheral white blood cells using standard methods. APOE genotype was determined using a microsequencing method on microtiter plates (AffiGen APOE, Sangtec Medical, Bromma, Sweden). Subjects without stored DNA for genotyping were frequently those with baseline exams done late in 1987 or in 1988 before the importance of genetic studies was fully realized. Efforts to obtain blood for DNA extraction from subjects assessed early were made at subsequent exams. They account for 25% of the blood samples drawn.

2.4. STATISTICAL ANALYSIS

The study was limited to the 1077 of 1124 genotyped subjects with one of the three common APOE genotypes: ε2/3, ε3/3, and ε3/4. The subjects were divided according to age (75–84 versus 85 and older). Genotype-specific cumulative *incidence* distributions from the time of the baseline examination during 1987–1989 until death or December 31, 1994 were estimated by the product limit method (Kaplan and Meier 1958) and compared with log-rank tests (Peto et al. 1977) for each age group. This approach was then used to detect genotypic differences in *prognosis* for affected subjects from the date of diagnosis. It was also used to compare genotypic differences in mortality for subjects without vascular diagnoses. The analysis was implemented using SAS procedure LIFETEST (SAS Institute 1988). All reported probability values are two-sided and statistical significance was declared at the 5% level.

3. Results

3.1. AGES 75–84

The relatively younger subjects aged 75–84 at entry into the Kungsholmen cohort did not demonstrate APOE genotypic associations with vascular disease or differences in prognosis if affected. A total of 229 (26%) were diagnosed as having vascular disease between entry into the cohort 1987–1989 and December 31, 1994. Figure 1a displays the proportion not affected at each time point within 5 years from entry into the cohort. Each year is ticked on the x-axis. The solid line represents ε23+ subjects; the dotted line represents ε33+ subjects; and, the dashed line represents ε34+ subjects. The genotypic distributions were indistinguishable (log-rank test: $\chi^2 = 1.09$ with 2 d.f., $p = 0.58$). Note that the first date of diagnosis was evaluated if there were several ICD-8 codes each with a date of diagnosis; use of the last date of diagnosis gave essentially the same result.

Prognosis, i.e., survival from the date of diagnosis, is displayed for the 170 subjects who received a diagnosis before age 85 (Figure 1c). Survival from the date of diagnosis was unrelated to APOE genotype ($\chi^2 = 2.28$, $p = 0.30$). One-year survival was 60%–70% for

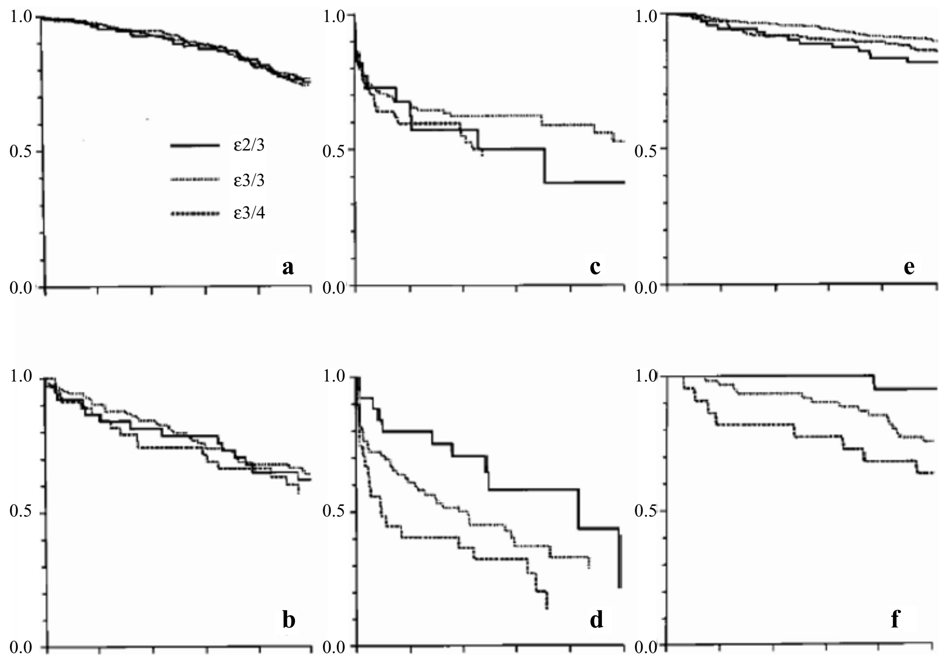

Figure 1. APOE genotype-specific risks. The cumulative occurrence of vascular diagnoses (1987–1989 to 1994), i.e., the proportion of unaffected subjects, who entered the cohort at (a) ages 75–84 versus (b) ages 85+. Prognosis following a vascular diagnosis, i.e., proportion surviving from the time of an occurrence at (c) ages 75–84 versus (d) ages 85+. Cumulative survival for persons without vascular diagnoses (available 1969–1994) who entered the cohort at (e) ages 75–84 versus (f) ages 85+.

each genotype leveling off from high hazard within the first 3 months. For subjects having more than one diagnosis, the date of the last-occurring ICD-8 code was evaluated. Use of the first date of diagnosis gave essentially the same result.

We then examined survival for persons without vascular diagnoses (1969–1994). Five-year survival was clearly better compared to affected persons but essentially the same for each genotype ($\chi^2 = 1.74$ with 2 d.f. $p = 0.42$) (Figure 1e). Hence, there was no evidence that either vascular disease or mortality at ages 75–84 were related to APOE genotype.

3.2. AGES 85 AND OLDER

Like the relatively younger subjects, the older age group did not demonstrate APOE genotypic differences in the occurrence of vascular disease (Figure 1b). There were 72 incident cases (33%) for subjects entering the cohort at age 85 or older. Genotypic distributions were indistinguishable (log-rank tests: $\chi^2 = 0.56$ with 2 d.f., $p = 0.75$).

However, prognosis at ages 85 and older varied 5-fold depending on APOE genotype. A total of 131 subjects received a diagnosis at ages 85 and older (Figure 1d). The genotypic differences in prognosis were appreciable and statistically significant ($\chi^2 = 7.38$ with 2 d.f., $p = 0.02$): 3-month survival was 92% for subjects who carried ε23, 71% for ε33, and 60% for ε34. Hence, five times as many APOE ε34+ subjects died compared to ε23+ subjects (40% versus 8%). Mortality differences were concentrated in the 3 months following a diagnosis. Survival from 3 to 12 months did not demonstrate wide variation (14%, 14%, and 31%, respectively). It might be added that the ε2/3+ subjects were more than a year older than the other subjects. The observed better prognosis for ε2/3+ subjects was found despite their older age.

Only a weak trend in mortality was found at ages 85 and older for persons without vascular diagnoses (1969–1994) ($\chi^2 = 4.08$ with 2 d.f., $p = 0.13$) implying that the survivability of vascular events at advanced ages may substantially account for the previously observed differences in all-cause mortality related to APOE genotype. Mortality within 1 year of entering the cohort was 0%, 3%, and 18% for ε2/3, ε3/3, and ε3/4, respectively. Mortality until the end of follow-up on December 31, 1994 was 25%, 44%, and 50%. A wider spectrum of relevant disorders might account for this trend. However, missed vascular events is another and plausible explanation.

3.3. SUBGROUP ANALYSIS

We tried to determine whether prognosis at ages 85 and older was associated with APOE genotype for subgroups based on sex, cognitive status, and diagnosis groups (cardio- and cerebrovascular diagnoses). Each subgroup demonstrated the same pattern of selective survival in the 5 years following diagnosis (Figure 2). A higher proportion of men were affected, but genotypic patterns of prognosis were similar for both sexes: 3-month mortality for women (Figure 2a; $n = 97$) was 11%, 31%, and 39% for ε2/3, ε3/3, and ε3/4, respectively; and 0%, 21%, and 43% for men (Figure 2b; $n = 34$). The 96 subjects who had intact cognition (Figure 2c) had better prognosis compared to the 35 who were cognitively impaired (Figure 2d): 3-month mortality for the intact group varied 8-fold from 5% to 21% and to 40% for ε2/3, ε3/3, and ε3/4; and 3-fold variation for impaired subjects—17%, 45%, and 57%. There was 8-fold variation in mortality within 3 months following a cardiovascular diagnosis (Figure 2e; $n = 97$): 5%, 31%, and 43% for ε2/3, ε3/3, and ε3/4 compared to 3-fold variation following cerebrovascular diagnoses (Figure 2f; $n = 46$): 14%, 22%, and 39%. Note that 12 subjects had both cardio- and cerebrovascular diagnoses. Nonischemic cardiovascular diagnoses including congestive heart failure and atrial fibrillation predominated (found for 91 of 131 subjects).

4. Discussion

The Kungsholmen cohort demonstrates selective mortality related to APOE genotype at ages 85 and older: ε2/3+ subjects were at low risk of death; ε3/3 had intermediate risk, and ε3/4+ were at high risk, 3-fold variation in hazard and a 2-year difference in mean survival (Corder et al. 1996). Selective mortality was not found at ages 75–84. We investigated whether or not vascular disease, common at ages 85 and older and rapidly fatal, might ac-

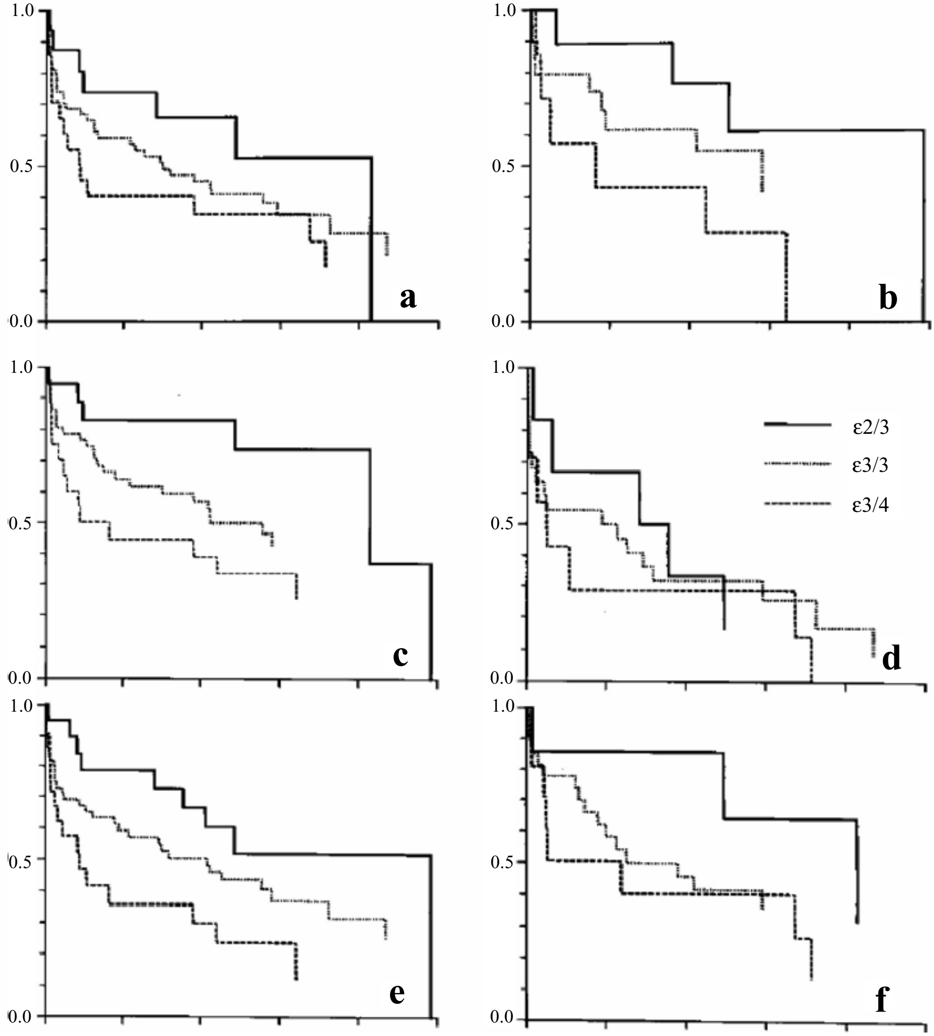

Figure 2. Subgroup analysis. The 131 subjects who had a vascular diagnosis at ages 85 and older (Figure 10.1d) were divided according to sex (a: women; b: men), cognition (c: MMSE 24–30 at entry into the cohort, i.e., relatively intact; d: MMSE 0–23), and according to type of diagnosis (e: cardiovascular; f: cerebrovascular). Mortality varied according to the same APOE genotype pattern for each subgroup: e3/4 > e3/3 > e2/3.

count for the selective all-cause mortality. A third of older subjects had a vascular diagnosis in the 5-year window of observation. For cases, there was a 5-fold variation in the risk of dying within 3 months of the vascular accident depending on APOE genotype: 8% for ε2/3, 29% for ε3/3, and 40% for ε3/4 ($p = 0.02$). Consistent results were obtained for subgroups based on sex, cognitive status, and type of diagnosis, although wider 8-fold variation in risk of death was found for persons having intact cognition (with otherwise better survival) and cardiovascular (rather than cerebrovascular) disease. The frequency of nonischemic cardiac diagnoses, primarily congestive heart failure and atrial fibrillation (91 of 131 subjects), speaks for itself. Possibly, the inclusion of "less well defined" cerebrovascular diagnoses with less well-defined dates of diagnosis may have attenuated the prognostic pattern for cerebrovascular disease. In short, the survivability of vascular accidents at advanced ages may depend on which combination of APOE alleles has been inherited. The weak trends in the same directions for subjects without vascular diagnoses may result from missed diagnoses. Alternatively, there may be a broader spectrum of APOE-related disorders.

The age- and APOE4-related accumulation of amyloid in vessels (Ervin et al. 2004), thinning of small vessel walls (Salloway et al. 2002) as well as frequent heart valve and muscle damage for APOE4+ persons (Corder et al. in preparation) is a potential explanatory underlying pathology. One speculation is that therapies devised to limit and reverse amyloid deposition in the brain to prevent/treat Alzheimer disease might also protect the vasculature. For example, monoclonal antibodies injected into the peripheral blood system may serve as a sink for amyloid, drawing it out of the brain and vessels allowing excretion. This system might prevent and reverse vessel amyloid deposits. If so, life might be extended and APOE-genotypic differences in survival be minimized by the use of such therapies.

In summary, survival at ages 85 and older for the Kungsholmen cohort varied according to APOE genotype. We investigated the occurrence of vascular disease and subsequent mortality for the cohort. Mortality within 3 months of diagnosis varied 5-fold depending on APOE genotype: 8% for $\varepsilon 2/3$, 29% for $\varepsilon 3/3$, and 40% for $\varepsilon 3/4$. Weak associations were found for subjects not having vascular diagnoses. Hence, the survivability of cardio- and cerebrovascular disease may substantially account for APOE-related selective mortality at advanced ages.

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CHAPTER 10. THE DANISH LONGITUDINAL CENTENARIAN STUDY*

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1. Introduction

Analyses of recent reliable demographic data from developed countries have shown that since the 1960s the steady decline of the mortality rates (1–2% per year) among 80+-year olds is the major contributor to the growing proportion of centenarians (Vaupel and Jeune 1995; Vaupel et al. 1998). Following this decline, the number of octogenarians has increased fourfold, the number of nonagenarians eightfold, while the number of centenarians has increased 20-fold in the period 1950–1990 (Kannisto 1994). In Denmark today, the number of Danish centenarians (aged 100 and over) is around 500. In the 1950s, the corresponding number was around 20, and in the 1870s only around three (Skytthe and Jeune 1995). Indeed, centenarians are a new generation emerging in the 1800s, growing slowly until the middle of the 20th century, after which there is a dramatic increase in the last half of the century (Jeune and Kannisto 1997). Additionally, the maximum length of life has increased by more than 10 years in the last decades of the 20th century (Jeune and Andersen-Ranberg 2000).

It was not until the beginning of the 1960s, when centenarians became less rare in countries with low mortality, that it became possible to conduct descriptive surveys of centenarians. Noteworthy are the pioneer studies in the 1960s by Haranghy (1965) and Franke et al. (1970). Within the last two decades of the 20th century the increasing number of centenarians has made larger and even population-based surveys possible, where health has been a main topic (Allard and Robine 2000; Beregi 1990; Deiana et al. 1999; Franceschi et al. 1995; Franke 1997; Hitt et al. 1999; Inagaki 1999; Louhija 1994; Samuelsson et al. 1997; Watanabe 1999a). But the various studies are heterogeneous, focusing on different aspects of longevity, and using different instruments.

Results from centenarian studies have been contradictory, the dissimilarities being more pronounced than similarities. Prevalences of common diseases vary greatly: Dementia from 27% (Hagberg et al. 2001) to 89% (Thomassen, van Schaick, and Blansjaar 1998), congestive heart failure from 27% (Samuelsson et al. 1997) to 60% (Louhija 1994), myocardial infarction from a few percent (Baggio 1999) to almost 30% (Franke and Schramm 1980),

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and diabetes from 1% (Watanabe 1999a) to 11% (Louhija 1994). Cancer varies from almost zero (Watanabe 1999a) to 29% (Louhija 1994; Olsen 1995). More comparable disease prevalence rates have been reported for stroke (∼10%) and hypertension (10–20%). Physical functioning also seems to be rather comparable with about 1/3–1/2 being independent in activities of daily living (Franceschi 1995; Franke 1977; Samuelsson et al. 1997). Despite these findings the general conclusions of most earlier studies seem to indicate that not only are centenarians relatively healthy (Beregi 1990; Candore et al. 1997; Franceschi et al. 1995;), but they have also been healthy most of their life until a few years before death as a centenarian (Hitt et al. 1999). Yet, one highly representative population-based study is challenging this concept by finding higher disease prevalence among centenarians than has been reported by others (Louhija 1994). So the question still remains: are centenarians selected healthy subjects or are they as diseased and frail as would be predicted from our knowledge of increasing morbidity with advancing age?

The Danish Longitudinal Centenarian Study was launched to describe the health characteristics of an unselected population of Danes aged 100 using standardized instruments of assessment and well-known definitions of diseases. Surviving participants have been revisited at the ages of $101\frac{1}{2}$, 103, 104, 105, and 106. Currently, the 107-year-olds are being visited. These annual visits are made by the same investigators and concentrate on physical and mental functioning as well as health status. Blood samples are also collected.

This chapter focuses on methods, feasibility, and results from the main study of the 100-year-old centenarians. Some of the major results have been published in detail elsewhere (Andersen-Ranberg, Vasegaard, and Jeune 2001a; Andersen-Ranberg, Schroll, and Jeune 2001b; Andersen-Ranberg et al. 1999a, b).

2. Material and Methods

2.1. STUDY POPULATION

To minimize selection bias due to high mortality a design with a dynamic cohort of people aged 100 was chosen. This was achieved by investigating subjects who entered the study and were eligible from the day they celebrated their 100th anniversary. Potential centenarians-to-be were identified in two steps. In March 1995 all living subjects born in 1895 were identified through the Danish Civil Registration System (CRS). In December 1995 the procedure was repeated, this time identifying all living subjects born in 1896. As a result, we identified 276 subjects living in Denmark and celebrating their 100th anniversary during the period April 1, 1995 to May 31, 1996. All these subjects were admitted to the study population continuously as soon as they reached 100 years of age. The validity of their age was verified later in a study on centenarian siblings, where the age of each individual was cross-checked with the birth registration year and the age in the following censuses.

When identified as eligible the subjects received a letter about 2 weeks after their 100th birthday. In the letter, the study was explained and we asked permission (informed consent) for a geriatrician (K. A-R.) and a geriatric nurse (Lone Vasegaard) to visit the centenarian in his/her domicile for an interview and a physical examination. At the same time another letter was sent to the local home care office or nursing home to inform the home helpers and nurses about the study. In this letter we pointed out that the centenarian would receive a letter from us, and that we would appreciate if they could help us by ensuring that the centenarian and/or family members were aware of the purpose of the study together with the implications of participating in it. When appropriate, the caregivers were asked to read and explain the study to the centenarian. A few days later we made contact by telephone with the centenarian, either directly or through a caregiver to obtain permission to pay them a visit shortly thereafter. If the answer was negative, no further attempt was made to enroll them in the study. In cases where the centenarian was unable to understand the letter, permission was obtained from a proxy. The seven regional Scientific-Ethical Committees approved this protocol (Trial numbers 95/93 and 95/93MC).

All centenarians were interviewed and examined by the same geriatrician and geriatric nurse at their place of residence (including institutions) within 3 months of their 100th birthday. Proxies and/or caregivers were encouraged to participate in the interview.

2.2. THE INTERVIEW

The interview was initiated with some socializing questions relating to why and how the subject had become that old, together with questions on what their secret was to enable them to become a centenarian. These introductory questions were followed by questions covering sociodemographic variables, and lifestyle factors. The management of activities of daily living was assessed by using different scales, among them the international and widely used scales of instrumental activities of daily living (I-ADL) by Lawton and Brody (1969), and Katz's Index of activities of daily living (Katz et al. 1963).

A structured interview including several common diseases was conducted and present medication was registered on location. Nursing home records were read on location when available. Additional questions related to health care were put to the caregivers of those subjects who received such help.

2.3. SCREENING TEST OF COGNITIVE FUNCTIONING

Cognitive functioning was screened using the Mini Mental State Examination (Folstein, Folstein, and McHugh 1975), applied at a time when the centenarian had become acquainted with the interviewers, but not when too tired from all the questions. When a subject did not reply adequately to a certain question it was noted whether this was due to (1) a wrong answer, (2) vision or hearing impairment, (3) severe dementia, or (4) refusal to answer. In order to get supportive information regarding cognition a proxy for each participant (n = 207) was interviewed regarding the subjects' short- and long-term memory, ability to recognize other people, find their way home, recall the time of the year, understand messages, and make decisions.

2.4. PHYSICAL EXAMINATION

The total physical examination had the following order: First, the weight was recorded on a simple bathroom scale, followed by a short physical function test (putting the hands behind the back and behind the neck; from a standing position picking up a folding rule from the floor, and turning around 360°). It was followed by a simple recording of hearing ability (with and without the use of hearing aids, when spoken to normally and loudly), and vision capability (by reading a standard text used in ophthalmology in Denmark), in the latter case with a simultaneous registering of the amount of light using a Lux-meter, and measuring the distance from the eyes (spectacles) to the text. Additionally, eye color and status of teeth were recorded.

Then the subject would be asked to take off their clothes, if possible. Any functional dyspnoea during the physical strain accompanying the preparation for the physical examination was recorded. The lungs were auscultated in a sitting position with a stethoscope. Then the heart would be auscultated in the supine position, and murmurs were noted. The pulse was palpated and measured. Electrodes were put on the subject to perform a standard 12-lead resting electrocardiogram (ECG) with a portable electrocardiograph unit (Cardiostat 31, Siemens-Elema AB, Stockholm, Sweden).

With the subject at rest and in a supine position the blood pressure was measured three times with a cuff on the right arm, using an appropriate cuff size and Hawksley's Random Zero Sphygmomanometer (Mk II) (Hawksley and Sons Ltd. Sussex, England). Then the cuff was moved to the left ankle, and the ankle blood pressure was measured using a pocket doppler (Mini Dopplex D900, Huntleigh Health Care, Cardiff, UK) with the probe over the a. dorsalis pedis sin. or a. tibialis post. sin. A fourth measurement of arm blood pressure would follow. A mean of these 4 arm blood pressure measurements was used in the analyses.

Bio-impedance was measured by using an Animeter (HTS-engineering Aps., Odense, Denmark). Height was assessed by using two indirect methods: knee-to-floor height (in a sitting position with the feet on the floor and the knee bent at a 90° angle) and supine total arm length (Haboubi et al. 1990). The latter has been shown to have the best correlation with total height, but becomes unsuitable when the elbow cannot be fully extended. On the other hand, knee-to-floor height is difficult to determine in bedridden subjects. The inspection of the lower extremities consisted of an assessment of varicose veins, ulcers, oedema, and amputation. In the neurological examination symptoms were sought to identify a stroke (affection of eye muscles, reflexes of the biceps, triceps, patella, Achilles and plantar, strength, and muscle tone). If the subject was able to understand a more complicated instruction, a spirometry would be carried out (Vitalograph R-Model, portable. Vitalograph Ltd. Buckingham, UK).

2.5. BLOOD SAMPLES

Finally, blood was collected by venipuncture, with the subject non-fasting, and irrespective of the time of the day.

2.6. ECG PARAMETERS

The ECGs were measured and analyzed by persons trained and certified in the Glostrup Population Studies according to the Minnesota code (Rose and Blackburn 1968).

2.7. ADDITIONAL HEALTH INFORMATION

Based on personal (oral and written) consent from the centenarian or a proxy, contact was made by letter to the centenarian's general practitioner (GP) shortly after our visit. In the letter we asked for permission to have copies of all available health records.

Additional information was retrieved from the Danish National Register of Patients (in existence since 1977), and from The Danish Cancer Register (in existence since 1943). Data were obtainable on all members of the cohort ($N = 276$).

For each subject all available health information was scrutinized, and only clear medical diagnoses made by doctors or obtainable from health registers were recorded in the data base, with the exception of hospitalizations earlier than 1977, and anamnestic information of having had infectious diseases at a younger age. All other self-reported diseases were disregarded unless medical records could verify them.

When the diagnoses were recorded a clear distinction was made between actual (ongoing) diseases and former diseases and chronic conditions.

The definition of diseases and chronic conditions was based on the International Classification of Diseases [International Statistical Classification of diseases and health related problems (ICD 10), World Health Organisation 1992]. Also the diagnosis of dementia was made according to WHO's criteria of ICD-10 (World Health Organisation—WHO), the ICD-10 classification of mental and behavioral disorders, clinical descriptions and diagnostic guidelines (1992). Dementia severity was rated according to the criteria of clinical dementia rating (CDR) (Hughes et al. 1982).

2.8. COMORBIDITY

Comorbidity included several diseases and chronic conditions, which were chosen because they can be regarded as potential threats to health and well-being. For details see Andersen-Ranberg, Schroll, and Jeune (2001b). Every single diagnosis or chronic condition was counted as one.

2.9. AUTONOMY

The term autonomy was used to describe centenarians who were able to live and maintain a reasonably independent life, i.e., being non-demented, non-institutionalized, and belonging to Katz gr. A, B, or C (relatively independent in the basic activities of daily living).

For current diseases and chronic conditions prevalence proportions were calculated as the number of affected subjects divided by the total number of subjects in the study ($N = 207$) and presented in percentages. Reported proportions of past illnesses were calculated and presented in the same way.

Statistical calculations were performed using the SPSS for Windows (v. 7.5.1 and v. 9.0) statistical software (SPSS Inc., USA). The following statistical tests were used, with a significance level of 5%: *Chi-square test*: Differences between participants and non-participants in relation to sex and living conditions. Differences in sex in the individual items of I-ADL, and between demented and not demented. *Mann–Whitney U test:* Differences between the sexes in the Katz' Index of ADL and in the MMSE scoring divided into four groups, as both dependent variables are ordinal. *Analysis of variance (F-test) and t-test for equality of means*: To compare number of diseases in relation to being autonomous versus non-autonomous. Both urinary incontinence and dementia were excluded from the analysis of autonomous/non-autonomous centenarians, as urinary incontinence is included in Katz' Index of ADL, and autonomous centenarians are defined as non-demented. Analysis of variance with repeated measures was also used to test the trend of number of hospitalizations among participants and non-participants.

3. Ethics

After a hearing in the seven regional Scientific-Ethical Committees, the study was approved by the local Scientific-Ethical Committee of the Counties of Funen and Vejle, Denmark. Permission to retrieve data from The Danish Cancer Register and from The Danish National Register on Patients on all the cohort members was obtained from the Danish National Board of Health.

4. Results

4.1. PARTICIPATION

In the 14-months period of April 1, 1995–May 31, 1996 a total of 276 Danes celebrated their 100th anniversary, of whom 207 (75%) accepted the invitation to participate in the study (Table 1). The female–male ratio among the participants was 3.6:1. The group of non-participants consisted of 56 persons who refused to take part in the study (non-respondents), and 13 who died within a few weeks after their 100th birthday and before contact was made (deceased). There were no significant differences between participants and non-participants regarding sex ($p = 0.115$), type of housing ($p = 0.072$) or hospitalizations in the period 1977–1997 ($p = 0.18$). All but three participants were visited within 3 months of the subjects' 100th birthday. With the exception of 11 subjects all were born in Denmark.

Table 1. Participation.

			Non-participants	
	Eligible	Participants	Non-respondents	Deceased
Males	54 (20%)	45 (22%)	6 (11%)	3 (23%)
Females	222 (80%)	162 (78%)	50 (89%)	10 (77%)
All	276 (100%)	207 (100%)	56 (100%)	13 (100%)

4.2. FEASIBILITY

Of the 207 participating centenarians 177 (85%) participated actively in the interview, while the remaining subjects were almost totally unable to communicate. With the exception of a few well-functioning centenarians all participants had a proxy present at the interview.

Almost all participants (or a proxy) completed most of the interview. Information on functional status (Katz' Index of ADL, Lawton's I-ADL) was obtainable for all participants, as well as supplementary information regarding memory functions, social behavior, and functioning, which was given by proxies and/or caregivers. An equivalently high response rate was not feasible in the clinical examination (Table 2). A complete physical examination (excluding spirometry) could only be obtained for 95 (45%) centenarians.

The reasons for not participating entirely or only partly in the major parts of the physical examination were visual and/or hearing impairments, severe dementia, proxy-denial in connection with demented subjects, acute/terminal illness, or reluctance/refusals. The same reasons also explain why only 3/4 ($n = 156$) of the centenarians were tested with the MMSE. Of the 156 subjects who were examined less than half ($n = 72$, 46%) went through a complete MMSE. In the remaining, 54% the major reason for an incomplete MMSE was visual impairment.

Copies of medical files from GPs were obtained in nearly all cases, with the exception of four subjects. Medical data from the National Board of Health's National Register of

Table 2. Number of centenarians who participated in the different parts of the examination ($N = 207$).

	n	%
Interviewer rating of hearing capability	198	96
Interviewer rating of vision capability	197	95
Dental status	192	93
Physical performance test	162	78
Inspection of lower extremities	159	77
Pulse	159	77
Blood pressure—right arm (4 times)	158	76
Mini Mental State Examination	156	75
Auscultation of the heart	151	73
Blood sample	148	72
ECG	142	69
Vision assessment (reading a standard text)	142	69
Height	141	68
Auscultation of the lungs	139	67
Blood pressure—right ankle	137	66
Bioelectrical impedance	133	64
Weight	116	56
Neurological examination	110	53
Lung function test/spirometry	36	17

Patients (National Discharge Register) and the National Cancer Register were available not only for all the 207 participants, but for the whole cohort ($N = 276$).

4.3. ACTUAL MEDICAL DIAGNOSES

Clinical findings in relation to all 207 participants are shown in Table 3. A cardiovascular disease [myocardial infarction, atrial fibrillation, angina pectoris, chronic heart failure, moderate to very severe hypertension (≥160/≥100), and pacemaker implant] was identified in 149 (72%) of the centenarians. Hypertension—in accordance with WHO's criteria from 1999 (Chalmers et al. 1999)—was found in about half of the centenarians, but only in a third when using the threshold of moderate hypertension (≥160/≥100).

Twenty subjects (10%) had diabetes. Three were being treated with insulin injections, two were on oral antidiabetics, and eight were treated with diet. Seven subjects were discovered to have diabetes at the time of our visit.

4.4. USE OF DRUGS

Nearly all centenarians (95%) received medicine prescribed by a doctor, the median number being 3.0 (range: 0–10; 5-, 25-, 75- and 95-percentiles being 0, 2, 5, and 8, respectively). The most frequently used drugs were diuretics (Table 4).

Table 3. Clinical findings ($N = 207$).

	N	%
Urinary incontinence	124	60
Osteoarthritis of knee, hip, shoulder, and spine	112	54
Hypertension (≥140/≥90)[a]	108	52
Dementia	105	51
Prostatic hypertrophy[b]	15	33
Chronic heart failure	67	32
Angina pectoris/ischemia	57	28
Atrial fibrillation/flutter	36	17
Diabetes mellitus	20	10
Stroke	19	9
Vitamin B12 or folic acid deficiency	19	9
Frequent urinary infections	15	7
Chronic obstructive lung disease	13	6
Dyspepsia	13	6
Others[c]		

[a]Hypertension (≥160/≥100): $n = 65$ (31%).
[b]Men, $N = 45$.
[c]Others: hypo- and hyperthyroidism, gout and lung fibrosis in 6 (3%) subjects each, schizophrenia or other psychotic symptoms in 4 (2%), emphysema, gastric ulcer, and iron deficiency in 3 (1.5%), pneumonia, asthma, and Parkinson's disease in 1 (0.5%) subject each.

Table 4. Actual use of drugs among 207 Danish centenarians.

	n	%
Cardiovascular drugs (thiazides, loop-diuretics, β-blockers, ACE-inhibitors, Ca^{++}-blockers, long-term NTG, and digoxin – either alone or in combination)	132	64
Diuretics (thiazides and/or loop-diuretics)[a]	123	59
Laxatives	90	44
Hypnotics (benzodiazepines given as a hypnotic)	59	29
Antihypertensives (β-blockers, ACE-inhibitors, Ca^{++}-blockers, and thiazides)	57	28
Analgetics (paracetamole, acetylsalicylic acid, dextropropoxyphene, and opioids)	47	22
Digoxin	35	17
Thrombosis preventive drugs (low-dose aspirin)	30	15
Neuroleptics, antidepressants, and sedatives (not used as hypnotics)	22	11
H_2-antagonists or proton pump inhibitors	22	11
Actual antibiotic treatment	19	9
Antihypertensives (β-blockers, ACE-inhibitors, and Ca^{++}-blockers)	12	6
Corticosteroids	9	4
Bronchodilators	9	4
Insulin	3	1
Anti-diabetics (oral)	2	1

[a] Thiazides alone: $n = 47$ (23%).

4.5. COGNITIVE FUNCTIONING AND MENTAL HEALTH

Among the 156 subjects who participated in the MMSE (Table 5) about one–fifth (22%) obtained a score of 24 or more, while a slightly higher proportion (28%) had scores below 18. There were no significant sex differences between the four MMSE groups (Mean Rank men: 68.5; women: 81.5, $p = 0.115$).

The prevalence of dementia ("mild", "moderate", and "severe") was found to be 51% ($n =$ 105), while 25% ($n = 52$) were diagnosed as having no signs of dementia (Table 6). Additionally, when including the 24 centenarians classified as having "probably no dementia"

Table 5. Mini mental state examination-score in relation to sex.

	Males ($N = 45$)	Females ($N = 162$)	All ($N = 207$)
MMSE 30–24 points	12 (27%)	33 (20%)	45 (22%)
MMSE 23–18 points	14 (31%)	38 (24%)	52 (25%)
MMSE 17–10 points	9 (20%)	28 (17%)	37 (18%)
MMSE 9–0 points	1 (2%)	21 (13%)	22 (10%)
Not tested	9 (20%)	42 (26%)	51 (25%)

Table 6. Clinical dementia rating in 207 centenarians.

Clinical evaluation	No dementia	Probably no dementia	Questionable dementia	Mild dementia	Moderate dementia	Severe dementia	Not classified	Total
	52 (25%)	23 (12%)	16 (7%)	35 (17%)	42 (29%)	28 (14%)	11 (5%)	207(100%)
Dichotomized		91 (44%)			105 (51%)		11 (5%)	207(100%)

this proportion rose to 37%, leaving a proportion of "questionable dementia" of 7%. When dichotomizing the clinical dementia evaluation into "demented" (including "mild", "moderate", and "severe dementia") and "non-demented" (including "no dementia", "probably no dementia", and "questionable dementia") more women than men were diagnosed as being demented, but this difference did not reach the significance level ($p = 0.08$). In 11 (5%) subjects it was not possible to make a valid clinical evaluation of their mental status either due to insufficient information ($n = 8$), terminal illness ($n = 2$), or frailty following a too early discharge from hospital ($n = 1$).

4.6. WORST-CASE SCENARIO

The crude evaluation of "suspected dementia"/"probably no dementia" in the 56 non-respondents showed that 23 (41%) could be evaluated as having "probably no dementia", 17 (30%) as having "suspected dementia", and 16 (29%) as unclassifiable/unknown. Among the 13 deceased the level of cognitive functioning prior to their death was unknown. If all the "unclassifiable/unknown" persons among participants and non-participants (including both non-respondents and deceased) were in fact demented (i.e., "worst-case scenario"), the prevalence of dementia in the total population would be 58.7%, which is not significantly different from the estimated prevalence among the participants.

4.7. COMORBIDITY

Comorbidity is presented in Figure 1, which shows the number of centenarians suffering from none (one subject) to nine (one subject) actual diseases and chronic conditions at the time of the investigation. The mean number of diagnoses was 4.5 (SD 1.87) when using the lower threshold for hypertension of 140/90 mmHg.

The most common combinations of diseases and chronic conditions were urinary incontinence in combination with dementia ($n = 78$; 38%), hypertension ($\geq$140/$\geq$90) in combination with osteoarthritis ($n = 66$; 32%), urinary incontinence in combination with osteoarthritis ($n = 63$; 30%), urinary incontinence in combination with hypertension ($\geq$140/$\geq$90) ($n = 60$; 29%), osteoarthritis in combination with dementia ($n = 57$; 28%), and urinary incontinence in combination with dementia and angina ($n = 29$; 14%).

4.8. CONDITIONS OF LIFE, ACTIVITIES OF DAILY LIVING AND AUTONOMY

A little more than one-half ($n = 114$) of the centenarians lived in nursing homes, 23 (11%) in sheltered houses and 70 (34%) in their own homes. There was no significant

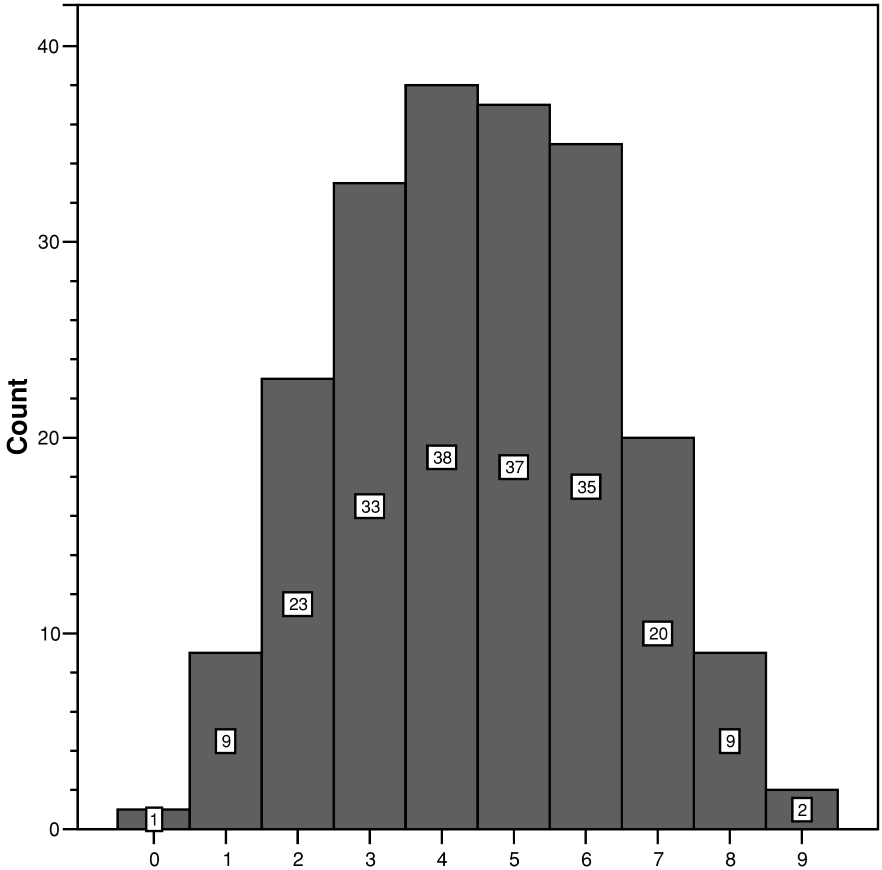

Figure 1. Comorbidity in Danish centenarians. Frequency of subjects with 0–9 actual diseases and chronic conditions when hypertension is defined as ≥140/≥90 (mean 4.5, *SD* 1.87).

difference between sex and type of housing ($p = 0.27$). Among the 93 non-institutionalized centenarians a little less than half ($n = 41$) did not have the service of a visiting nurse at all and 13 (five men and eight women) did not receive any help at all from home-helps. However, of these 13 subjects 9 were living together with another person in the same household. Thus, only 4 (2%) were living alone and were totally independent.

When trichotomising Katz' Index of Activities of Daily Living (Table 7) about two-fifths were categorized as being relatively independent of help (Katz gr. A–C), about one-fourth were categorized as being relatively dependent on help (Katz gr. D–E), while about one-third were categorized as being very dependent on help (Katz gr. F–G, + special category).

Subjects independent in I-ADL are shown in Table 8. Around 40% of the centenarians were able to dial a telephone number, including only precoded numbers, while practically no one

Table 7. Katz' Index of activity of daily living trichotomized in relation to sex.

	Males ($n = 45$)	Females ($n = 162$)	All ($n = 207$)
Relatively independent "Katz gr. A-C"	21 (47%)	64 (39%)	85 (41%)
Relatively dependent "Katz gr. D-E"[a]	14 (31%)	35 (22%)	49 (24%)
Very dependent "Katz gr. F-G"[b]	10 (22%)	63 (39%)	73 (35%)

[a] Including 3 subjects from "other".
[b] Including 4 subjects from "other".

(only four subjects) was able to do their personal laundry alone. Significantly more males than females were able to handle their medication, transportation (traveling), finances, or shopping independently. Only one-third of the centenarians were able to administer their own medication, either completely or after a weekly (or fortnightly) dosage by a nurse.

Table 8. Independency in instrumental activities of daily living in relation to sex (I-ADL). Number of subjects.

	Males ($n = 45$)	Females ($n = 162$)	All ($n = 207$)
Ability to use telephone including dialing precoded telephone numbers	23 (52%)^{ns}	61 (38%)	84 (41%)
Responsibility for own medication—including when dosed weekly by others	23 (51%)**	46 (28%)	69 (33%)
Transportation—arranging travels (public or private)	13 (29%)*	21 (13%)	34 (16%)
Housekeeping—including when only able to do light, but daily house work	7 (16%)^{ns}	25 (15%)	32 (16%)
Ability to handle finances	10 (22%)**	7 (4%)	17 (8%)
Shopping,—including only small purchases	8 (18%)**	6 (4%)	14 (6%)
Food preparation of adequate meals	3 (6%)^{ns}	11 (6%)	14 (7%)
Laundry—personal laundry completely	2 (4%)^{ns}	2 (1%)	4 (2%)

^{ns}not significant.
$^{*}p < 0.05$.
$^{**}p < 0.01$.

Among the relatively independent centenarians (41%), those centenarians who were simultaneously classified as being non-demented and non-institutionalized were identified. They constituted a subgroup of 25 centenarians (12%), so-called “autonomous” centenarians, while those who could not accomplish all these criteria were grouped as “non-autonomous”. No difference in the mean number of diagnoses (excluding dementia and urinary incontinence which are included in the definitions) could be found when comparing autonomous centenarians to non-autonomous centenarians [autonomous centenarians: $n = 25$, mean 3.0, SD 1.70 versus non-autonomous centenarians: $n = 182$, mean 3.3, SD 1.59; $p = 0.368$, a mean difference of 0.31 (95%CI: −0.37; 0.98)].

4.9. CENTENARIANS’ FORMER HEALTH

Based on information from medical files, centenarians had suffered from several different diagnoses; the most frequent being pneumonia (40%), fractures of hip, shoulder, or pelvis (38%), and myocardial infarction (27%) (Table 9). When we looked only at selected diseases with a relatively high mortality such as stroke, myocardial infarction, malignant cancer (excluding skin cancers), and hip fracture, 124 (60%) had suffered from one or more of these conditions previously. When including pneumonia the number augments to 158 (76%).

Only nine subjects had never been hospitalized, leaving a proportion of more than 95%, who had been hospitalized at least once. The median number of hospitalizations was five (range: 1–23). One-hundred and sixty-two (78%) subjects had undergone a major operation (median number of operations: 2). Seventy-two (35%, 4 men and 68 women) subjects had been operated for a hip fracture and 11 men (24%) for prostatic hypertrophy. Fifty-four (26%) of the centenarians had had a cataract operation on one or both eyes.

Table 9. Number of former diagnoses confirmed in medical files ($N = 207$).

	n	%
Pneumonia	81	40
Fracture of hip, shoulder, or pelvis[a]	78	38
Myocardial infarction	56	27
Stroke or transient ischemic attack	46	22
Low grade skin cancers	42	20
Gastric ulcer	37	18
Gallbladder disease	36	17
Transitoric cerebral ischemia	35	17
Erysipelas	28	14
Cancer[b]	25	12
Dyspepsia	22	11
Herpes zoster	22	11

[a]Hip fracture alone: $n = 72$ (35%).
[b]Cancers of colon or rectum ($n = 12$), bladder ($n = 4$), breast ($n = 3$), hematological ($n = 3$), uterus including the cervix ($n = 3$), the larynx, the pyloric channel, and an ovarian ($n = 1$, in one subject each).

5. Discussion

5.1. PARTICIPATION

The study reports data from a nationwide, population-based survey of 207 out of 276 Danish centenarians examined shortly after their 100th birthday. The strength of this study is that it was nationwide, population-based, with a high overall participation rate (75%) of easily identified subjects in a cohort.

Population studies of extremely old people such as centenarians can be biased by the selection of relatively healthy survivors due both to a high mortality and to the sampling methods. This bias was minimized by using a cohort of 100-year-olds who entered the study consecutively as soon as they turned 100. All were identified through a central person register and very few died between identification and examination. The fact that there was no significant difference between participants and non-participants regarding sex, type of housing, and number of hospitalizations indicates that the examined centenarians were unselected.

5.2. IDENTIFICATION OF AND CONTACT TO ELIGIBLE SUBJECTS

The identification of the centenarians is supposed to have been complete, and the possibility of a centenarian not existing in the CRS seems unlikely; especially as health services and pensions are using the CRS for identification. Date of birth, and hence age, are believed to be valid as all the subjects have been cross-checked both with church books and a population census held in 1924.

Great effort was put into the procedure of both contacting and explaining the study not only to the centenarians, but also to the proxies and caregivers. The goal was to make sure that the subjects, their proxies, and their caregivers fully understood the purpose of the study, and to give them the opportunity to clarify some questions before deciding whether they wanted to participate or not. Yet, the chosen procedure posed some ethical questions in relation to addressing a population with a known high degree of cognitive impairment, and a consequent impaired ability to judge the implications of their consent to participate. These problems were discussed thoroughly with the Scientific-Ethical Committee.

5.3. FEASIBILITY

The completeness of answers to the questions on ADL's and other questions, e.g., regarding social functioning, is not surprising as these questions were also collected from proxies and caregivers. About 75% of the participants took part in the clinical examination, but a complete physical examination was only performed in 45%, which is in contrast to the Swedish and the Finnish centenarian studies, 100% and 97% respectively (Louhija 1994; Samuelsson et al. 1997).

The difference is difficult to explain, as details regarding how the different examinations were carried out in the Finnish and the Swedish studies have not been presented. In the

Hungarian study (Gergely et al. 1990; Kepecs and Lengyel 1990) only about half (n = 123) of the centenarians were clinically examined; the rest either refused, or were evaluated in advance by a layperson as not capable of going through a clinical examination. In this study, some of the Danish centenarians would only allow us to do certain parts of the physical examination, while a minority would not participate in the physical examination at all, but only in the interview. The reasons for this could vary, but many did not want to expose themselves by taking off their clothes. In general, the examinations with the lowest participation rate were also those which would require the most undressing.

One of the weaknesses of the present study is related to the difficulties in examining centenarians given their high rate of sensory impairments. These impairments especially influence cognitive functioning and pose some difficulties in the application of the MMSE and other cognitive functioning tests (Andersen-Ranberg, Vasegaard and Jeune 2001a; Holtsberg et al. 1995; Mazzoleni et al. 1996; Silver, Jilinskaia, and Perls 2001). In the Swedish centenarian study a highly variable proportion of the centenarians was able to pass the different sub-tests in a neuropsychological assessment battery (43–76% of the subjects) (Samuelsson et al. 1997). Sensory impairments are very common and present a big challenge to performing only the MMSE, so special adaptations are needed to circumvent this problem.

However, the difficulties in performing the MMSE testing did not affect the diagnosing of dementia or the dementia rating according to the chosen criteria, as we used additional information from the interview (recalling during the interview, I-ADL functioning etc.), as well as from caregivers and proxies/family members. Together with the clinical impressions these information were sufficient to make both a diagnosis and a dementia rating according to the chosen criteria. The MMSE items were only used as supportive information.

It was a deliberate choice to use the ICD-10 criterion for dementia. Firstly, in contrast to the widely used DSM-IV criterion of the American Psychiatric Association, the ICD-10 employs activities of daily living in its criteria, and these data were easily collected through caregivers and proxies. Secondly, the ICD-10 is the official WHO classification of mental and behavioral disorders.

Comparing disease prevalences with previous studies on centenarians is rather difficult given the various differences in study populations, use of methods, and collection of data. Nevertheless we found higher disease prevalences in the present study than has been published in other studies. The higher prevalence of urinary incontinence (60%) among Danish centenarians compared to others (33–54%) (Bauco et al. 1996; Louhija 1994; Mazzoleni et al. 1996) may be explained by the nature of the question challenging the intimacy of the centenarian. Osteoarthritis in major joints (knee, hip, shoulder, and spine) was rather common (54%) but might have been even higher, when taking into account the complaints of backache, and pains in the knee and hip. No other study refers to the diagnosis of osteoarthritis in centenarians.

The high prevalence of hypertension reported in the present study is primarily due to a lower definition threshold. But even when using the threshold of moderate hypertension (160/100) the prevalence (31%) is still higher than in other studies using approximately the same definition (7–19%) (Gareri et al. 1996; Gergely 1990; Louhija 1994; Samuelsson et al. 1997; Watanabe 1999b), and is probably owing to the lack of inclusion of subjects under current antihypertensive treatment in these studies. Only the large French centenarian study demonstrated a similar level with 31% (212 out of 690) of the French centenarians having a systolic blood pressure between 150 and 210 mmHg (Allard et al. 1996).

Altogether, cardiovascular disease is the most prevalent disease among centenarians affecting 72% of the Danish centenarians. The rather high prevalence is supported by a similar finding (70%) in the presently most representative centenarian study, the Finnish centenarian study (Louhija 1994). In the largest study, the French centenarian study, a cardiovascular disease affected 60% of the centenarians as reported by their GP (Allard and Robine 2000).

The high proportion of centenarians using drugs prescribed by a doctor (95%) reflects the rather high prevalence of disease and chronic conditions. Almost similar proportions of drugs were found among Hungarian, Finnish, and Swedish centenarians (Gergely 1990; Louhija 1994; Samuelsson et al. 1997). Among the Danish centenarians the most widely utilized drug was a cardiovascular drug, naturally reflecting the high prevalence of cardiovascular diseases, and again highly comparable with the Finnish study thereby confirming the comparability to this other comprehensive Nordic study. Also in the French centenarian study the most frequently used drugs were cardiovascular, although the proportions were generally lower (Allard and Robine 2000).

Very few studies on centenarians have presented results on comorbidity. As comorbidity increases with age it would be interesting to know whether centenarians have benefited from having fewer concomitant diseases than could otherwise have been predicted. No such data exist. But a mean number of diagnoses in the present study of 4.5% enarian seems not to be different from the 4.0 found in the New England Centenarian study (Hitt et al. 1999). In one of the Italian centenarian studies (Mazzoleni et al. 1996) comprising 28 randomly chosen centenarians, 25% presented 0–3 pathologies, and the remaining 75% more than three diseases, suggesting a high mean number of diseases.

The proportion of demented subjects in the present Danish centenarian population is compatible with the findings in most other centenarian studies. Among Finnish centenarians (Sobel et al. 1995) the proportion of moderately to severely demented Finnish centenarians was 33% (versus 34% in the present study), whereas 44% could be classified as being non-demented according to DSM-III-R criteria (similar to the present study). Also among Hungarian, Italian, Japanese and North American centenarians the dementia prevalence seems to be around 50–60% (Hagberg et al. 2001; Iván 1990; Powell 1994; Ravaglia et al. 1999; Silver et al. 2001—Japanese results). Only a few and selected studies have reported higher proportions of demented subjects (70–89%) (Asada et al. 1996; Thomassen, van Schaick, and Blansjaar 1998). All in all, the results from the present study show that a substantial proportion of Danish centenarians are demented. But of importance is also the finding that a significant proportion of centenarians are still non-demented. Thus, dementia is not inevitable at very great ages (Andersen-Ranberg, Vasegaard, and Jeune 2001a).

While practically none of the centenarians could be described as being healthy, an interesting finding was the identification of a small proportion of centenarians (12%) who were non-demented, non-institutionalized and relatively independent in ADL, and yet had the same mean number of diseases as the rest. Such subjects were described as autonomous. However, we do not know why these centenarians were autonomous. It may be that their aging process has been slower, or that their comorbidities have been less severe, or maybe they have been better treated. It may also be that they possess special coping strategies whenever they experience a loss or deterioration.

The former medical history of a subject can be difficult to ascertain. Self-reported data are not accurate enough for several reasons: benign forgetfulness, tiredness, cognitive dysfunction, and the earlier medical tradition of not telling everything to the patient. Therefore, it was a deliberate choice to rely primarily on GP files, medical records and registers. However, such documentation may be insufficient. But, by using the national register of discharge, i.e., the Danish National Register of Patients, as well as The Danish Cancer Register, it became possible to achieve information on all participants regarding hospital admissions, diagnoses, and operations within the last 19 years and cancer diagnoses within the last 52 years. The fact that the maximum number of verified medical diagnoses from past medical illnesses was not obtainable implies that the reported proportions of diseases should be considered as being minimum proportions. The same argument can be used in the estimation of the prevalences of actual diseases and chronic conditions, as the thorough physical examination in spite of a somewhat low examination rate disclosed many unknown pathological signs (e.g., unknown hypertension, myocardial infarction on ECG's, minor strokes, diabetes etc.). Therefore, the prevalence of diseases and diagnoses found in Danish centenarians should be regarded as a minimum number, or even a "best case scenario".

Few centenarian studies report data on past illnesses (Louhija 1994; Samuelsson et al. 1997; Watanabe 1999a). As in the present study, pneumonia is one of the most frequent former diagnoses found in centenarians. Another frequent disease entity is major fractures (hip, shoulder, or pelvis). About one-third had had a hip fracture at some point in their later years. All in all, 72 Danish centenarians had suffered a total of 90 hip fractures. The reported prevalence of hip fracture at the age of 100 (35%) is the same as found in Swedish centenarians (34%) (Samuelsson et al. 1997), while a lower proportion (21%) is reported among Finnish centenarians (Louhija 1994), and can partly be explained by the fact that they have only retrieved data 10 years back. The hip fractures among Hungarian centenarians (Gergely 1990) were somewhat lower (11%) which is difficult to explain, if not caused by a lower survival rate in Hungary of people suffering from a hip fracture, and consequently making the centenarians a more selected group. Also, osteoporosis may be less prevalent in Hungarian centenarians or the diseases and chronic conditions leading to falls may be fewer.

Cardiovascular and cerebrovascular diagnoses were recorded relatively frequently in the medical files of Danish centenarians, reflecting one of the most important disease groups in the elderly population. Interestingly, about one-fourth of the Danish centenarians had a diagnosis of myocardial infarction, evaluated on the basis of ECG and former medical diagnoses, which is equivalent to the West German study by Franke (22–29%) (Franke, Bracharz, and Gall 1973; Franke and Schramm 1980). Only 10% of Finnish centenarians were identified to have suffered a myocardial infarction, but this was only defined as a pathological Q-wave (Minnesota codes 1–1, 1–2, 1–3), and did not include previous diagnoses of myocardial infarction. Also based on ECG alterations (but not described further) is the low prevalence of about 4% found among 96 Hungarian centenarians (Rohla and Lengyel 1990).

The Danish Longitudinal Centenarian Study was launched in order to describe the health characteristics of an unselected population of Danish centenarians according to standard assessments and methods. Based on the present findings it can be concluded that centenarians have not survived due to a healthy life free from diseases, nor are they healthy at the age of 100 years. So why are they still alive?

Probably centenarians have had the advantage of better medical treatments than older cohorts, e.g., the emergence of antibiotics in the 1940s, and the increasing use of cardiovascular drugs, letting them survive diseases they would otherwise have died from at younger ages. This is suggested by the findings of rather high percentages (60–75%) of subjects having suffered from one or more of major diseases with relatively high mortalities, and the fact that nearly all centenarians had been hospitalized at least once, with nearly 80% having had at least one major operation during their 100 year long life. Although it can be discussed to which extent major operations augment the chances of becoming a centenarian (e.g., operations for gall bladder stones), some of them together with modern medical treatments have certainly changed the odds for several of the centenarians, not only at younger ages but also more recently. In support of this are data from consecutive Japanese autopsy records (1958–1995) on 141 mainly institutionalized centenarians, which showed a shift from a few, if any, pathologies in the early period (1958–1987) to multiple pathologies in the later period (1988–1995) (Tauchi and Sato 1999). In the earliest period death due to infections was the most frequent diagnosis, while a growing number of cancers or other general lesions were recorded as death causes in the later period. These data not only support the advantageous effects of improved medical treatments on people surviving to become centenarians, but may also explain why earlier studies found centenarians-to-be a more selected group. Additionally, as the proliferation of centenarians started approximately at the same time in all developed countries it may be seen as a period effect rather than a cohort effect (Kannisto 1994). The period effect consists of the beneficial effects of not only improvement of lifestyle and reduction of risk factors (primary prevention), but also the more active treatments (including secondary prevention) and surgery even in very old people. These factors should, in fact, be considered as the largest contributors to the increased survival of 80+year-olds (Jeune 2002). As a consequence, reaching the age of 100 today is not reserved for people free from potentially mortal diseases.

Although the above-mentioned improvements have augmented the chances for an individual to reach the age of hundred, other factors may also play a role. We cannot ignore that those who made it to 100 compared to those who did not may have possessed some special characteristics. It could be a well-preserved adaptability in the maintenance of a number of physiological and psychological functions (Andersen-Ranberg et al. 1999b) due to genetic robustness (Jeune 2002). This may have given them the possibility of postponing disease onset until later ages, or to have a specific disease in a milder form, making them relatively healthier than their fellow birth cohort members who did not reach the age of 100. Such a possible selection could explain why some diagnosed potentially mortal diseases like diabetes, stroke and some malignant cancers do not seem to be higher among Danish centenarians than what is expected among octo- and non-agenarians (Andersen-Ranberg, Schroll and Jeune 2001b). Also, psychological factors related to higher coping strategies may too be part of an explanation (Hagberg and Nordbeck 2000).

We do not know the fundamental nature of this selection but based on the above-mentioned improvements and results from earlier centenarian studies we may assume that yesterday's centenarians were more selected than today's centenarians. But how will tomorrow's centenarians be? The results of the present study indicate that people seem to survive in spite of a wide range of more or less handicapping diseases and chronic conditions, thus supporting the more gloomy perspectives of an aging society. But a more optimistic view can also be applied where the increasing implementation of both primary and secondary preventive measures and treatments may render tomorrow's rising population of oldest-olds less dependent on help.

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CHAPTER 11. GENDER AND HEALTHY AGING

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1. Introduction

The interaction between gender and healthy aging is complex and in many respects paradoxical. In current cohorts of older people, women are generally poorer and less well educated than men, but they live longer, so much so that in France and, until recently in Britain, men of the highest social status had a shorter life expectancy at birth than women of the lowest (Hattersley 1999; Vallin 1995). Although their mortality is lower, older women do not enjoy better health than older men; on the contrary they spend proportionately more of their later lives affected by disability (Robine, Jagger, and Romieu 2001; Verbrugge 1989). Largely because of their longer life expectancy, older women are much less likely than older men to be married and much more likely to live alone. Nevertheless, some studies suggest that it is among men that the proportions lacking emotional support or with few social ties are higher (Gierveld 2003; Grundy, Bowling, and Farquhar 1996; Wenger 1995). Even so, older women appear to be at higher risk of depression, or at least depressive symptomatology, but suicide rates are much higher among older men (Meehan, Saltzman, and Sattin 1991; Sonnenberg et al. 2000). Given these paradoxes, and the feminization associated with population aging, it is perhaps surprising that associations between gender and aging have not been studied more extensively. Although the literature on this topic is growing (Arber and Cooper 1999; Arber and Ginn 1993; Arber, Davidson, and Ginn 2003; Verbrugge 1989; Weitz and Estes 2001), Barer (1994) has pointed out that gender in old age has received relatively little attention and that many of the influential early studies of aging processes were based on male-only samples (Schock et al. 1984; Vaillant 1990).

In this chapter, these paradoxes are explored and gender differences in various dimensions of healthy aging examined. The areas of life important to older people have been identified in empirical research as good physical functioning, psychological well being, having relationships with others, and social activity (Grundy and Bowling 1999). I therefore focus predominately on these domains of life. The underlying conceptual model is that healthy aging depends on maintaining a positive balance between reserve, or resources available, and challenges faced in old age. Resources available, including health, material assets, convoys of support and coping strategies, are those acquired throughout life, often in gender specific ways. Challenges, such as bereavement or trauma, may also be gender influenced. Initially, though, it is useful to review the demographic context, namely differences in the representation of women and men in older populations and the mortality differences which underlie them.

Zeng Yi et al. (eds.), Longer Life and Healthy Aging, 173–199

The chapter focuses on relationships between gender and aging in the more developed parts of the world, particularly Europe, and many examples are drawn from Britain. However, it is important to note that many populations in less developed regions of the world are now aging rapidly and that some of the relationships between gender and aging maybe of even greater importance because of more sharply delineated gender roles. Elsewhere in this volume, Zeng et al. consider gender differentials in their analysis of healthy aging in China and there is now a growing body of research on less developed countries relevant to this issue (Adamchak et al. 1991; Knodel 1999; Martin and Kinsella 1994; Rahman et al. 1994; Zeng et al. 2001).

2. Population Aging and Population Feminization

In all populations which have experienced population aging, this process has been associated with population feminization, a consequence of the near universal longer life expectancy of women compared with men. The tendency for female mortality rates to decline faster than those of men during at least the initial phases of mortality transition, coupled in some populations by particular deficits of males in cohorts depleted by war, has amplified this trend, to varying degrees, in today's elderly populations (Carlson 1990; Preston 1976). This is illustrated in Figure 1, which shows the ratio of men to women in the populations aged 65 and over and 85 and over in selected European countries. Women predominate numerically to a considerable extent in all these (and nearly all other populations) and among those aged 85 and over, there are in general around only 40 men per 100 women, and in some cases considerably fewer.

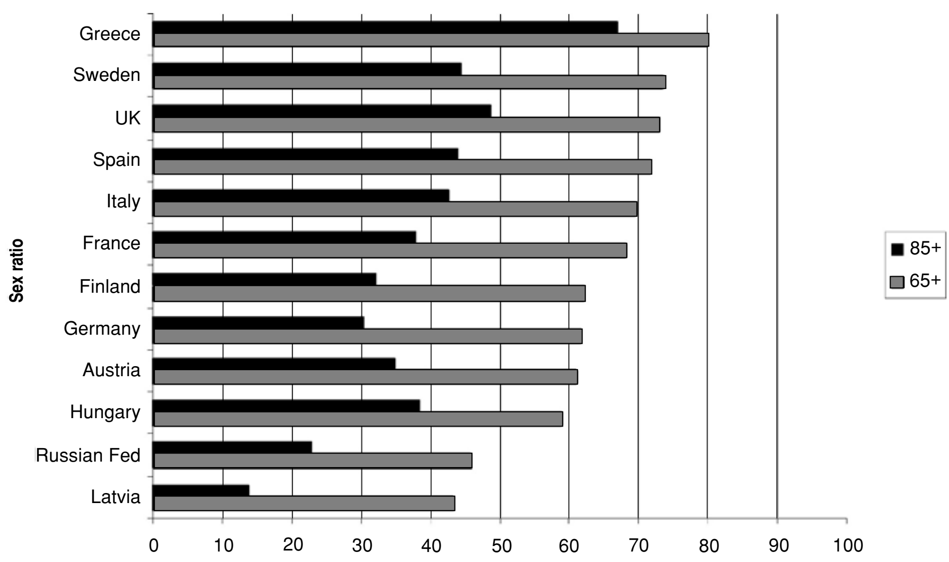

Figure 1. Sex ratios (males per 100 females) in the elderly population, selected European countries, 2000.

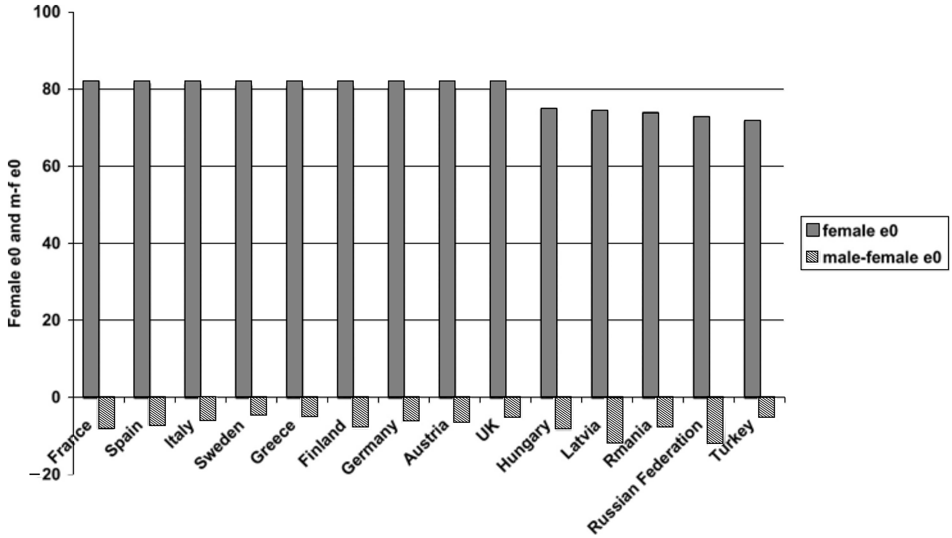

Figure 2. Female life expectancy at birth and difference between female and male life expectancy at birth, selected European countries 1995–2000.

3. Gender Differences in Mortality

Figures 2 and 3 show current gender variations in life expectancy at birth and at age 65 for a range of European countries. In Russia, Latvia, and a number of other Eastern European countries female life expectancy at birth exceeds that of men by a decade, partly reflecting the heavy toll of excess alcohol consumption among men (Velkoff and Kinsella 1993). The gap between men and women in Southern Europe is less marked, possibly because nutritional and lifestyle factors may protect men from risks which some of their peers elsewhere are exposed to. Further life expectancy at age 65 is also consistently higher for women than for men, with women generally enjoying at least 3 or 4 years of additional life.

The period indicators shown in Figures 2 and 3 are based on current rates of mortality. Examining the fate of particular cohorts (as is implicitly done in Figure 1, which presents information on survivors from cohorts born roughly in the 1900–1935 period) highlights the divergent destinies of boys and girls born in the late 19th and early 20th centuries even more strikingly. This is illustrated in Table 1, which shows survivorship to age 80 for men and women born between 1861 and 1921 in England and Wales. Of those born in 1861, a mere 10% of boys and 16% of girls lived to age 80. Among those born 50 years later in 1911, 23% of males and 41% of females reached this age while nearly half the women (but only 29% of the men) born in 1921 became octogenarians. The trends underlying these variations by gender are complex and still not fully understood. They include not only substantial improvements in survival through infancy and adulthood, but also large changes in the relative survival chances of adult men and women.

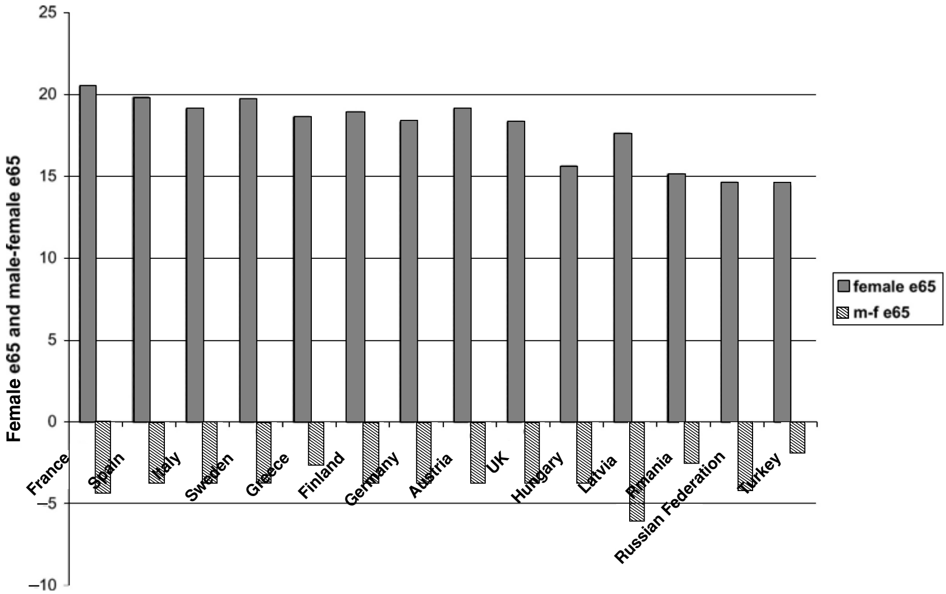

Figure 3. Female life expectancy at age 65 and difference between female and male life expectancy at age 65, selected European countries, 1995–2000.

The tendency for mortality decline to be associated with a greater gender divergence in life expectancy is illustrated in Table 2. Between 1900/1901 and the early 1970s, the gap between male and female life expectancy at birth increased from less than 1 year to more than 5 years in Japan and from less than 4 to over 7 years in France. In both these countries this difference increased further in the last part of the 20th century, although in France (and Sweden) this peaked in the mid-1990s and in the UK and the USA the sex differential in life expectancy at birth has narrowed slightly since 1970/1971. In both these countries, the gender difference in further life expectancy at age 65 was also greatest in the early

Table 1. Survival to age 80 by birth cohort, England and Wales.

	% surviving to age 80	
Year of birth	**Men**	**Women**
1861	10	16
1881	14	25
1901	17	34
1911	23	41
1921	29	47

Source: Data from Government Actuary's Department.

Table 2. Trends in life expectancy at birth and at age 65 by gender, selected developed countries.

	Life expectancy (years)					
	At birth			At age 65		
Year and country	M	F	Difference	M	F	Difference
1900/1901 England and Wales	44.8	48.7	3.9	10.1	11.1	1.1
France	43.2	46.9	3.8	10.0	10.9	0.9
Japan	44.0	44.9	0.9	10.1	11.4	1.2
Sweden	50.8	53.6	2.9	12.1	13.0	0.9
USA	46.4	49.0	2.6	11.4	12.0	0.7
1950/1951 England and Wales	65.3	70.3	5.0	10.8	13.4	2.6
France	63.4	69.2	5.8	12.2	14.6	2.4
Japan	57.6	60.9	3.3	10.9	13.0	2.1
Sweden	69.8	72.4	2.6	13.5	14.3	0.8
USA	65.6	71.1	5.5	12.8	15.1	2.3
1970/1971 England and Wales	68.8	75.0	6.2	11.9	15.8	3.9
France	68.4	75.8	7.4	13.0	16.8	3.7
Japan	69.3	74.7	5.4	12.5	15.4	2.8
Sweden	72.2	77.2	5.0	14.3	16.9	2.6
USA	67.2	74.9	7.7	13.1	17.1	4.0
1995 England and Wales	74.4	79.6	5.2	14.8	18.4	3.6
France	73.9	81.9	8.0	16.1	20.6	4.5
Japan	76.4	82.8	6.4	16.5	20.9	4.4
Sweden	76.2	81.5	5.3	16.0	19.7	3.7
USA	72.4	79.3	6.9	15.3	19.2	3.8
2000–2002/2005 England and Wales	75.9	80.6	4.7	16.0	19.1	3.1
France	75.2	82.8	7.6	16.3	21.2	4.9
Japan	77.8	85.0	7.2	17.4	22.6	5.2
Sweden	77.6	82.6	5.0	16.7	20.5	3.8
USA	74.6	80.4	5.8	15.6	19.2	3.6

Sources: Data from Government Actuary's Department (E&W), Berkeley Mortality Data Base (http://demog.berkeley.edu/wilmoth/mortality); Ministry of Health and Welfare (Japan), Statistics and Information Department, 18th life tables, Tokyo, 1998; United Nations, 2002.

1970s, but in the other countries shown in Table 2 (and elsewhere) this gender difference has continued to increase.

Reasons for the widening gap between male and female mortality during most, or all, of the 20th century have been reviewed by Waldron (1986, 1993) and Verbrugge (1989) and include, in the early phases of the mortality transition, declines in causes of death specifically or predominantly affecting women (such as maternal mortality, cancer of the uterus, and respiratory tuberculosis) and possibly changes in the intra household allocation of resources by gender. Gender differences in health related behavior, particularly

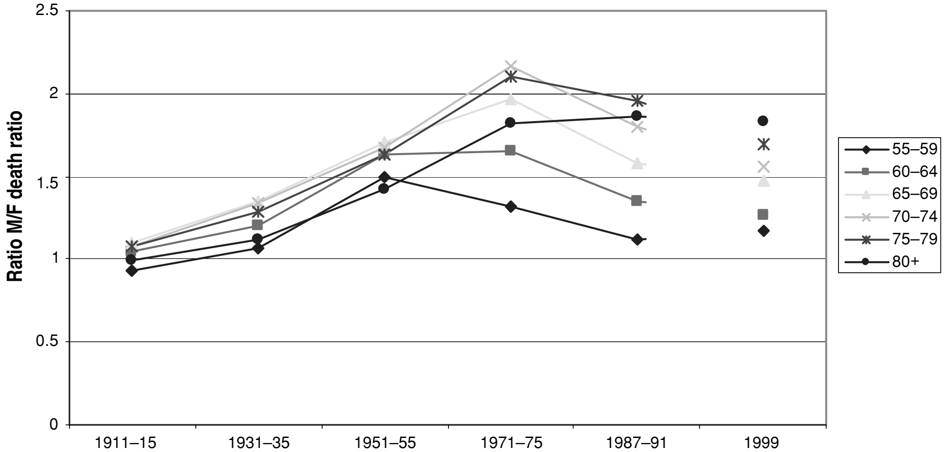

Figure 4. Sex ratio of death rates from neoplasms by age group, England and Wales, 1911–1915 to 1999.

smoking, in exposure to occupational hazards and perhaps the greater susceptibility of men to stresses associated with socio-economic change have been suggested as important reasons for the widening gap between male and female mortality for much of the 20th century. In particular the 20th century epidemic of coronary heart disease affected only men in most industrialized countries. In England and Wales, for example, the sex ratio of age-standardized mortality from coronary heart disease remained close to 1.5 during the 1920s, 1930s, and 1940s but then rose rapidly, peaking at 3.5 in 1971 (Lawlor, Ebrahim, and Smith 2001). One hypothesized explanation, apart from differences in stress and in smoking already referred to, is possible gender variation in both consumption of red meat ("preferentially" allocated to the male breadwinner) and biological response to dietary fat (Lawlor, Ebrahim, and Smith 2001).

Changes in the relative propensity of men and women to smoke are undoubtedly an important factor in the recent slight narrowing of the sex differential in mortality in England and Wales and the USA (and some other western populations). Figure 4 shows the ratio of male to female death rates from neoplasms for periods during the 20th century for groups aged 55–59 to 80 and over. This ratio rose until the mid-century in younger groups, until 1971–1975 in the 70- to 74-year-old age group and until the late 1980s in the 75- to 79-year-old age group but then began to fall as cohorts with less sex divergent smoking exposures reach the relevant age group. This pattern is clearly indicative of an interaction between gender and cohort effects. Similarly, Manton (2000) has demonstrated that differences in male and female cohort mortality rates underlie many of the period changes for heart disease, stroke, and lung cancer mortality evident in the USA between 1962 and 1995.

A further narrowing of sex ratios in mortality is anticipated in some populations, such as that of England and Wales with consequent increases in the projected ratio of men to women in the older population (Shaw 2004).

Table 3. Indicators of health problems/disability by age and sex, Great Britain (private household population only).

		Age					
		65–69	**70–74**	**75–79**	**80–84**	**85+**	**65+**
Reported limiting long standing illness[a]	M	34	39	46	48	51	41
	F	33	41	40	45	57	41
Health in general in preceding year "not good"[a]	M	19	23	31	33	31	25
	F	17	24	28	32	36	25
Reported inability to manage one or more locomotion activities on their own[a,b]	M	8	10	12	18	35	12
	F	9	16	21	29	50	21
Reported inability to usually manage bathing/showering/washing all over on their own[a]	M	3	3	6	7	18	5
	F	3	7	7	14	23	9
Raised BP[c]	M	50	53	56	55	53	53
	F	52	58	65	71	76	60
Psychological morbidity (GHQ 4+)[c]	M	10	12	13	17	18	12
	F	13	15	19	21	21	17
Taking 3+ prescribed medications[c]	M	17	21	25	25	23	21
	F	18	20	23	31	30	22

Source: 2001 General Household Survey, National Statistics 2003; author's analysis of 1993–1995 Health Survey for England data.

[a] Great Britain, 2001.

[b] Getting up and down stairs; getting around the house; going out of doors and walking down the road; getting to the toilet; getting in and out of bed.

[c] Results for England only, 1993–1995.

4. Gender and Health Status

Although elderly women have lower mortality rates than elderly men, rates of morbidity and disability are higher, at least among those aged 75 and over. This is illustrated in Table 3, which shows the prevalence of various health conditions and indicators of disability by gender in the elderly population of Great Britain. On the more general indicators of self-reported health or morbidity, such as self-reported limiting long-standing illness or self-rating of general health as "not good", differences between men and women are not marked except in the oldest groups (and in some cases are higher among men than women in young elderly groups). However, women report more disability than men in all age groups (for example, difficulty with bathing) particularly in the oldest groups and also include higher proportions, again in older groups, taking three or more prescribed medications. Similar differences have been found in numerous studies undertaken in a wide range of populations (Baltes, Freund, and Horgas 1999; Crimmins, Saito, and Reynolds 1997; Robine, Jagger, and Romieu 2001; Verbrugge 1989; Zeng et al. 2001). Rates of psychological morbidity, here indicated by a score of four or more on the General Health Questionnaire, a well-validated indicator (Goldberg and Williams 1988), are also higher for women than for men, in this case throughout the elderly age range.

A number of factors may underlie these differences. Firstly, possible gender differences in sources of bias and in reporting patterns need to be considered. Many surveys of health status, including those drawn upon in Table 3, include only the population living in private households and so exclude the most disabled living in institutions. As discussed below, higher proportions of older women than men live in institutions so this means that gender differences in more serious disabilities may often be underestimated. Gender differences in reporting of health indicators also need to be considered. Allen et al. (1993) have pointed out that indicators of disability based on questions about receipt of assistance with instrumental activities of daily living (ADL) (such as cooking and cleaning) may overestimate the extent of male disability if it is assumed that all men in receipt of help are disabled, as help with these tasks may be provided for role-related, rather than health-related reasons (see the following section for a discussion of this). Both these sources of potential bias might lead to underestimation of gender differences in late life disability, in the former case through underestimation of female disability and in the latter through overestimation of some types of disability in men. It has also been suggested that such differences may be overestimated as women may be more likely to report health problems than men both because of a greater willingness to admit difficulties and because of a lifelong higher rate of contact with health professionals occasioned by their role as mothers (Mechanic 1978). The supporting evidence for this thesis is far from conclusive. Blaxter (1990), for example, in her analysis of the British Health and Lifestyles Survey, found that although more women than men (in all age groups) had poorer psychosocial health, women who were so categorized were less likely than men to report their overall health as poor. Gender differences in the reporting of restrictions with ADL and functional limitations have been investigated by Merrill et al. (1997) who compared reporting of restrictions with observed performance in a large sample of elderly people in the USA. They found that performance differences accounted for all of the gender difference in reported difficulties with ADLs and most of the reported differences in functional limitations (the so called "Nagi" measures). In short, it seemed that the gender differences in disability found were real, rather than an artifact of reporting.

Differences in the risks of common health conditions and in the dynamics of disability have been identified as important underlying factors. Women have a much higher prevalence of musculo-skeletal disorders such as osteoporosis and arthritis. In the USA, for example, 51% of all women aged 85 and over have bone densities low enough to meet the WHO definition of osteoporosis, compared with only 14% of men of the same age (Kramarow et al. 1999). Women also have higher rates of hypertension and visual impairment than men (as illustrated for the United States population in Figure 5), although a lower prevalence of disability related to cardiovascular disease and hearing impairments. Conditions such as osteoporosis or arthritis are major predictors of the development of functional limitations (Boult et al. 1994) but are not immediately life threatening. Cardiovascular diseases by contrast, are associated with common causes of death among elderly people. Analyses of the dynamics of disability have shown that the higher prevalence of disabling conditions among older women reflects longer survival with disablement (related to the type of disablement), rather than differences in incidence (Grundy and Glaser 2000; Hayward, Crimmins, and

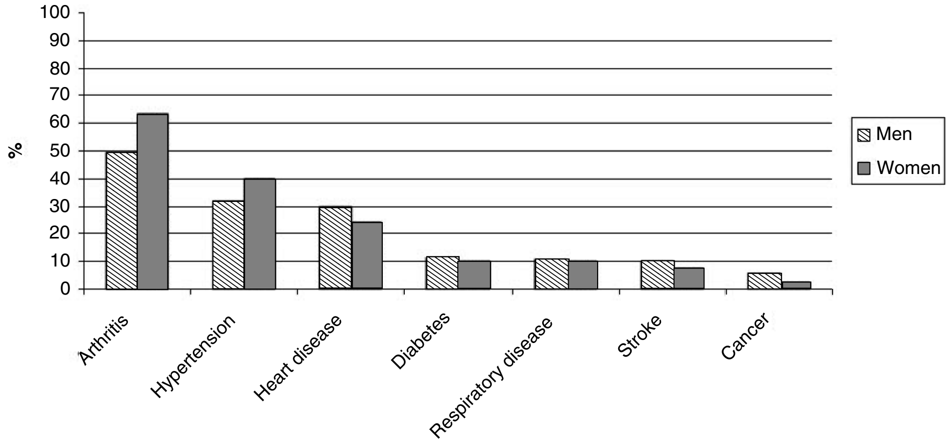

Figure 5. Persons aged 70 and over reporting selected chronic conditions (%), USA 1995.
Source: Adapted from Kramarow et al., 1999.

Saito 1998; Manton, Corder, and Stallard 1993; Manton, Stallard, and Corder 1997), in short is associated with gender differences in the distribution of types of disability and their association with mortality. Gender differentials in survival to older ages may also play a role. As a larger proportion of women than men survive to later old age (see Table 1), they may represent a more heterogeneous and less "selected" group including a larger proportion with potentially unfavorable health characteristics (Vaupel, Manton, and Stallard 1979). The narrowing of gender differentials in mortality observed in extreme old age groups (Thatcher, Kannisto, and Vaupel 1998) supports this argument.

Differences in the types of morbidity and consequent disability that men and women appear at risk of undoubtedly have both biological and environmental components. Greater female risks of musculo-skeletal disease among women, for example, have been associated with physiological differences. The higher prevalence of hearing impairments among current cohorts of men reflects gender-specific occupational exposures, as well as possible biological differences.

At a more general level, the effects of gender differences in environmental influences may partly underlie observed gender differences in health. One aspect of this issue which has attracted considerable interest is the question of whether the higher mortality of men may reflect increased hazards associated with employment. Vallin (1995), for example, investigated whether differences in the occupation structure of the male and female population aged 30–64 in France contributed to the sex differential in mortality. His analysis showed that when only broad occupational categories were used, the differing occupations of men and women in fact served to reduce, rather than increase, male disadvantage (in short if the distribution of occupations among men was the same as among women, male mortality would be even higher). However, when more detailed analysis was undertaken, allowing identification of specific high-risk occupations, this suggested that a modest component of the gender differential in mortality could be accounted for by male involvement in these occupations. In analysis of a similar Finnish data set, also restricted to persons in middle and early old age (35–64), Koskinen and Martelin (1994) investigated reasons for the observed lower extent of socio-economic differentiation in female mortality rates than in male ones. They found that the major explanation seemed to lie in the different cause of death structure of men and women. Additionally, they noted that socio-economic mortality differences were as large among unmarried women as among men, but considerably lower in the large married female population. In general many studies suggest that socio-economic variations in the health status of the female population may not be as marked as among men, although this may be changing as the involvement of women in the labor market increases. In England and Wales, for example, it is only relatively recently that variations in female mortality by socio-economic status have come to follow the graduated pattern long observed in male populations (Hattersley 1999).

These gender variations in associations between socio-economic and socio-demographic circumstances and health may of course partly reflect the problems in assigning and measuring socio-economic status to groups not in the labor market. In the older population, especially the older female population, measuring socio-economic status is particularly difficult (Grundy and Holt 2001). Indicators based on current occupation are largely irrelevant and those based on past occupation may be complicated by changes in the occupational structure of populations over time and more particularly by major differences between men and women in both types of employment and labor market involvement. Differentiation on the basis of education is also difficult because in current cohorts of elderly people in Europe the extent of heterogeneity in educational qualification levels is low, again particularly among women (Martelin 1994). Despite these problems, numerous studies have demonstrated that socio-economic variations in both mortality and morbidity persist in older age groups (Acheson 1998; Fox et al. 1985; Grundy and Glaser 2000; Grundy and Sloggett 2003; Marmot and Shipley 1996; Preston and Taubman 1994). A related large body of work has shown variations in health status by socio-demographic indicators such as marital status and social network size (although with some differences between men and women in the pattern of association) (Gliksman et al. 1995; Goldman, Korenman, and Weinstein 1995; Grundy, Bowling, and Farquhar 1996; Hahn 1993; Hu and Goldman 1990). This suggests that the rather different socio-economic and socio-demographic circumstances of older men and women need to be considered as a possible influence on gender differentials in health.

Older men are more likely than older women to be married; they have higher levels of education, larger incomes, and more material assets than older women, all factors shown in studies of health inequalities to be associated with both mortality and morbidity. Older women also suffer greater exposure to challenges such as bereavement. This raises the obvious question of whether these factors might contribute to the generally poorer health of older women (although why differentials in mortality are in the opposite direction remains paradoxical). This argument perhaps has particular salience when we consider that it is in the oldest old groups that women appear most disadvantaged in health, and in the oldest groups too that women are most likely to be at risk of poverty and reduced social networks (Holtz-Eakin and Smeeding 1994).

The hypothesis that the poorer environments of older women could contribute to their higher morbidity has been examined most closely in connection with psychological health.

Sonnenberg et al. (2000), for example, assessed gender differences in depression (measured using the Center for Epidemiological Studies Depression Scale) in a sample of Dutch people aged 55–85. They found, as have other studies using these kinds of instruments, that the prevalence of depression among women was about twice as high as among men. Sex differentials in patterns of association with risk factors were small, but female exposure to these risk factors (such as low income, low education, chronic physical illness, and not being married) was much higher. As a result, in analysis in which these factors, and age, were controlled, the relative risk of depression among women compared with men was 1.3, a ratio that was significantly raised but considerably lower than the unadjusted ratio of 1.8.

Viewing psychological health from a positive rather than a negative perspective, a Spanish study (Fernandez-Ballesteros, Zamarron, and Ruiz 2001) similarly found that being male was associated with higher life satisfaction, but that this association ceased to be significant once marital status, income, and level of education were controlled for.

The contribution of differences in socio-economic and socio-demographic circumstances to observed gender differences in cognitive impairment was investigated in the Berlin Aging Study, a very detailed longitudinal study of some 500 Berliners aged 70–100. In analyses in which age, but no other characteristics, were controlled for, Helmchen et al. (1999) found that women's risk of dementia was 1.6 that of men's. However, this gender effect ceased to be significant once socio-economic and socio-demographic differences were allowed for and fell below 1 (although not significantly so) when adverse life experiences were also controlled for.

These findings suggest that gendered experiences and circumstances may account for at least some of the difference in the psychological health of older men and women. However, although women generally appear disadvantaged when compared with men on indicators of depression and psychological well-being (before control for other risk factors), the proportion of older men with more serious depressive illness may be just as high (Lindesay, Briggs, and Murphy 1989). Several studies also suggest that it is older men who are at greater risk of social isolation (Grundy, Bowling, and Farquhar 1996), although in the Berlin Aging Study there was no difference between women and men in the proportion who were socially isolated and the proportion of older women who were emotionally isolated appeared higher than that of men (Baltes, Freund, and Horgas 1999). Elderly men also have consistently higher suicide rates than older women, possibly reflecting differences in the distribution of other risk factors (such as alcohol abuse) (Dennis and Lindesay 1995; Meehan, Saltzman, and Sattin 1991; Ruzicka 1995).

In this chapter, data from the three rounds (1993–1995) of the Health Survey for England, a large nationally representative survey described in detail elsewhere (Bennett et al. 1995), are used to examine the extent to which differences in socio-demographic and socio-economic circumstances may be associated with gender differences in indicators of health. A valuable feature of the survey is that it includes information on both self-reported health indicators, such as self-reported health status and long-standing illness, and also observational measures such as a count of prescribed medications and blood pressure measured by a nurse. Unfortunately, however, responses to this latter measure were not as good as for the self-reported measures which may be a source of bias and so this indicator

Table 4. Percent distribution of men and women aged 65–84 by socio-economic and socio-demographic characteristics, England, 1993–1995.

		Men		Women	
		65–74	**75–84**	**65–74**	**75–84**
Marital status	Married	76.5	68.2	55.4	28.7
	Single	6.8	5.0	5.8	7.4
	Widowed	12.3	24.1	33.3	61.3
	Div./sep.	4.5	2.7	5.4	2.7
Perceived social support	No lack	52.4	53.7	61.6	61.9
	Some or severe lack	47.6	46.3	38.4	38.0
Education	Qualification	42.0	39.2	28.9	22.2
	No qualification	58.0	60.8	71.1	77.8
Tenure	Owner occupier	71.8	64.8	67.6	58.4
	Tenant	28.2	35.2	32.4	41.6
Receipt of income support	No	92.0	87.5	86.8	76.8
	Yes	8.0	12.5	13.2	23.2
Smoking status	Never	19.0	22.3	47.3	57.4
	Ex	53.5	55.4	34.1	30.6
	Current	27.5	22.3	18.6	12.0
N(=100%)		2694	1213	3271	1951

Source: Author's analysis of 1993–1995 Health Survey for England data.

is not used here. A further weakness of the survey is that it excludes those in institutions, who form a sizeable minority of the very old population. The analyses reported here are therefore restricted to persons aged 65–84. (Census derived data available for 1991 showed that in this broad age group only 2% of men and 4% of women resided in institutions, so the bias arising from excluding them is minor (Grundy, Glaser, and Murphy 2000).) The socio-economic indicators used in the analysis comprise an indicator of whether respondents had any educational qualifications, housing tenure, and whether respondents were in receipt of income support—a means-tested supplement paid to those on very low incomes. Socio-demographic indicators, apart from age and gender, were marital status and a measure of perceived social support. Data on smoking status (past, current, or never) was also available and the results presented here control for this, and for age.

As shown in Table 4, the distribution of male and female respondents according to these variables differed substantially. Fewer women were married, had an educational qualification or lived in an owner occupied dwelling, while higher proportions were in receipt of income support. More positively from the female perspective, the proportion of those who have never smoked was much higher for women and the proportions reporting a lack of social support slightly lower. Table 5 shows which of these covariates were significantly associated with the indicators of health status used in, respectively, the male, female, and total sample. Results in the bottom panel for both sexes combined also show odds ratios

Table 5. Summary results from logistic regression models of associations between socio-economic and socio-demographic factors and indicators of health among men and women aged 65–84, England 1993–1995.

	Bad health	Long-standing illness	2+ conditions	3+ medicines	GHQ 4+
Men					
Single					
Wid.	+			++	++
Div.			+		
Some or severe lack of social support				+	++
No quals.				++	++
Tenant	++				+
Receives income support	++	+	++	++	++
Women					
Single	–		–		––
Wid.	–				
Div.			–		
Some or severe lack of social support	++		+		++
No quals.	++				++
Tenant	++	++	++	++	
Receives income support	++	++	++	++	+
Persons					
Single			–		––
Wid.				+	+
Div.			+		
Some or severe lack of social support	+	+	+	+	+
No quals.	++			++	++
Tenant	++	++	++	++	+
Receives income support	++	++	++	++	++
Female OR unadjusted	0.98 NS	1.01 NS	1.08 NS	1.05 NS	1.32 ++
Female OR adjusted	0.92 NS	0.93 NS	1.08 NS	1.00 NS	1.33 ++
N	8672	8684	8665	7391	8420

Included in model but not shown separately: five-year age group; smoking status. Reference categories: Married; no lack of social support; has some qualifications; owner occupier; not in receipt of income support; male. + or $-p < 0.05$, ++ or $-p < 0.001$.

Source: Analysis of data from Health Survey for England.

for each outcome for women as compared with men, firstly adjusted only for age, and secondly adjusted for all the covariates in the model (including age and smoking status). Results show that among men, being in receipt of income support increased the risk of all of the five indicators of poorer health; being widowed increased the odds of three. Tenants, those with no educational qualifications and those reporting a lack of social support had higher odds of two of these outcomes (although not the same ones). In the larger female sample, receipt of income support, being a tenant, no qualifications and a lack of social support were also associated with higher odds of two or more of these indicators. However, associations between marital status were in the opposite direction from those in men, with single (never-married) women having significantly lower odds than married women (the reference group) of self-reported bad health, two or more long-standing illnesses or minor psychiatric morbidity. In the combined sample, being female was associated with a significantly raised odds of psychiatric morbidity, however this ratio was virtually identical in the model in which only age was controlled and that in the full model, and indeed the only difference apparent between controlled and uncontrolled ratios was for reported long-standing illness, and this was slight.

This does not mean that the higher risks of, for example, poverty in the older female population are not associated with risks of poorer health, but it seems that in considering the relative health of men and women, and the associations with socio-demographic and socio-economic factors, there may be offsetting influences. More women are in poverty, but more are lifelong non-smokers. Many more women are unmarried, but proportions reporting a lack of social support are if anything slightly lower and being single does not seem to carry the same risks for women as for men, at least in this sample.

5. Home and Hearth

One consequence of shorter male life expectancy, coupled with the common pattern of women marrying older partners and the lower remarriage chances of widows and divorced women compared with widowers and divorced men, is marked differences in the marital status distributions of older male and female populations, as partially illustrated in the data for England presented above. In most European populations, half or more women over 65 are widows (Grundy 1996a; Kinsella and Velkoff 2001). In Eastern Europe this proportion is particularly high, while in the Nordic countries it is rather lower than in the rest of Europe. These patterns reflect variations in the extent of sex differences in mortality (see Figures 2 and 3); past variations in nuptiality (those who have never married cannot be widowed), and the extent to which divorce has become a competing risk to widowhood [in Sweden in 1991, 8% of elderly women were divorced or separated (Kinsella and Velkoff 2001)]. Among the older old, the prevalence of widowhood is of course even higher with only very small proportions of women aged 85 or over still married. The majority of older men, by contrast, are married and it is only at very old ages (over 87 in England and Wales) that widowers outnumber married men.

Although, or perhaps because, experiencing the death of a spouse is far more usual for women than men, some studies suggest that the effect of conjugal bereavement on health and well-being may be more serious for men (Bowling 1987; Goldman, Korenman, and

Weinstein 1995). Several studies have found that married men tend to rely on their wives to a much greater extent than married women for emotional support, for example only mentioning their wives when asked to name a confidante, rather than both spouse and friend as is more usual among older women (Antonucci and Akiyama 1987). Older widows, it has been suggested, may have been better prepared for the death of their spouses than older widowers, who have stronger alternative emotional bonds and in some cases may even find positive aspects to widowhood, in the form of increased autonomy and freedom from domestic and caring responsibilities (Davidson 2001).

An important associated difference is the much higher proportion of older women who live alone. In the USA and most Northern and Western European countries at least half of all women aged 75 and over live alone; these proportions are lower in Southern European countries but still high. A related feature of importance is the much higher proportion of older women than men who live in institutions, in most contemporary (although not historical) western populations. This reflects both the much lower proportion of older women who are married and the higher prevalence of serious disability among women. Additionally, some studies suggest that even older women who are still married have a higher risk of entry to an institution than married men of the same age (Grundy and Glaser 1997). In Britain in 1991, for example, 18% of married women aged 85 and over who had a limiting long-standing illness were resident in institutions compared with 11% of comparable men (Grundy 1996b). This may be because men find it harder to assume the role of carer for a disabled spouse. Studies from the United States suggest that men caring for disabled wives provide less care (and receive more help) than do women caring for disabled husbands (Allen 1994). Carrière and Pelletier (1995), however, found that in an analysis of Canadian data, gender had no significant effect on the risk of institutional residence after controlling for the effects of age, health and marital status, family income and education.

Gender differences in marital status and living arrangements interact with gender differences in employment histories and the acquisition of material assets (including pensions); with the consequence that elderly women living alone have particularly high rates of poverty and the overall proportion of older women in poverty is higher than that of men (Holtz-Eakin and Smeeding 1994).

The gendered nature of life course experiences may also have other implications for health and well being in later life. Among women, for example, parity is associated with differentials in mortality (Kington, Lillard, and Rogowski 1997). In analyses of data from the British Retirement Survey, Grundy and Holt (2000) found that demographic history, including number of marriages, parity, and timing of marriage and the start of childbearing, was associated with health in early old age, even after control for socio-economic factors, particularly among women.

A further important difference between men and women in later life may be that the salience of traditional gendered roles changes as the relevance of the work related world recedes and that of life at home becomes more important. In this regard women's domestic skills may become of relatively greater importance and men's weaknesses in these areas potentially more of a disadvantage, especially for widowers. Figure 6 illustrates this by showing the

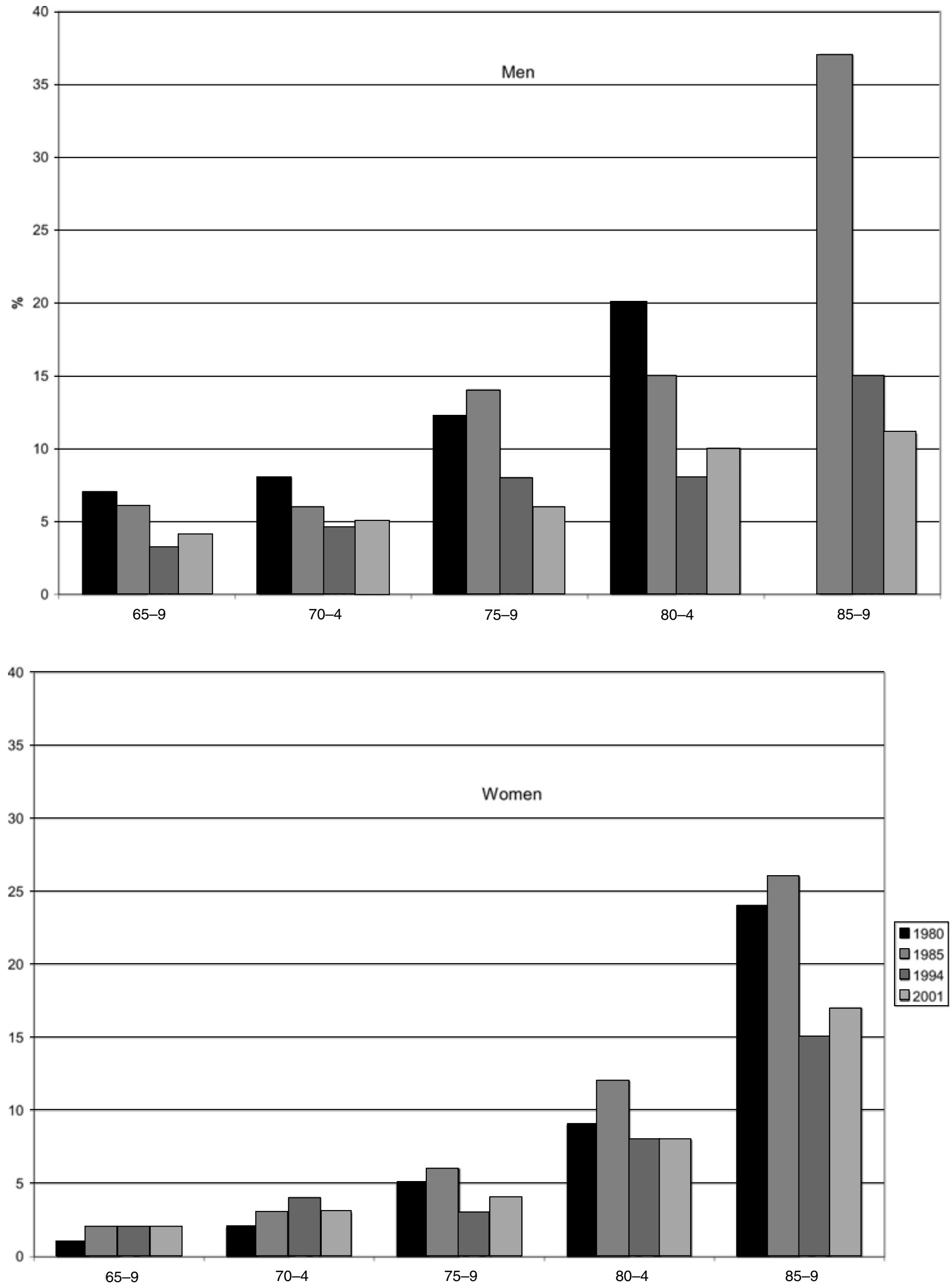

Figure 6. Percentage of older people unable to cook a main meal by gender and age group. Great Britain, 1980–2001.
Source: Author's analysis of General Household Survey data.

proportions of older men and women in Britain unable to cook a meal on their own as reported in nationally representative surveys conducted in 1980, 1985, 1994, and 2001. In the two earlier years the proportions of men unable to do this were higher than those of women (despite the higher prevalence of disability among women). However, the extent of male "disability" in this regard shows clear signs of diminishing over time, with the result that by 1994 in age groups over 80, the proportions of men and women unable to cook a meal unaided were the same and by 2001 the proportion of women aged 85 or over unable to cook a main meal exceeded that of men of the same age. Changes in gender roles may underlie this shift, together perhaps with the greater availability of convenience foods and other aids to cooking, such as microwave ovens, which may have made preparing meals less challenging.

6. Kin Contact and Intergenerational Exchange

Women, as discussed above, are far more likely in later life to be unmarried and to live alone than older men. However, these deficits in potential intra-household support may be compensated for by higher reserves of extra-household support; this may account at least in part for the gender differences in associations between marital status and health noted earlier in this chapter. Gender has been identified as an important dimension in family contact and intergenerational exchange in a wide range of studies. Women's traditional role as "kin keepers" (Gerstel and Gallagher 1993) is reflected both in higher levels of contact between female relatives, including daughter–mother and sister–sister dyads than between equivalent male pairs and reported gender differences in levels of emotional closeness (Bonvalet and Maison 1999; Greenwell and Bengtson 1997). Silverstein and Bengtson (1997), for example, report that adult children have weaker links with fathers who have been widowed, as well as with those who have been divorced, in contrast to the pattern of increased contacts with widowed mothers reported in some studies (Roan and Raley 1996).

Women's wider social networks also appear to be stronger than those of men, at least in Western countries. Kramarow et al. (1999) reported that in the 1994 United States National Health Interview Survey supplement on aging, 90% of women aged 70 and over reported at least three social activities in a 2-week reference period compared with 84% of men. Although this difference is not large, the women surveyed were on average older and more disabled than the men, both factors associated with lesser social contact.

In this section of this chapter, we examine this issue using two British data sets which collected data on availability of, contacts with and exchanges of support with extra resident kin, especially children. The first of these chronologically is the Office for National Statistics Retirement Survey, a two round nationally representative survey in which 3543 adults aged 55–69 were surveyed first in 1988/1989 and then again in 1994. Although the survey was largely concerned with economic issues, marital and fertility history data was collected—allowing estimation of numbers of children—together with information on living parents and data on exchanges of support with both children and parents. The other source used is a module on living kin and contacts with kin designed by Grundy and Murphy and included in two rounds of the 1999 Omnibus Survey of Britain. In this survey, we collected data on living kin of various degrees, on contacts with some of these kin and

Box 1.

Question on help included in the ONS Retirement Survey and follow-up

Provision of help:

“Nowadays do you/does either of you regularly or frequently do any of the things on this card for your child(ren)”

Receipt of help:

“Nowadays does your child/children regularly or frequently do any of the things on this card for you/either of you”

Give lifts in your car (if you have one)

Providing or cooking meals

Shopping

Looking after children

Helping with money

Washing, ironing or cleaning

Helping to sort out paperwork—like financial or legal affairs

Decorating, gardening, or house repairs

Anything else?

replicated the questions of provision and receipt of support of various kinds included in the Retirement Surveys (see box).

Information on contacts with close kin from the Omnibus Survey module supported results from other studies in showing a gender dimension in extent of contact. The proportion of adult children with at least weekly face-to-face contact with a parent, for example, was highest for daughter–mother and lowest for son–father dyads (Figure 7). Thus, over half of daughters aged 40–54 with a mother still living saw her at least once a week compared with a third of sons of the same age with a father still alive. Contacts between grandparents and grandchildren were also found to be gender related, with a higher proportion of grandmothers than grandfathers seeing their eldest grandchild at least weekly (Grundy, Murphy, and Shelton 1999).

Results from multivariate analyses, summarized in Table 6, showed that daughters were significantly more likely than sons to have at least weekly face-to-face contact with parents. Contact of this frequency was also associated with education, housing tenure, proximity (itself associated with gender), and number of siblings (Grundy and Shelton 2001). Interestingly, after allowance for all these factors, frequent contact with father was found to be significantly lower when the adult child’s mother was dead. This suggests, in line with Greenwell and Bengtson’s (1997) findings that contacts between adult children and their fathers may sometimes be a by product of contact with mothers and

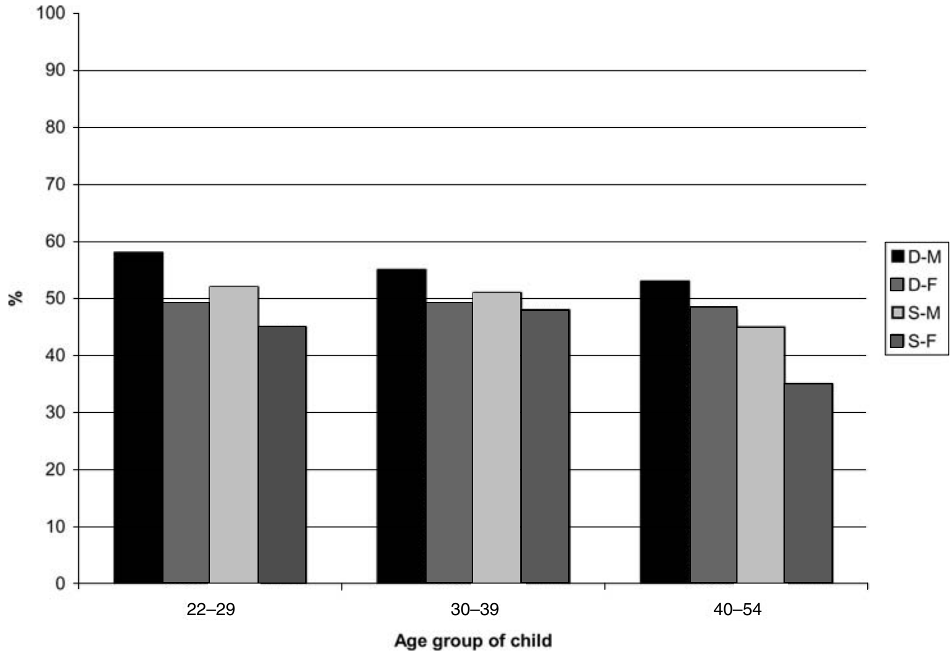

Figure 7. Non co-resident children with at least weekly face-to-face contact with a parent (%), by gender of child and parent, Britain 1999.
Source: Analysis of 1999 Omnibus Survey module on kin and kin contact.

that far from increasing visits as a response to the father's widowhood, level of contact drops.

Analysis of the provision and receipt of help using data from the Retirement Survey (which included a larger sample in the relevant age groups, together with information on health), also showed a strong gender dimension. In this survey, the questions about help

Table 6. Summary results of logistic regression model of demographic factors associated with at least weekly face-to-face contact with mother/father among adults aged 22–54 with a living mother/father, Britain 1999.

Co-variate	Contact with mother	Contact with father
Daughter (versus son)	++	++
Age (adult child's)	−−	NS
No. sibs	−−	−−
Has dependent child	−−	NS
Co-parent dead	NS (OR = 1.2)	−−(OR = 0.6)
N	1847	1506

Controlling for education; proximity to parent; region and housing tenure. ++ or −− $p < 0.001$.
Source: Analysis of 1999 Omnibus Survey module on kin and kin contact.

Table 7. Provision/receipt (%) of regular help to/from children by adults aged 55–69 at baseline (1988), Britain.

	Help to children		Help from children	
	1988	**1994**	**1988**	**1994**
Men				
Married	65	68	30	31
Unmarried	34	40	41	47
All	62	63	32	33
Women				
Married	65	61	30	34
Unmarried	55	49	55	62
All	57	56	37	44

Source: Author's analysis of ONS Retirement Survey data.

administered to married respondents asked about help provided by or received by the couple and therefore do not reveal gender differences. However, results for unmarried respondents (nearly all of whom were widowed or divorced) suggest a clear differentiation. As shown in Table 7, 47% of unmarried men included in the 1994 round of the survey (when they were aged 60–75) reported receiving regular help from at least one child compared with 62% of women. Unmarried men also were less likely to report providing regular help to a child, particularly in 1988. Multivariate analysis, not shown here, in which other relevant factors such as disability status and age were allowed for, confirmed this association and showed that women in this "Third Age" group were more engaged in support exchanges with their adult children than were men.

Gender was also associated with sample members' ties with their own parents, where they still survived. Among men who still had a living parent, 59% lived within 10 miles of their parent and 22% provided regular help. Comparable figures among women were 70% and 45%. This is consistent with a wide range of studies which have found that women play a larger role than men as caregivers for very old people. In a Canadian sample of people aged 80 and over in need of assistance, for example, 22% reported receiving care from a daughter compared with 12% who had a caregiving son (Legaré and Martel 2000).

7. Discussion

In all developed countries, and indeed in all but a very few other countries, women's life expectancy at birth and at age 65 considerably exceeds that of men and nearly all older populations are predominantly female. However, this boon of longer life for women is accompanied by a number of disadvantages. Firstly, the very differential in mortality, coupled with the common pattern of women marrying older men, means that far fewer women than men have a spouse available to provide companionship, care, and support in later years. A further consequence of common spousal age gaps, coupled with gender differences in role expectations, is that more older women than men assume the role of caregivers; a role which although not without satisfactions, is associated with risks for psychological well-being (Askham, Grundy, and Tinker 1992; Miller and Cafasso 1992). Both as a result of widowhood (which is the "normal" condition for most women over the age of 75 or so) and of different patterns of work during life, older women are far more exposed to poverty in later years than are men. Additionally, they are far more likely than are men of the same age to live alone and have a higher likelihood of institutional residence. A further very important disadvantage is that women have a higher prevalence of disability in late life and a higher proportion of their total life is spent in poor health. Other disadvantages of being female in later life include possibly greater exposure to ageist stereotyping and discrimination (Grundy and Bowling 1996), including discrimination in access to health care interventions (Bowling et al. 2001).

There is some evidence that a component, although perhaps not a very large one, of women's poorer health in late life may be related to the disadvantages noted above, this seems clearest for psychological and mental health. In the analysis reported in this chapter, little was found to support the hypothesis that gender differentials in the indicators of morbidity considered could be accounted for differences in the socio-economic and socio-demographic characteristics of men and women. However, this analysis did not include measures of disability (only morbidity) and was restricted to those aged 65–84. Additionally, the choice of covariates available in the data set used was limited. Perhaps more tellingly, it is hard to see why, if women's generally poorer circumstances result in poorer health, it does not also result in higher mortality. The answer to this seems to lie in the different types of conditions which predominantly affect men and women and particularly the higher prevalence of musculo-skeletal disorders among women. In short, both biological and social factors, and interactions between the two, would seem to be implicated in observed gender differentials in healthy aging.

It is important too to bear in mind the many advantages that current cohorts of older women have. These include stronger family and social links, which may buffer the effects of stress and provide practical support, lower exposure to unhealthy lifestyles, and greater skills in domestic areas.

Clearly our knowledge of interactions between gender and healthy aging is still very limited. It is also unclear how this relationship will change as cohorts with experience of less rigidly gender differentiated lives reach old age. Future cohorts of women, for example, will be much less disadvantaged in terms of education, will include proportions with larger material assets and may also have different coping styles gained from greater exposure to paid work. Less positively, their exposure to smoking and other unhealthy lifestyles will have been much closer to that of men and possibly they will no longer have such a marked advantage in terms of social and family support, particularly when current very low fertility cohorts reach later life. Men in some populations already seem to be benefiting, in terms of reduced mortality, from environmental and lifestyle changes. It seems too that the proportions with domestic skills may be increasing, but less is known about changes in patterns of social interactions. Possible gains to those fathers who play a more involved role with children may be offset by increases in the proportions with no or little family contact [for example, a proportion of divorced men (Lye et al. 1995)].

These recent changes come as a sequel to the enormous changes in behavior and individual life courses primarily responsible for the shift to population aging which is now close to being a global phenomenon. The lower fertility rates responsible for increases in the relative representation of older people, coupled with the lower mortality which has recently amplified this trend, means that women's lives are to a much lesser extent dominated by the roles of childbearing and childrearing. Anderson (1983) estimated that the "median" woman born in England and Wales in 1851 would only live for a further 5 years after the marriage of her youngest child. For the woman born 100 years later, this gap had expanded to close to 30 years. In many populations, two, or even one, child families are now the norm and delayed motherhood means that women may spend much of their early life, as well as their later life, without responsibility for children, and have reduced potential support from children. These changes mean both that the problems that sometimes accompany aging at the individual and the population level demand our attention and also suggest that the relationship between gender and aging may be changing.

In order to determine whether or not these, and other, social changes will lead to a greater convergence in the experience of aging, we clearly need to extend our knowledge both of the determinants of healthy aging and the role that gender plays in this. In the meantime attention must be paid to the burden of disability which some older people, especially women, experience and proven means of preserving and enhancing function, such as exercise regimes (Skelton et al. 1995), widely extended.

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CHAPTER 12. FEMALE DISADVANTAGES AMONG THE ELDERLY IN CHINA[1]

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1. Introduction

It is widely known that older women are generally more socially and economically disadvantaged than older men. It is also known, though less widely, that older females tend to be less healthy than older males. Less recognized is the severity of the combination of these two kinds of disadvantages among the oldest-old women. This chapter examines this important issue in China, providing evidence about gender differences in health and socioeconomic status. Two broad age ranges are examined: the young-old aged 65–79 and oldest-old aged 80–105.

[1] Using data from both oldest-old and younger elderly interviewees collected in the 2002 wave of Chinese Longitudinal Healthy Longevity Survey, this chapter presents a substantive extension and updating of our previous study based on the 1998 CLHLS baseline survey which collected data on oldest-old only (Zeng, Liu, and George 2003). The CLHLS survey was supported by NIA grant P01 AG 08761 with matching input contributed by Peking University and China National Research Center on Aging. UNFPA and China National Social Science Foundation provided matching funds for extending the 2002 CLHLS wave to add the sub-sample of younger elders aged 65–79. The Max Planck Institute for Demographic Research provided support for the international training. We sincerely thank all interviewers and interviewees who were involved in the survey project. We thank Danan Gu, Wang Zhenglian, and Ren Qiang for their research assistance.

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2. Data Resource and Method

Data used in this chapter are from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which is the largest longitudinal study of very old people in a developing country. It is also the largest longitudinal study of centenarians, nonagenarians, and octogenarians conducted anywhere. The baseline survey and the first and second follow-up waves (with replacement of respondents who died or were lost follow-up) were conducted in 631, 777, and 850 counties/cities, randomly selected from about half of the counties and cities in 22 Chinese provinces, in 1998, 2000, and 2002, respectively. The increases in the numbers of survey units were due to two things. First, some townships had become cities after the baseline interviews. Second, some counties/cities had no centenarians in 1998, but did in 2000 and 2002 (see discussion below on centenarians). The 1998 and 2000 surveys include about 9000 and 10,000 oldest-old respondents (aged 80 and above.) In the 2002 wave, we also included a subsample of nearly 5000 young-old respondents aged 65–79, in addition to about 11,000 oldest-old respondents. The 22 surveyed provinces are Liaoning, Jilin, Heilongjiang, Hebei, Beijing, Tianjing, Shanxi, Shaanxi, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shangdong, Henan, Hubei, Hunan, Guangdong, Guangxi, Sichuan and Chongqing (there are 31 provinces in total in China). These provinces have a population of 985 million, constituting 85% of the total population of China. An interview and a basic health examination were conducted at the interviewee's home. The data collected include demographic and socioeconomic status; family structure; living arrangement; number, age, and proximity of children; Activities of Daily Living (ADL); physical performance; self-rated health; self-reported life satisfaction; cognitive function; medical care; social activities; diet; smoking and alcohol consumption; psychological characteristics; economic resources; caregiving and family support; and other information.

The survey team interviewed all centenarians who agreed to participate in the study. For each centenarian, the survey team tried to interview one near-by octogenarian (aged 80–89) and one near-by nonagenarian (aged 90–99) of a pre-designated age and sex. The term "near-by" is loosely defined to include the same village or the same street or, if applicable, the same town, country, or city. The pre-defined age and sex criteria were used to ensure that approximately equal numbers of male and female nonagenarians and octogenarians were randomly identified, based on the code numbers of the centenarians. The aim was to have more or less randomly selected comparable numbers of male and female octogenarians and nonagenarians at each age from 65 to 99 (see endnote 4 in Zeng et al. 2002 for details). To maintain the sample size and structure, those interviewees who died or were lost to follow-up between the waves were replaced by the new respondents of the same sex and age.

Coale and Li (1991) concluded that the self-reported age of very old persons in those provinces of China where Han Chinese constitute the majority were reliable. But in other regions (such as Xingjiang), where the majority or a significant proportion of the population belongs to ethnic groups other than the Han, age reporting may be inaccurate. This is the main reason why we restricted our survey to the 22 provinces where Han Chinese are the overwhelming majority. The other nine provinces (Xinjiang, Qinghai, Ningxia, Inner Mongolia, Tibet, Gansu, Yunnan, Guizhou, and Hainan), all of which have a high proportion of inhabitants belonging to ethnic minorities, were not included in the survey. We did not include these nine provinces because we were not sure about the quality of age reporting of the ethnic minority groups in these provinces, and we had no detailed age-ethnic-specific data to evaluate them.

A study focusing on the age validation of Chinese Han centenarians through comparison of demographic indices with Sweden, Japan, France, and Italy is consistent with Coale and Li's findings (Wang et al. 1998). We found similar age distributions for the centenarians interviewed in our 1998 survey and for Swedish centenarians (see Figure 1 in Zeng et al. 2001). These findings lead us to believe that age reporting in the Chinese Healthy Longevity Survey is generally acceptable up to age 105. A careful evaluation (based on reliability coefficients, factor analysis, the rates of logically inconsistent answers, etc.) showed that the data quality of the Chinese Survey on Healthy Longevity is generally good (Zeng et al. 2001, 2002). Reliability coefficients for the 10 categories of variables are reasonable (e.g., see Table 3 in Zeng et al. 2001). The factor analysis demonstrated that the interviewees' answers to multiple questions on the same topic were generally consistent. The rate of logically inconsistent answers were reasonably low (see Appendix B in Zeng et al. 2001).

Our analysis in this chapter is based on data derived from a sample of 15,798 elderly persons aged 65–105 interviewed in 22 provinces in the 2002 survey of the CLHLS. This sample includes 635 and 2332 male and female centenarians aged 100–105, 1584 and 2163 male and female nonagenarians aged 90–99, 2128 and 2111 male and female octogenarians aged 80–89, and 2438 males and 2407 females aged 65–79, respectively.

Descriptive analyses are used in this chapter. Because we deal with gender differentials in several dimensions (demographic and socioeconomic status, ADL, physical performance, Mini-Mental State Examination (MMSE), self-reported health and life satisfaction), we cannot present detailed results for each variable. We will focus on the gender differentials and the age patterns of one (or two) categories for each variable that represent the key features of the statuses, while simplifying the presentation and discussion. For example, we present only the proportion of illiteracy and omit the detailed categories of primary, middle school, high school, and college education levels, which all together constitute a small proportion among the Chinese oldest-old, especially women. In the case of ADL, we focus on the proportions who are "active", and do not go into detail about degrees of disability. This strategy enables us to make clearer and more focused comparisons of gender differentials, while keeping the chapter at a reasonable and manageable scale.

The method adopted in this chapter is a univariate analysis adjusted only for sex and age to ascertain the "de facto" gender differentials in socioeconomic status, health and subjective well-being. Other possible confounding factors are not controlled. For example, as discussed later in this chapter, we found that the gender gap of cognitive function among the Chinese oldest-old becomes extremely large (about 15–20 percentage points) at and after ages 85–89. However we cannot quantitatively determine which factors caused this large gap. Is it due to gender differences in education, economic status, or frequency of practicing reading/writing and participation in social activities? To answer such questions, it is necessary to employ multivariate statistical methods, which are beyond the scope of this chapter. Moreover, age-adjusted analysis offers useful insights about the current status of gender differentials among the Chinese elderly.

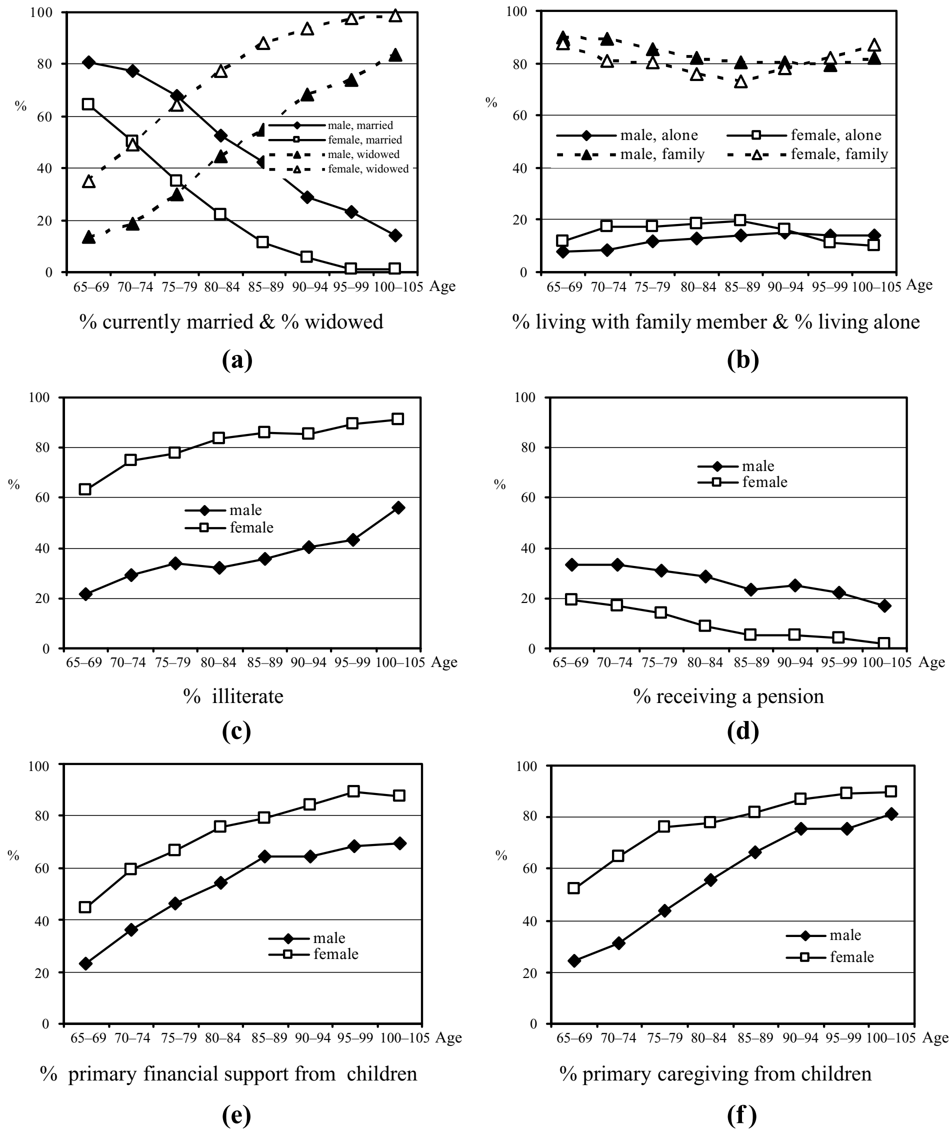

Figure 1. Gender differentials in sociodemographic and economic status, and care dependency.

3. Findings

The gender differentials and their age patterns in sociodemographics, economic, and care dependency variables are depicted in Figure 1. Figure 2 shows the gender differentials and

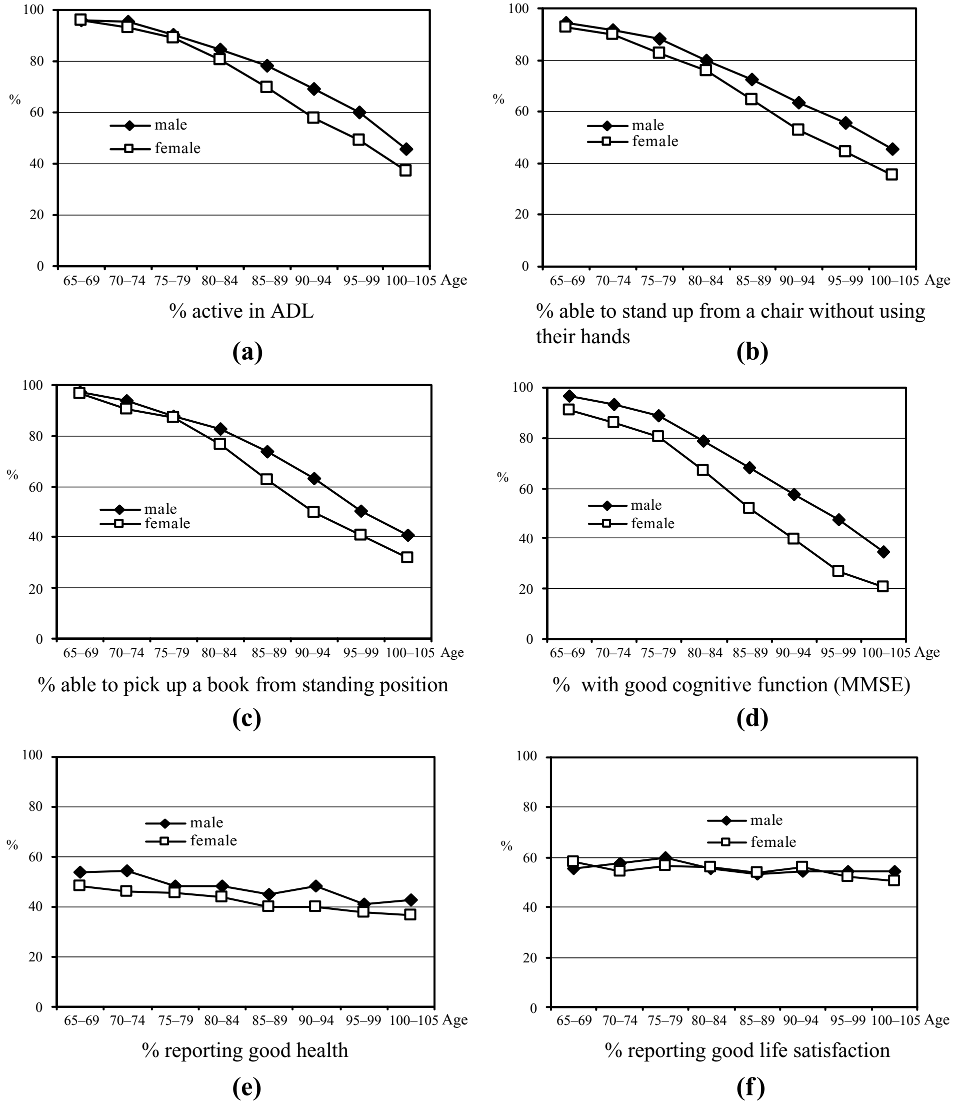

Figure 2. Gender differentials in functional capacity and self-reported health and life satisfaction.

their age patterns in ADL, physical performance, cognitive function, self-rated health and life satisfaction. Each figure contains six graphs and all the graphs have the same scale values to facilitate cross-graph comparisons. The findings are summarized in the next four subsections.

3.1. SOCIODEMOGRAPHIC STATUS

Figure 1a describes age and gender difference in the proportions of currently married and widowed respondents. As expected, male elders are much more likely to be married. The percent of the female elders who had co-residing spouses is much lower than their male counterparts. Among the non-married, the overwhelming majority was widows and widowers: 35–65% of females aged 65–79 and 77–98% of females aged 80–105 are widows, proportion that are much higher than those for their male counterparts. It is clear that female elders are much more likely to be disadvantaged in marital status (i.e., much more likely to be widowed) than are male elders, due mainly to gender differentials in mortality and the largely unbalanced gender composition at advanced ages. The proportions of divorced elders are extremely low: 0.4–1.5% for the males and 0.1–0.4% for the females. The proportion of those who were never married among the elder males is very low: 1.6–3.8%; it is even negligibly lower among the females: 0.1–0.7%. Although the extremely low proportions of the never married and divorced among the Chinese elderly men and women documents a nearly universal and stable marriage pattern in the past, females are more likely to be ever-married and not divorced, than their male counterparts.

Figure 1b presents the gender and age specific percentages of respondents who live with family members (including children, grandchildren, spouse, and other family members) and living alone. The overwhelming majority of the Chinese elderly live with family members: 73–87% for females, 80–90% for males. A large majority of the old Chinese (51–85% for women, and 46–75% for men, not shown in Figure 1b) live with their children;[2] the higher the age, the higher the proportion of those living with their children. Female elderly in all age groups are more likely to live with their children because elderly women are more likely to be widowed and economically dependent.

The proportion of elderly men who live with only their wives decreases from about 40% at ages 65–79 to 6% at ages 100–105, compared to 29 and 0.3% for their female counterparts. The percentages of women who lived alone were somewhat higher than those for men up to ages 90–94, but the gender differential disappears beyond age 95.

Figure 1c presents the gender and age specific percentages of illiteracy (with no schooling): many more females than males are illiterate. About 63–91% of the female elderly are illiterate, compared to 22–56% of their male counterparts. We may define those with 1–2 years of schooling as semi-illiterate. The proportions of illiterate plus semi-illiterate are 80–94% for females aged 80–105. The corresponding figures for males are 39–70%. Clearly, most Chinese elderly were completely illiterate or semi-illiterate. A very large majority of the female elders had no education at all and the gender differentials are enormous.

3.2. ECONOMIC AND CARE DEPENDENCY

Figure 1d shows that the percentage of Chinese women who receive pensions is much lower than those for their male counterparts. The majority of Chinese elders rely mainly on their

[2] Children include grandchildren hereafter, unless otherwise specified.

children for financial support; women rely on their children more than men (see Figure 1e). The gender differentials in primary source of financial support are enormous; the females are much more seriously disadvantaged than their male counterparts. Government at all levels and Chinese society more broadly need to pay serious attention to such enormous gender differentials in pension support for elderly persons.

About 25–81% of the males aged 65–105 reported that their primary caregivers when they were sick were their children. The corresponding figures for the females are 52–90%. Clearly, the females rely more on children as caregivers than do males (Figure 1f), who are more likely to rely on a spouse. This is consistent with the fact that a much higher proportion of female than male elderly are widowed.

3.3. ADL, PHYSICAL PERFORMANCE, AND COGNITIVE CAPACITY

Self-reported ADL functional status is based on questions about eating, dressing, transferring, using the toilet, bathing, and continence. ADL measures have proven useful in measuring functional capacity and service needs in numerous previous studies. Some investigations report that ADL is also a significant predictor of mortality (e.g., Scott et al. 1997). In this study, if none of the six ADL activities is impaired, the elder is classified as "active".

Proportional distributions of the ADL active status of the elderly classified by gender and age are presented in Figure 2a. The curve for men who are active in daily living is substantially higher than the curve for women after age 85–89. It is interesting to note that the gender differences are larger for the nonagenarians and centenarians than for the octogenarians and there is no gender difference among younger elders aged 65 to 79. The oldest-old men do better than the oldest-old women in ADL, and the gender differentials are statistically significant[3]

Similar gender differentials in active status among the oldest-old have been found in other studies. For example, based on the data from the US Long Term Care Surveys (1982–1994), Manton and Land (2000) found that, although women have a longer total life expectancy at ages 80–85, men's active life expectancy at oldest-old ages is longer than women's. This male advantage continues to the end of the life tables.

Self-reported ADL status may not always accurately measure elder persons' actual physical performance capacity. For example, adaptation to poor service facilities in rural areas may result in better ADL capacity among the rural elderly than among their urban counterparts, but the rural elderly may not necessarily be stronger in physical health (Zeng et al. 2001). Some people may feel ashamed to admit difficulties in some daily activities

[3] "Statistically significant" in this chapter means $p < 0.01$ or at most $p < 0.05$. Since the p values vary among different age groups, we do not present the p values in the text because that would result in lengthy and tedious statements. Furthermore, whether the gender differentials are significant can be most clearly seen from the male and female curves in Figure 1 and Figure 2, so we do not even mention "statistically significant" when it is obviously depicted in the figures.

such as continence. Therefore, we conducted objective examinations to measure oldest-old subjects' physical performance. We present and discuss the results of gender differentials in standing up from a chair and picking up a book from the floor.

More than 80% of the males and females younger than 80 could stand up from a chair without using their hands, and the gender differentials are very small. However, this percentage decreases very quickly and gender differentials become large after age 80 (see Figure 2b). About 78% and 72% of the male and female octogenarians can stand up from a chair without using their hands. About 62 and 46% of the male nonagenarians and male centenarians can stand up from a chair without using their hands, compared to 51 and 35% for female nonagenarians and female centenarians. The gender differences at oldest-old ages are all statistically significant—male oldest-old perform better than female oldest-old; the gender gap becomes larger after age 85–89 (see Figure 2b).

The age and gender distributions for picking up a book on the floor from a standing position are similar to those of the performance of standing up from a chair without using hands (see Figure 2b and c). Male oldest-old perform this task significantly better than their female counterparts (Figure 2c).

The cognitive capacity of the Chinese elderly, including the oldest-old, was screened using the Chinese version of the MMSE, which was translated into the Chinese language based on the established international standard of the MMSE questionnaire, and carefully tested in pilot survey interviews (Zeng and Vaupel 2002). We use the same cutoffs as the MMSE international standard, defining a score of 24+ as "good" cognitive function (see, e.g., Deb and Braganza 1999; Osterweil et al. 1994).

Figure 2d demonstrates that the cognitive capacity of the Chinese elderly declines quickly across age groups. The gender gap of cognitive function, with females more disadvantaged, is substantial among the elderly at all ages, and becomes extremely large (about 15–20 percentage points) at and after age 85–89.

3.4. SELF-REPORTED HEALTH AND LIFE SATISFACTION

Many previous studies have demonstrated that self-assessed health is a significant and independent predictor of the functioning and mortality of older people (e.g., Lee 2000). Figure 2e presents the proportions of male and female elderly who self-reported "good health"[4]. About 41–54% of the male elderly reported "good health", in contrast to 37–48% of the female elderly. Female disadvantage is again evident for self-reported health (see Figure 2e), although it is less serious than that for other variables discussed above.

The proportions of self-reported good health among Chinese male and female elderly do not decline quickly across age, which differs from the age patterns for ADL, physical

[4] In the survey, we asked a question "How do you rate your health at present?" with multiple choices of answer "very good, good, so so, bad, very bad, and not able to answer". The category of self-reported "good health" includes those provided an answer of "very good" or "good" to this question.

performance, and MMSE. The fact that, with increase in age, self-reported health does not decline as quickly as functional capacity is probably related to changing expectations, namely, the older the age, the lower the expectation.

In addition to self-rated health, we also asked, “How do you rate your life at present?” Results for self-reported good life satisfaction[5] are depicted in Figure 2f. The proportion of Chinese male and female elderly who are satisfied with their lives does not decline or declines only slightly across age groups (see Figure 2f), in contrast to their functional capacity, which declines quickly with increasing age (see Figures 2a, b, c, and d). Again, this is probably related to changing expectations—the higher the age, the lower the expectation for life satisfaction, which is consistent with previous studies in other countries (e.g., Blazer et al. 1991; Field and Millsap 1991).

Another interesting finding is that gender differences in self-reporting good life satisfaction among the Chinese elderly are not significant in all age groups (see Figure 2f). At the same time, the oldest-old Chinese women are seriously disadvantaged in ADL and physical performance, and all elderly Chinese women are seriously disadvantaged in MMSE and socioeconomic status, as well as disadvantaged (to a less serious degree) in self-reported health (see Figure 1 and Figures 2a, b, c, d, and e). Based on these findings, we believe that Chinese elderly women’s general expectations for life satisfaction are lower than their male counterpart’s. What mechanisms account for the gender differentials in life satisfaction and happiness, and their contributions to longevity? Better adaptability to a changing environment or less stress in daily life? Further research based on the longitudinal data is needed to answer these questions.

4. Conclusion

Based on a unique data set with a large sample size of the oldest-old and a comparison group of younger elders, this chapter documents the gender differentials in sociodemographic, economic and care dependency status, functional capacity, self-reported health status, and life satisfaction of the elderly in China. We conclude that among the younger elderly aged 65–79, females are seriously disadvantaged in socioeconomics and cognitive function while the gender differentials in ADL and physical performance capacity are not substantial. Among the oldest-old aged 80–105, females are seriously disadvantaged compared to males in both socioeconomic and health characteristics. Elderly women in all age groups over 65 are disadvantaged (to a less serious degree) in self-reported health. But gender differences in self-reporting good life satisfaction are not significant in all age groups, which may indicate that Chinese elderly women’s general expectations for life satisfaction are lower than their male counterpart’s. These findings about the Chinese oldest-old and younger elders are consistent with our previous study based on the 1998 CLHLS baseline survey, which collected data on only the oldest-old (Zeng, Liu, and George 2003). The

[5] The multiple responses to this question concerning life satisfaction are “very good, good, so so, bad, very bad, and not able to answer”. The category of self-reported “good life satisfaction” includes those provided an answer of “very good” or “good” to this question.

conclusions from our analyses of both oldest-old and younger elders in this chapter are also generally consistent with other related studies in China (e.g., Yu et al. 1989; Wang et al. 2000; Woo et al. 1996) and elsewhere (e.g., Andersen-Ranberg et al. 1999; Pi, Olive, and Esteban 1994).

Although elderly women are disadvantaged in socioeconomic status and health characteristics, in 1990, Chinese female life expectancy at ages 80, 90, and 100 are 23, 21, and 20% higher those for Chinese males, respectively (Zeng and Vaupel 2000). Why do oldest-old Chinese women's advantage in mortality and serious disadvantage in functional capacity and socioeconomic status coexist? We do not have satisfactory explanations yet and further careful research is needed.

The analyses presented in this chapter are univariate, adjusted only for sex and age to ascertain the "de facto" gender differentials and to gain some useful insights about the current status of male and female elderly in China. A major limitation of the study is that other possible confounding factors are not controlled and we cannot offer causal explanations. Thus, further multivariate statistical analysis is warranted.

In sum, old women's disadvantages in socioeconomics and health plus their longer life and higher percentage in the elderly population[6] imply that long-term care service programs should take into account the disadvantaged status of the elderly women. Very careful attention should be given to ensure that any old age insurance and service programs to be developed or reformed will benefit older women and men equally—and perhaps provide greater resources to the most disadvantaged of both genders.

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CHAPTER 13. THE RELATIONSHIP BETWEEN OCCUPATIONAL STATUS, MOBILITY, AND MORTALITY AT OLDER AGES

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1. Introduction

As mortality has fallen at older ages over the last couple of decades, the growth of the elderly population has raised new concerns, especially regarding the provision of health services. This "emerging" group, long been under-represented in research, has recently become a focus of research. While life expectancy continues to increase at older ages, the health status of the elderly, especially their functional health status, has become a key issue in public health. In this context, the evidence for social inequalities in health at very old ages raises important questions (Desplanques 1993; Hayward, Pienta, and McLaughlin 1997; Marmot and Shipley 1996; Martelin, Koskinen, and Valkonen 1998). For instance, it is essential to assess whether gains in life expectancy and disability-free life expectancy have been equally shared in the population (Cambois, Robine, and Hayward 2001). Consequences in terms of care needs in future years will depend on these trends, and be reinforced by socially differentiated health care needs and health care use (McNiece and Majeed 1999).

A stream of research in the field of social differentials provides evidence of a delayed effect of childhood and young adulthood circumstances and behaviors on health status at later ages. Indeed, mortality in old ages is driven by early life conditions (Mare 1990; Moore and Hayward 1990; Pavalko, Elder, and Clipp 1993). More precisely, evidence indicates that deprivation in childhood, and during pregnancy, may contribute to the development of risk factors and conditions such as cardiovascular diseases, respiratory diseases, and some cancers (such as stomach cancers); behaviors in adulthood also contribute to the development of other diseases and causes of death (Hart, Smith, and Blane 1998; Holland et al. 2000; Smith et al. 1998a, b). Morbidity and disability in late life are partly determined by adulthood conditions (Cassou et al. 2001; Kuh and Ben-Shlomo 1997; Ross and Wu 1995). Studies indicate not only working conditions, residential conditions and behaviors (see for instance, Marmot et al. 1991; Shrijvers et al. 1999), but also the role of events and situations over the life course (Smith et al. 1997; Wunsh et al. 1996). Therefore, persistent differentials in mortality and disability among the young adult population, as recently observed in France for instance, presage future social differentials among the elderly population (Cambois et al. 2001). Such trends should be monitored in order to anticipate the population's health status and care needs.

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Compared to social inequalities in health or in mortality at other ages, inequalities at old ages are poorly documented, especially in France, mainly due to the lack of suitable data. For instance, studies on life expectancy differentials in France are based on data sets that fail to adequately represent mortality among the elderly population (Calot and Febvay 1965; Desplanques 2001). Due to the very high mortality risks and the small number of survivors over age 70 at the time these data sets were set up, the sparseness of data on the elderly population was not considered a problem. Now that we are increasingly concerned with documenting health, mortality, and social differentials among the elderly population, issues of data quality, completeness and modeling techniques are debated. The study of social differentials at old ages raises two major methodological questions.

To assess social differentials in mortality, due to the small number of deaths by stratum in samples stratified by age and social status, age-specific mortality risks of population sub-groups are generally estimated through modeling the outcome of death in order to smooth the random variability. While the Gompertz model fairly accurately fits observed mortality from ages 30 to 80, this is more debatable after age 80. Therefore, modeling with small samples after age 80 is not straightforward. In recent years, researchers have begun using alternate models to represent age-specific mortality trajectories through extremely old ages. But while knowledge on this topic has increased considerably, there is still much to be learned about the level and trend in mortality differentials among older people. However, the following assumptions about health differentials at older ages can be made and their implications examined. First, selection effects would make age-specific mortality risks increase less rapidly for groups with higher mortality than for groups with lower mortality. As a result, *relative* risks should decrease with age among older people, thus prolonging the pattern commonly observed among persons aged 30–65. Second, there could be a socially differentiated health deterioration process or a socially differentiated response to health events: life-long exposure to risks could induce a wearing effect, accelerating the health deterioration process for some groups. As a result, mortality risk should increase more rapidly with age for disadvantaged groups than for more protected groups. Relative risks should tend to be larger in older ages compared to younger ages. Third, mortality trajectories at very old ages may not be socially differentiated and the level of mortality in each group may depend only on the level it reaches at younger ages: in this case, after a certain age, relative risks would be maintained.

Finnish studies have shown mortality differentials by occupation and education to converge from age 80 until age 95 (Martelin 1994). In France, although the results are not published, recent work from the French National Statistical Institute (INSEE) tends to confirm the Finnish findings. Nevertheless, these congruent conclusions do not provide any evidence of the mortality trajectories by age across social groups: trends other than convergence in the relative risks could be hidden by the high mortality level and limited number of survivors at very old ages. Kohler and colleagues recently provided insight in another direction (Kohler, Kohler, and Vaupel 2001); they proposed a model in which a socially differentiated frailty component is introduced to determine mortality trajectories at the individual level instead of the population level. In this model, the reference to frailty heterogeneity within different social groups allows for assumptions other than converging relative risks of mortality. In this context, while a consensus regarding general mortality trajectories at older ages has not yet been achieved, the question of differential parameters for modeling trajectories according to social group appears to be premature.

The second major methodological problem in measuring health inequalities among the elderly population is the choice of the relevant social criteria to distribute the population by social background. Socioeconomic differentials in health have been gauged using metrics such as income, education, occupation, and race or ethnicity in the United States. The choice of the socioeconomic metric is often governed by methodological requirements or data availability, particularly when trends in socioeconomic differentials are studied over time (Cambois and Robine 2000). The objective is to categorize individuals with similar social and economic characteristics into a single group so as to evaluate the relationship between health status and these characteristics. Two points are important to consider when choosing a metric to gauge socioeconomic differentials in health expectancy: the first point applies generally to studies on health differentials, while the second applies more to comparative studies (over time or between populations).

First, the metric should categorize individuals according to the stratification mechanisms giving rise to mortality and morbidity differentials. For example, although the association between health and income is well known, it is not clear that categorizing the population according to income level adequately captures the primary stratification mechanisms influencing health. French studies show, for example, that primary school teachers historically had the lowest mortality rates despite relatively low incomes (Desplanques 1985, 1993). From this first point follows the need for creating groups that are representative of an individual's socioeconomic position and the full range of characteristics known to influence health. Related is the issue of creating groups capturing individuals' permanent (or relatively permanent) socioeconomic position rather than transitory circumstances that are likely to change or have changed. For this reason, the level of education is often chosen to classify the population, especially the adult population, as educational attainment changes little over the adult years. The second point is that the groups should be stable over time in terms of population distribution. This is important in order that differential trends are not disturbed by changes in the selection of individuals into the specific social groups under consideration. In this respect, some criteria such as educational level or occupational status pose problems due to changes in the social structure of the population from generation to generation.

Regarding the specificity of the elderly population, some other points need to be raised. First, educational criteria are quite difficult to use. The majority of the French elderly population is not highly educated and therefore such a criterion is not discriminating enough. Occupational class, often used in French studies, can be more useful when controlling for changes in the occupational distribution over time. Nevertheless, the difficulty with occupational class at older ages is occupational mobility over the working life, especially in the later working ages, as a result of health problems or promotion shortly before retirement. Therefore, the relevance of occupation in characterizing differentials in health or mortality is questionable due to the occupational mobility that may change the distribution. Furthermore, in some studies of mortality differentials, there was a long period between the determination of occupational status (e.g., a population census) and death. The impact of occupational mobility over this period on the estimated mortality risks attributed to the occupational class has not been assessed so far. Occupational mobility and its relationship with health or mortality risk have been mainly examined to assess the impact of joblessness through the study of trajectories from occupation to unemployment or inactivity. These studies describe the poor health responsible for being inactive or unemployed, the "healthy worker effect" and the negative effect on health of becoming inactive or unemployed compared to those who remained within occupation, controlling for occupational class (Bouchayer 1994; Desplanques 2001; Fox and Chewri 1988; Fox, Goldblatt, and Adelstein 1982; Goldblatt 1989; Moser et al. 1987; Mesrine 2000; Mutchler et al. 1999).

But few studies have looked at trajectories between occupational classes to document the correlation between health risks and upward and downward occupational mobility. Such concerns are becoming increasingly relevant in time of greater job mobility within the labor force as well as from the labor force to inactivity. Studies on this topic would help us to better understand the role of occupational differentials in social inequalities in most countries, including France. Stern (1983) modeled the underlying hypotheses concerning the impact of occupational mobility on social differentials and Goldblatt (1988, 1989) used the Longitudinal Study census sample to document this topic for the male population of England and Wales. In those studies, taking account of mobility between occupational classes, including inactivity, indicated great differences in the type of pathways and showed that the mortality risk of the movers was, in general, between the average risks of the class of origin and the class of destination. Recently, Bartley and Plewis found similar relationships between occupational mobility and health, using the question on "limiting long standing illness" from the 1991 British census (Bartley and Plewis 1997). These studies point to a life course process in the relationship between health and social status, and a correlation between health risks and occupational mobility for men. Therefore, a population not only experiences mortality differentials by occupational status, but also mortality differentials within occupational classes related to the class previously occupied.

The present study aims to assess differentials in mortality related to occupational classes for the French population and to shed light on the possible impact of changing status on the relationship between mortality and occupational status. In doing so, the study provides some evidence pertinent to the two methodological questions raised above. First, occupational differentials in mortality are estimated for the whole adult population, with a particular focus on the elderly population, in order to assess the magnitude of social inequalities across ages. Second, mortality risks are estimated with respect to pathways between occupational classes, to partly control for occupational mobility. Building on Stern's example, this study uses available French data to provide evidence of the possible influence of changes in occupational status on occupational differentials in mortality.

2. Data

The *Echantillon démographique permanent* (EDP), or Permanent Demographic Sample, was developed to better document pathways between different social and demographic statuses as well as migration patterns. The EDP was based on a 1% sample of the 1968 population census and is followed up and repeated from census to census (1975, 1982, and 1990). The new entrants were new-born and immigrants meeting the inclusion criteria (being born on one of the four reference days selected from the 365 days of the year). The sample does not include those who emigrated from French territory and those who died. As a result, the EDP was a representative sample of the general population at any census date, which can also provide longitudinal information when used to follow development from census to census. The database provides census information (education, occupation, place of residence, etc.), as well as civil registry data on marriages, childbirth, and death. It was therefore possible to study changes in various individual characteristics linked to mortality risks.

The present study was based on the section of the EDP with longitudinal information, consisting of adult men and women included in both the 1975 census and the 1968 census with information on occupational status at two dates reflecting the individual occupational trajectories to be related to mortality risk. The sub-sample used for this study constituted a closed population representative of the French population in 1975, except for those whose occupational class had not been identified in either the 1968 or 1975 census, thus excluding those who entered the EDP in 1975, essentially recent immigrants. Death record linkage covered the 1975–1980 period using the national identification registry. This registry is limited to those born after 1891, born in French metropolitan territory and with French nationality, thus excluding those born in French overseas territories and foreigners. The study population was limited to the age range 30–84 at the 1975 census. All together, the study population represented about 92% of the 1975 EDP.

The study population consisted of 98,635 men and 114,357 women aged 30–84. Among them, the study focused on the elderly population, 30,094 men and 42,877 women aged 60–84. Occupations were classified in seven categories. *Upper occupations* (intellectual occupations, upper managerial staff and administrators, medical doctors, independent professionals, and engineers) and *intermediary occupations* (managerial staff, schoolteachers, skilled technicians, foremen, medical and social workers, intermediary managerial and administrators, and clergy) represented skilled, non-manual occupations requiring a high level of education and training. *Farmer class* only included farm managers and not farm workers. *Craftsmen and trade related workers* (craft and trade) were independent shop or business owners. *Clerk class* included either those employed in administrative departments, police and army, or in craft and trade related businesses as well as private household workers. *Manual workers* class encompassed skilled manual workers, farm workers, semi-skilled manual workers, and unskilled manual workers. Those who did not work at the time of census report their current activity status (student, unemployed, retired, and inactive) and their former major occupation if they used to work. For this study, retired people and unemployed people were classified according to their former major occupation reported at census. Lastly, *inactive class* included those who did not work at the time of census, except retired or unemployed who report former occupations (students, housekeepers, disability pensioners, etc.).

The study population was distributed according to the individual's occupational class reported in the 1975 census, and for each of these classes, according to the status reported 7 years before, at the 1968 census. This distribution resulted in 49 occupational pathways to be estimated in the population. Mortality risks were estimated for each of these pathways, based on deaths occurring over the period 1975–1980. While mortality risks changed between 1968 and 1975, as indicated above, this study did not aim to document this change. The interest of this study on occupational mobility required a focus on the sub-population alive at two dates. The study reflected mortality risks among 1975 occupational class, mortality risks among 1975 occupational classes according to 1968 class of origin and mortality risks among 1968 classes, for those who survived until 1975, according to 1975 class of destination. The possible selection effect operating on survivors was also studied and findings are discussed later in this chapter. For the younger part of the elderly population, the period between the two censuses corresponded to the final years of working life. The youngest members of the study population were 53 years old in 1968 so it was possible to determine occupational mobility before retirement. The results for the elderly population (aged 60–84) are compared to the results found for the whole adult population (aged 30–84).

3. Estimation of the Mortality Risks

This analysis was based on deaths occurring in the study population from 1975 to 1980, a period with the most complete death data. The death registry was matched with only half of the sample after 1982. With longitudinal data such as these, mortality risks are usually estimated using annual prospective age-specific probabilities, or the probability of dying in a population aged x at the beginning of the year. Age-specific mortality risks can be assessed over a period of several years rather than yearly in order to increase the number of events and strengthen the estimations. In this case, average annual prospective mortality probabilities are estimated as shown in Figure 1: the numerator is the sum of deaths occurring in each year of age during each year of the period and the denominator is the sum of survivors at each age at the beginning of each year of the period.

Age-specific mortality probabilities were estimated for each occupational class as reported in 1975 and as reported in 1968 and for each possible occupational pathway between 1968 and 1975. Because of the limited size in the group in the various pathways, the analysis

$$q_{60} = \frac{\sum_{i=1975}^{1979} d_{60}^{i}}{\sum_{i=1975}^{1979} S_{60}^{i}}$$

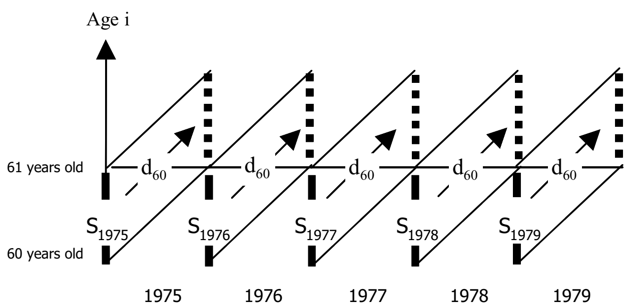

Figure 1. Formula and corresponding Lexis diagram for the perspective mortality probabilities. The sum of deaths recorded for each year (1975, 1976, . . . , 1979) at age *i* is rated by the sum of the survivors of age *i* at the beginning of each year.

used 5-year age groups to increase the statistical power of the estimates. Mortality in each class was estimated first by age-standardized mortality risks, to compare mortality levels in the occupational classes using the estimated annual mortality risk in the whole age range under consideration (AMR), for each 1975 class. In each class, the age-specific probabilities obtained as described above were applied to the corresponding age groups of the 1975 reference population (overall population differentiated by sex): the estimated total number of deaths was divided by the total 30- to 84-year-old reference population.

Second, in order to compare mortality levels, standardized mortality ratios (SMR) were also computed to assess excess or reduced mortality associated with the 49 possible occupational pathways between 1968 and 1975. It consisted of an indirect standardization: the total number of deaths of each population group was divided by the hypothetical number of deaths obtained if the age-specific mortality probabilities for the total population applied to different population groups. The reference mortality risk (Base 1) was the mortality level in the whole population. Contrary to age-standardized mortality probabilities, SMRs depend on each group's age structure instead of being based on a common age structure. The use of indirect standardization was required by the limited number of individuals and death events in some age groups among the groups experiencing occupational change.

4. Results

4.1. OCCUPATIONAL DISTRIBUTION OF THE STUDY POPULATION AND RELATED MORTALITY DIFFERENTIALS

Table 1 shows the 1975 occupational structure for males and females in the study population, for the whole adult population (ages 30–84) and for the elderly population (ages 60–84). Inactive persons, defined as not working (except retired and unemployed who were categorized by reported former major occupation), were only a small proportion of the male adult population (3%). They were also a small part of the elderly population (5%), including those retired but who did not report a former occupation. The largest class was "manual workers", representing 32% of the elderly men and 37% of all adult men. The difference between the proportion of manual workers in whole adult and elderly populations was partly explained by occupational mobility over the working life, with frequent moves out of this class at later ages. At 20% "farmers" were the second most common occupation class among the elderly population. Farmers constituted less than 13% of all adult men, attesting to the greater importance of the agricultural sector earlier in the century (a cohort effect). Conversely, the two upper classes constituted less than 20% of the elderly population, while they are almost 25% of men aged 30–84, reflecting the more highly qualified workforce and development of the service sector in recent decades.

In the female elderly population, inactivity reached 44%. There was a slightly higher proportion inactive in the whole adult female population than in the elderly population. Clerks represented the second largest class after the inactive, but were a smaller proportion of the elderly female population than of the whole adult population. This was also the case for the "upper and intermediary occupations" classes, which constituted only a small proportion

Table 1. Distribution of the whole adult population (30–84 years old) and of the elderly population (60–84 years old) according to the occupational status reported in 1975.

	Men		Women	
Occupational class	Whole adult population (%)	Elderly population (%)	Whole adult population (%)	Elderly population (%)
Upper managerial staff, professional	9	8	2	1
Intermediary occupations	15	10	7	5
Farmers	13	20	8	13
Craft, trade, and firm managers	11	12	5	7
Clerks and trade related employees	11	13	21	18
Manual workers	37	32	11	13
Inactive	3	5	46	44
Total	100	100	100	100
Sample size	98,635	30,094	114,357	42,877

of the female population. Conversely, "farmers", "craft . . . ", and "manual workers" were a higher proportion among elderly women than among all adult women.

Table 2 shows the AMR for the occupational classes in 1975, for deaths occurring over the period 1975–1980. Differentials were not all significant for men. The data indicate a mortality gradient, as usually observed in such studies. The upper classes (upper and intermediary occupations) had the lowest mortality risk, statistically different from the risk of manual workers and those inactive for both the elderly and all adult men, and also statistically different from the risk of clerks in all adult ages. The inactive class had 2.5 times higher mortality risk than those in upper classes in the whole adult population and 1.9 times higher in the elderly population. This pattern reflects the fact that among men, being inactive is often the result of impaired health status. Manual workers had a 1.5 higher risk compared to the upper classes in the whole adult population and 1.4 higher in the elderly population. Differentials still existed at the older ages but to a smaller extent than at all ages.

For women, differentials were not significant, although this is partly the result of the large proportion inactive. Still, the risk for the upper classes was lower than the risks in other

Table 2. Annual mortality risks in the 1975 occupational classes, over period 1975–1980, standardized to the age structure of the whole study populations differentiated by sex and relative risks for manual workers and inactive compared to upper classes (males and females, 30–84 years old and 60–84 years old).

	Upper classes	Farmers	Craft, trade …	Clerks	Manual workers	Inactive	Total	Manual workers *vs.* upper Class	Inactive *vs.* upper class
				30–84 years old					
Men	1.22%	1.34%	1.35%	1.61%	1.83%	3.08%	1.58%	1.50	2.52
CI*	[1.08–1.36]	[1.15–1.54]	[1.13–1.57]	[1.38–1.85]	[1.70–1.97]	[2.48–3.69]	[1.51–1.66]		
Women	0.90%	1.02%	0.93%	0.99%	1.06%	1.15%	1.06%	1.18	1.28
CI*	[0.71–1.08]	[0.82–1.22]	[0.69–1.16]	[0.86–1.11]	[0.88–1.23]	[1.06–1.24]	[1.00–1.12]		
				60–84 years old					
Men	3.17%	4.01%	3.57%	3.96%	4.46%	6.14%	4.05%	1.41	1.94
CI*	[2.69–3.65]	[3.52–4.51]	[2.95–4.18]	[3.36–4.56]	[4.05–4.87]	[4.93–7.34]	[3.83–4.27]		
Women	1.92%	2.67%	2.30%	2.18%	2.54%	2.67%	2.50%	1.32	1.39
CI*	[1.39–2.45]	[2.24–3.09]	[1.76–2.84]	[1.85–2.51]	[2.13–2.95]	[2.44–2.90]	[2.35–2.64]		

*95% Confidence interval.

classes and, in contrast to men, the risk for the inactive was very close to the average risk for the female population.

4.2. OCCUPATIONAL MOBILITY AND MORTALITY RISK

Tables 3 and 4 provide SMRs associated with occupational pathways for men and for women, respectively. The top rows in these tables indicate the proportion of the population in the class and the associated SMRs, with 95% confidence intervals. The cells below give the same information related to each possible pathway that led individuals to the class reported in 1975. The total column on the right hand side of the tables provides the SMRs in the study population, based on the retrospective information on occupational status in 1968 instead of the most recent information. The reference mortality risks used to compute the SMRs were those in the overall population, so the SMRs associated with pathways can be compared in each case to the average SMRs in the class of origin (right column) and in the class of destination (top row). The confidence intervals associated with each SMR allowed us to determine whether the risks are statistically different. Differences were more often significant for the whole adult population than they are for the elderly, and for men than for women.

Occupational classes were ordered following the mortality gradient found for SMRs in 1975 (top row). Therefore, the diagonal in the table from top left to bottom right corresponded to the SMRs of the stable groups (same class at both dates). Upward moves referred to occupational moves toward a class with higher risks (lower part of the tables) and downward moves toward a class with lower mortality risk (upper part of the table).

Tables showed that the pathways between the seven classes under consideration did not have the same proportion of the population. Most individuals remained in the same occupational classes between 1968 and 1975. Overall mobility was not as frequent among the elderly as it was in the entire adult population. Over this period, 80.5% of adult men remained in the same occupational class, 11.5% moved upward, and almost 8% moved downward; 71.5% of adult women remained in the same class, 17% moved upward, and 11.5% moved downward. For men, most of the movers came from the manual worker class. Higher mobility for women was due to a large movement from and toward inactivity, and most of these moves were among clerks.

Regarding the associated SMRs, Table 3 showed that differentials related to the occupational pathways were larger than differentials related to the occupational classes shown in the top row. Because SMRs were based on indirect standardization, differentials in Table 3 were larger than differentials based on AMRs in Table 2, due to the small age effect even in the elderly population. For the elderly population, SMRs related to occupational classes were 0.81 for upper classes and 1.46 for the inactive class. Meanwhile almost a 1.1 point gap separated the extreme SMR associated with the pathways from "upper classes" to "farmers" (SMR = 0.50) and with the group of those remaining inactive at both dates (SMR = 1.59). The risks associated with pathways appeared to be closer to the risk of the class of destination (read in columns) than to the risk of the class of origin (read in rows) (Table 3).

Table 3. Men's standardized mortality ratios (SMR) over the period 1975–1980 associated with the trajectories between the occupation class of 1968 and the occupation class of 1975, in reference to the risk of mortality in the total male population.

Class in 1968	Occupation class in 1975: Upper classes	Craft, trade . . .	Farmers	Clerks . . .	Manual workers	Inactive	Total
Men, 30–84 years old							
All together %	24.1%	10.6%	13.4%	11.2%	37.5%	3.2%	100%
SMR	0.75	0.86	0.88	1.01	1.17	1.73	1.00
CI	[0.73–0.76]	[0.83–0.88]	[0.86–0.90]	[0.98–1.03]	[1.15–1.18]	[1.64–1.82]	
Upper classes %	18.1%	0.7%	0.1%	0.9%	0.8%	0.3%	20.7%
SMR	0.74	0.89	0.76	1.02	0.82	1.58	0.78
CI	[0.73–0.76]	[0.79–0.99]	[0.54–1.08]	[0.92–1.12]	[0.74–0.91)	[1.33–1.88]	[0.77–0.80]
Craft. trade . . . %	0.5%	7.9%	0.1%	0.2%	0.9%	0.2%	9.8%
SMR	0.74	0.83	0.86	1.01	1.06	1.57	0.87
CI	[0.65–0.84]	[0.81–0.86]	[0.67–1.12]	[0.84–1.22]	[0.96–1.17]	[1.28–1.93]	[0.85–0.90]
Farmers %	0.1%	0.1%	12.3%	0.1%	0.7%	0.2%	13.5%
SMR	0.83	0.90	0.87	1.06	1.12	1.34	0.89
CI	[0.61–1.13]	[0.70–1.14]	[0.85–0.89]	[0.81–1.38]	[1.01–1.24]	[1.11–1.62]	[0.87–0.91]
Clerks %	1.8%	0.3%	0.1%	7.9%	1.1%	0.3%	11.4%
SMR	0.84	1.17	0.72	0.97	1.09	1.09	0.97
CI	[0.79–0.90]	[1.00–1.36]	[0.52–1.00]	[0.94–1.00]	[1.00–1.19]	[0.92–1.29]	[0.95–1.00]
Manual workers %	2.7%	1.4%	0.7%	1.9%	33.4%	1.2%	41.2%
SMR	0.59	0.93	1.07	1.16	1.17	2.01	1.18
CI	[0.56–0.63]	[0.87–1.00]	[0.97–1.19]	[1.09–1.24]	[1.15–1.18]	[1.86–2.19]	[0.16–1.20]
Inactive %	1.0%	0.1%	0.1%	0.3%	0.7%	1.1%	3.3%
SMR	1.15	1.11	1.11	1.31	1.58	1.86	1.52
CI	[1.05–1.25]	[0.88–1.40]	[0.88–1.40]	[1.10–1.55]	[1.42–1.75]	[1.71–2.03]	[1.45–1.60]

(*cont.*)

Table 3. (*Continued*)

Class in 1968	Occupation class in 1975: Upper classes	Craft, trade…	Farmers	Clerks…	Manual workers	Inactive	Total
Men, 60–84 years old							
All together %	17%	12%	20%	13%	32%	5%	100%
SMR	0.81	0.87	0.92	0.97	1.14	1.46	1.00
CI	[0.76–0.85]	[0.83–0.92]	[0.89–0.95]	[0.93–1.01]	[1.11–1.16]	[1.36–1.56]	
Upper classes %	14.8%	0.3%	0.1%	1.2%	0.7%	0.5%	17.6%
SMR	0.79	1.23	0.50	1.05	0.88	1.34	0.84
CI	[0.76–0.83]	[0.94–1.61]	[0.26–0.94]	[0.91–1.22]	[0.73–1.07)	[1.06–1.68]	[0.80–0.87]
Craft. trade… %	0.4%	10.0%	0.2%	0.3%	1.0%	0.4%	12.2%
SMR	0.68	0.85	0.77	1.04	0.93	1.51	0.87
CI	[0.54–0.87]	[0.81–0.89]	[0.54–1.11]	[0.77–1.42]	[0.79–1.10]	[1.16–1.97]	[0.83–0.91]
Farmers %	0.1%	0.2%	18.5%	0.2%	0.6%	0.4%	20.0%
SMR	0.67	0.93	0.92	1.03	1.09	1.16	0.93
CI	[0.39–1.15]	[0.67–1.29	[0.88–0.95]	[0.68–1.54]	[0.88–1.34]	[0.91–1.47]	[0.89–0.96]
Clerks %	0.9%	0.2%	0.1%	9.8%	1.0%	0.6%	12.7%
SMR	1.01	1.07	0.67	0.94	1.07	1.03	0.96
CI	[0.86–1.19]	[0.78–1.48]	[0.44–1.03]	[0.90–0.99]	[0.91–1.26]	[0.84–1.26]	[0.92–1.00]
Manual workers %	0.7%	0.5%	1.0%	1.6%	27.9%	2.0%	33.7%
SMR	0.92	0.86	1.04	1.03	1.14	1.63	1.15
CI	[0.76–1.12]	[0.69–1.07]	[0.89–1.21]	[0.91–1.17]	[1.11–1.18]	[1.45–1.82]	[1.12–1.19]
Inactive %	0.3%	0.2%	0.3%	0.4%	1.2%	1.2%	3.8%
SMR	1.26	1.11	1.16	1.13	1.48	1.59	1.39
CI	[0.96–1.66]	[0.80–1.53]	[0.89–1.53]	[0.89–1.43]	[1.28–1.71]	[1.37–1.85]	[1.28–1.51]

Note: %: Proportions of the trajectory groups within the population; SMR: Standardized Mortality Ratio; CI: 95% confidence intervals;—represent less than 0.05% of the population.

Table 4. Women's standardized mortality ratios (SMR) over the period 1975–1980 associated with the trajectories between the occupation class of 1968 and the occupation class of 1975, in reference to the risk of mortality in the total male population.

	Occupation class in 1975						
Class in 1968	**Upper classes**	**Craft, trade . . .**	**Clerks . . .**	**Farmers**	**Manual workers**	**Inactive**	**Total**
Women, 30–84 years old							
All together %	8.8%	5.5%	20.8%	8.5%	10.9%	45.5%	100.0%
SMR	0.82	0.87	0.92	0.97	0.99	1.08	1.00
CI	[0.80–0.84]	[0.84–0.90]	[0.91–0.94]	[0.94–1.00]	[0.97–1.02]	[1.07–1.10]	
Upper classes %	6.4%	0.1%	0.5%		0.1%	0.6%	7.7%
SMR	0.78	0.30	1.01	—	1.38	1.32	0.84
CI	[0.75–0.80]	[0.22–0.40]	[0.90–1.14]		[1.03–1.85)	[1.19–1.46]	[0.82–0.87]
Craft. trade . . . %	0.1%	3.4%	0.3%	0.1%	0.2%	1.0%	5.1%
SMR	0.31	0.89	0.85	1.97	1.19	0.90	0.91
CI	[0.23–0.40]	[0.86–0.93]	[0.74–0.98]	[1.40–2.78]	[0.97–1.46]	[0.83–0.97]	[0.88–0.95]
Clerks %	1.1%	0.4%	13.2%	0.1%	0.8%	3.3%	18.9%
SMR	0.90	0.83	0.91	0.84	0.86	1.14	0.95
CI	[0.83–0.97]	[0.73–0.95]	[0.89–0.93]	[0.66–1.07]	[0.79–0.95]	[1.09–1.19]	[0.93–0.97]
Farmers %			0.1%	5.8%	0.1%	2.0%	8.2%
SMR	—	—	0.71	0.98	0.98	1.04	0.99
CI			[0.57–0.89]	[0.95–1.01]	[0.79–1.23]	[0.98–1.10]	[0.96–1.02]
Manual workers %	0.2%	0.1%	1.1%	0.1%	6.4%	2.1%	9.9%
SMR	1.17	0.78	1.06	1.39	1.02	1.37	1.10
CI	[0.94–1.44]	[0.63–0.97]	[0.98–1.15]	[1.09–1.75]	[0.99–1.06]	[1.30–1.45]	[1.07–1.13]
Inactive %	1.1%	1.3%	5.6%	2.4%	3.4%	36.4%	50.1%
SMR	1.09	0.84	0.93	0.91	0.94	1.07	1.03
CI	[1.01–1.19]	[0.79–0.91]	[0.90–0.97]	[0.86–0.95]	[0.90–0.98]	[1.05–1.08]	[1.01–1.04]

(*cont.*)

Table 4. (*Continued*)

Class in 1968	Upper classes	Craft, trade . . .	Clerks . . .	Farmers	Manual workers	Inactive	Total
	Occupation class in 1975						
Women, 60-84 years old							
All together %	6.8%	12.9%	17.6%	5.9%	13.1%	43.6%	100.0%
SMR	0.86	0.88	0.93	0.99	1.00	1.07	1.00
CI	[0.82–0.91]	[0.84–0.93]	[0.90–0.96]	[0.95–1.02]	[0.96–1.04]	[1.05–1.09]	
Upper classes %	4.8%	0.1%	0.3%		0.2%	1.4%	6.8%
SMR	0.82	0.37	0.98	—	1.37	1.41	0.88
CI	[0.77–0.87]	[0.22–0.63]	[0.81–1.18]		[0.85–2.22]	[1.14–1.75]	[0.83–0.93]
Craft. trade . . . %		8.6%	0.1%		0.2%	2.5%	11.4%
SMR	—	0.89	0.77	—	1.23	0.84	0.90
CI		[0.84–0.95]	[0.59–1.00]		[0.94–1.61]	[0.75–0.95]	[0.86–0.95]
Clerks %	0.3%	0.2%	11.8%	0.5%	0.9%	2.9%	16.6%
SMR	0.91	0.99	0.91	0.87	0.80	1.14	0.95
CI	[0.75–1.10]	[0.77–1.28]	[0.88–0.95]	[0.65–1.15]	[0.70–0.92]	[1.05–1.23]	[0.92–0.98]
Farmers %			0.5%	4.8%	0.1%	0.4%	5.9%
SMR	—	—	0.84	1.00	0.90	1.09	1.02
CI			[0.57–1.23]	[0.96–1.05]	[0.64–1.26]	[1.00–1.18]	[0.98–1.06]
Manual workers %	0.1%	0.2%	0.9%	0.1%	8.2%	2.4%	11.9%
SMR	1.42	0.77	1.15	1.44	1.04	1.35	1.12
CI	[0.88–2.31]	[0.54–1.10]	[1.00–1.33]	[1.08–1.92]	[0.99–1.09]	[1.23–1.47]	[1.07–1.16]
Inactive %	1.5%	3.8%	4.1%	0.4%	3.6%	34.0%	47.4%
SMR	1.23	0.84	0.95	0.91	0.94	1.04	1.01
CI	[1.01–1.51]	[0.75–0.94]	[0.89–1.01]	[0.85–0.98]	[0.87–1.00]	[1.02–1.07]	[0.99–1.03]

Note: %: Proportions of the trajectory groups within the population; SMR: standardized mortality ratio; CI: 95% confidence intervals;—represent less than 0.05% of the population.

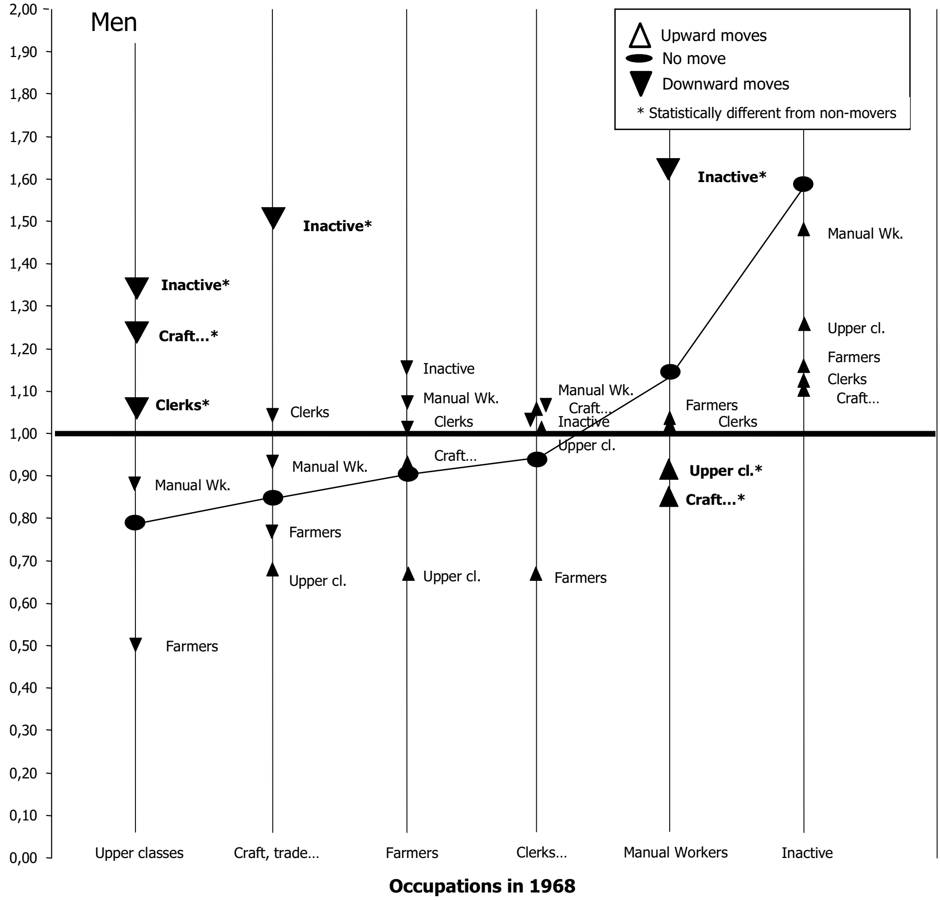

Figure 2. Men's standardized mortality ratios over the period 1975–1980 associated with the trajectories between the occupation class of 1968 and the occupation class of 1975, in reference to the risk of mortality in the total male population aged 60–84.

Relative to those who reported the same status at both dates, there was a higher mortality risk associated with downward mobility or to pathways out of the labor force and a lower mortality risk associated with upward mobility. The SMR of movers were "in between" the overall SMR of the class they left and of the class they joined. This pattern clearly appears in Figure 2.

Figure 2 illustrates the SMRs for elderly men. The axis of the graph represents the occupational classes reported in 1968 and for each of them, the SMRs associated with the pathways (i.e., occupational status in 1975) are plotted on the vertical axes. Triangles illustrate downward and upward mobility. The risks of non-movers are plotted with circles. SMRs which were statistically different from risks of the non-movers are in bold type.

Because SMRs are represented according to the class of origin (the row in Table 3), this graph shows large disparities in each vertical axis. The representation of SMRs according to the class of destination (the column in Table 3) would have shown smaller disparities on each axis.

For elderly men, the SMRs of the non-movers constitute a clear line between the higher SMRs associated with downward mobility (located above the line), and lower SMRs associated with upward mobility (located below the line). This highlights the lower risks of those who have moved up and the higher risk of those who have moved down. In the whole adult population (not shown here), the pattern appeared similar, and differences in SMRs were more often statistically significant. Figure 2 also illustrates the overall higher SMRs of those who were inactive at both dates, but also of those who had become inactive, especially when the former class was "upper classes", "Craft . . . ", and "manual workers". For elderly men, in the other classes of 1968, becoming inactive was not associated with an SMR statistically different from those who remained in the same class. Those inactive in 1968 who entered any of the occupational classes in 1975 had a lower SMR than those who remained inactive. Although SMRs were not statistically significant after age 60 due to the small proportions of the population involved in such moves, they were significant among the 30- to 84-year-old population (Table 3). Also, these risks were higher than the average risk in the class of destination. For elderly men, upward mobility toward the "upper classes" was associated with SMRs close to or smaller than 1, but these pathways were not the most "protective" pathways. In the elderly male population, those becoming "farmers" between 1968 and 1975 had among the lowest SMRs, and lower than the SMRs of those who were farmers at both dates. In contrast to the elderly population, moves toward the farmer class among the whole adult male population did not represent an important part of the overall mobility and were associated with a high SMR (Table 3). The most protective pathway among the whole adult population was from manual workers to the upper classes, representing the upgrading of skilled manual worker to foremen or technicians (part of the intermediary occupations).

Figures for females are presented in Table 4 and illustrated in Figure 3. Table 4 shows that in the female elderly population, as in the male elderly population, the SMRs associated with the occupational pathways were larger than the SMRs associated with the occupational classes. Among elderly women, the lowest and highest SMRs among the occupational classes were 0.86 for the upper class and 1.07 for the inactive. The gap between extreme SMRs reached 1.05 points, with the lowest risk being associated with the pathway from "upper classes" to "Craft . . . " (SMR = 0.37), and the highest risk associated with several pathways from upper classes or manual workers to inactivity or from manual workers to upper classes (SMR = 1.42).

Graph 2 shows that for elderly women, the relationship between the SMRs and the direction of the moves was less clear than it was for men. The SMRs of the non-movers did not clearly distinguish between the upward moves and the downward moves, as it did for men (Figure 3). Nevertheless, the graph illustrates higher SMRs for pathways from "upper classes", "Clerks", and "manual workers" to inactivity compared to those who remained in their class. For women, even at older ages, those who entered activity had lower SMRs than those who remained inactive (except for those who entered the upper

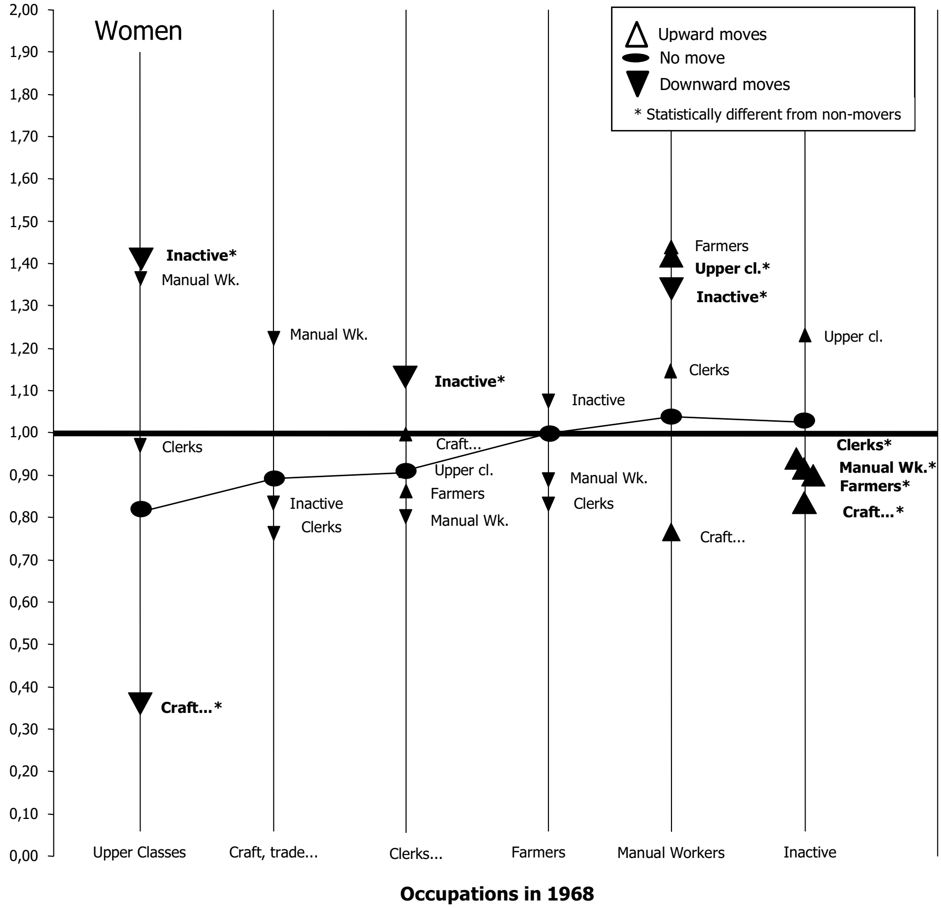

Figure 3. Women's standardized mortality ratios over the period 1975–1980 associated with the trajectories between the occupation class of 1968 and the occupation class of 1975, in reference to the risk of mortality in the total female population aged 60–84.

classes). Similar conclusions can be drawn for the whole adult female population. For women, no clear pattern emerged to define the relationship between SMRs and the direction of the occupational mobility. Nevertheless, some specific pathways were identified, among which some had the same association with mortality as for men, such as pathways to inactivity.

This analysis based on pathways has shown large dispersion in SMRs among women. Usually, inequalities in mortality based on educational level, occupational classes or income appear smaller for women than for men, such as shown with occupational classes in this study in Table 2. These figures in fact allowed us to highlight some pathways clearly correlated with higher and lower SMRs for both men and women, while these differences are hidden in the average SMRs of a class.

4.3. MOBILITY, MORTALITY, AND THE OCCUPATIONAL DIFFERENTIALS

Due to the occupational pathways, the mortality differentials estimated for the study population were different if they were based on the 1968 or on the 1975 occupational distribution. This study showed that the estimated differentials were not statistically significantly different depending on the year used except for inactive women and men. For this class, the average SMR, assessing mortality over the 1975–1980 period, was significantly higher with the later status (1975) than with the earlier status (1968). Becoming inactive, whatever the class of origin, was associated with higher SMRs and, as a result, the average risk of the inactive class was higher when considering the occupational distribution of 1975 rather than the distribution in 1968. For men, this pattern was similar for all the classes not only for the inactive class, but changes were not statistically significant. Indeed, this pattern was the result of the SMRs of the movers being between the SMRs at destination and the SMRs at origin. Mobility led to a homogenization of the SMRs in the classes, which are less dispersed with 1975 occupational status. As a result, at least for men, differentials between upper classes and the other classes were slightly wider using the 1975 information than using the 1968 information.

These differences were linked to the choice of the occupational distribution, the later one or earlier one, while the population under consideration was the same. This study showed that the time lag between baseline when occupational status was determined and the beginning of mortality follow-up might constitute an artifact in the magnitude of the differentials estimated, even though the direction is identified.

5. Conclusion

This research helps answer questions related to the assessment of social inequalities in mortality in old age. The first issue is related to trends in relative mortality risks with age with respect to social inequalities. The second issue is related to the relevance of using a cross sectional occupational distribution of the population to measure social inequalities in health, due to occupational mobility over the working life. It would be useful to monitor the effects of mobility on estimated mortality differentials, as the time lag between the self-report of occupational status and death can be larger or shorter from one study to the other. This outcome is also of particular interest because for an increasing number of national surveys, data linkage techniques are used to follow-up mortality over the ensuing decades to study mortality differentials and determinants.

The data available for this study covered the period 1968–1975 for the occupation status reports and 1975–1980 for the death records. More recent data exist from the same database, but the sample size was reduced after 1982, because only half of the sample was matched to death records. As the confidence intervals were already large with the sample used in this present study, the exercise based on recent data would lead to results with weak statistical reliability. This analysis was intended to illustrate the mechanisms at play, based on an appropriate sample size, before confirming the conclusions in a future analysis of more recent data.

It is noteworthy that the study population was not representative of the 1968 general population; it only represented the part of those who survived until 1975. Because we only have information on 1968 and 1975 status and not on the date of change, if there was a change, we cannot control for an effect of time exposure. This issue also raises the question of a selection effect applying to the study population, as occupational pathways have also occurred among those who died between 1968 and 1975. Some pathways might have been more exposed than others and the study population might only represent selected groups who survived. Or in other words, those who only changed occupational status shortly before 1975 were not "exposed enough" to their new status to represent the level of risk of the pathway. An additional analysis, not shown here, was conducted to test for the consistency over time of the pattern found here, looking at those who survived until the 1990 census. Because the entire sample is not linked to the mortality registry, we used as a proxy the fact of being present in EDP at the 1990 census. The attrition between 1975 and the 1990 EDP population encompassed both death and migration out of EDP; but the study population was limited to French individuals born in France, migration, often linked to return to a home country, should be limited. A logistic regression provided odds ratios for being in the 1990 EDP sample according to the occupational pathways between 1968 and 1975. The logistic regression was run for each class of 1968, the reference risks being those associated with the non-movers. The odds ratios showed that while patterns found with mortality remained consistent for men, some of the findings were not replicated for women. Women entering the craft and trade class appeared protected immediately after 1975, but this effect faded away with time. An explanation could be that women with high mortality risks among those who take such pathways between 1968 and 1975 might have died before 1975; women who have undergone this pathway and have survived until 1975 might have changed occupational status just before 1975 and progressively lost their mortality advantage with time. Panel data with both occupational pathways and mortality follow-up would be more appropriate to properly interpret this issue.

The magnitude of the SMR differentials was smaller at older ages than in the whole adult population. Therefore, SMRs at ages younger than 60 were larger than those in the 60- to 84-year-old population. This is congruent with the Finnish conclusions presented in the introduction showing a converging trend in relative risks with age until later ages. This answers the first question raised in Section 1. At older ages, relative risks of mortality were smaller than at younger ages, but due to the rapid increase in mortality with age, these small relative risks led to large social differences in term of years of life expectancy.

Occupational mobility was less frequent among the elderly than among the whole adult population. A high proportion of the elderly population was retired at both dates, and most reported the same status at both dates. But some pathways were still associated with different mortality risks compared to those who reported the same occupational status in 1968 and 1975. The size of the movers' group was not large enough to change the occupational mortality gaps in the male and female populations observed the using 1975 or 1968 information. What can still be said is that occupational mobility has a different effect on the observed differentials for the male and female populations. Differentials were larger in the male population when using the most recent occupational distribution and narrower in the female population, except for inactivity. Our results for men support Goldblatt's findings (1988, 1989). Not only pathways from activity to inactivity affected the mortality risks but also mobility between the occupational classes. The impact of mobility differed according to the occupational class, and consequently can change the position of the classes on the mortality gradient. The impact appeared to vanish when looking at the elderly, at least when the elderly encompasses mostly retired individuals. Therefore, the time lag separating the occupational status information and the death record can become an important issue when comparing differentials in mortality over time or across countries. As a general pattern, it seems that for men, the closer the date of the status report and the beginning of the death record period, the larger the social differentials. Within the time left between the status report and the death record, classes are reorganized in a more homogeneous way with respect to mortality risk. For women, the closer the date of the status report and the death record, the narrower the social differentials.

These results based on pathways also highlight the specificity of the heterogeneous group of inactive persons by providing the SMR not only for the inactive but also for those who were inactive, those who become inactive, and those who remain inactive. At this stage, these results do not help in disentangling those who remained inactive voluntarily from others, including those who have been exposed to a health damaging environment. Nor do they help to disentangle those who enter activity who are "healthy", such as students and those who were voluntarily inactive, and those who get back into the labor market after health problems. The results have indicated that some groups of women who become inactive have a higher level of mortality as well as those who remained inactive compared to those who enter activity. A further step would be to introduce information about the incentives for moves to better understand the relationship between occupation and mortality risk.

Therefore, these findings provide new insights for further research. For men, mortality and occupational mobility were correlated and assumed to have common determinant; that is, similar factors protect health and prevent downward moves or cause bad health and prevent upward moves. Determinants may be health and its correlates (education, work condition, income). For most women, additional determinants for mobility might include marital status, children, household income, spouse's occupation. But in some cases, pathways could be driven by health status and its correlates as for men. For instance, for those who become inactive when they were previously in upper classes. Analysis based on pathways between classes usefully completes the information on occupational class differentials, especially for women for which occupational class does not represent an optimal criteria for the study of health inequalities. Together with the search for these common determinants of mobility and mortality, and in order to confirm these suggested relationships, the next step in this work will be to use more recent data on which such an analysis could be repeated to complete the information.

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Part III

The Family and Healthy Aging

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Introduction

Populations are aging at the same time as family household structures are changing (e.g., Wolf 1994). Even in developed countries, the elderly depend on children for emotional and psychological support, and occasionally for financial resources. In the developing world, where pension and social security systems are not widely available, the elderly depend on the family as their main source of support in old age. Past research has established that family care is an important part of long-term care, and has a substantial impact on caregiving arrangements for the elderly (e.g., Angel, Angel, and Himes 1992; Jamshidi et al. 1992; Soldo and Freedman 1994; Suzman, Manton, and Willis 1992; Soldo, Wolf, and Agree 1990). In particular, the use of institutional long-term care has been shown to vary by family characteristics and availability (Freedman 1996).

Individuals in industrial countries who will become the elderly of the 21st century have been at the leading edge of the family revolution. These cohorts have experienced a tremendous rise in divorce, increased cohabitation and childbearing out of marriage, and an overall decline in fertility, marriage, and remarriage. These changes in family structure and fertility indicate that the future elderly of the developed world will have fewer children and are much less likely to be married than the elderly of today (Goldscheider 1990). Long-term care costs in the US, for example, have doubled during each decade since 1970, reaching an annual level of $106.5 billion in 1995. Home health care costs grew approximately 91% from 1990 to 1995, in contrast to a 33.4% increase in institutional care costs (Stallard 1999). The policy of the mix of home-based and institutional care has been shifting towards home health care, especially for the oldest-old (Cutler and Meara 1999).

Family structure and living arrangements of elderly have changed considerably in the past few decades in developing countries. The demographic availability of offspring care for the forthcoming much larger elderly cohorts in the next a few decades will be markedly lower than that of the elderly today. These trends are caused by the rapid fertility decline plus substantial changes in social attitudes and economic mobility related to co-residence between older parents and adult children.

Changes in family structure strongly affect various aspects of healthy aging, such as care-giving, the long-term care health service system, life quality, and health-related policy

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making (Doty 1986; Himes 1992). Papers included in this section deal with family relationships, living arrangements, and healthy aging.

Using data from the Netherlands Living Arrangements and Social Networks Survey, de Jong Gierveld and Dykstra (Chapter 14) explore the impact of living longer on caregiving from children. In general, parents aged 75 and over receive more support from children than do younger parents, and the provision of support increases when parents are confronted with more physical limitations. The partner status of older parents affects children's support. Only a small percentage of children of divorced parents are involved in caregiving. Furthermore, findings show that adult children who experience widowhood or divorce in their own lives do not refrain from providing support to parents in need.

Based on the Chinese Longitudinal Healthy Longevity Survey (CLHLS) data, Guo Zhigang (Chapter 15) shows that the majority of the oldest-old in China live with their children. Controlling for various confounding factors, multivariate logistic regression analysis reveals that age, rural/urban residence, previous job, and marital status are significant factors that predict parents living apart from or with children. This study also explored the influence of the demographic availability of children on the living arrangements of the Chinese oldest-old. Guo found a threshold number of available children impacts living arrangements, and that the sex composition of children is important in measuring demographic availability.

Analysis of the CLHLS data presented in Chapter 16 by Zhou Yun and Ren Qiang found that parental longevity is associated with children's life span. The larger the proportion within a family reaching the age of 80 or more, the greater the familial transmission of longevity. Controlling for parental length of life status, the percentage of daughters who lived 80+ years is higher than that of sons. The CLHLS data shows that those lower in birth order have a greater chance of reaching 80 years of age. More in-depth analysis including biological studies is needed to further investigate the causality of these findings.

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CHAPTER 14. IMPACT OF LONGER LIFE ON CARE GIVING FROM CHILDREN

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1. Introduction

The past decades have witnessed major sociodemographic changes that profoundly affect the *composition* of families, and *exchanges* in families, e.g., the extension of life expectancy, delay of marriage and parenthood, decline in the birthrate, and increasing instability of partner relationships. In this paper we will use data from the Netherlands to illustrate recent developments in Western societies.

One of the most dramatic changes of the last century is the *extension of life*. Life expectancy has risen at a rapid pace and changed people's lives over the course of the last century. Just over half the men and two thirds of the women born at the beginning of the last century survived beyond the age of 65. Among the cohorts born in the 1960s, however, a mere 15% of men and 11% of women are expected to die before they reach the age of 65 (Liefbroer and Dykstra 2000). Reaching (current) retirement age will therefore be the rule; dying before that age will become the exception. At an individual level, the increase in life expectancy means that individuals now have a greater chance of growing old. In a sense, the course of people's lives has become more predictable. People expect to reach a respectable age and they live their lives accordingly. However, there are also implications for family life. Deaths have become more predictable. Unexpected losses, such as the decease of loved ones at a young age, are no longer part of daily reality, which, in turn, has consequences for the way in which these events are experienced. Early deaths (of parents, of children) are exceptional occurrences, and for this very reason are a more devastating experience than they used to be. People do not anticipate these events and are not prepared for them. When they do happen, peers will generally be unable to provide support because they have not had a similar experience themselves.

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Apart from changes in the life span, *changes in the birth rate* determine intergenerational family structures. The average family size showed a marked decline over the past century. Whereas Dutch women born between 1935 and 1940 had an average of 2.4 children, those born between 1965 and 1970 are expected to have an average of 1.8 children. On top of that, women born after 1944 are delaying the birth of their first child (Bosveld 1996). The Netherlands, supposedly, is the world champion of "late motherhood" (Beets 1997). There are few countries in the world where women have their first child at such an advanced age as in the Netherlands where the average age at first birth is now well over 29.

The rise in childlessness has been receiving much attention. For Dutch women born around 1960, the expectation is that 18% will never give birth. From a historical point of view, this is not a very high percentage. Among women born at the beginning of the 20th century, higher proportions remained childless: close to 25% of women never gave birth (Liefbroer and Dykstra 2000). In the older cohorts, many remained childless because they never married. In the younger cohorts, women are remaining childless in marriage. The present rise tends to be attributed to "voluntary" factors, such as increased options for a fulfilling life outside the domain of parenting. Delay of marriage and delay of parenthood are other important determinants of the rise in childlessness. Not only have the reasons for childlessness changed, family circumstances have changed too—at least in quantitative terms. The older childless have been embedded in extensive family networks throughout their lives (large number of siblings, cousins, nieces, and nephews). Current childless men and women are part of much smaller family networks.

Changing patterns of mortality and fertility have led to changes in the architecture of families. First of all, families have become narrower from a horizontal perspective (the beanpole family): there has been a decline in *intra* generational relationships, that is to say, ties between members of the same generation, such as brothers and sisters and cousins, owing to the fact that couples are having fewer children. Analyses of genealogical data illustrate this (Post et al. 1997). In 1930 people under the age of 20 had an average of 3.1 brothers and siblings. This had declined to an average of 1.6 in 1960 and to 1.3 in 1990. Similarly, in 1930 the under-20s had an average of 11 cousins compared with 10.6 in 1960 and an average of 6.1 in 1990.

A second development is the ongoing verticalization of families. Families are made up of several generations. Due to the extended life span, older family members are living longer than they did in the past. This means that three, four, or even five generations may be alive at the same time. Having said that, three-generation families are the norm in the Netherlands, not four generations as many people believe. Since Dutch women have children at a relatively late age, the intergenerational distance (in years) also tends to be relatively large.

One of the consequences of the extension of the life span is that family ties have a duration of unprecedented length. Family members are alive together for increasing lengths of time. It is not uncommon for parents and children to share a period of 50 or 60 years! The bulk of the family literature focuses on that relatively short period in the life course during which people have dependent children; *not* on the longer period during which both parents and children are adult members of society.

In this paper we will investigate the familial bonds during that period in life when both parents and children are adult members of society. More specifically, we are interested to know more about the quality and intensity of familial exchanges when parents reach older ages. So, our first research question is: Does adult children's support to parents increase as parents become older? In this context we focus on parents aged 65–89 years of age, and examine the support they receive from their adult children.

Characteristic of a western, individualized society is—among other things—an increased likelihood of the dissolution of unions by divorce (of the parents' and/or the children's generation), and of repartnering after union dissolution. The support adult children provide to their parents is not independent of events that occur during the life course of parents and children. So, apart from changes in mortality and fertility patterns, changes in marriage patterns have led to changes in family networks. The composition of families has become more complex as a result of the increase in divorce, second and third marriages, and unmarried cohabitation. This complexity is rather new. As the Norwegian sociologist Gunhild Hagestad points out, our vocabulary has difficulty keeping up with social reality. We not only need to get used to the idea of adult grandchildren who can have families of their own, we also lack the words for relationships shaped by divorce and remarriage (Hagestad 1981).

Divorce not only disrupts horizontal ties between marital partners, it can also be a threat to vertical ties, such as those between parents and children, or grandparents and grandchildren. Additionally, attention has to be paid to the effects of divorce of adult children on contact with their parents. In some families, there is a drop in support due to increasing difficulty on the part of the divorced child to provide support. The consequences of repartnering for intergenerational family ties are largely unknown.

Family constellations have undergone rapid and dramatic changes during the past decades. "We", researchers, are still in the process of charting these changes and attempting to understand their implications. There are many unanswered questions and many myths about family change. In this context we formulate our second research question: What are the implications of partner status transitions in the lives of both the older and the younger generation for the quality of intergenerational relationships and support arrangements?

2. Explanatory Framework

2.1. BONDS BETWEEN PARENTS AND CHILDREN

Adult children and their parents engage in reciprocal exchanges. Older parents and their adult children have close bonds (Klein Ikkink, Van Tilburg, and Knipscheer 1999), with mothers receiving more support than fathers. Adult children tend to support their parents in carrying out household and personal care tasks, whereas parents tend to provide financial support to their adult children (Kohli et al. 2000). Children respond to the onset of physical decline in their parents by increasing their support provision (Broese van Groenou and Knipscheer 1999): sons tend to specialize in the provision of instrumental support, whereas daughters are more likely to provide emotional support. In the event of crises and prolonged periods of impairment, both sons and daughters continue to meet support demands (Eggebeen and Adam 1998). In this paper we start with an examination of support provision by *the age* of the older parent to assess the consequences of longer life for the overall functioning in daily life and familial embedment. Is there truth in Lillian Rubin's (2000:189) statement that "Older friends, those in their sixties and seventies, tell me that their children have grown more attentive, that they phone more often and invite their visits more urgently"?

2.2. OLDER PARENTS WITH AND WITHOUT PARTNERS

In investigating the support children provide to old parents, it is imperative to take into account the household composition or the availability of a partner in the household of the parent. Surveys from different countries show that the vast majority of older adults who are in need of assistance in either the self-care activities of daily living or the home-management activities of daily living receive this assistance from the spouse, if available (De Jong Gierveld 2004; De Jong Gierveld and Van Tilburg 1989; Dooghe 1992). Generally speaking, this puts couples in a better situation than those living alone, especially women. One's spouse can and will serve as the best (long-term) provider of emotional as well as instrumental support. Nearly all husbands rely on their spouses (Kendig et al. 1999). Spouses have the proximity, the long-term commitment, and the similarity in interests and values that underlie this type of support (Dykstra 1993). Now that elderly male persons are much more likely to be married than women, with surprisingly little variation between European regions, being (very) old proves to have very different implications for men and women. For men, being old generally means being attached, that is, having a spouse available for assistance and care. For women, it generally means being spouseless, that is, having to turn to others when they are no longer able to cope by themselves.

Children of widows and widowers "step in" when their parents need help (Klein Ikkink, Van Tilburg, and Knipscheer 1999; Lopata 1996; Wolf, Freedman, and Soldo 1997). Children whose mothers are widowed are more likely to visit their mothers frequently than those with currently married mothers, and these effects are interpreted as a permanent change in the relationship between the widow and her adult children (Roan and Raley 1996).

2.3. REPARTNERED PARENTS

A non-negligible part of the parents living in a couple household are involved in a second (or third) partner relationship after widowhood or divorce (De Jong Gierveld 2004). Repartnering creates a variety of new marital and complicated extramarital family patterns. Repartnering may be a *stressful event* (Henry and Lovelace 1995) because many changes have to be faced, such as moving to a new home and adapting to new household rules. Stress is a potential characteristic of the new partner relationship, the more so when those involved have lived alone for a considerable period of time, or are at a somewhat older age. After a period of living alone, people tend to have adopted fixed habits, and it might be difficult to adjust and change them. Repartnered adults require time and energy to invest in each other, which might have resulted in less time for their children (Spitze and Logan 1992; White 1992).

The *incomplete institutionalization hypothesis* introduced by Cherlin (1978) draws attention to another mechanism: the absence of social guidelines for repartnered couples (see also Coleman, Ganong, and Fine 2000). People who start a new partner relationship are confronted with a lack of norms regarding their role and how to deal with the problems of everyday family life. The repartnering of a parent profoundly affects children's life-worlds as well. The arrival of a newcomer who takes the special place of the (deceased) father or mother is distressing (Ganong et al. 1998) and might give rise to ambiguous feelings. This is all the more so when children face the risk that some of the potential inheritance might be lost in favor of the new partner (De Jong Gierveld and Peeters 2003). Consequently, repartnered older people who form part of a stepfamily may have structurally less close-knit familial networks than older adults in first marriages or older adults living alone after widowhood (Cherlin and Furstenberg 1994; Dykstra 1998; White 1994), and particularly so when repartnering has been preceded by divorce.

2.4. THE CONSEQUENCES OF DIVORCE EXPERIENCED BY PARENTS

The consequences of divorce are worth studying in their own right: both the economic and social effects. Several studies have shown that women tend to be affected by financial setbacks and a severe reduction in socioeconomic status after divorce, while men suffer reductions in their personal relationships (Cooney 1993; DeGarmo and Kitson 1996; Doherty, Su, and Needle 1989; Uhlenberg 1994). Divorced men are less likely to be in touch with their adult offspring and family members, and to have rewarding interactions with them than divorced women, a finding that is reported for the United States as well as for several European countries (Doherty, Kouneski, and Erickson 1998; Dykstra 1998; Terhell, Broese van Groenou, and Van Tilburg 2001). This difference is related to factors such as a decline in involvement as a non-residential parent, a failure to pay child support, and feelings of anger and blame which are more often directed at fathers than mothers (Cooney and Uhlenberg 1990; Cooney et al. 1986; Furstenberg, Hoffman, and Shrestha 1995; Strain and Payne 1992; Uhlenberg, Cooney, and Boyd 1990; US Bureau of the Census 1987; White 1994). Consequently, transfers of time, money, and all kinds of support between adult children and their fathers after divorce, are lower than those between adult children and fathers in first marriages (Dykstra 1998).

Divorce can have long-term consequences, as was pointed out by Fethke (1989): poor relationships between parents and young adult children do not improve when parents age, only perhaps when savings serve to encourage children to stay in touch or when the children feel a sense of moral obligation to stay in touch (Hagestad 1987; Knipscheer 1990). A negative effect of divorced single-parent families on parent–child solidarity in adulthood is also reported by Lye et al. (1995). Children of divorce have weaker relationships with their parents, particularly with the non-custodial parent, partly due to the fact that divorce poses a threat to the attachment that has developed between parents and children (Bowlby

1969). This low-attachment pattern will likely continue to exist as both the children and their parents age.

2.5. THE CONSEQUENCES OF DIVORCE EXPERIENCED BY CHILDREN

Intergenerational relationships are vulnerable to the stresses and strains produced by life changes affecting either generation (Kaufman and Uhlenberg 1998). For that reason, we also consider the effects of disruptive events in the life courses of the children, and more specifically, widowhood and divorce. It is not inconceivable that upward transfers decline, at least temporarily, given that divorced adult children are too preoccupied and too busy to be of much help to their parents. Research suggests that downward transfers increase rather than decrease in response to younger generation divorce as the older generation steps in to help their offspring (Dykstra 1998).

2.6. EFFECTS OF HEALTH SITUATION, NUMBER OF CHILDREN, AND DISTANCE TO CHILDREN

The support from children to parents is related to the number of living children, the travel distance between children and parents, motives that guide children, financial gifts from the parent to children, income and employment status of the children (Dooghe 1992; Henretta et al. 1997; Mancini and Blieszner 1989; Rossi and Rossi 1990; Silverstein, Parrott, and Bengtson 1995). Both the number of children and the travel distance between children and older parents are related to the socioeconomic level of the parents (and the children). In the Netherlands, the number of children per women of the birth cohorts under investigation is significantly higher for the lower social strata than for the higher strata (De Jong 1997). Moreover, the children of parents of higher socioeconomic strata have had better access to higher education, and opt for higher level jobs at greater distances from their parents than the children of lower strata families. For that reason, social class differences, number of live children, and travel distance to children are considered explicitly in the analyses.

The receipt of support will also be related to the severity of handicaps with which the older parents are confronted. In cases of minor handicaps, older individuals will be able to cope by themselves, either alone or with the support of the partner, if available. Some older adults will be able to purchase some assistance (e.g., to clean the house). In the event of increasing handicaps and frailty, support from children will be welcomed.

The previous considerations form the basis for the following hypotheses.

Hypothesis 1: With increasing age, parents are more likely to receive support from their adult children. *Hypothesis* 2: Divorced parents, fathers in particular, are less likely to receive support from their children than parents whose marriages remained intact. *Hypothesis* 3: Repartnered parents are less likely to receive support from their adult children than parents whose marriages remained intact or parents who did not repartner. *Hypothesis* 4: Parents are less likely to receive support from their adult children in families with a marital disruption in the younger generation than in families with no marital disruption in the younger generation.

3. Method

3.1. RESPONDENTS

The data are from the Dutch "Living arrangements and social networks of older adults survey" (NESTOR-LSN). In 1992 interviews were conducted with 4494 men and women, aged 55–89 years. The sample was stratified according to sex and year of birth. Older people, particularly men, are oversampled. For reasons of efficiency and cost control, the selection of respondents was restricted to three regions: the northeast, the southeast, and the west of the Netherlands. These regions represent differences in culture, religion, urbanization, and aging. In addition to the choice of regions, a wide range of differences in urbanization was also accomplished by selecting at least two municipalities in each region, a large- and a medium-sized city, and one larger rural town or several smaller ones. The sample includes both the institutionalized and older adults living in their own homes. Not all 4494 respondents completed a full interview. A short interview was completed with 342 (7.6%) of all respondents who were characterized by physical and mental deficiencies that prevented them from participating in a lengthy, 1.5 h interview. The overall response rate, defined as the number of interviews that were actually completed, divided by the number of all sampled cases in which an interview could have been completed is 61.7%. Considering the non-response problems when interviewing an elderly population, the results are satisfactory. The realized sample was fairly representative of the underlying population. Further details on the survey can be found in Broese van Groenou et al. (1995).

The first phase of the analysis in this paper is restricted to respondents aged 65–89, living in private households, with at least one living child ($N = 2313$). In the second phase we concentrate on those of the respondents aged 65 and over, living in private households, with at least one living child, experiencing one or more functional limitations, that is, limitations with self-care and/or mobility, and limitations in carrying out household activities. These restrictions resulted in a sample size of 1643. By considering only those with functional impairments, we obtain a picture of older adults' support networks when they actually require help. We refrained from introducing older parents' official marital status as an explanatory factor for differences in help received from children. Older adults' marital status is no longer a reliable indicator of their partner status and living arrangements. As a consequence of the changing system of values concerning marriage and intimate relationships, consensual unions are not uncommon among younger and older adults (Chevan 1996; Coleman, Ganong, and Fine 2000; Peters and Liefbroer 1997). In this study we explicitly asked all the respondents about partner availability independent of their marital status. In addition, marital history is introduced as an explanatory factor. The following typology was constructed. The selected respondents were distinguished firstly on the basis of current partner status: living with or without a (marriage or consensual) partner in the household. Secondly, we differentiated according to marital history: (1) those in first marriages, (2) the ever-widowed (who have never divorced), and (3) the ever-divorced (regardless of whether the divorce pertained to a first or a subsequent marriage). Non-negligible proportions of the ever-widowed men, and of the ever-divorced men were living with a partner either married or unmarried, at the time of the interview. Due to the small numbers of repartnered widowed women ($N = 12$), and repartnered divorced women ($N = 14$) these groups were excluded from the analyses. A small proportion of the first married (nearly 2%; 9 men and

12 women) were not living with their partners because the latter had been institutionalized. This group was also excluded from the analyses.

3.2. PROCEDURE

In this article we first provide descriptive information on the respondents and their families differentiating the respondents according to age group. Secondly, we investigate whether help because of experienced functional limitations is received from children. Multiple classification analyses are performed to determine the contribution of age and marital history types of the parents' as well as of the children's generation to the explanation of differences in the reliance on help from children.

3.3. MEASURING INSTRUMENTS

Health is assessed via two measures. The first is the mobility and self-care capacity, ranging from 4 to 20. Those not experiencing difficulties in either walking up and down stairs, walking for 5 min outdoors without resting, getting up from and sitting down in a chair, or dressing and undressing (including putting on shoes, doing up zippers, fastening buttons) are assigned a score of 20, and those not able to perform any of the four activities investigated are assigned a score of 4. The second is the capacity to carry out household activities, ranging from 4 (not able to perform household activities such as doing daily groceries, preparing hot meals, changing the sheets on the bed, doing the laundry, and regularly cleaning the house) to 20 (not experiencing any difficulties with the four activities investigated).

Help because of functional limitations: Respondents with functional limitations, that is limitations with self-care and/or mobility, and limitations in carrying out household activities were asked if they received help and if yes, from whom they received help. This study looks at whether non-resident children or partners were cited as sources of support. Unfortunately, the data do not allow us to distinguish precisely which children provide the support. We only have information on the generic category "non-resident children". In other words we cannot examine whether, as is often the case (Cooney et al. 1986; Dwyer and Coward 1991; Kendig et al. 1999; Lopata 1996), daughters are more often support-providers than are sons.

Socioeconomic resources: Educational attainment is used as the measure of socioeconomic resources. Respondents were asked about the highest educational grade they had attained. To enhance comparability, we calculated the number of years of education it would take to attain this grade, taking the shortest route possible.

Child characteristics. The number of surviving children is the first measure used. Children are biological (virtually 95% of all children) as well as adoptive and stepchildren. Secondly, the travel time to the nearest child (in minutes) is included. Thirdly, information is used about children being ever-widowed or divorced. For each of the living children we know the frequency of contacts with the parents; contacts include face-to-face, telephone, and mail interactions.

4. Results

4.1. BACKGROUND CHARACTERISTICS

Table 1 presents descriptive information on characteristics of the older parents by age groups.

As the table shows, the percentage of older adults living with a partner in the household decreases sharply after the age of 75, as expected. In the oldest age group of 85–89 years only 38% of the respondents live with a partner. The mean number of living children ranges between 3.3 and 3.6, but the mean number of children contacted at least on a weekly basis differs more sharply. Across age categories, there is a steady decrease in the

Table 1. Reports of family embedment, and demographic variables of parents aged 65–89, by age groups: descriptive statistics ($N = 2313$).

Variables[a]	**65–69 ($N = 486$)**	**70–74 ($N = 456$)**	**75–79 ($N = 554$)**	**80–84 ($N = 495$)**	**85–89 ($N = 322$)**	***T***
Percent with partner in household***	73[b]	72[b]	63[c]	49[d]	38[e]	60
Number of children alive (mean)	3.3	3.3	3.4	3.6	3.3	3.4
Number of children contacted at least weekly (mean)***	2.3[b]	2.2[b,c]	2.0[c]	2.0[c]	1.7[d]	2.1
Number of children and/or children in law contacted at least weekly (mean)***	3.5[b]	3.2[b,c]	3.1[c]	3.0[c]	2.5[d]	3.1
Travel time to nearest child (in minutes)	21	18	22	24	26	22
Educational level in years*	8.6[b]	8.4[b,c]	8.1[c]	8.2[b,c]	8.1[c]	8.3
Percent with one or more self-care or mobility limitations***	23[b]	33[c]	38[d]	52[e]	67[f]	44
Percent with one or more household activity limitations***	46[b]	55[c]	64[d]	76[e]	88[f]	67

*$p < 0.05$; ***$p < 0.001$.

[a]For significant relationships results from Waller–Duncan tests are provided. Non-overlapping letter codes (b,c,d,e,f) within rows indicate significant differences between age groups.

mean number of children contacted on at least a weekly basis from 2.3 to 1.7. Apparently, the circumstances of younger-old parents (in good health, with partner, recently retired, and ready to support the families of children and grandchildren) are more conducive to frequent contact with children than those of older parents. When contacts with children and children-in-law are taken together, the findings show that in each of the age groups, there are contacts on at least a weekly basis with between 2.5 and 3.5 members of the younger generation. The conclusion is warranted that Dutch older adults are well embedded in family interactions. Given a mean traveling time of about 22 min, we can assume that the majority of the weekly contacts are face-to-face. Table 1 also shows that the oldest age groups have the lowest levels of education, and the highest levels of functional limitations.

Findings for respondents confronted with one or more functional limitations are presented in Table 2. This pertains to 53% of the respondents in the age group 65–69 years; the

Table 2. Reports of family embedment, and demographic variables of parents with functional limitations, aged 65–89, by age groups: descriptive statistics ($N = 1643$).

Variables[a]	65–69 ($N = 257$)	70–74 ($N = 288$)	75–79 ($N = 392$)	80–84 ($N = 408$)	85–89 ($N = 298$)	*T*
Percent with partner in household***	77[b]	75[b]	65[c]	49[d]	39[e]	60
Percent receiving help from partner (alone or together with other support)***	51[b]	49[b]	45[b]	35[c]	23[d]	40
Number children alive (mean)	3.4	3.4	3.4	3.7	3.3	3.5
Number of children contacted at least weekly (mean)***	2.3[b]	2.3[b]	2.0[c]	2.1[b,c]	1.7[d]	2.1
Number of children and/or children in law contacted at least weekly(mean)***	3.5[b]	3.4[b,c]	3.1[c]	3.1[c]	2.5[d]	3.1
Percent receiving help from children (alone or together with other support)***	23[b]	22[b]	33[c]	41[d]	47[d]	34
Travel time to nearest child (in minutes)	16	17	23	24	22	21
Educational level in years	8.6	8.4	8.1	8.1	8.1	8.2

***$p < 0.001$.

[a]For significant relationships results from Waller–Duncan tests are provided. Non-overlapping letter codes (b,c,d,e) within rows indicate significant differences between age groups.

percentage increases with age and reaches 93% for the age group 85–89 years. As Table 2 shows, when there is a partner in the household, that person is frequently cited as the one who helps perform activities of daily living: more than 60% of the respondents co-residing with a partner, list the partner as support giver. In the oldest age group, the partner is cited least often, partly because a large proportion of this age group has no partner, and partly because the partner is not able to provide support due to health restrictions.

The pattern of findings for the mean number of children alive, mean number of children contacted on a weekly basis, and mean number of children and/or children-in-law, contacted on a weekly basis more or less resembles that presented in Table 1. Children are frequently involved in contacts with their old parents, and support giving is an important aspect of intergenerational family ties. With increasing age, the parents are more and more likely to receive support from their adult non-resident children.

Overall, 34% of the respondents with functional limitations cite children as support providers. The support from children is either in the form of support from children alone, or help from children together with other sources of support, such as the spouse, or other informal support providers (cousins, friends, colleagues), and/ or formal support (e.g., a community nurse). In the next section we will address several factors that might account for differences in older parents' reliance on support provided by children.

4.2. EXPLAINING SUPPORT BY NON-RESIDENT CHILDREN

Previous studies have indicated substantively different patterns of care use among older adults who are currently married and those who are unmarried (Mutchler and Bullers 1994; Wolf, Freedman, and Soldo 1997). In our study it is possible to differentiate further between older adults, taking into account gender and marital histories as well. We would like to highlight a number of differences between the groups, which are evident in Table 3.

All the differences registered in the bivariate analysis remain significant in the multivariate analysis. Age at the day of the interview is again significantly and positively related to support from children: the oldest old have a greater likelihood of being supported by children than the younger old, after controlling for all the covariates and the other independent variables. About 2.2–6.3% more children support their parents aged 80 years and over as compared to the mean situation, and among the parents aged 74 or younger 3.8–6.5% fewer children are involved in support giving.

Table 3 indicates that marital history, partner status, and gender are very important, significant predictors of support from children to parents coping with limitations. The deviations from the grand mean of 34% are registered, both before and after controlling for the covariates and other independent variables: large, positive deviations from the grand mean are found for widowers and especially widows who live alone. The deviation, adjusted for the covariates and for the other independent variables, is +23.8% for widows and +14.9% for the widowers. The largest negative deviations from the grand mean are indicated for divorced men: –24.2% for divorced men without new partners, and –24.7% for divorced men co-residing with a new partner. Moderate negative deviations from the grand mean are found for parents in their first marriage.

Table 3. Support from children (alone or together with other sources of support, 0 = no, 1 = yes) as received by parents aged 65–89 with functional limitations (in percentages of the subsamples); by age, current partner status, marital history and gender, and by marital history characteristics of the children; results of multiple classification analyses ($N = 1643$).

	N	Deviation[a]	Deviation[b]	F	*P*	B	Beta
Main effects							
Age				3.562	0.007		0.090
85–89 years	298	12.8	6.3				
80–84 years	408	7.0	2.2				
75–79 years	392	−1.0	0.3				
70–74 years	288	−11.9	−6.5				
65–69 years	257	−11.2	−3.8				
Marital history, partner status and gender of parents:				28.320	0.000		0.349
Parent in first marriage							
+ partner							
M	669	−13.5	−13.7				
F	235	−7.8	−3.8				
Parent ever-widowed (no divorce)							
+ partner							
M	57	−16.6	−16.8				
F	n.a.	n.a.	n.a.				
− Partner							
M	162	18.3	14.9				
F	418	25.9	23.8				
Parent ever-divorced							
+ Partner							
M	36	−31.4	−24.7				
F	n.a.	n.a.	n.a.				
− Partner							
M	20	−29.1	−24.2				
F	46	−5.9	−0.4				
Marital history of children:				1.154	0.283		0.024
Children ever-divorced							
No	1303	0.5	0.6				
Yes	340	−1.8	−2.2				

Table 3. (*continued*)

	N	Deviation[a]	Deviation[b]	F	*P*	B	Beta
Children ever-widowed (no divorce)				0.872	0.350		0.021
No	1574	−0.1	0.2				
Yes	69	2.1	−4.7				
Covariates				12.724	0.000	−0.014	
Self-care and mobility capacity (4–20)							
Household activities capacity (4–20)				0.510	0.475	−0.001	
Educational level				93.409	0.000	−0.032	
Number of children				24.100	0.000	0.024	
Travel time				10.234	0.001	−0.000	

[a]Deviation from the grand mean (34.1%) unadjusted for the covariates and the other independent variables.
[b]Deviation from the grand mean (34.1%) adjusted for the covariates and the other independent variables. R^2 = 21.4%.

We also investigated the effects of severe life course events of the adult children on giving support to older parents. The coefficient for ever having been confronted with widowhood was not significant, although those confronted with widowhood tend to be less frequently involved in support giving to older parents (−4.7%). The coefficient for divorce was also not significant. Divorced children are 2.2% less involved in support providing to older parents than registered as the grand mean for support of children to parents. Apparently, the dedication of children who have been confronted with widowhood or divorce is family directed in the sense that they give priority to supporting their parents in need of help, notwithstanding the extra burden they are confronted with themselves.

Significant differences are also found for health. The better the self-care and mobility capacity, the less likely it is that support from children is obtained. There is a negative, but not significant association between the capacity to carry out household activities and the likelihood of receiving support from children.

Educational level is also a significant and negative predictor of support given by children to older parents. The lower the educational level of the parent, the more support from children is obtained. Not surprisingly, the number of living children is another significant predictor of support provided by children: having only one child raises the risk of receiving no support from the younger generation as compared to those older adults with more living children. The more time that is needed to travel the distance between the older adult and the nearest non-coresident child, the greater the risk that the older adult will not be supported by the child(ren). The outcomes suggest that larger families, in the lower educated sectors of society, especially if the parents and children live in the same neighborhood, constitute a support reservoir for older adults with health limitations, and/or limitations in carrying out specific household activities, such as collecting daily groceries, and cleaning the house: a child will always be "there" to take care of the shopping, the cleaning of the house, or to help the parent with visits to the hospital.

5. Discussion

The aim of this study was to investigate the relationship between older parents and adult children, including support from children to older parents. Given an increasing life expectancy for both men and women, and the likelihood of a higher prevalence of limitations and frailty among the oldest olds, it is important to have information about care giving patterns oriented to older parents. The present study involved both parents who are confronted with self-care and mobility limitations and limitations in carrying out household in activities, and parents who are not in need of assistance. In a society that is characterized by increasing life expectancy other social and demographic indicators are changing too. We explicitly aimed at exploring the long-term effects of important events in the life-course of the older adults: widowhood, divorce, and repartnering after a marital break-up. Additionally, we investigated the effects of widowhood and divorce in the children's generation.

For this purpose we selected those older adults from the "Living arrangements and social networks of older adults survey" (1992; $N = 4449$), who were 65–89 years of age, living in private households, and had living children. In the second phase of the analyses we concentrated on a subsample: those with functional limitations. This subsample includes by definition an older segment of the NESTOR-LSN sample, and concomitantly affects the likelihood of including widowed respondents (over-represented in the subsample), divorced respondents (under-represented in the subsample), and repartnered respondents (under-represented in the subsample). In the Netherlands, the divorce rate increased sharply after 1974, the year in which a new more liberal divorce law was introduced. Before the mid-1970s divorce was a statistically rare phenomenon and not socially accepted. A societal stigma was attached to divorce, a stigma affecting not only the divorced persons themselves but also their families and their children. The likelihood of having experienced divorce is still rather low among Netherlands' cohorts of older adults, and most prominent among the young old (Liefbroer and Dykstra 2000). As a consequence the numbers of ever-divorced older adults in the subsample is relatively low. It is not uncommon for widowed and divorced men and women in their 30s and early 40s, to enter into a new partnership (Uunk 1999). The proportion of men and women who repartner after having become single at later ages is relatively low, but increasing (Liefbroer and Dykstra 2000).

Our first hypothesis addressed the relationship between a higher age of the parents and the contact frequencies and support of children to their parents. The data showed that older adults have at least weekly contacts with 2.5–3.5 of their children and children-in-law. Parents aged 75 and over receive significantly more support from children than younger parents. This relationship between age of parents and support of children remains significant after controlling for health and other relevant variables. We conclude that older adults in general are well embedded in the network of children and children-in-law. On the premise that the vast majority of older adults who are in need of assistance because of functional limitations actually receive this assistance, either from their spouse (if available), or from their children, we investigated data about help-giving by the (partner and) children. More than 60% of the older adults with partners cited the spouse as a support provider, whereas 34% of all respondents cited one or more of the children as support providers. At first sight, this seems to be a rather low percentage. However, one should take into account that the majority of the respondents with functional limitations were only moderately handicapped, and their preference is to manage on their own and to be independent for as long as possible. Our data clearly indicate that children give less support to parents with only minor self-care and mobility limitations, but support giving increases when parents are confronted with more functional limitations.

Further research (not explicitly reported here) showed a U-shaped pattern for children's support provision and their parents' functional capacity (see also Roan and Raley 1996). Parents with only minor self-care and mobility limitations are least likely to receive support from children. The likelihood of support from children increases with increasing self-care and mobility limitations but only to a certain level. Older adults characterized by very poor health (self-care and mobility capacity scores of 11 or lower) are less likely to receive support from children than are parents with milder forms of health problems. A possible explanation for this finding is that those with the poorest health rely most heavily on formal sources of support and for that reason have less need for support from adult children. Many parents in modern individualist societies prefer—finances permitting—to hire required services, rather than rely on the assistance of unpaid family members (Pyke 1999). In doing so, they guarantee their independence from childrens' support for as long as possible. Klein Ikkink, Van Tilburg, and Knipscheer (1999) who report parallel outcomes, related their findings to the reciprocity in parent–child dyads: parents with a relatively good self-care and mobility capacity give more support to their children, and thus also receive more support. So, children's support-giving to their parents is—to a certain extent—governed by reciprocity. We would also like to point out that more intense self-care and mobility limitations require more energy, time, and caring capacities of support providers. Not all children are optimally equipped to provide a greater volume and more personal support on a regular basis. More support giving may increase distress and may be too burdensome to midlife and older children (Silverstein and Chen 1996); support from formal sources might be needed to assist adult children.

In answer to the second hypothesis, the data point out that relationships between divorced fathers and their children are not very supportive and do not appear to improve after a period of "slumber" when the fathers age and are confronted with functional limitations. Few differences were observed between ever-divorced fathers with and without a new partner. Ever-divorced men generally do not receive help from their children. Ever-divorced women are more likely than are their male counterparts to receive support from their children. But the data showed convincingly that widows and widowers (without new partners) are most likely to be supported by children in case of need. In line with what has been found by Wolf, Freedman, and Soldo (1997) children of widowed parents seem to "step in" when parents without partners need help. In contrast, children of divorced parents generally tend not to be involved in caregiving, or only small percentages of them do so. Apparently, the state of divorce decreases the likelihood of optimal "fathering" and "mothering" in the short run, and the possibilities for reciprocal rewards in the long run. One might have assumed that offspring become more willing to assist when their parents become more impaired, even when situations have created tension or ill feelings in the past. Our study provides little evidence for this assumption. Apparently, parental impairment does not constitute a condition under which children of divorce are more likely to be support providers to their parents. The negative effects of parental divorce on later caregiving have been reported for the United States (Cooney and Uhlenberg 1990; Furstenberg, Hoffman, and Shrestha 1995; Strain and Payne 1992; Uhlenberg, Cooney, and Boyd 1990; White 1994). In this article we found similar effects for the Netherlands.

Among the repartnered widowers the likelihood of receiving support from non-resident children is more or less comparable to men in first marriages. Only the subgroup of repartnered ever-divorced men receives less support from children. This outcome provides partial support for our third hypothesis, that repartnering of ever-widowed or ever-divorced older adults increases the risk that children will refrain from providing support to their older parents.

The risk of receiving no support at all is significantly higher for ever-divorced men without a new partner than for ever-widowed men without a new partner, and for ever-divorced women without a partner compared to ever-widowed women without a partner. An explanation that immediately presents itself is that the findings should be attributed to the relatively favorable health status and the younger ages of the ever-divorced as compared to the widowed men and women without new partners. Presumably, then, the ever-divorced without new partners receive little help from children and others because they have little need for it. Additional multivariate analyses revealed, however, that after controlling for health (and other background characteristics), the likelihood that ever-divorced fathers and mothers without partners receive help from their children is significantly lower than for widowed fathers and mothers without partners. An alternative explanation focuses on the offspring of the ever-divorced, following the notion that the relationship between fathers (and mothers) and children requires sustenance, and if this relationship is disturbed by divorce or nonresidential parenthood, it is more likely to lack intrinsic and reciprocal rewards, and to be characterized by feelings of anger. Of course, the findings also reflect the dominant custody arrangements: in most cases children live with their single mothers after divorce. In general, the findings indicated that ever-divorced men are most likely to be estranged from their adult children. This is in line with statements by Cooney and Uhlenberg (1990) and Rossi and Rossi (1990) that when adult children reach adulthood they have little desire, feel only marginally obliged, or see few opportunities to maintain or renew contacts with their ever-divorced fathers.

In order to investigate hypothesis four we estimated the effects of disruptions in the life courses of the adult children on support giving to older parents. The coefficient for having been confronted with widowhood was not significant. The coefficient for divorce was not significant either. The findings suggest that adult children, though they are experiencing trouble in their own lives, do not refrain from providing support to parents in need. Some caution is advised, however. In this study we were unable to take into consideration the time that had passed since the disruption of the adult children's marriages. It could well be that so much time has passed that the children have reached a new balance in their lives and experience few restrictions to help their aging parents. Empathy on the part of adult children who themselves have faced setbacks for the needs of their old parents might also play a role. Feelings of empathy might be particularly strong among those who received support from their parents while coping with the dissolution of their marriages. We conclude that if the bonds between parents and children are close and based on lifelong warm reciprocal feelings, the children will opt to support their older parents, reciprocating the support they received, irrespective of the problems of their own situation.

The results of this study underscore the importance of looking at the biographical history of the parent–child relationship to understand the motives of children being or not being involved in care-provision, such as feelings of affection based on having shared many years together, feelings of obligation shaped by the social and cultural milieu of the family, the desire to reciprocate earlier parental help, and the quality of the parent–child relationship (Suitor et al. 1995). Our findings suggest that information on the family's past contributes to an understanding of support-giving by children over and above assessments of current circumstances, such as living with or without a partner.

Our findings also show that the distance to the nearest child and the number of children are important determinants in and of themselves. We found a positive association between family size and the likelihood of receiving support from children. In line with findings by Uhlenberg and Cooney (1990) this study reveals that older adults with larger families are more likely to list a child as support-provider than are those with smaller families. Given that the provision of instrumental support is strongly contingent upon geographic proximity, our finding that having children living nearby increases the likelihood that they serve as support providers does not come as a surprise. Note, however, that when parents and children live near to each other, we do not know why this is the case. They might always have resided at short distances from one another, the child might have decided to move closer to the parent to provide care, or the parent may have moved to allow the child to provide care. Few Dutch older adults are geographically isolated from their offspring: of the parents in the NESTOR-LSN sample, only 14% had no children living within a 30 min traveling distance (Dykstra and Knipscheer 1995).

Considering that older adults' level of education is associated with the likelihood of divorce, health, family size, and the distance to the nearest child, it is interesting that we still find a significant association between education and the likelihood of listing a child as support provider, once these determinants have been taken into account: the higher the level of education of the older adult, the less likely she/he is to have a child as a support provider. It is not entirely clear how to account for this finding. From other research we know that older adults' educational level reflects a preference for certain types of assistance (Timmermans, Heide, and De Klerk 1997). The better educated prefer not to rely on family members when help is needed but rather to purchase help or to do without assistance. A reluctance to become the dependent party in the relationship with children might underlie the low levels of reliance on support by adult children reported by older adults with higher levels of educational attainment.

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CHAPTER 15. LIVING ARRANGEMENT OF THE OLDEST OLD IN CHINA

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1. Background

Traditionally, elder support is one of the major functions of the family in China. China is currently facing rapid population aging, so many efforts have been devoted to investigating the living arrangements of and societal support patterns for the elderly.

The living arrangements of the elderly are closely related to the family system. The nuclear family has an empty-nest phase, which means that the elderly do not live with their adult children. This pattern is sharply different from traditional family patterns (both the stem and joint family patterns). Therefore, family nuclearization concurs with the change in living pattern of the elderly in China. In the past two decades, the portion of elderly who live with their offspring is declining. The percentages of the elderly aged 65 and above living in multi-generational family households are 73.1 in 1982, 72.5 in 1990 (Guo 2000: 109), and 65.8 in 2000 (Guo 2004), according to the population census data.

Three sets of constraints were proposed by Kobrin and Goldscheider (1982) on residential arrangements for the elderly, including demographic availability, economic feasibility, and normative desirability. A study of parent–child co-residence in Japanese households (Kojima 1986) reveals that children availability is the most important factor when education, occupation, urbanization, and residence ownership are held constant. Chen and Speare (1990) found in a study of Taiwan that children availability was not important as a reason for the decline in the co-residence of the elderly with children. Instead, they suggest that the observed increase in living apart is simply a result of structural change such as changing mortality, changing attitudes toward living arrangement, selectivity of the 1949 migration from mainland China, and the selectivity of migration in the 1980s.

There has been a debate concerning the relation between quality of life and living arrangement of the elderly and their adult children. Xia and Ma (1995) found in their analysis of survey data that older people do not rely on their adult children economically, so how many children they have does not correlate with their life quality. But another analysis (Guo 1996) of the same data suggests that, since Xia and Ma's analysis is based on only a simple aggregate analysis without controlling for age, their conclusion reflects the younger elderly, who made up the majority of the sample. When the elderly are divided by age, it can be seen that older people demanded and obtained more support and care from their adult children, and that the number of children does make a difference in life quality and

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living arrangement for the elderly. In addition, data from the population census (Guo 1992, 2000) verifies that the number of surviving children does affect the living arrangement of the elderly in China. In addition, the surviving children's sex is also an influential factor.

The healthy longevity survey of the oldest old in China conducted in 1998 enables us to examine the frequency of co-residence of the oldest old with their children and it provides an opportunity to search for the determinants of residential patterns.

2. Data and Measurement

This study uses the baseline data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) conducted in 1998. A general introduction of the CLHLS data sets is presented in Section 2 of Chapter 13 in this book and thus is not repeated here.

In the CLHLS, the oldest old themselves are the references for classifying the living arrangement of other members. Seven categories of living arrangements are defined in this chapter: (1) live alone; (2) with spouse (but not with children); (3) 2 generations; (4) 3 generations; (5) 4+ generations; (6) with other people only; and (7) institution (namely, nursing home).

Although these categories are literally the same as those used in the CLHLS baseline data collection book (Research group of healthy longevity in China 2000), their definitions are somewhat different. The CLHLS data collection book stresses the number of generations, yet this study places more attention on which generations are covered. For example, if an elder lives with a grandchild only, the data collection book defines it as 2 generational arrangement. Such a case is defined as a 3 generational (i.e., quasi-3 generational) living arrangement in this study, however. Unlike the data collection book, I do not distinguish "living with" and "not living with" persons other than spouse/children in each of the lineal kin co-residence types.

Some studies (Kobrin 1981; Soldo 1981; Thomas and Wister 1984; Wister and Burch 1983) use children-ever-born from the population census data as a rough indicator of potential kin availability. Considering that the Chinese oldest old experienced high mortality, especially infant mortality, in the first half of the 20th century, children alive is chosen as a better indicator of kin availability in this study.

3. Main Features of the Living Arrangement of the Oldest Old

Cross-tabulation analysis provides the living arrangement of the oldest old by age, sex, and residence type. The main features are summarized as follows:

(1) In all age/sex/residence cross-groups, multi-generations take quite a large share, varying from 54% to 89% (see Figure 1). This indicates that co-residence with children prevails for the oldest old. Figure 1 also indicates differences by area of residence, sex, and age. In general urban multi-generational residence is lower than rural, male is lower than female, and younger is lower than older.

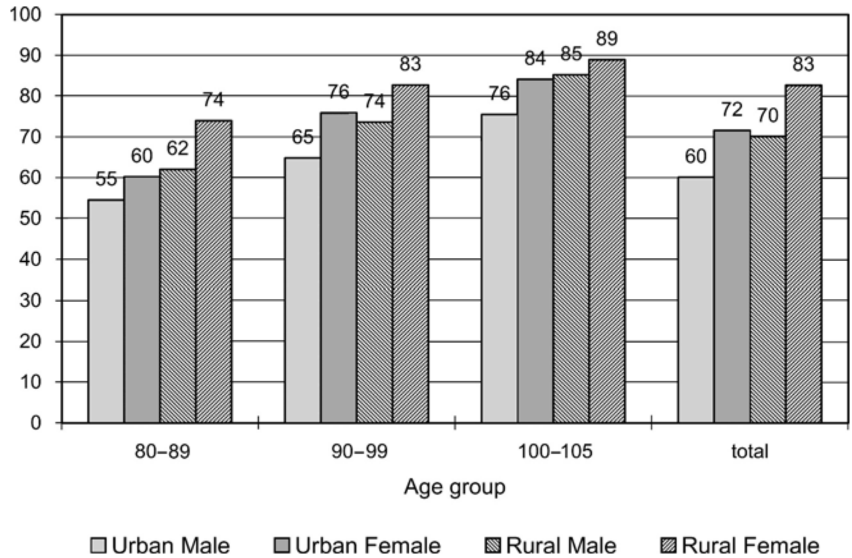

Figure 1. Percentages of oldest old living in multi-generation household.

(2) Shares of those living with a spouse (but not with children) show patterns that differ from those of multi-generations, with a higher likelihood for persons who are urban, male, and younger age (see Figure 2). These patterns reflect that more urban elderly do not live with their children due to the better economic and social conditions. The

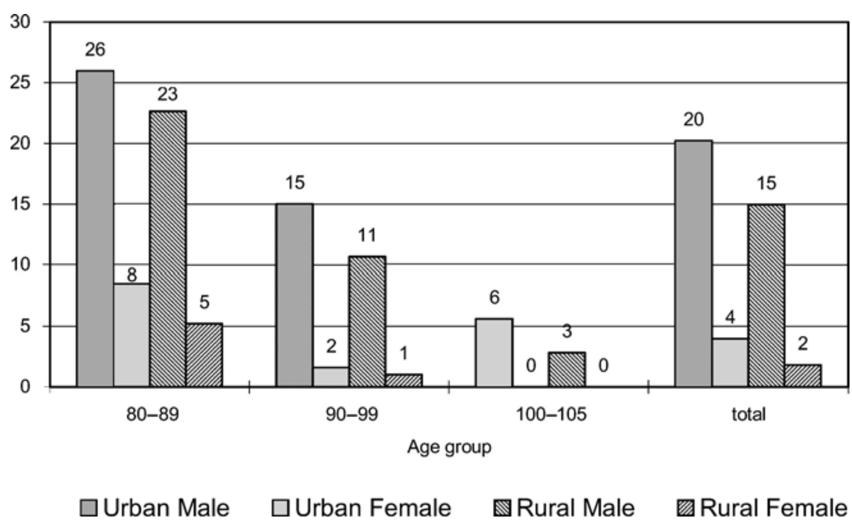

Figure 2. Percentages of oldest old living with spouse only.

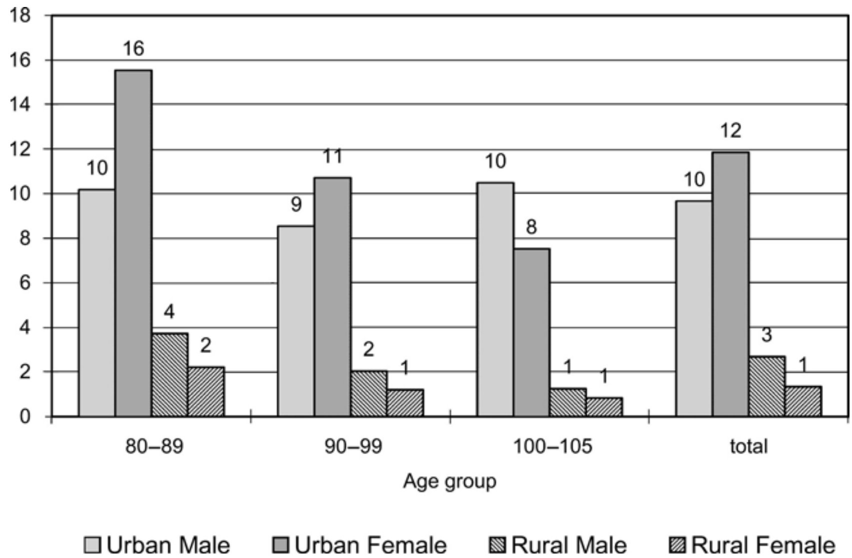

Figure 3. Percentages of oldest old living in institutions.

age difference reflects the process of losing functioning ability with increasing age. The difference between males and females is the most striking and largely results from the sex differential in mortality. Women survive longer than men, so a large proportion of women at late life are widows.

(3) Comparing the share living in institutions indicates a quite significant urban–rural difference (see Figure 3). Whether for male or female, and for every age group, the urban proportion institutionalized is much higher than its rural counterpart. Additionally, it can be seen that, in age groups 80–89 and 90–99, the proportion for females is higher than that for males in urban areas. Age group 100–105 is an exception, and may be attributed to statistical instability due to the scarcity of cases at this age group. Institutionalization is generally rare in rural areas, however.

(4) A male is more likely to live with a spouse and less likely to live alone than is a female. Figure 4 shows that the male proportion living alone is generally lower than that of their female counterparts, except in the highest age group. This reflects that more oldest old women are widowed, and also indicates that oldest old men are less able to live alone. Another interesting feature is that the rural elderly are more likely to live alone than are the urban elderly of both sexes. This phenomenon cannot be interpreted as the result of superior independent conditions for the oldest old in rural areas. On the contrary, it seems that the larger proportions living alone among rural persons are due mainly to having no alternative (such as a nursing home) for those oldest old who have no spouse or children. So living alone should be attributed to a lower level of socioeconomic development in rural areas, as compared to urban areas.

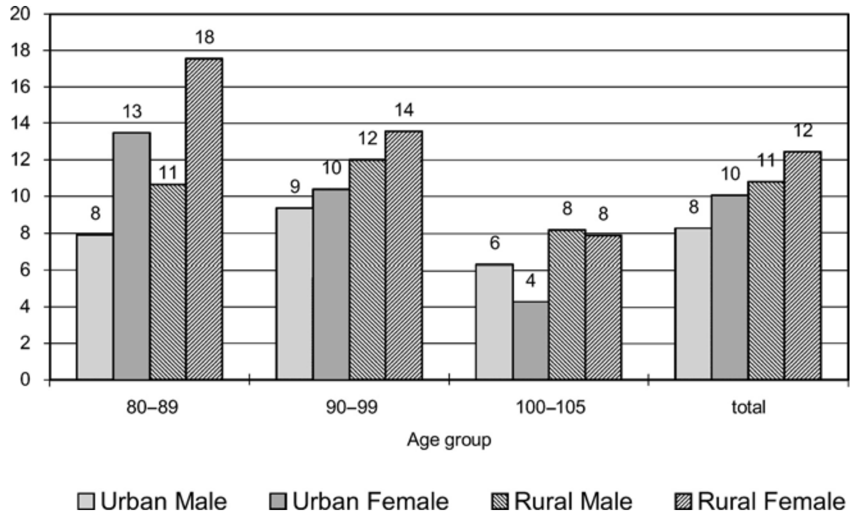

Figure 4. Percentages of oldest old living alone.

The category of living with those other than a spouse and children is not analyzed because the number of cases is too few.

4. Living Arrangements and Number of Surviving Children

This section explores the effect of demographic availability on the living arrangements of the oldest old. Since China is a dualistic society, the residence type is also used as a classification criterion. The analysis focuses on the associations between the living arrangements of the oldest old and the number of living children.

Note that someone without surviving children could still be categorized as living with offspring since that elderly person might live with a grandchild. In addition, according to the finding based on the 1990 population census (Guo 1992), 40% reported zero children ever born yet were co-living with their adopted children. Therefore, most of these adult children could have been adopted. In addition, some older people may live with children-in-law when their own children are dead.

Figure 5 illustrates the distribution of living arrangement by number of children.

(1) Among urban residents, 14% of the oldest old lack surviving children; among their rural counterparts the figure is only 9%. The higher proportion of those lacking surviving children for urban residents can be partly attributed to lower fertility.[1] Consequently, the higher proportion of those without surviving children for urban

[1] The mean number of children ever born for urban old is 4.4, and the corresponding statistic for rural old is 4.8, as computed from the data.

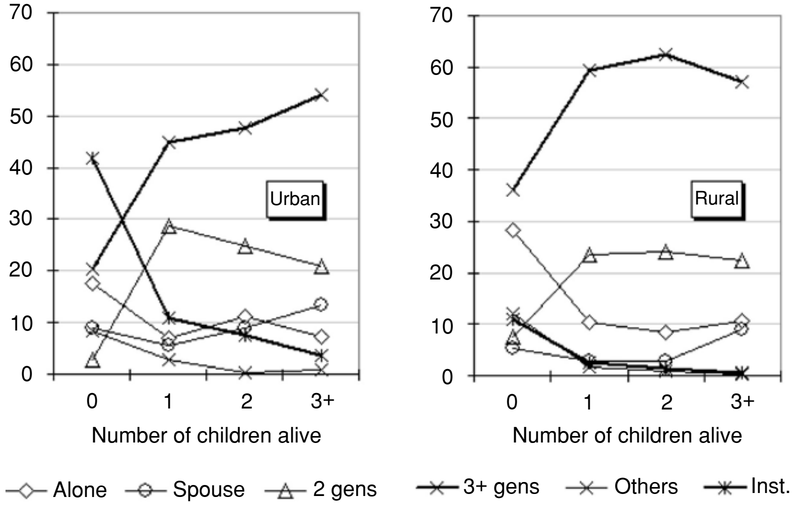

Figure 5. Distribution of living arrangements by number of children alive.

residents can be one of the explanations for the higher proportion not living with next generations.

(2) It is clear that, whether residency is urban or rural, the shares of those either living in an institution or with others are negatively associated with the number of surviving children. Shares of the other sub-types (empty-nest, alone, and with spouse only), however, show a U-shaped pattern as the number of surviving children increases for urban and rural areas. The shares decline noticeably when the number of surviving children increases from 0 to 1, but when the number of children becomes larger, the shares become larger. The share living with only a spouse is at a maximum for those with three or more children. Therefore, the association between living arrangement and the number of children is not simply a linear pattern.

(3) For the two types (2 generations and 3+ generations) of co-residence with offspring, we find the percentages are positively associated with the number of surviving children as it increases from 0 to 1 child, but it does not continue to increase when the number of children further increases. For 2 generations, it continues to rise in urban areas while it declines for rural areas, as the number of surviving children increases from 2 to 3 and more. For 3+ generations, one child is the turning point for both areas, but the proportions show a more striking decline in urban areas than in rural areas. In fact, this phenomenon is negatively symmetrical to what we find in dynamics of living alone and with spouse only, mirroring the threshold in the effect of the number of children. The most remarkable effects are found between those who are childless and those who have only one child for these arrangement types, yet further increases in the number of children has only a marginal effect in the same direction or effects in the opposite direction. This suggests a hypothesis to be tested with statistical controls.

(4) Urban–rural difference in the effect of the number of children can be seen in all living arrangement categories. Besides the threshold effects patterns, the magnitude of the shares also shows a significant difference. The most striking difference is found in the shares of those institutionalized. The shares for the urban oldest old are as high as 42% for the childless and 11% in total, compared to much lower corresponding rural shares, 11% and 2%, respectively. Oppositely, the share of living alone for the rural childless is 28%, much higher than the corresponding figure (18%) for the urban childless. For the category of 3+ generations, the rural statistics overwhelm the corresponding urban statistics, indicating that the rural family pattern is more traditional and the rural elderly depend more upon family support.

5. Multivariate Logistic Regression Analysis of Living Apart from Children

In this section, multivariate logistic regression analysis is conducted on the oldest old's living apart from children. The dependent variable "living apart from children" is built by merging the living arrangement categories according to whether or not the elderly live with their offspring. Therefore, the categories of living alone, with spouse only, with others, and in an institution are counted as living apart from children; the other three categories of multi-generations are assigned as not living apart from children.

Independent variables include age, sex, residence, marital status, previous occupation, years of schooling, number of surviving children, and the sex composition of surviving children. Some basic descriptive statistics are provided in Table 1. In addition, the reference category is denoted for dummy variables.

Most of the independent variables convey their meanings via their names. Those that need to be defined are as follows: farmer is the combination of people engaged in agriculture, fishery, and housework; cadre is the combination of professional, technical, managerial personnel, and military personnel; and worker is the combination of industrial, commercial workers, and others undefined.

For this analysis, the number of surviving children is used to test the effects of the number available, yet a set of dummy codes to classify the sex combination of surviving children is applied to test the compositional effect. Here the demographic factors are tested while controlling for other socioeconomic variables.

Fourteen independent variables are involved in model 1, and Table 2 shows the results of the logistic regression of model 1 explaining living apart from children. The analysis generally confirms impacts from both social and demographic variables. Of the 14, eight independent variables are statistically significant at the 0.05 level.

As expected, age has a significant negative effect on living apart, but it may have two possible interpretations. The age effect refers to the phenomenon that getting very old may reduce the propensity of living apart from children; 1 year of age leads to a decline in the odds by 5.7%. The cohort effect may imply a stronger propensity toward living apart in

Table 1. Mean and standard deviation of variables.

Variable	Mean	Standard deviation
Living apart (yes = 1, no = 0)	0.265	0.441
Age	91.132	7.834
Sex (reference = female)		
Male	0.399	0.490
Years of schooling	1.805	3.576
Residence (reference = rural)		
Urban	0.377	0.485
Occupation (reference = farmer)		
Worker	0.175	0.380
Cadre	0.083	0.277
Marital status (reference = married and live with spouse)		
Separated	0.015	0.121
Divorced	0.006	0.077
Widowed	0.788	0.408
Never married	0.012	0.111
Number of surviving children	3.094	2.104
Sex of surviving children (reference = both sexes)		
No living child	0.113	0.316
Only male children	0.190	0.393
Only female children	0.118	0.322

Note: The mean of those dummy variables in fact indicates the proportion of the coding to 1. For example, a 0.399 mean of males indicates that males constitute 39.9% of the sample.

the future as society further develops. But with the available data, these effects cannot be distinguished.

Although the cross-tabulation analysis in the previous sections showed a remarkable sex difference in living arrangements, sex turns out not to be a significant factor in the regression analysis controlling for covariates. The regression coefficient (B) for sex indicates that men are only slightly more inclined to live apart from children than are women. Standardized coefficients (β) show that the relative explanatory power of sex is quite low as compared to that of age.

Years of schooling do not have statistical significance either. This is partly because there is only slight variability in this measure. Table 1 shows that the value of the mean years of schooling is less than 2 years, namely, the majority of the oldest old had no schooling whatsoever. In fact, the share with no schooling is about two-thirds; another 30% has from 1 to 6 years of schooling. Therefore, such a small amount of schooling does not produce an influence on living apart from children, yet the direction of its effect is the same as was hypothesized: the more education, the more independence.

Urban living has a significant positive impact on living apart as compared to rural living, while the other factors remain equal. We can attribute this to the pension and insurance

Table 2. The logistic analysis of living apart—model 1.

Dependent variable	**Chi-square**	**df**	**Sig.**	***N***
Living apart	1925.730	14	0.000	8959
Independent variables	***B***	**Sig.**	**Exp(*B*)**	***β***
Age	−0.059	0.000	0.943	−0.254
Male	0.096	0.147	1.101	0.026
Years of schooling	0.009	0.305	1.009	0.018
Urban	0.142	0.023	1.153	0.038
Cadre	0.422	0.000	1.524	0.064
Worker	0.110	0.155	1.116	0.023
Separated	−1.239	0.000	0.290	−0.083
Divorced	−0.655	0.045	0.519	−0.028
Widowed	−1.134	0.000	0.322	−0.255
Never married	0.220	0.469	1.246	0.013
Number of surviving children	0.032	0.095	1.032	0.037
No surviving child	2.534	0.000	12.603	0.442
Only male children	−0.007	0.942	0.993	−0.001
Only female children	0.769	0.000	2.158	0.137
Constant	4.410	0.000	82.285	0.000

Notes: The term "separated" refers to a situation in which the couple's members do not live in the same place currently.

system, better service and health care, and more convenient living conditions in urban areas. The estimates indicate that the urban oldest old have 15% higher odds than do the rural oldest old in terms of living apart from children. Compared to former farmers, the old who were formerly cadres are more inclined to live apart from their children, but the former workers have a similar proportion living apart from children.

Marital status also makes a difference in the living arrangement of the elderly. The divorced, and especially the separated (namely, a married person who does not live with a spouse regularly) and the widowed, are more inclined to live with their children as compared to the reference (one who is currently married and living with a spouse). Of these three kinds, those separated have the largest difference in terms of odds ratio [exp(B)], but the widowed show much more variation in living apart in terms of β, because nearly 80% of this sample are widowed. Unexpectedly, the difference of those never married is not significant; further investigation is needed to determine the reason.[2]

The number of surviving children does not make as much of a difference as was expected when other individual characteristics are controlled. This outcome recalls the threshold pattern found in the previous cross-tabulation analysis: living arrangement shares change greatly when the number of children changes from 0 to 1, but the dynamics are not the

[2] Some single elderly may have adopted children in order to gain security during old age (see Guo 1992, 1996, 2000).

same in size or direction when the number of children increases further. This implies that the marginal effect of the number of surviving children will be reduced heavily.

Of major interest is the impact of the sex composition of children. Having no living child makes the most striking effect. The odds ratio of having no child of either sex in respect to living apart reaches 12.6 times. But, somehow, it can be regarded as a quantity measure of demographic availability as well. It is interesting to note that having only male children is the most insignificant factor, yet its impact is in the direction of reducing living apart, as is expected. On the contrary, having only female children has a very significant positive impact on living apart; the odds ratio is over double that of both sexes, namely, the odds of living apart for those who have only female children is double that for those who have both male and female children. This reflects the patrilineal norm in Chinese society.

Since the number of surviving children is not significant in model 1, we have reason to doubt its effect of exerting influence in a more complicated way rather than in a simple, linear way. So in model 2, in addition to the variables included in model 1, a new variable, the square value of the number of surviving children, has been added to fit the effect of children in a quadratic form. The results of model 2 are given in Table 3.

In fact, after the square value is added to the model, most of the output statistics remain almost unchanged. Therefore, we will concentrate on discussing the meaningful changes in the estimates.

Table 3. The logistic analysis of living apart—model 2.

Dependent variable	**Chi-square**	**df**	**Sig.**	***N***
Living apart	1930.294	15	0.000	8959
Independent variables	***B***	**Sig.**	**Exp(*B*)**	***β***
Age	−0.059	0.000	0.943	−0.254
Male	0.095	0.152	1.100	0.026
Years of schooling	0.009	0.341	1.009	0.017
Urban	0.148	0.018	1.159	0.039
Cadre	0.430	0.000	1.537	0.065
Worker	0.118	0.128	1.125	0.025
Separated	−1.234	0.000	0.291	−0.082
Divorced	−0.637	0.052	0.529	−0.027
Widowed	−1.134	0.000	0.322	−0.255
Never married	0.227	0.456	1.255	0.014
Number of surviving children	0.159	0.011	1.173	0.185
Square value of NCA	−0.014	0.034	0.986	−0.124
No surviving child	2.783	0.000	16.166	0.485
Only male children	0.059	0.534	1.060	0.013
Only female children	0.852	0.000	2.343	0.151
Constant	4.157	0.000	63.899	0.000

NCA stands for “number of children alive”.

In model 2, both the number of surviving children and its squared value are statistically significant, so the total effect of the number of children can be regarded as the sum of its linear effect and its quadratic effect, which is an upside down U-like curve considering the two regression coefficients. This pattern seems difficult to interpret because it is similar to the patterns of multi-generations' shares other than those patterns categorized as living apart as the number of children increases, shown in Figure 5. It should be pointed out that the regression models contain a specially designed dummy variable representing no child, so the marginal effect before the threshold of one child is partly reflected by this dummy variable, and the total effect of the number of children refers mainly to the marginal effect after the threshold, namely the increments from 1 to more. Besides, the effects of the number of children are net because many other variables have been controlled.

The second change in model 2 is that the regression coefficients for no living child and having only female children become more significant, and having only male children now has a positive value instead of the negative one as in model 1, yet it is still insignificant. In model 2 the dummy variable of divorced now fails to attain significance at the level of 0.05, though the magnitude of change in statistics is not large.

6. Summary

Cross-tabulation analysis shows that the majority of the oldest old live with their children. There is significant difference in the distribution of living arrangement by sex, age, and residence type. This study confirms by multivariate logistic regression that the living arrangement of the oldest old is influenced by demographic availability and socioeconomic characteristics. After multivariate controls, age, residence type, previous job, and marital status are still significant predictors of the oldest old living apart from their children. But sex does not produce a significant net explanation for not living with children, unlike the original difference shown in the distribution of living arrangement. Years of schooling are not significant, either, due to little variation in the variable.

This study has tested demographic availability in respect to both quantity and sex composition of surviving children. It is found that a threshold phenomenon exists when the number of children impacts living arrangement. Another new finding suggests that the sex composition of children should be paid more attention when we measure demographic availability.

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CHAPTER 16. LONGEVITY AMONG CHINESE CONSANGUINES

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1. Introduction

The life expectancy of humans has been improved dramatically throughout the world as a result of the development of medical technologies and increases in the standard of living. In China, life expectancy was 35 years in the 1930s (China Health Yearbook Editorial Committee 2002: 488), and has increased to 71 years in 2000 (Department of Population, Social, Science and Technology Statistics 2003: 201). Even though there are differences in life expectancy among different populations, there are always individuals who live longer than others. Interest in longevity among family members dates back as early as in the beginning of 20th century. For example, Bell (1918) found that children who were lower in birth order tended to live longer than those who were higher in birth order. Many studies in China show that longevity runs in or along family lines and that children's longevity usually relates to that of their parents (e.g., Chen et al. 1985; Huang and Wen 1986; Shi and Shen 1992; Su and Xu 1986; Wang et al. 1988; Zheng et al. 1991; Zhu, Liu, and Sheng 1984). Similar characteristics are found in other populations. For example, based on life span data for the members of European aristocratic families, Gavrilov and Gavrilova (2001: 212–214) concluded "when fathers lived less than 80 years there was very weak familial transmission of life span from fathers to sons and virtually no familial transmission of life span from fathers to daughters". For cases in which fathers lived more than 80 years, however, there were remarkable improvements in the survival rates for both sons and daughters. Also, paternal life span seems to be a more important predictor of offspring life span than is maternal life span for sons and probably for daughters. Westendorp and Kirkwood (2001: 229–231) have found that the life spans of parents affect children's longevity differently and the effect varies within periods included in their study. Robine and Allard (1998) studied longevity among family members of Jeanne Calment, the longest-living person ever recorded, and found that 24% of her ancestors lived long lives (over 80 years old) and five out of six of her immediate ancestors lived more than 70 years. Among ancestors of another long-lived woman Marie-Louise Meilleur, 21% lived to age 80 or above (Desjardins 2001: 239).

Different factors (such as social, environmental, or genetic) may affect individual longevity (e.g., Jazwinski 1996; Zhang and Tong 1997). McGue et al. (1993: B243) found evidence for genetic influence in a sample of Danish twins: heritability of life span in the population is estimated between approximately 20% and 35%. They believe that environmental factors,

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especially non-shared ones, have a significant effect on the length of life. Herskind et al. (1996: 322) estimated that the heritability of longevity among the Danish twins was 26% for males and 23% for females. All these figures imply that longevity is only moderately heritable (Carey and Judge 2001:23). Time is needed to demonstrate the role(s) of different factors in affecting human longevity. We are at the stage of gathering information and analyzing any possible relationship between longevity and other factors. Examining longevity within a family and providing more detailed family information on longevity are part of the research on determinants of healthy longevity in general.

This chapter uses a valuable set of data to discuss longevity status among consanguines of the oldest-old Han Chinese. More specifically, this chapter will descriptively analyze the longevity status between two generations (parents and children) and compare the status within one generation. 80+ is a critical age for this study. We tried to identify the proportion of different consanguines who lived to that age and to examine mortality patterns among those who have already died. Very basic statistical analyses will be used to evaluate the relationship of longevity among consanguines. Consanguines in this study include father, mother, brothers, and sisters.[1] The goal of this study is to paint a picture of the history of family longevity in the population, to show patterns of longevity among consanguines, and to identify some relationships in terms of longevity among those family members.

2. Data

Data for this study are taken from the first wave (baseline) of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) conducted in China in 1998. A general introduction of the CLHLS data sets is presented in Chapter 13 of this book and thus is not repeated here. Although the survey was not designed specifically to study the familial transmission of longevity, we are able to identify relationships among individuals within a family through a few questions asked in the survey. Interviewees were asked the vital status of their parents (alive or dead), age at death if a parent was deceased, and information regarding their sib-set (age, sex, living or deceased, and birth order among the sib-set). Birth order among interviewed elderly was also asked in the survey. This information is crucial for the analysis presented in this chapter.

Regarding the number of families involved, since 8805 interviewees aged 80–105 were included, it means that characteristics of 8805 families (including 8805 mothers, 8805

[1] The Chinese Han kinship classification system is different from that of many western systems (e.g., the US system). Generation, relative age, gender (including gender of linking relatives), lineality versus collaterality, consanguineal versus affinal kin, and side of family are criterion to classify consanguines into different kin groups. Brothers and sisters are one example of the difference. In the US kinship system, two sibling kinterms (brother and sister) are used for four sibling kintypes (older/younger brothers, older/younger sister). In the Chinese Han kinship system, four kinterms are used for the four kintypes: "Xiong" for older brother(s), "Di" for younger brother(s), "Jie" for older sister(s), and "Mei" for younger sister(s). When one has more than one older or younger sibling, an ordinal number is used to differentiate them, e.g., 1st older sister or 3rd younger brother.

fathers, and numerous siblings related to interviewed persons) can be used for this longevity status study. While the numbers of elder fathers and mothers should equal 8805, respectively, numbers of elder siblings will be greater than 8805, depending on the fertility level of their parents. When the survey was carried out, the elderly interviewed were more than 80 years old, and the siblings of the interviewees would be older or younger than 80 years old. These characteristics are important for interpreting different distributions of longevity among consanguines in this study.

Several criteria were used for data selection: clear generational relationship (between two generations and within one generation), age (at death or at survey time, if surviving), and gender of each individual within a family. We knew the birth year of the elderly interviewed, but we were not able to identify the year of birth of their parents since most of the parents were dead at the time of survey, and the survey asked only their age at death. Since the focus of this study is longevity status, which is closely related to age (i.e., years that the individual lived), but not the calendar year of birth or death, we will not be concerned about the exact years of birth and death of the parents and siblings. Table 1 summarizes the characteristics of the data for this study. Because we are analyzing longevity status among the consanguines by the proportion of parents and children who lived 80+ years by birth order, and by mortality among parents and children, we need data with different criteria for different types of analyses. For example, when analyzing the proportion of deceased parents and siblings, we need only the reported vital status; when analyzing mortality patterns by age, we need reported age at death. The more detailed information required regarding parents or siblings of the elderly interviewed in the survey, the greater the chance that data will be missing. Reported birth order, living status, and age at death, however, are generally the most important factors we consider for the analysis.

One characteristic of these data should be kept in mind: the data are not about a population whose lives have ended. Because some of the family members are still alive, the analysis of longevity status among this population is cross-sectional in nature.

Table 1. Characteristics of data for this study.

Type of individuals	Total no. (1)	No. of individuals qualified for this study (2)	Reasons for the discrepancy [(1)–(2)]
Elderly interviewed	8805	8805	—
Father of the elderly	8805	8740	Missing value of reported age at death
Mother of the elderly	8805	8766	Missing value of reported age at death
Siblings of the elderly	33,101	33,101	—

Table 2. Number and percentage of parents (out of 8805 families) with information on age and living status.

	With age		With vital status	
Type	**No.**	**%**	**No.**	**%**
Mothers	5707	64.82	8766	99.56
Fathers	5176	58.78	8740	99.26
Both parents	4781	54.30	8729	99.14

3. Results

3.1. LONGEVITY BETWEEN TWO GENERATIONS

Two generations are considered: elderly interviewed in the survey (the children generation) and parents of the elderly (the parental generation). Data for this section should include a clear parent and children relationship, living status (alive or dead), and the number of individuals who lived to 80 years in each category. Among the 8805 elderly interviewed (aged 80–105), 99.6% and 99.3% reported the survival status of their mothers and fathers; 65% and 59% reported the age at death of their mothers and fathers (Table 16.2). The missing cases of survival status and age at death of mothers and fathers do not affect this part of our analysis, since we are interested in the proportion of parents who lived 80+ years. Those interviewees without information on their parents' age at death are among those whose parents died at younger ages, since the elderly usually are able to remember ages at death of their parents who lived to age 80+.[2] For convenience, we used 8805 as the total number of fathers and of mothers for calculation purposes, because each elderly interviewed has one father and one mother. Of 8805 mothers and fathers of the elderly, 21.3% of the mothers and 11.3% of the fathers lived 80+ years (Table 16.3, column 1). Although in 31.8% of the sample neither parent lived 80+ years, 4.3% of the interviewees had parents who both lived to 80 years. Considering the birth years of the parents (more than 100 years ago) and comparing this percentage with the general surviving probability in 1929–1931 and 1945–1949, the proportion of the parents who are 80+ years in this group of the oldest-old interviewees is relatively high.[3]

Columns 2 and 3 in Table 3 present the percentage of children (sons and daughters) who lived 80+ years. Among all the sons that were birthed by mothers who lived 80+ years, 37.5% lived 80+ years; and among all daughters birthed by mothers who lived 80+ years, 49.5% lived 80+ years. Out of the children of fathers who lived 80+ years, 41.7% of the sons and 47.7% of the daughters also lived 80+ years. For families in which neither parent lived

[2] Longevity is an ideal for most Chinese; families with long-lived parents are very proud of this achievement. The funeral of an elder who lived to 60+ and died without suffering from disease is called *Xi-sang* (a happy funeral) (e.g., Zhang, 2000: 298).

[3] According to Qiao (1945: 106), the probability of a birth cohort surviving to age 80 and above is 0.076 at the mortality level in 1929–1931, and according to Hou (1993: 33–41), the probability is 0.016 at the mortality level in 1945–1949.

Table 3. Number and percentage of parents and children reaching or not reaching 80+ years.

Types by living status of parents	(1) Parents		(2) Sons living to 80+ years		(3) Daughters living to 80+ years	
	No.	%	No.	%	No.	%
Mother lived 80+ years	1867	21.20	1586	37.53	1904	49.52
Father lived 80+ years	994	11.29	997	41.70	932	47.72
Both parents lived 80+ years	379	4.30	434	44.06	373	47.94
Neither parent lived 80+ years	2803	31.83	2462	37.65	2633	46.93

Note: (1) The number in column (1) is calculated by dividing the number of parents who reached 80+ years in different types of families by the total number of parents (8805). (2) The numbers in column (2) represent information of parents as well as sons' living status (to 80+ years) by different types of parent families (mother, father, or both parents). It is calculated by dividing the number of sons who lived 80+ years by the total number of sons in different types of parent families. (3) Numbers in column (3) represent information of parents' as well as daughters' living status (to 80+ years) by different types of parent families (mother, father, or both parents). It is calculated by dividing the number of daughters who lived 80+ years by the total number of daughters in different types of parent families.

80+ years, 37.7% sons and 47.0% daughters lived 80+ years.[4] The percentage increases slightly for families in which both parents lived 80+ years (44.1% for sons and 47.9% for daughters). The percentage of children who lived 80+ years varies with the longevity status of their parents, but that of daughters is higher than that of sons in different calculations.

It should be noted that the classification of parents by their longevity status in Table 3 is mutually exclusive or independent. Data are sorted and calculated for each category independently; the actual percentage of children living 80+ years may be higher since there are children still alive and younger than 80 years old at the time of the survey.

Correlation analysis shows that parental longevity statuses are associated with children's longevity, and the effects are statistically significant (Table 4). When mothers or fathers lived 80+ years, their children are also more likely to live 80+ years. Examining longevity status of parents and children by gender separately, however, it seems that when a mother lives 80+ years, her daughters, but not sons, have a tendency to live 80+ years; when a father lives 80+ years, his sons but not daughters have a tendency to live 80+ years.

3.2. LONGEVITY AND BIRTH ORDER

Siblings of the elderly interviewed and the elderly themselves are the focus of this analysis of reported birth orders. In the survey, the elderly were asked about the number of their

[4] A further study can explore the age to which these parents lived and its relationship with the ages that their children reached.

Table 4. Correlation of surviving or not surviving to age 80+ between parents and children.

		X^2	df	*p*-Values
Father	Son	14.31	1	0.001
	Daughter	0.192	1	0.3
	Son and daughter	4.979	1	0.0283
Mother	Son	0.02	1	0.3
	Daughter	5.316	1	0.0218
	Son and daughter	3.4	1	0.0317

biological siblings (including those who have died) and the birth orders of the siblings. There are cases in which interviewees omitted their siblings' age at death or the age of those who are still alive, thus we have to rely on the reported birth order of siblings instead of calculating the order by the reported age. We assumed that the elderly interviewed are capable of identifying the exact birth orders of his or her siblings because these individuals are their very close and important family members.[5]

Table 5 describes the birth order of siblings of the elder (or aged) generation and its relationship to the longevity of elders. A total of 33,101 individuals (the elderly interviewed and his or her siblings) have complete birth order information (though not limited to those 80+ years old). Of them, 42.4% (14,046) lived 80+ years (Table 16.5, column 2). In each birth order, the percentage of individuals who lived 80+ years varies. In the lower birth orders, however, more individuals lived 80+ years. If we evaluate the percentage by the number of individuals in the 80+ years category in each birth order, divided by the total number of siblings in all birth orders, we find that the percentage declines as birth order increases (Table 16.5, column 3). The lower the birth order, the more individuals live 80+ years. If we use individuals who are 80+ years old as the denominator and calculate the ratio, the result still shows that lower birth order results in a higher percentage of individuals who were 80+ years old (Table 16.5, column 4). Fewer individuals who place higher in birth order reached 80+ years old than did those who place lower in birth order. Among those who lived 80+ years, 76% were in first to third birth orders. If we add individuals in the fourth orders, the percentage increases to 88%. Or, most 80+ years old elderly in the survey (the elderly interviewed and their siblings) are the first to fourth born in their family.

[5] Child mortality was high in China during the period of our subjects' childhood. This may affect the retrospective reports of the elderly interviewed and thus our analysis on birth order, especially when siblings were older than the elderly interviewed and died at a very young age, because the elderly would be too young to remember the events. Since birth orders (called "Pai Hang") are not named by the elderly interviewed, however, but by their parents, the birth order is determined after each birth and, therefore, is not changed if a death occurs. Furthermore, the events of death might occur to a child in any birth order, and thus can be treated as a random factor affecting all birth orders. We are interested in the proportion but not the absolute numbers that lived 80+ years, thus our analysis of birth order and longevity should not be substantially affected by this factor.

Table 5. Distribution of elderly by birth order and longevity status.

Birth order	**(1) No. of individuals**	**(2) % of individuals aged 80+ with a birth order among persons with whatever ages and the same birth order, in the baseline data set**	**(3) % of individuals aged 80+ with a birth order among all persons with whatever ages and birth orders, in the baseline data set**	**(4) % of individuals aged 80+ with a birth order among persons aged 80+ with whatever birth orders, in the baseline data set**
1	8278	55.98	14.00	32.99
2	7482	48.02	10.85	25.58
3	6202	40.04	7.50	17.68
4	4587	34.92	4.84	11.41
5	2947	29.59	2.63	6.21
6	1721	24.99	1.30	3.06
7	942	25.27	0.72	1.69
8	486	19.34	0.28	0.67
9	220	19.09	0.13	0.30
10	117	25.64	0.09	0.21
11	57	17.54	0.03	0.07
12	30	40.00	0.04	0.09
13+	32	18.75	0.02	0.04
Total	33,101	42.43	—	100.00

Note: (1) % in column (2) = number of individuals aged 80+ years old in a birth order/total number of people in the birth order (including those who did not and those who have not yet reached 80+ years). (2) % in column (3) = number of individuals aged 80+ years old in a birth order / total number of people in all birth orders (i.e., 33,101; including those who did not and those who have not yet reached 80+ years). (3) % in column (4) = number of individuals aged 80+ years old in a birth order/total number of people aged 80+ years old in all birth orders (14,046, only those 80+ years old).

It is possible that individuals in higher birth orders are still alive and have not reached 80+ years yet. But this chance may change the pattern of longevity by birth order only a little because of the small percentage of siblings still alive and the higher mortality rate among the elderly (60+ years old).

4. Discussion

This study analyzes the possible relationships among consanguines' longevity, based on data collected from the oldest-old aged 80+ in different generations, kin types, and birth orders.

In this sample it is found that the larger the proportion within a family reaching age 80+, the greater the familial transmission of longevity. The different percentages of those who reached 80+ years old in different generations indicate that younger generations live longer than the older generation. By the standard of life expectancy in the years in which those parents lived, however, the life span of the oldest-old interviewees' parents is longer than that of the average in the parents' own generation. Our data show that parental longevity affects children's length of life.

There is also a gender difference in longevity. Mortality among different types of male family members is higher than that of female members. Among those who lived 80+ years, the percentage of daughters is higher than that of sons in families with different parental longevity statuses.

Birth orders among siblings may also affect an individual's longevity. Data show that those lower in birth order have a greater chance of reaching 80 years old. More studies are needed to further investigate and explore the causes of this pattern. If the negative relationship between birth order and longevity does exist, we may explain the improvement of life expectancy in a way associated with fertility. That is, in addition to developments in medical technology and increases in living standards, low fertility puts most individuals in a much lower birth order than that of those in a population with high fertility. This may contribute to the increasing life expectancy.

Using a valuable set of data about the oldest-old Han Chinese, this chapter analyzes longevity statuses among consanguines of the interviewees and draws some general conclusions based on the analysis. Data for this research cover most Han Chinese residential areas; thus, the findings explain a general trend in longevity among a population covering large geographical areas. This study improves our knowledge of the association of longevity among Chinese consanguines. We understand that there are limitations to this study because of the nature of the data and the descriptive feature of the analysis. Further study could evaluate the proportion and relationships in longevity by more sophisticated statistical analyses, especially by information collected through following the interviewees until they die. A complete family life history would be more useful to identify a familial relationship in longevity statistics.

Although the data show a tendency for many children of long-living parents to live 80+ years, this study is not able to determine whether this is a genetic factor, familial environmental factor, or social factor. Many factors may affect human longevity, and scientists from different fields are working hard to unveil the myth of longevity from different aspects. By progressively adding new knowledge to the existing information on longevity, we hope to understand and improve human longevity in the near future.

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Part IV

Community Effects on Healthy Aging

YVES CARRIÈRE

Introduction

The age structure of a population can have a significant impact on a society. Of course, demography is not the only aspect that must be considered, but it is one factor that cannot be omitted. Its importance can be open to debate, but the fact that it does shape past, present, and future societies is hard to question. What do we know about the age structure of tomorrow's industrialized countries? We can assert with certainty that they will have older age structures. The proportion of elderly persons will increase as they will likely account for at least one out of five individuals; in some countries it will be more than one in four. How will this affect the overall picture of future communities and societies? How can we adjust to current societies to be better prepared for the future? How much vitality will older communities have? What will be the effect on economic growth? Will public pensions and health care systems be overwhelmed by this aging population structure? These are only some of the questions that can be raised.

Opinions differ greatly on the consequences of population aging for tomorrow's societies. Part of the reason for this relates to views on the state of the economy in the future and how we will address the economic challenges of an aging population over the coming years. One very important aspect to consider in evaluating this includes looking at the characteristics of future elderly populations. These characteristics will reflect the life course of baby boomers and successive younger generations. The life course and the institutions that influence this life course will determine our characteristics as an older person. Comparing the life courses of today's elderly with those of tomorrow's elderly makes us realize that extrapolating the aging experiences of today's elderly to future cohorts is a particularly hazardous endeavor.

Comparing yesterday's elderly to today's elderly makes it clear that one of the major differences is in health status. Older persons in 2005 are very different from those who were older 40, 20 or even 10 years ago. How different will tomorrow's elderly be from today's? Once they reach the age of 65, how many more years will they be expected to live? Will these added years of life also be added years of health? When disabled, who will provide assistance in daily life? Will older persons benefit from the presence of a spouse or a child? Will reaching the age of 90 in 2050 be as likely as reaching the age of 75 in 2000? If this is the case, will public pension and health care systems be sustainable? And

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if they do live to be 90 and over, can we expect these oldest-old to be active members of society?

The answers to these questions impact the direction social policy should take in responding to the challenges of an aging population. The chapters in this section address some of these important issues. Although one may not necessarily agree with the solutions that are sometimes proposed, they will certainly assist in nurturing debates in countries coping with a rapidly aging population.

Among the characteristics that will of tomorrow's elderly population, we know that they will reach old age with fewer surviving children than the current cohorts of elderly. Many of them will have gone through a divorce and they will be better educated. Carrière et al. (Chapter 17) have looked at the potential effect of such changes on the characteristics of tomorrow's disabled elderly Canadians on the use of formal assistance (assistance provided by other than family, friends, and neighbors). Responding to the needs of the elderly requiring assistance in their daily life will require a substantial increase in public and private agencies providing home care services.

The debate over pay-as-you-go public pensions has been ongoing for a number of years. Some have stated that these systems are unsustainable in the longer term because of population aging. Countries with no funding provision for their public pension systems are of course experiencing more problems than those with partial funding provision. Also, countries where age of full entitlement to benefits is lower will be faced with greater difficulties than those where the age is higher. Canada has a partially funded system and age of entitlement fixed at 65 since the late 1960s. Canada has taken steps to assure the sustainability of its public pension system for at least the next 60 years. But sustainability is based on a set of assumptions on a number of factors including mortality. What would happen if the increase in life expectancy is such that the 2000 cohort reaches 100 years of age on average? What would be the impact of this scenario on the proportion of elderly persons? How would we then be able to finance a universal health care system? Légaré et al. (Chapter 18) examine the implications of such a scenario for the province of Québec with a universal public health care system and propose that we should look at how some countries are financing their public pension systems to better prepare for the unexpected.

Focusing on the impact of population aging on the health care system, Rochon (Chapter 20) discusses the main challenges that arise with increasing longevity. By concentrating on the baby boomers, she discusses problems in the financing of long term care services based on existing systems and demographic, economic, and health trends. Many issues are raised including what types of services will be needed and how will they be financed. By looking at the situation in the province of Québec, Rochon considers important socioeconomic characteristics of the baby boomers and macro level adjustments that will likely occur and temper the impact of population aging.

When we think about the oldest-old, we tend to visualize frail or disabled persons in need of assistance in their daily lives. We don't consider that a significant number of the oldest-old could be aging successfully. Andrews et al. present exploratory predictors of successful aging among a sample of elderly Australians (Chapter 19). If greater longevity is characterized by disablement and disengagement from society, how will we an increasing proportion of our populations participate? While the results are from a fairly small sample of oldest-old, they point to the benefit of developing interventions that maintain personal sense of worth and contribution to family, community and society.

Because the four chapters presented in this section address important issues related to community effects of healthy aging and increasing longevity, they should foster more discussion among decision makers interested in improving the quality of life of the population in the context of population aging.

CHAPTER 17. SOCIO-DEMOGRAPHIC FACTORS ASSOCIATED WITH THE USE OF FORMAL AND INFORMAL SUPPORT NETWORKS AMONG ELDERLY CANADIANS

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1. Introduction

The last two decades have seen population aging become one of the major reasons put forward when discussing the need to adjust social policies to a changing society where public expenditures are expected to increase substantially. Of course, public retirement schemes and health care services are the two programs that are more likely to be targeted by these discussions. This study focuses on the possible effects of changing demographic trends on the use of home care services by examining characteristics associated with the use of different sources of these services for the elderly population.

When projecting the future aging of a population, we concentrate mostly on the proportion of older persons and discuss its relative magnitude. However, focus on the proportion of older persons, or the age structure ignores important changes at the family level. Because of past fertility, parents of the baby boomers have many children and when they are in need of assistance in performing their daily activities, they can count on spouses and children. Baby boomers also have brothers and sisters who may be in a position to give them assistance in old age. However, their potential support network of children is limited as this generation began the experience of fertility below replacement level. This generation of children of

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the baby boomers will, in turn, have very few brothers and sisters in addition to having fewer children of their own.

These demographic trends are particularly important knowing that 70–80% of care provided to disabled elderly persons living in private households is delivered by informal caregivers (Hébert et al. 2001). In fact, according to Keating et al. (1994), families in Canada are expected to be the basic unit of care for older people, especially spouses and children. More precisely, it is adult daughters who assume the greater amount of caregiving responsibility toward elderly parents (Guberman and Maheu 2000; Keating et al. 1994).

Keeping in mind these changes affecting the family structure within an aging population, the objective of this article is to identify factors associated with the use of different networks (informal, formal, or both) among the disabled elderly population living in private households. Even though their numbers and proportion are not as important now as they will be in the future, within today's disabled older population there are some who have no children and who are not living with a spouse. Examining people in this situation today, we can begin to draw preliminary conclusions as to the possible effect of the changing family structure associated with an aging population in the future.

1.1. UTILIZATION OF FORMAL AND INFORMAL SUPPORT NETWORK

Although there are many studies on the use of health care services, few have looked at the use of formal and informal sources of assistance for home care services among older persons. This distinction among different types of health services is important because the determinants of service utilization can be quite different for different types of service (Cafferata 1987; Eve 1988; Wan 1987; Wolinsky and Johnson 1991).

This is particularly the case for home care services which can be viewed as more social than medical and can thus be provided by the informal support network. These services are not primarily intended to cure an individual from a chronic or acute condition, but to provide assistance in daily life. Wister and Dykstra (2000) found that formal and informal care providers do not offer the same types of care. Care needs that are routine, predictable, and require some level of technical expertise may be better handled by formal helpers, while tasks that require proximity and flexibility can be better performed by informal helpers. Having informal assistance readily available will significantly reduce the use of formal home care services (Greene 1983; Soldo and Manton 1985; Tennstedt et al. 1990; Wan 1987). It is not surprising to find that living arrangement has a significant impact on the use of the formal support network (Béland 1984, 1992; Choi 1994; Grabbe et al. 1995; Greene 1983; Tennstedt et al. 1990; Wan 1987). For example, Grabbe et al. (1995) found that those living alone are more inclined to use formal services. Choi (1994) found that the childless elderly and the elderly living apart from their children were more likely to use social services than were the elderly living with their children.

American studies have shown that older age is one of the factors most associated with more utilization of formal home care services (Evashwick et al. 1984; Grabbe et al. 1995; Wan and Odel 1981). Gender was also shown to have an effect on the use of formal home care services; studies found that women tend to use more of these services (Evashwick et al. 1984; Grabbe et al. 1995), although this was not found by Wan and Odel (1981). As expected, functional limitation is the best predictor of formal home care services utilization.

Formal and informal support networks should not be seen as competitors or substitutes for one another. Unless there is a total breakdown of the informal network or the absence of such a network, formal services are used in conjunction with informal services. In a review of the literature, Penning and Keating (2000) conclude that having informal caregivers did not appear to reduce or stop involvement when formal caregiving is available. It is what Keating et al. (1997) call a "caring partnership" and can be depicted in what we will call use of "mixed services". In what follows, we not only look at factors associated with the use of formal and informal services, but also at those associated with this third category where disabled elders receive assistance from both types of networks.

2. Data and Methods

The data used for this study come from Statistics Canada's General Social Survey, Cycle 11: Social and Community Support. Two of the survey's objectives are to learn about the types of assistance Canadians provide or receive, as well as to gain a better understanding of the dynamics that links a person's social network and the assistance this person gives and/or receives. To this end, the questionnaire was designed to collect detailed information on the type of assistance provided or received for the following activities: meal preparation, house cleaning, laundry and sewing, house maintenance and outside work, grocery shopping, transportation, banking and bill paying, personal care (bathing, toileting, care of toenails/fingernails, brushing teeth, shampooing and hair care or dressing) as well as moral or emotional support. As our underlying focus of interest is the effect of the changing socio-demographic characteristics on the demand for home care services, we concentrated on four activities that are associated with those services: everyday housework, shopping for groceries, meal preparation, and personal care. With the information collected in the survey, we are also able to identify the reasons behind the need for assistance: temporary or long-term health or physical limitations, temporary difficult times, task sharing in the household, time constraints, etc. We are here focusing on assistance received due to long-term health problems.

The target population for the GSS was all Canadians 15 years of age and over living in private households.[1] Data were collected using Computer Assisted Telephone Interviewing (CATI), systematically excluding households without telephones.[2] In total, the sample consists of 12,756 respondents. The response rate was 85.3%. For the purposes of this study, we examine information on people aged 65 and older who received assistance because of

[1] Full-time residents of institutions as well as residents of the Yukon and Northwest Territories are excluded. Since we are interested in home care services, exclusion of institutionalized individuals is not a major concern in our study. However, one can define institutionalized individuals as using formal services. This would in turn cause biases in our results. This issue will be addressed in our discussion.

[2] Statistics Canada estimates that less than 2% of the target population resides in this type of household and that their characteristics are not different enough from those of the rest of the target population to have an impact on the estimates. Survey estimates have been adjusted (i.e., weighted) to account for persons without telephones.

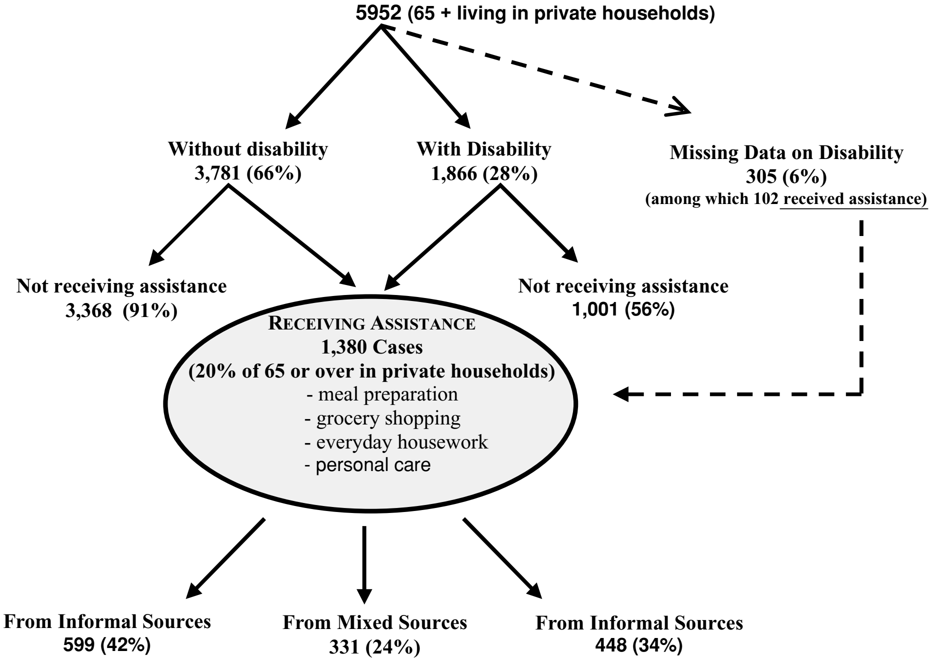

Figure 1. Distribution of the elderly population living in private households within the 1996 General Social Survey according disability, physical dependence, and source of assistance.[4]

long-term health problems for at least one of the four activities mentioned above. Figure 1 shows that out of the 5952 respondents aged 65 and over, 1866 (28%—percentages are weighted while numbers are unweighted) could be identified has being disabled. Disability can be related to problems of vision, hearing, speech, mobility, dexterity, or cognition. Out of those disabled persons, 865 (44%) needed assistance in performing one of the four activities mentioned above. Among those without disability, 9% needed assistance because of a long-term health problem. In total, 1380 older persons (20% of the elderly population living in private households) received assistance in performing at least one of the activities considered in this study.[3] Because of missing data on some of the independent variables, the sample utilized was reduced to 1143 cases.

[3] Other respondents may have expressed a need for assistance, but if they did not provide information on the sources of the assistance received, they will be excluded from our subpopulation. Also, although other elderly persons may have expressed a need for assistance, they may not have received any assistance. Again these individuals will be excluded from our subpopulation. The figure of 20% is therefore underestimating the percentage of elderly persons living in private households who need assistance to perform everyday activities.

[4] Percentages between parentheses are weighted. Numbers are unweighted. Among the 1380 cases receiving assistance, 2 had missing data on sources of assistance.

Our dependent variable is the source of information on assistance provided by informal and/or formal networks. By informal network, we mean help given by the spouse, children, brothers or sisters, other members of the family, friends, and neighbors. Alternatively, the formal network includes paid employees, government or non-government offices, and volunteers. Thus, our dependent variable has three categories: informal network only, formal network only, and a mix of both informal and formal networks. No distinction was made for the level of assistance networks actually provided respondents.

Eight independent variables are included in the analysis: age, gender, living arrangement, number of surviving children, number of surviving siblings, level of schooling, and a composite measure of functional health. Age groups were subdivided into 5-year age groups from 65–69 to 85 years and over. Three categories of living arrangements were created: living alone, living with a spouse (including those living with a spouse and other persons), living with others (either family or non-family members, excluding the spouse). Level of schooling was also divided into three categories ranging from less than secondary school to at least some college education (including technical school). Income was dichotomized into those receiving the Guaranteed Income Supplement (GIS) and those not receiving this supplement. Those receiving GIS can be considered less fortunate since it is provided to those aged 65 years and over with an annual income of less than approximately $12,500. Finally, health status is measured with the Health Utility Index (HUI) composite indicator. This is based on the Comprehensive Health Status Measurements System (CHSMS) and it takes into account both quantitative and qualitative aspects of health (Torrance et al. 1996). First, it includes information on the functional health of an individual using the following attributes: vision, hearing, speech, mobility, dexterity, cognition, emotion, and pain and discomfort. The HUI is a single numerical value ranging from 0 to 1 which takes into consideration all possible combinations of levels of the eight self-reported health attributes, using preference weights by health states based on previous research. Instead of using this continuous variable varying between 0 and 1, we have dichotomized this variable into those with a HUI equal or greater to 0.66 (the average for the group receiving assistance) and those with a HUI lower than 0.66. The data file also has missing values on the HUI for a number of respondents. These were included with those who had a HUI less than 0.66. Bivariate analysis showed similar needs for assistance for these two groups, thus providing some indication of their similarity in functional health status.

We hypothesize that characteristics related to the family environment of elderly people in need of assistance will be strongly associated with the use of specific sources of assistance. For example, those living alone, with no surviving children and no surviving siblings should have a higher probability of using only formal assistance. Conversely, those with an extended family network should rely more heavily on their informal network. Because of this, we hypothesize that the shrinking family network should, other things being equal, increase the demand for formal home care services.

The model used to derive estimated probabilities of receiving formal, informal, or mixed assistance is a multinomial logistic regression, as the dependent variable has three categories. By using this type of regression procedure, the estimated probabilities of receiving a particular type of help are computed at the same time. Thus, the model takes into account competing risks; the probability of receiving formal assistance, for example, is not independent of using informal care. For better understanding of results, probabilities were computed using the estimated parameters for each category of the dependent variable. These probabilities are easier to interpret than the odds ratios in a multinomial logistic regression.

3. Results

Before looking at the results specific to the disabled older Canadian population, we will first compare respondents who received assistance to those who did not receive any. As expected, Table 1 shows that, on average, the former are approximately 5 years older than the latter (77.4 years compared to 72.6 years). It also shows that the HUI of those receiving assistance is 30% lower, which illustrates that they are in far worse functional health. Considering the difference between the average age of both groups, it is not surprising that we find a higher percentage of women among those needing assistance. Also, those who receive assistance are more prone to live alone or with someone other than their spouse, to receive the GIS and have no surviving siblings.

When focusing on the older population receiving assistance, Table 2 shows, using bivariate analysis, how each of our independent variables can be associated with a specific source of assistance. First, we note that 42% received assistance only from their informal network, 34% from the formal network, and the remaining 24% received assistance from both networks. It is among the youngest group (65–69) that we find the highest proportion (60%) of respondents receiving assistance only from their informal network. Among all the other characteristics shown in Table 2, the only group comparable to the 65–69 age group is of those living with someone other than their spouse. Among the latter, 64% received assistance exclusively from their informal network. Conversely, those with no surviving children have the greatest proportion (47%) using only the formal network. Similarly, 45% of those with better functional health status (HUI ≥ 0.66) received assistance only from the formal network.

We used a multinomial logistic regression in order to control for other variables and to better understand the effect of each independent variable on the use of different sources of assistance among the older population. This analysis shows that living arrangement, health status, age, education, and number of surviving children are strongly associated with the source of assistance. Table 3 shows the parameters (β) and the odds ratios (e^{β}) of each category of our independent variables for informal versus mixed, formal versus mixed, and formal versus informal network. When the ratio is greater than 1, there is a greater chance of using the source of assistance that is being compared, but only in relation to the reference category of the independent variable. For example, those with no surviving children, compared to those with at least two surviving children, have twice (1.95) as many chances of using their informal network rather than using both networks (mixed). When the ratio is less than 1, the interpretation is reversed. For example, those living alone, compared to those living with their spouse, have half (0.45) the chance of using their informal network rather than using both networks. The interpretation of the odds ratios in a multinomial logistic regression is not particularly straightforward because of the number of categories among the dependent variable. To better understand the results of this model, we have computed the probabilities using the parameters of the regression shown in Table 3.

Table 1. Characteristics of the Canadian population aged 65 and over living in private households according to whether or not they receive assistance to perform daily activities (preparing meals, grocery shopping, everyday housework, and personal care).

	No assistance	With assistance	Total
Sex			
Males	45.8	54.2	33.0
Females	67.0	43.3	56.7
Age group			
65–69	36.8	15.5	32.6
70–74	30.2	23.3	28.9
75–79	19.2	23.8	20.1
80–84	9.7	18.9	11.5
85 and over	4.0	18.5	6.9
Average age	72.6	77.4	73.5
Living arrangements			
Living alone	28.7	41.0	31.1
Living with spouse	62.0	41.0	57.9
Living with others	9.2	18.0	10.9
Education			
No or elem. school	22.7	30.6	24.1
Secondary school	43.6	43.9	43.6
Post-sec. school	33.7	25.6	32.2
Guaranteed income supplement			
Yes	22.7	32.9	24.7
No	77.3	67.1	75.3
Children			
0	11.3	13.8	11.8
1	10.7	13.5	11.3
2+	78.0	72.7	76.9
Siblings			
0	14.9	22.4	16.3
1	20.4	19.0	20.1
2+	64.7	58.6	63.5
Health Status			
Health Utility Index < 0.66[a]	19.0	59.0	26.8
Health Utility Index ≥ 0.66	81.0	41.0	73.2
Health Utility Index (average)	0.87	0.66	0.83

Source: Statistics Canada, General Social Survey, 1996.

[a] We have grouped together those with a HUI less than 0.66 and those who did not answer all the questions needed to compute this index. Bivariate analysis showed similar needs for assistance for these two groups, giving some indication of their similarity regarding their functional health status.

Table 2. Percent distribution of the Canadian population aged 65 and over living in private households and receiving assistance to perform daily activities according to the source of assistance.

	Informal only	Formal only	Mixed	Total
Total	42.1	34.1	23.8	100.0
Age***				
65–69	60.2	26.5	13.3[a]	100.0
70–74	39.9	41.8	18.4	100.0
75–79	39.4	34.8	25.8	100.0
80–84	33.6	37.9	28.5	100.0
85+	42.0	25.9	32.1	100.0
Sex**				
Men	47.4	34.3	18.3	100.0
Women	39.5	34.0	26.5	100.0
Living arrangements***				
Living alone	29.3	40.9	29.8	100.0
Living with spouse	45.2	36.0	18.8	100.0
Living with others	64.1	14.3[a]	21.6[a]	100.0
Education***				
No or elem. school	54.9	23.9	21.2	100.0
Secondary school	40.6	37.9	21.4	100.0
Post-sec. school	34.0	42.9	23.1	100.0
GIS**				
Yes	44.7	27.7	27.5	100.0
No	43.0	37.2	19.8	100.0
Children**				
0	31.3	46.6	22.2[a]	100.0
1	41.9	30.4	27.7[a]	100.0
2+	44.6	32.6	22.8	100.0
Siblings				
0	39.5	36.0	24.5	100.0
1	35.8	36.7	27.4	100.0
2+	46.1	32.4	21.5	100.0
Health Status***				
HUI < 0.66 or n.a.[b]	43.4	26.4	30.2	100.0
HUI ≥ 0.66	40.2	45.2	14.6	100.0

Source: Statistics Canada, General Social Survey, 1996.

** $p \leq 0.01$.

*** $p \leq 0.001$.

[a]High sampling variation associated with the estimate and should be interpreted with caution.

[b]Not available. We have grouped together those with a HUI less than 0.66 and those who did not answer all the questions needed to compute this index. Bivariate analysis showed similar needs for assistance for these two groups, giving some indication of their similarity regarding their functional health status.

Table 3. Parameters and computed odds ratios of the multinomial logistic regression model on the risk of using only formal assistance, only informal assistance or a mix of both.

	Informal/Mix		Formal/Mix		Formal/Informal	
	β	e^{β}	β	e^{β}	β	e^{β}
Intercept	1853	—	1396	—	−0.457	—
Age***						
65–69	—	Reference	—	Reference	—	Reference
70–74	−0.731	0.48*	0.275	1.32	1.005	2.73***
75–79	−0.911	0.40**	−0.126	0.88	0.785	2.19**
80–84	−1.312	0.27***	−0.193	0.83	1.119	3.06***
85+	−1.050	0.35**	−0.336	0.72	0.714	2.04*
Sex						
Women	−0.408	0.66	−0.193	0.83	0.216	1.24
Men	—	Reference	—	Reference	—	Reference
Living arrangements***						
Living alone	−0.809	0.45***	−0.539	0.580*	0.269	1.31
Living with spouse	—	Reference	—	Reference	—	Reference
Living with others	0.353	1.42	−0.897	0.41**	−1.251	0.29***
Education***						
No or elem. school	0.810	2.25**	−0.055	0.95	−0.866	0.42***
Secondary school	0.449	1.57	0.100	1.11	−0.350	0.71
Post-sec. school	—	Reference	—	Reference	—	Reference
GIS						
No	0.276	1.32	0.309	1.36	0.0337	1.03
Yes	—	Reference	—	Reference	—	Reference
Children**						
0	0.670	1.95*	1.186	3.28***	0.517	1.68*
1	0.055	1.06	−0.171	0.84	−0.226	0.80
2+	—	Reference	—	Reference	—	Reference
Siblings						
0	0.041	1.04	0.171	1.19	0.129	1.14
1	−0.571	0.57*	−0.210	0.81	0.361	1.43
2+	—	Reference	—	Reference	—	Reference
Health Status***						
HUI < 0.66 or n.a.	−0.531	0.59**	−1.223	0.29***	−0.692	0.50***
HUI ≥ 0.66	—	Reference	—	Reference	—	Reference

Source: Statistics Canada, General Social Survey, 1996.
*$p \leq 0.05$.
**$p \leq 0.01$.
***$p \leq 0.001$.

Table 4. Computed probabilities of using only formal assistance, only informal assistance, or a mix of both according to living arrangements, number of surviving children, age, and health status.

	No child		
Living alone	**Informal only (0.56)**	**Formal only (0.35)**	**Mixed (0.09)**
65–69			
HUI < 0.66 or n.a.	0.50	0.35	0.15
HUI ≥ 0.66	0.39	0.54	0.07
70–74			
HUI < 0.66 or n.a.	0.28	0.54	0.18
HUI ≥ 0.66	0.19	0.73	0.07
75–79			
HUI < 0.66 or n.a.	0.30	0.46	0.23
HUI ≥ 0.66	0.22	0.68	0.10
80–84			
HUI < 0.66 or n.a.	0.23	0.50	0.27
HUI ≥ 0.66	0.17	0.72	0.11
	2+ children		
65–69			
HUI < 0.66 or n.a.	0.50	0.21	0.30
HUI ≥ 0.66	0.46	0.38	0.16
70–74			
HUI < 0.66 or n.a.	0.30	0.34	0.37
HUI ≥ 0.66	0.25	0.57	0.18
75–79			
HUI < 0.66 or n.a.	0.29	0.27	0.44
HUI ≥ 0.66	0.27	0.49	0.24
80–84			
HUI < 0.66 or n.a.	0.22	0.28	0.49
HUI ≥ 0.66	0.21	0.52	0.27

The probabilities have been computed to show the effect of living arrangement, health status, age, and number of surviving children, while using the reference category for the other variables in our model (men, post-secondary education, receiving the GIS and at least two surviving siblings). These probabilities make it easier to understand the effect of the independent variables on each of the three types of assistance. Tables 4–6 show the probabilities for those living alone, those living with their spouse, and those living with someone other than their spouse, respectively.

We note that, all things being equal, the greatest probabilities of receiving assistance from only the formal network are for the respondents with no children, either living alone or with their spouse. Conversely, it is those living with someone other than their spouse, with or without any children, who have the greatest probabilities of receiving assistance only

Table 5. Computed probabilities of using only formal assistance, only informal assistance, or a mix of both according to living arrangements, number of surviving children, age, and health status.

	No child		
Living with spouse	**Informal only (0.56)**	**Formal only (0.35)**	**Mixed (0.09)**
65–69			
HUI < 0.66 or n.a.	0.60	0.32	0.08
HUI ≥ 0.66	0.47	0.50	0.04
70–74			
HUI < 0.66 or n.a.	0.37	0.53	0.10
HUI ≥ 0.66	0.25	0.71	0.04
75–79			
HUI < 0.66 or n.a.	0.40	0.47	0.14
HUI ≥ 0.66	0.28	0.66	0.06
80–84			
HUI < 0.66 or n.a.	0.32	0.52	0.16
HUI ≥ 0.66	0.22	0.71	0.07
	2+ children		
65–69			
HUI < 0.66 or n.a.	0.63	0.20	0.17
HUI ≥ 0.66	0.56	0.35	0.09
70–74			
HUI < 0.66 or n.a.	0.41	0.36	0.23
HUI ≥ 0.66	0.33	0.57	0.11
75–79			
HUI < 0.66 or n.a.	0.42	0.29	0.28
HUI ≥ 0.66	0.36	0.50	0.14
80–84			
HUI < 0.66 or n.a.	0.34	0.33	0.33
HUI ≥ 0.66	0.28	0.55	0.17

from the informal network. Although this result may not be surprising considering that living with others can be seen as a strategy to have easy access to informal assistance, it is still interesting to see that the majority are not using any formal assistance, especially at younger ages. At older ages, the formal network has a much greater probability of being involved, either alone or in conjunction with the informal network. Finally, we find the greatest probabilities of receiving assistance from a mix of formal and informal sources among respondents who live alone and have at least two surviving children.

The computed probabilities show other interesting results. Compared to those in better health, those with a lower HUI double their chances of receiving a mix of informal and formal assistance. For example, for respondents who live alone, have no surviving children and are in the 65–69 age group, the probability of receiving assistance from both

Table 6. Computed probabilities of using only formal assistance, only informal assistance, or a mix of both according to living arrangements, number of surviving children, age, and health status.

	No child		
Living with others	**Informal only (0.56)**	**Formal only (0.35)**	**Mixed (0.09)**
65–69			
HUI < 0.66 or n.a.	0.80	0.12	0.08
HUI ≥ 0.66	0.74	0.22	0.04
70–74			
HUI < 0.66 or n.a.	0.62	0.26	0.12
HUI ≥ 0.66	0.51	0.43	0.06
75–79			
HUI < 0.66 or n.a.	0.64	0.21	0.15
HUI ≥ 0.66	0.55	0.37	0.08
80–84			
HUI < 0.66 or n.a.	0.55	0.26	0.20
HUI ≥ 0.66	0.47	0.43	0.10
	2+ children		
65–69			
HUI < 0.66 or n.a.	0.78	0.07	0.15
HUI ≥ 0.66	0.77	0.14	0.09
70–74			
HUI < 0.66 or n.a.	0.61	0.15	0.24
HUI ≥ 0.66	0.58	0.29	0.13
75–79			
HUI < 0.66 or n.a.	0.60	0.12	0.28
HUI ≥ 0.66	0.60	0.24	0.16
80–84			
HUI < 0.66 or n.a.	0.51	0.14	0.35
HUI ≥ 0.66	0.51	0.28	0.21

Source: Statistics Canada, General Social Survey, 1996.

networks increases from 7% to 15% when they have a lower HUI compared to those with a higher HUI. This probability will again double if there are at least two surviving children, increasing from 15% to 30%. It is important to note that having no surviving children has very little effect on the probability of receiving only informal assistance when compared to those who have at least two surviving children. However, it does affect the demand for formal services by increasing by more than 40% the probability of receiving only formal assistance. For example, for the 65–69 age group with a higher functional health, those living alone without any surviving children will see their probability of receiving only formal assistance increased from 0.38 to 0.54 (a 42% increase compared to those who have at least two surviving children). Similarly, living with a spouse has very little effect on the probability of using only formal assistance compared to those living alone. Nevertheless, it does increase the probability of using only the informal network by roughly 20%, while lowering by about 50% the probability of using both the formal and informal networks. This transfer eases the pressure on formal services.

As can be seen in Tables 4–6, age has a significant impact on the computed probabilities. For example, the probability of using only informal support decreases by about 50% between the 65–69 and the 80–84 age groups. We notice that the most significant differences are among the 65–69 age group and all other age groups. Only for mixed sources do we observe a steady increase in the computed probabilities at each age group. As for the 85 and over age group, our results show that this group is quite similar to the 75–79 age group as far as using formal or informal networks only (probabilities not shown in Table 4). However, the oldest-old are very similar to the 80–84 age group when looking at the probability of receiving assistance from both networks.

Finally, among the other independent variables, having post-secondary education, compared to having less than 9 years of schooling, doubles the risk of using the formal network only compared to using the informal network only. The possible effect of this last result on the future demand for home care services provided by the formal network will be discussed in the next section.

4. Discussion and Conclusions

Contrary to most studies done in the past, we have limited our sample to those older individuals who received assistance. Many studies have looked at factors associated with the use of formal services, but among older population in general. Of course, health then becomes the main predictor of the use of formal services. Our starting point is a sample of older persons who already receive assistance because of long-term health problems. We are then interested in factors associated with the use of different sources of assistance once a need has been expressed and partially or totally answered. Since our focus is on the changing informal network, the discussion will emphasize the results pertaining to the effect of living arrangement and the number of surviving children on the source of assistance.

Before proceeding with the discussion, we want to acknowledge certain limits that need to be considered when interpreting the results. First, we have to remember that our sample is limited to the population living in private households. Although we are controlling for health status, there is a selection effect resulting from the exclusion of those living in nursing homes. Functional limitation is a factor strongly associated with institutionalization (Trottier et al. 2000), but other factors like the nature and extent of the informal network can be significant in making the decision to place an older adult in a nursing home. Moreover, even if there is the presence of an informal network, those within this network may be quite old themselves and be limited in the amount of assistance they can provide, increasing the probability of the oldest-old to be in a nursing home.

Regarding the informal network, although we were able to control for the number of surviving children and siblings, the data set did not include any information on their health status or their geographic proximity. This information could have a significant impact on their ability to provide assistance. For example, being assisted by children does not require simply having surviving children, but, among other factors, also requires that these children live close by.

Also, home care policies in Canada fall under provincial jurisdiction. Each province has its own policy, which affects use of formal and informal networks. Unlike medical services, home care services are not explicitly covered under the Canada Health Act. In fact, home care services fall under the *extended health care services* and not under the *insured health care services* of the Canada Health Act. The health aspects of home care are covered, but services like preparation of meals, grocery shopping, everyday housework, and personal care are excluded. Provinces have their own policies regarding these services, affecting the probability of using either the formal or informal network. Also, access to institutions varies between provinces affecting these probabilities. Limiting the entry into an institution will, other things being equal, increase the demand for services from both formal and informal networks. Conversely, higher rates of institutionalization will lower the demand for home care services. Thus, the results for Canada as a whole can hide important regional differences.

Finally, since the survey provides cross-sectional data, it can be hazardous to interpret the different categories of our dependent variable as a progression from formal or informal services to a mix of assistance from both networks. Longitudinal data would certainly add important information in this regard and help to better understand the dynamic process that exists between the different sources of assistance.

The bivariate table showed a significant relationship between all the independent variables, except number of siblings, and our dependent variable (source of assistance). However, the multivariate approach showed that gender, low income, and number of siblings are not significantly associated with a specific type of assistance. Like most studies in the past, we found that living arrangement is the best predictor of the source of assistance. When living with someone other than their spouse, disabled elders are more likely to use informal support. Also, compared to those living alone, living with a spouse increases the probability of receiving assistance only from the informal network, even though it does not decrease the probability of using only assistance from the formal network. On the other hand, the number of surviving children has very little effect on the probability of using assistance exclusively from the informal network. However, having at least two surviving children reduces the probability of receiving assistance only from the formal network and increases the probability of receiving assistance from mixed sources.

It is clear from our study that demographic trends will have an impact on the use of formal home care services. A decline in fertility affects the extent and the nature of our immediate social environment. With a total fertility rate well below replacement level, the baby boom generations will reach old age with fewer children to provide them with assistance when needed. In view of our results however, it seems that there are no significant differences between having one surviving child and having at least two. A decline in fertility accompanied by an increase in the proportion of women having no children should have a much stronger effect on the use of formal services compared to a decline in fertility mostly related to an important drop in the proportion of women having more than two children.

Among other demographic trends, we have to consider the possible impact of increasing divorce rates within the baby boom generations. Trends show that a greater proportion of these cohorts will enter old age as divorced individuals (Martel and Carrière, forthcoming) and may have an increased probability of living alone. This may in turn increase the need for formal home care services among those needing assistance. Moreover, relationships that end in divorce may distance parents from their children (Bornat et al. 1999; Bulcroft and Bulcroft 1991), making it more difficult to expect children to provide needed assistance in old age, especially for the older male population (Kaufman and Uhlenberg 1998; Shapiro and Lambert 1999).

Of course, other factors than those related to demographic trends can affect the demand for formal home care services in the future. For example, the level of schooling of the population has increased considerably over the last 30 years. The proportion of those who have less than secondary schooling will be fairly small when the baby boomers reach old age. Our results show that higher educational levels are associated with a greater probability of using the formal network among those needing assistance. This could very well be interpreted as a cultural effect. Within the cohorts under study, those with a low level of schooling may be more apprehensive in having the formal network involved in the provision of their home care services. They may also be less knowledgeable about the services provided by the formal network and the process involved to access these services. With the increasing level of schooling in the population, it is quite possible to see, all things being equal, an increase in the demand for formal home care services.

If factors such as lower fertility and the possible increase in the number and proportion of people living alone might increase the demand for formal home care services, other factors might partially compensate for it. For example, we saw that functional health is a major factor associated with the source of assistance. Those with a low functional health status have a greater probability of using both informal and formal assistance. The added pressure is then on both networks. When looking at these results, we have to remember that this study focuses on the population receiving assistance; it is not examining factors associated with a need for assistance. The factors mentioned above have the effect of increasing the demand for formal home care services once there is a need for assistance. Tomorrow's older population will have socio-economic and demographic characteristics that may very well increase the demand for home care services, but only for those in need of assistance. If it is true that, all things being equal, an increasing level of schooling may induce an increasing demand for formal services, it is also possible that this improvement in the overall educational level will raise the overall health of the older population. In this case, an improvement in the level of education will decrease the relative number of those in poor functional health, while at the same time decreasing the relative number of older people needing assistance. It would then be misleading to conclude that an increase in the educational level will automatically have the effect of increasing the demand for formal home care services.

As mentioned earlier, home care policies have a major impact on the use of formal and informal networks. Although demographic pressure can have an impact on these policies, they also respond to changing values among the population. For example, it is possible that an increasing need for independence and autonomy among tomorrow's elderly population could increase pressure on governments to add financial and human resources toward home care services. While this would not necessarily improve their autonomy in performing daily activities, disabled elderly would feel more independent from their children. For example, Harlton et al. (1998) found that for older adults, relying on family members was seen as relinquishing some control. Therefore the use of formal, i.e., public or paid services, allowed older adults to maintain their independence. They emphasize that in sharp contrast to policy makers, older adults themselves appeared not to subscribe to the "families first" philosophy. They wished to avoid being a burden to their families or making family members feel tied down (Harlton et al. 1998).

This study demonstrates the need for a better understanding of the factors underlying the use of different sources of home care services. When solely considering the changing nature and extent of the informal network, the results point to a relative increase in the demand for formal home care services in the future. This increase demand will either be met by an increase in the provision of services by government agencies or by the private sector. Expenditures related to home care services, either public, private, or both, will undoubtedly increase with population aging. Policy makers will have to decide how best to serve the disabled population, especially the oldest-old, so that their needs for assistance will be met. A better understanding of the nature, extent, and availability of the informal network as the population ages will assist in addressing this issue.

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CHAPTER 18. VARIATION IN COHORT SIZE AND LOWER MORTALITY IN THE ELDERLY: IMPLICATIONS FOR PAY-AS-YOU-GO HEALTHCARE SYSTEMS

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1. Introduction

The changing age structure in industrialized countries is raising concern among policy-makers over the funding of social security programs, especially pensions and healthcare. The aging of the population, i.e., the increased percentage of the elderly, appears at first glance to be the determining factor in the growth of costs. In Canada, the most recent population forecasts suggest that the proportion of people aged 65 and over will reach 25% by 2041. For the same year, the Institut de la Statistique du Québec (ISQ) estimates this proportion at 29% for the population of Québec. In addition to these changes in the population age structure, governments are worried about increased public spending on healthcare. For example, in the United States, the cost of the two major healthcare plans, Medicare and Medicaid, topped $376 billion in 2001, i.e., over 13% of the GDP. In Canada, healthcare accounted for 9.3% of the GDP in 1998, i.e., a growth of over 30% for the period 1980–1998 (OECD 2001).

The age effect is evident when comparing various components of *per capita* public spending (Figure 1). In 1998, public *per capita* spending on social security in Québec represented less than CAN$3000 for people under age 55 (excluding education), and then rose sharply to over CAN$25,000 for people aged 85 and over. In the latter group, healthcare and social services costs represented 64.3% of total public spending on social security, compared with 25.3% for the 65–69 age group.

Given this context, it is important to examine the consequences of changes in cohort size and lower mortality when financing social security with pay-as-you-go systems, a managing mode favored by many governments. Population aging will accelerate in the near future, resulting in a heavier burden on the working population which is mainly responsible for the bill, keeping in mind, however that the elderly also pay income and consumption taxes. Accordingly, the implementation of complementary funded plans would appear necessary to lighten the load on future birth cohorts that are proportionally less numerous. With this in mind, the reforms made in the area of pensions could be used by policy-makers as a model for healthcare in its broadest sense.

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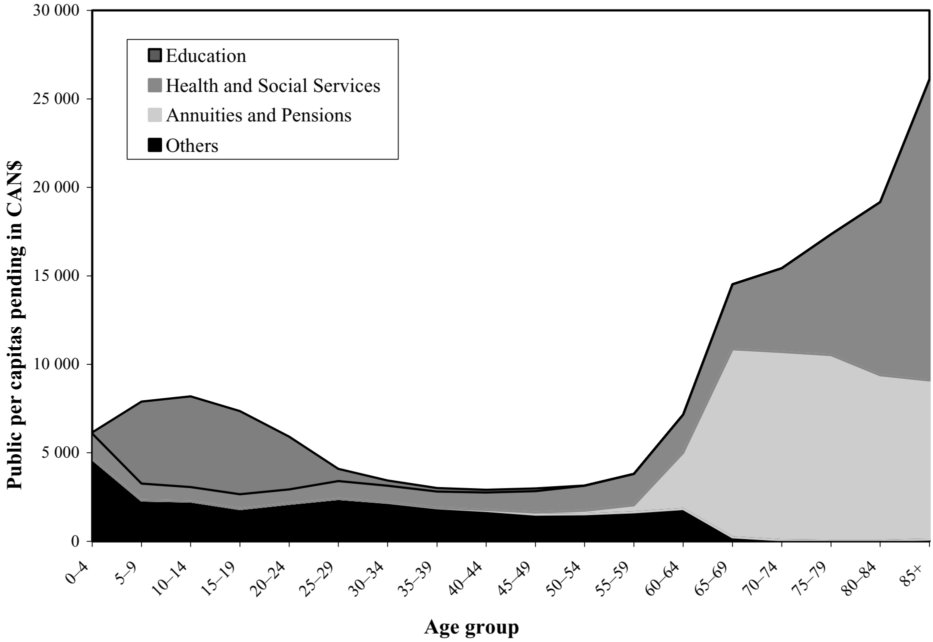

Figure 1. Public spending per capita according to sector and age, Québec, 1998.
Source: From ISQ data 2003

Our study focuses on the situation in Québec, the second largest Canadian province in population size. Firstly, we will discuss the various factors behind rising healthcare costs resulting from two unchallenged phenomena—variation in cohort size and lower mortality in the elderly. Secondly, we will examine the amplifying effects of a much lower than the officially forecast mortality on pay-as-you-go systems.

2. Some Considerations on Healthcare Costs for the Elderly

Numerous studies have tried to characterize the relationship between age and levels of healthcare spending. Accordingly, if we separate out the main components of healthcare spending, namely medical, hospital, and pharmaceutical services (often called the healthcare sector) and the homecare and long-term care sector (often called the social services sector), we see a major difference in the age-spending issue. Many studies have shown there is a leveling off or decline in costs related to healthcare services for the elderly (Demers 1998; McGrail et al. 2000), whereas spending on homecare and long-term care increases steadily with age; this is particularly true in Québec (Figure 2). The growth in healthcare and social services spending as people get older is essentially due to the rising cost of homecare and long-term care beyond age 70.

Medical and hospital spending on elderly patients has been widely studied, with particular attention being given to the costs incurred at the very end of life. Lubitz and Prihoda (1984)

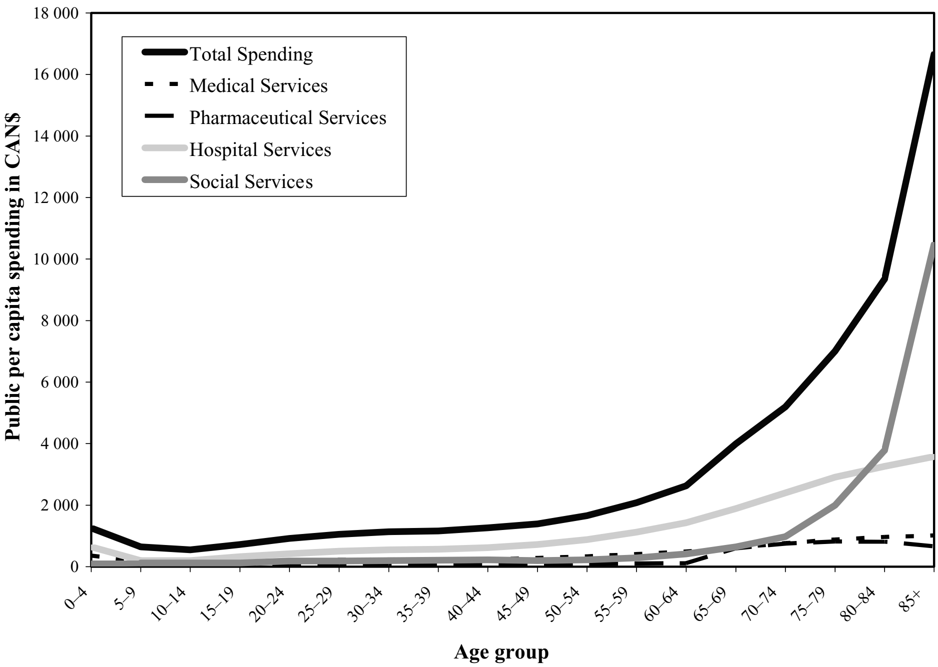

Figure 2. Public spending per capita on health and social services per category of spending and age, Québec, 1999–2000.
Source: From MSSS data 2003

showed that in 1978, 27.9% of spending in the Medicare program—which covers the major portion of hospital and medical costs for the elderly in the US—was attributable to a very small number of recipients, i.e., the 5.9% of the people who died during the year. Similarly, McCall (1984) showed that those in the 65 and over age group who die during a year incur costs 6.4 times higher than do survivors. Many authors have confirmed these results, demonstrating that healthcare spending at the end of life is more a function of proximity to death than of age (Roos, Montgomery, and Roos 1987; Zweifel, Felder and Meier 1999; McGrail et al., 2000; O'Neill et al., 2000).

According to a conclusion of Zweifel et al. (1999), it is the number of deaths, not the increase in the number of elderly people that determines the major portion of healthcare costs. As we have seen, numerous studies have discussed the increase of *per capita* healthcare costs as a function of age, whereas this phenomenon actually stems from the fact that more elderly people are in their last year of life.

Figure 3 shows the distribution of *per capita* healthcare costs in the last year of life for people who died after age 65. Three samples from retrospective studies, two Swiss and one American, yielded similar trends—costs clearly increased in the final 3 months of life. Thus, some 60% of healthcare spending by Medicare on Americans who died at age 65

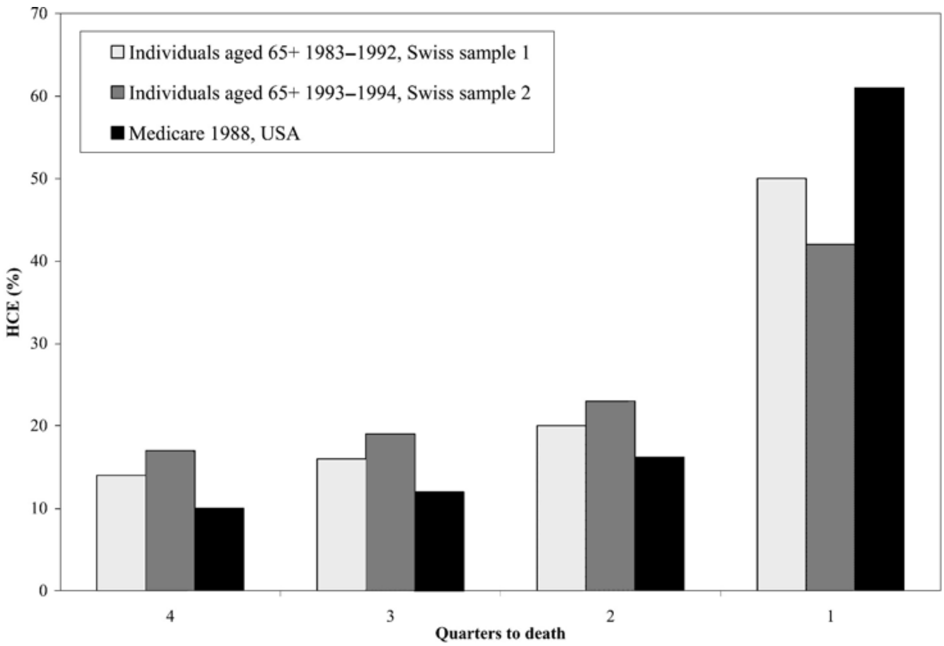

Figure 3. Distribution of health care expenditures over the last four quarters of life.
Source: Zweifel et al. 1999: 489

and over was incurred in the final 3 months of life. For the two Swiss samples, this figure was 49% and 42%.

Moreover, Zweifel et al. decry what they call the *fallacy of composition* of studies on healthcare for the elderly, i.e., that the increase in healthcare costs as a function of age stems from the fact that later in life, there are more people in their last year of life than there are at an earlier age, given that the probability of dying increases with age.

The relationship between age, intensity of care, and type of care, i.e., hospital and homecare or long-term care has also been examined. The goal was to determine whether an inordinate portion of resources is allocated to people whose death is imminent. Accordingly, when both types of care are taken into account, the overall costs increase with age (Rochon 1997; Roos et al. 1987; Scitovsky 1984), or remain basically the same when a period of more than one year prior to death is considered (Temkin-Greener et al. 1992). From this, it has been deduced that the increase in costs goes hand-in-hand with an increase in the number of deaths. Lastly, studies that examined only the relationship between hospital care and age concluded that older age groups are not so much more expensive and often less expensive than younger ones (Demers 1998; Felder, Meier, and Schmitt 2000; Hogan et al. 2000; Lubitz and Riley 1993; Scitovsky 1988). This supports the hypothesis that physicians are less inclined to expend great effort on individuals perceived as having attained a fairly advanced age (Felder et al. 2000; Lubitz and Riley 1993).

We see, therefore, that the issue of healthcare costs in a context of population aging is extremely complex. We know that the post-war birth cohorts will soon be reaching old age, and that they will live to increasingly advanced ages. What will be the respective effect of these two factors on the funding of healthcare and social services spending?

2.1. THE EFFECT OF COHORT SIZE ON RISING HEALTHCARE COSTS

With the arrival of large cohorts of baby-boomers at ages where they will need increasing hospital and medical care, as well as long-term care and homecare, it is clear that, all things being equal, medical and hospital costs will inevitably spiral in the medium and long term and the pay-as-you-go system will no longer be able to meet demand. The burden for the working age population will be substantially greater for succeeding cohorts unless, in the future, gains in productivity are much greater or other changes are observed, e.g., either to the healthcare system or the health of the older population. In effect, the population of 20–64 year olds, which will be responsible for providing a large proportion of social security funding, is expected to increase up to 2011 in Québec, when the first baby-boomers reach the age at which they will be eligible for public retirement programs. At that time, it should peak at around 63% of the total population, but then decline steadily until 2041 to represent 54% of the total population, based on the ISQs mortality forecasts. Accordingly, when we take into account the evolution of the 20–64 age group, as presented in Figure 4, the demographic dependency ratio of the 65 and over age group to the working age

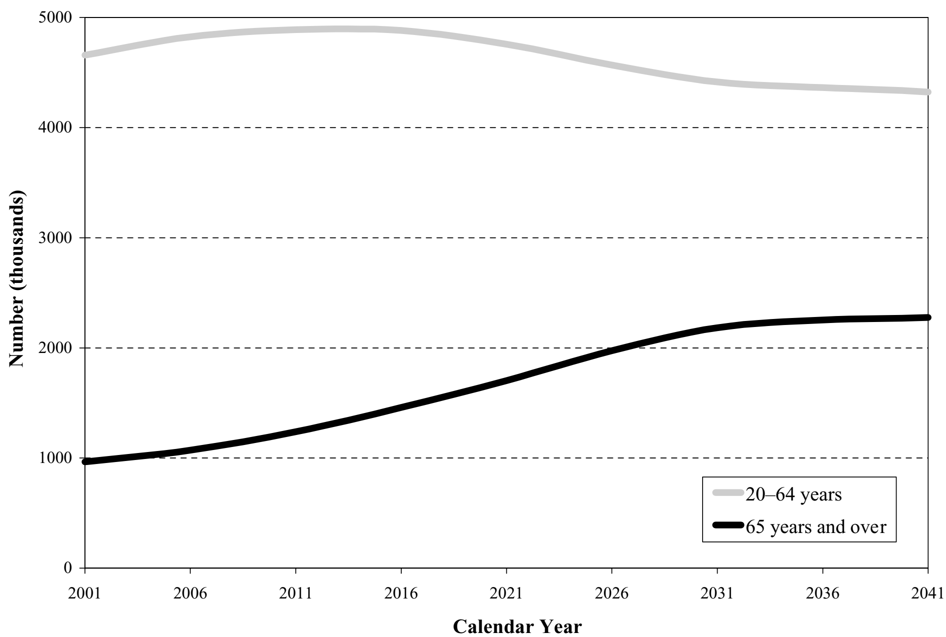

Figure 4. Changes in the 20–64 and 65 and over population, Québec, 2001–2041.
Source: From ISQ data 2000

population (the 20–64 age group) in Québec could reach 0.5 (or 1 elderly person for every 2 people of working age) by 2041.

2.2. THE EFFECT OF LOWER MORTALITY ON SLOWING DOWN THE RISE OF HEALTHCARE COSTS

Numerous studies have associated lower mortality beyond age 50 with a possible reduction in healthcare costs because interventions at the end of life are more costly in the younger age groups (age 50–65) since they are often related to the use of advanced technology at the approach of death. In fact, it was an increasing use of costly technology and a greater offer of services than was actually required by the elderly that led to the explosion in healthcare costs observed at the end of the last century (Barer, Evans, and Hertzman 1995).

The 3 months preceding death is the period where *per capita* medical and hospital costs are highest, thereby increasing spending on these services as a function of age. This stems from the fact that there are more people in their final years of life at age 75 than at age 50, and that the majority of deaths now occur and will occur above age 65 and even age 80. In 2001 in Quebec, for example, as a proportion of the total, deaths at age 65 and over and at age 80 and over were 75% and 23%, respectively. According to the ISQ mortality forecasts, in 40 years' time, these figures will reach 93% and 45%. The expected future

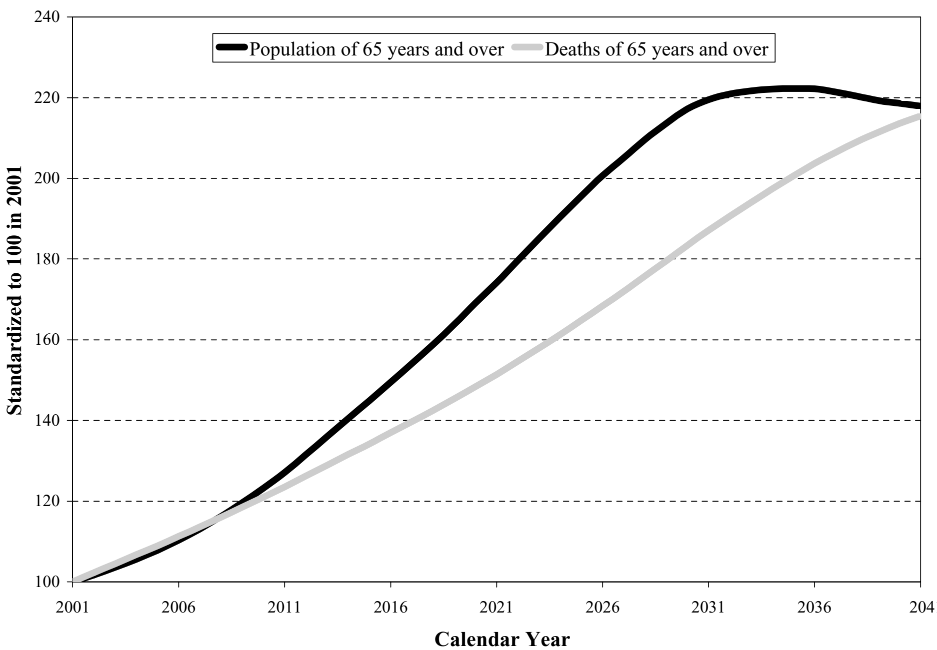

Figure 5. Relative changes in the population and deaths of the 65 and over age group according to two mortality assumptions, Québec, 2001–2041.
Source: From ISQ data 2000

reduction in the number of deaths in people under age 70 could lead to a reduction in healthcare costs, provided that the higher number of deaths beyond age 70 due to the size of the aging cohorts does not cancel out these expected reductions in medical and hospital costs. However, the expected number of deaths at age 65 and over for a given year increases much slower than the number of elderly people for the same year (Figure 5), and may be a more important indicator for the projected costs of healthcare services, in addition to the number of elderly people for the said year. Accordingly, the proportion of people likely to die at an advanced age will enable us to better determine the healthcare costs they will incur at the time of their death.

We must, however, anticipate an increase in overall healthcare and social services costs in the coming years, due in large part to homecare and long-term care services, which will themselves increase steadily as the baby-boomers reach advanced ages. But the proportional increase in healthcare costs should be significantly lower than the increase in the proportion of elderly.

2.3. PENSION PLAN FUNDING: A MODEL FOR KEEPING SOCIAL GAINS IN TERMS OF HEALTH?

Pensions represent a unique type of spending, since the benefits paid to the elderly do not generally increase as a function of age. However, this spending sector is highly sensitive to cohort size and an increase in longevity (Blanchet 2002; Gauthier 2004). It is very simple to illustrate this phenomenon. In 1959, at the peak of the baby-boom, there were 144,459 births in Québec; then, because of lower fertility, this number fell to just 73,500 in 2001 even though the population of women of child-bearing age was much larger. When the first generations of baby-boomers retire, the succeeding cohorts stemming from a period of lower fertility will be unable to support the costs of the plan, unless certain forms of funded pension plans have been introduced. Furthermore, as people are living much longer thanks to progress in lowering mortality at more advanced ages, this increase in life expectancy leads to much larger state transfers, given that the phenomenon results in a much longer period of eligibility for pension plan benefits.

It is useful to briefly examine how the income security system works for retirees in Québec. The system is based on *the four pillars* of income model (Chen 1996). The public old age pension system is run jointly by the federal government and the provincial government (Régie des Rentes du Québec 2000), both on a PAYG system. Individuals' pensions are bolstered by income by employers' pension plans, income from registered retirement savings plans (RRSP)[1] and general savings and, lastly, income the elderly possibly draw from continuing to work. This plan, therefore, is based in large part on a funded system, which reduces the burden that population aging imposes on pay-as-you-go systems. This, therefore, is complementary to the pay-as-you-go system, and attenuates the Bismarkian approach of risk mutualization, with an aim of achieving intergenerational balance especially when the burden appears heavier for the smaller generations following the baby boom.

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[1] RRSP is a tax credit program offered by financial institutions with the support of the federal and Québec governments to promote savings for retirement in capitalization funds. The amounts set aside (capped at a fixed amount) are tax-free at the time of deposit, as is the interest they generate.

But as suggested by Chen (1996), the proportion of each of these income sources in the total income of elderly people has varied with time. For example, in the United States in 1994, the largest portion came from the public social security system, in this case 42%. However, the proportion of pensions derived from the public sector in the income of the elderly is much larger in some Western European countries, while aging in these countries is generally more marked than in North America. These countries already dedicate a large portion of their GDP to retirees and will have to dedicate an even larger amount in the future.[2]

The evidence suggests that age structure changes have major implications on the cost of pensions to be assumed by public administrations. With respect to the calculation of pensions to be paid to the elderly, these are made on the basis of various hypotheses on future demographic changes (fertility, migration and, of course, mortality). An overestimation of future fertility or an underestimation of the change in mortality at advanced ages can lead to significant errors. In this respect, the Régie des Rentes du Québec, which increased contributions by 75% between 1997 and 2003, assumed that the total fertility rate would rise to 1.65 children per woman by 2015 (Régie des Rentes du Québec 2000). Some authors decry these government actuarial practices, and criticize demographers who are often too optimistic as to fertility rates in the coming years.[3]

Even though imperfect, a funded pension plan system that enables each cohort to accumulate in a reserve a good portion of its income for the retirement years is clearly more likely to leave room to maneuver for future administrators of the social security system than solely a pay-as-you-go system.

Given the explosion in healthcare and social services costs, both current and anticipated, is it not time for Québec authorities and others to consider a similar solution for healthcare, namely the implementation of a complementary system based on a funded plan? As with pension management, this diversity would ensure more inter-generational fairness in the funding of social programs.

3. Social Security Systems Confronted with a Much Lower Mortality: A Bold Scenario for the Future

Imagine now a situation where mortality might be substantially lower than the level expected by official organizations. What would be the implications of such an increase in longevity on pay-as-you-go pension plans, but especially for healthcare and social services? The second part of this study takes up the challenge of imagining a world where not

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[2] For example, if the trends continue, *ceteris paribus*, France, which spent 12.1% of its GDP on retirement pensions in 2000, anticipates that this figure will rise to 15.9% by 2040. Similarly, the figures for Germany are 11.8% and 16.8% for 2000 and 2050, respectively; for Belgium, 8.8% for 2000 and 14.1% for 2050. Conversely, the figures are 5.1% and 10.9% for Canada, and 4.4% and 6.2% for the Unites States. See OECD (2001), p. 26.

[3] "Actuaries were rather puzzled when they had to apply the very conservative hypotheses they used for future mortality to pension schemes! If you estimate too early an age at death for older persons, insufficient funds will be available to pay pensions! The same applies to demographers who were still projecting a quick return to replacement level fertility, irrespective of the fact that cohort fertility behaviour was changing completely, and was always on the decline" from Légaré (1999), p. 3.

only survival at age 65 would be quasi-universal, but also where survival at age 85 would be the norm.

The data used here to present this bold scenario of a much lower mortality is drawn from an earlier study (Bourbeau, Desjardins, and Légaré 2005) on the implications of a scenario where life expectancy at birth would be 100 years for the year 2000 birth cohort. Our simulations are based on population estimates by age and sex from 2001 to 2041, and life-table death rates provided by the ISQ.[4] To simulate lower mortality, we will artificially accentuate the drop in mortality by multiplying the coefficient of the decrease in the death rates from one year to the next, at each age and for both sexes, by a specific factor.[5] This will not only accentuate aging, but will also reduce the number of annual deaths of people aged 65 and over for the period in question.

3.1. THE IMPLICATIONS OF LOWER MORTALITY ON PENSION EXPENDITURES

Changes in mortality, as well as the changes in fertility, lead to consequences of an unexpected magnitude for public pension plans. Since the increase in life expectancy occurs more at advanced ages, and the effective retirement age has not changed at the same rate as the projected life expectancy in the cohorts, the period of eligibility of individuals in the plan tends to increase.[6] This latter observation stems from the fact that in industrialized countries, except in Sweden,[7] administrative, institutional, and societal rigidities have prevented a rise in retirement age parallel to the rise in individual life expectancy (with or without disability).

Accordingly, mortality assumptions used for projecting the future costs of pension plans appear somewhat conservative, given past trends in life expectancy and in the reduction of mortality. For example, the Régie des Rentes du Québec predicts life expectancy in

[4] The simulations made in this study use the probabilities of death given in the ISQ multiregional projection model (2000 version). These simulations are not intended to generate projections, but rather to provide insight for those who set public policy as to potential changes in the 65 and over population and deaths in this population based solely on the mortality rate set by the ISQ, and the consequences of such a change. Also, an assumption of low mortality is an additional analytical tool for investigating the sensitivity of social security plans to mortality rates that could prevail in the future. In both simulations, the migration of the 65 and over population is discounted, since it can be considered as marginal.

[5] The operation consists in reducing the life-table death rates for each year, starting in 2001, to arrive at a life expectancy for birth cohort 2000 of approximately 100 years (our boldest mortality assumption). See Bourbeau, Desjardins and Légaré (2005) on this topic.

[6] Many industrialized nations have adopted legislation aimed at delaying the age for drawing a pension. The increase in retirement age is a convenient way for public administrations to save money; accordingly, the retirement age in the United States will rise from 65 to 67 by 2022. In the United Kingdom, the retirement age for women will gradually rise from 60 to 65 between 2010 and 2020. In Japan, the retirement age will rise from 60 to 65 between 2001 and 2013 for men, and between 2006 and 2018 for women. Also, many other measures have been implemented to ensure future public funding for retirement: Pension indexation of net revenue, incentives for workers to stay in the labor market after the official retirement age and penalties for retiring too early, extending the qualifying period to receive full benefits, increased contributions, incentives for individual retirement savings, incentives for a greater distribution of private pension funds, etc. On this topic, see OECD (2001), pp. 35–37.

[7] See Blanchet (2002).

2050 at age 65 to be 18.8 years for men and 22.1 years for women (Régie des Rentes du Québec 2000). Conversely, according to the ISQ's most optimistic mortality forecasts, life expectancy at age 65 for the same year are 22.1 and 24.6 years, respectively. However, when we consider our lower mortality simulation, life expectancy at age 65 becomes 27.9 years for men and 29.6 years for women—a situation that would cause serious problems for the public funding of retirement programs.

Improvements in longevity are likely to significantly increase the burden of pension benefits, especially those provided by the pay-as-you-go system. Based on a lower mortality, people aged 65 and older could represent 31.7% of the population in 2041, compared with only 26.5% based on RRQ estimates.

Furthermore, should mortality drop more significantly than expected, the demographic dependency ratio of the 65 and over age group to the 20–64 age group could be more significant and cause funding problems for the entire social security system, all things being equal. In effect, the simulation of lower mortality shows the population of people aged 65 and over increasing 2.6-fold between 2001 and 2041, whereas the population of people aged 20–64 would only benefit marginally from such a decline in mortality, it already being very low at these ages.

3.2. THE IMPLICATIONS OF LOWER MORTALITY ON HEALTHCARE AND SOCIAL SERVICES

A more significant than expected increase in longevity could have much greater than expected consequences in the area of healthcare and social services. It could lead to higher morbidity, a tendency toward comorbidity and a greater chronicity of pathologies. Such an escalation of costs is even more likely, since inflation in medical technology costs and extensive use of technology could lead to funding problems of unparalleled scale in healthcare systems. As we are not in a position to estimate the impacts of such eventualities on healthcare costs, then an essential condition for curbing this trend is to stop funding the healthcare sector solely on a pay-as-you-go basis. In summary, the major portion of future healthcare costs will be determined by the incidence of morbidity and prevention efforts in the area of chronic disease. However, cohort phenomena, such as better education, healthier lifestyles, and a higher standard of living could somewhat slow the trend toward inflated healthcare costs.

3.2.1. Healthcare Services Expenditures

With the fine-tuning of studies on the subject of healthcare costs at the end of life, policymakers are more able to make informed choices. The implication of mortality declining at a faster rate than expected would be the following: increased aging, but a lower number of annual deaths in the simulation than is obtained with the ISQ mortality forecasts (Figure 6). In fact, a lower number of deaths each year in the medium term could slow the rate of expected healthcare spending. The number of annual deaths increases 2.2-fold between 2001 and 2041 based on the ISQ mortality forecasts compared with 1.8 for an assumption of lower mortality. However, this latter assumption causes an accentuation of population aging, since it delays the death of its members. The number of elderly people increases 2.2-fold over the period 2001–2041 according to the ISQ estimates, compared with 2.6-fold

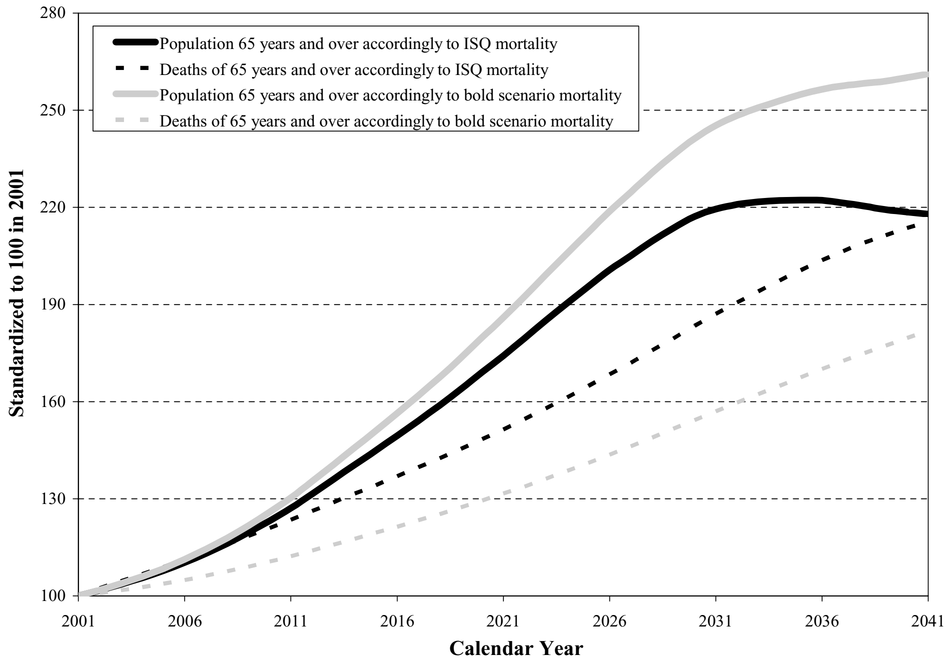

Figure 6. Relative changes in the population and deaths of the 65 and over age group according to two mortality assumptions, Québec, 2001–2041.
Source: From ISQ data 2000.

for the assumption of lower mortality. Such a lowering of mortality could appear as good news for healthcare services costs for the reasons given earlier. However, although it may alleviate the situation in the medium term, let us not forget that costs related to death are simply put off to a later date.

3.2.2. Social Services Expenditures
In such a context, social services costs would rise sharply following an increase in aging, unless there is a net reduction in disability among the elderly.

This sector is in fact very sensitive to a decline in mortality, given that associated spending increases with age: The very old are then at a time in life where the use of this type of service is at its most intensive. After age 75, homecare and long-term care services gradually become the most significant item of expenditure. Conversely, spending on medical services and medications tends to stabilize within the very old, and the same could also be true of hospital services, at least up to age 75.[8] The effects of a changing age structure for retirement as shown above also apply to homecare and long-term care services.

[8] Scitovsky (1988) is very clear on this issue: "By contrast, those aged 80 years and over, constituting 43% of all decedents, accounted for only 28% of all hospital expenses and 23% of all physician expenses; they were responsible, however, for almost 3/4 of total nursing home and home healthcare expenditures" (p. 649).

Spending on homecare and long-term care inevitably poses a challenge to public administrations. Can the pay-as-you-go system actually support the onset of large baby-boom cohorts at an age where a great many of them will require these services? It is legitimate to question whether the informal support networks of these individuals in the future, in particular the family, will suffice to prevent an over-extensive use of formal services in a context of very low fertility (Keefe, Carrière, and Légaré 2004). Also, is it not likely that the growing instability of couples will increase recourse to institutionalization, given that the presence of a spouse or partner is a primary factor in keeping people at home? (Trottier et al. 2000).

Being closely related to functional status, which alters with advancing age, the use of social services could also intensify with an increase in longevity. Accordingly, changes in morbidity and life expectancy without disability versus life expectancy for all health statuses take on major importance,[9] since disability determines the use of these services (Légaré and Carrière 1999).

4. Conclusion: An Unavoidable Complement to the Pay-As-You-Go Healthcare System—A Health Fund

Out of concern for intergenerational fairness, we believe, as demographers, that public administrations must rapidly set up measures designed to create health funds. For Quebec, this would involve setting up a plan similar to that implemented for pensions so as to ensure a fair distribution of costs related to the healthcare sector. Such a plan could, as for retirement, be based on several pillars and comprise public and private sector components, while retaining its universality, the cornerstone of the Canadian healthcare system.

The goal of this study is clearly not to criticize the pay-as-you-go system for healthcare, but rather to provide strong arguments in favor of adding a funded healthcare plan that would be fairer for future generations. The pay-as-you-go funding of healthcare is inherited from a period in time where each cohort was larger than its predecessor; it is now outmoded in a world where demographic dynamic is quite different. The phenomenon of imbalance between succeeding cohorts in terms of aging and increased longevity, together with the use of costly technologies at the end of life, could seriously impede our ability to fund public pension plans and the healthcare and social services sector.

Spillman and Lubitz (2000) also address this situation: "Increases in longevity after the age of 65 years may result in greater spending for long-term care, [...]" (p. 1409).

[9] The work of the International Network on Health Expectancy (REVES), which brings together numerous researchers in the field of aging, suggests that life expectancy without disability does not increase as quickly as life expectancy. Accordingly, Légaré (2001) addressed this issue: "The experience of the last 30 years in industrialized countries (Canada and many UN/ECE countries, Japan, Australia and New Zealand) supports the first scenario: disability-free life expectancy has stagnated, if not worsened, while life expectancy has improved greatly, a situation which reflects the worst scenario, namely pandemic disabilities. However, if only severe disabilities are taken into account, both indices improve" (p. 115).

Therefore, this analysis is meant to be far more than simply a simulation exercise—it is intended as a modest tool, among others, for public policy-makers so that they can make informed decisions. There should also be more efforts to look at the efficiency of the system itself and of some medical interventions that can be very costly without any real knowledge of their efficiency. Also, expectations of baby-boomers themselves regarding the healthcare systems may have to be tempered: should they expect the healthcare system to fight death at all costs or should they not be more reasonable considering that any healthcare system has limited resources, no matter if the population ages or not?

However, implementing a health fund that keeps social gains and ensures intergenerational fairness is becoming one of the most pressing issues for today's policy-makers in industrialized societies, as a part of a bigger solution that involves a more efficient healthcare system.

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CHAPTER 19. SUCCESSFUL AGING AMONGST THE VERY OLD—EVIDENCE FROM A LONGITUDINAL STUDY OF AGING*

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1. Introduction

The oldest old (those aged 85 years and older) have been recognized as the most rapidly growing population age group in many societies (Suzman, Willis, and Manton 1992). They have also been commonly characterized as having considerable age-related decline in function, high rates of morbidity, dementia and frailty, and to be high consumers of formal and informal care. Generally lumped into the so-called "4th age" their collective situation is frequently considered to be rather bleak and associated with dependency, isolation, institutionalization, and high costs of care (Fries et al. 2000).

However, wide variation in the experience of aging has increasingly been recognized and has led to more attention being paid to so called *healthy, robust, positive,* or *successful* aging in older age (Rowe and Kahn 1987, 1998). Several studies have now sought to identify subgroups of older people in the population that exhibit minimal functional limitations, using a variety of approaches (Berkman et al. 1993; Garfein and Herzog 1995; Harris et al. 1989; Jorm et al. 1998; Strawbridge et al. 1996; Suzman et al. 1992). Prominent among these approaches is the MacArthur study of successful aging in the United States, first reported by Berkman et al. (1993). The MacArthur studies aimed to identify, within a population-based cohort of older men and women, a subgroup with higher levels of

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physical and cognitive function, and to compare their characteristics in a range of domains with those of subgroups functioning at intermediate and lower levels, respectively.

Recent evidence has emerged that the stereotypic view of very old age may not be accurate and at least some individuals at very old ages may continue to enjoy an active, participatory life either free from or well adapted to chronic conditions, disability or age-associated functional decline (Von Faber et al. 2001). This chapter explores the situation of an oldest old group of survivors in a longitudinal study of the oldest old in an Australian urban population—the Australian Longitudinal Study of Aging (ALSA).

2. Method: Participants and Procedures

ALSA is a large population-based study that aims to gain increased understanding of how psychosocial, biomedical, economic, and environmental factors are associated with health and psychosocial well-being in old age. Details of the study have been described elsewhere (Andrews, Cheok and Carr 1989; Andrews, Clark, and Luszcz 2002; Clark and Bond 1995; Finucane et al. 1997). In summary, a stratified random sample of people aged 70 years and over who lived in the Adelaide Statistical Division (the wider City of Adelaide), South Australia were interviewed at length in their normal place of residence about their demographic, medical, psychological, social, and economic characteristics. A random sample was initially drawn from the database of the South Australian Electoral Roll (Andrews et al. 1989). From this sample, eligible persons (defined as those individuals aged 70 years and over as at 30 June, 1992 and who were at the time resident in the Adelaide Statistical Division) were included. The Electoral Roll sample was stratified to provide estimated equal numbers in 5-year age and sex cohorts from 70 to 84 years and 85 or more. Males were deliberately over-sampled to compensate for anticipated higher mortality over the period of the study.

A total sample of 3263 individuals was drawn from the Electoral Roll, of which 2705 were eligible for inclusion in the study and 1477 agreed to participate. In addition spouses and others aged 70 and over in the household were recruited into the study resulting in a total sample for Wave 1 of 1947.

Face-to-face interviews were carried out by a team of interviewers who were all trained in interviewing techniques at intensive workshops. The interview schedule covered a comprehensive set of domains, including demography, health, depression, morbid conditions, hospitalization, cognition, gross mobility and physical performance, activities of daily living (ADL) and instrumental activities of daily living (IADL), lifestyle activities, exercise, education, and income.

Following the face-to-face interview, participants were invited to participate in a functional assessment, and to self-complete mail-back questionnaires. The latter included additional psychological measures of self-esteem, morale, and perceived control.

In the functional assessment, both physical and cognitive functioning was assessed. The physical examination included blood pressure, anthropometry, visual acuity, audiometry, and spirometry (subsample). The cognitive assessment included measures of memory, processing speed, and verbal ability. The functional assessment findings have not been used in this analysis.

Self-reports of medical conditions were obtained by asking participants to indicate which of a comprehensive list of conditions they had ever suffered from. The assessment of ADL and IADL was based on that used in the Older American Resources and Services program (Fillenbaum 1988). Gross mobility and physical performance were assessed using the items developed by Nagi (1976) and Rosow and Breslau (1966). Domestic and social activities were assessed using the Adelaide Activities Profile (AAP; Clark and Bond 1995), which asks older people to provide responses reflecting their performance of 21 activities in a typical 3 month period. Each activity is scored 0, 1, 2, or 3 to indicate increasing frequency of activity. Four scales are derived from the AAP: domestic chores, household maintenance, service to others, and social activities. The scoring of each scale is standardized to a mean of 50 and a standard deviation of 20, with higher scores indicating greater activity. The reference group for comparison is people aged 70 years and over. The assessment of physical exercise (Finucane et al. 1997) was used to classify exercise intensity as none, moderate, or vigorous. Depression was measured using the CES-D (Radloff 1977). Items from the Mini Mental State Examination (MMSE; Folstein, Folstein, and McHugh 1975) assessing orientation, registration, attention, calculation, and recall gauged current global cognitive status and impairment.

3. Waves 2–6 Data Collection

Telephone interviews (Wave 2) were conducted in 1993–1994 approximately 1 year after the baseline interview. A total of 1779 interviews were completed from the 1975 potential respondents who survived to the time of second contact.

For Wave 3, which entailed full household interviews and detailed clinical reassessment, a response rate of greater than 90% was achieved. A similar level of participation was experienced in the Waves 4 and 5 telephone interview.

The Wave 4 telephone interview was conducted at September 1995 and Wave 5 at February 1998. A further full household interview and clinical reassessment (Wave 6) was conducted during October 2000 to March 2001. At this stage 956 participants from the original sample had deceased, 791 were interviewed (521 assessments), and the response rate for eligible participants was 74.13%. This analysis draws on the findings from baseline (Wave 1) and Wave 6.

4. Results

A range of findings are reported in this chapter for the 307 persons aged 85 years and over interviewed at Wave 6 of the ALSA. Of these 307 people, some 211 or 69% were living in the community. The simple descriptive findings presented in Section 4.1 are related to this group of 211 (except MMSE), and establish a profile of community dwelling persons aged 85 years and over. The Section 4.2 presents statistical analysis on potential risk or protective factors of healthy aging.

4.1. SIMPLE DESCRIPTIVE FINDINGS ON PROFILE OF COMMUNITY DWELLING OLDEST OLD

4.1.1. Gender

Fifty-one percent were male and 49% female, reflecting the original over-sampling at baseline of older males in the study design.

4.1.2. Living Arrangements

- The majority live in their own house (60%), with 35% in a unit or flat, 72% in independent living, 17% in group living, and 11% in a retirement village;
- the majority are widows (64%), but 33% are still married;
- 98% have been married at some time in their life;
- 76% indicate one or more children living.

4.1.3. Health

- The average number of reported medical conditions was 5;
- arthritis is the most commonly reported condition (47%), followed by cataracts (30%), hypertension/high blood pressure (26%), heart condition (24%), corns, bunions, calluses on feet (23%), and angina (18%)
- the average number of medications is 4;
- 68% report their health to be good, very good or excellent, while 23% say their health is fair and 9% poor;
- 60% indicate that their health is better than others of their own age, with 30% saying it is about the same as others;
- 46% report their health to be about the same as it was 12 months previously, while 11% say it is better and 43% say it is not as good;
- 31% indicate that they were hospitalized at least once overnight in the previous 12 months;
- only 4 of the 211 report attendance at day therapy centers or day care;
- 6% smoke and 67% report that they drink alcohol.
- MMSE scores were obtained from 215 of the 307 participants aged 85 years and above. These participants had a mean MMSE score of 27.4, with a standard deviation of 3.0. Using the standard cutoff of 23/24, 11.2% of participants were classified as cognitively impaired. This is a relatively low figure, and is probably an underestimate of the true value, given that almost 30% of participants were not assessed.

4.1.4. Daily Activities and Social Contact

- 8% report doing up to 10 hours a week voluntary or paid work;
- 49% indicate that they have guests in their home at least once a fortnight or more;
- 64% report spending time on a hobby once a week or more;
- the majority read 2 hours a week or more, with 35% reporting reading more than 10 hours a week;
- 55% report watching TV one to 3 hours a day, and 28% 3–5 hours per day;
- 67% never attend religious services;

Table 1. Adelaide activities profile: means and standard deviations for participants at Wave 6 aged 85 years old and over.

Scale	Mean	SD
Domestic chores	42.2	20.9
Household maintenance	39.0	18.8
Service to others	46.2	17.8
Social activities	39.9	17.6

Note: The standardized mean AAP score of the reference group of those aged 70 years old and over is 50.

- 25% report participating in outdoor social activities once a month or more;
- 22% report participating in outdoor recreational activities once a month or more;
- most do not participate in exercise, vigorous or otherwise, but 50% indicate that they had a walk in the previous 2 weeks (average of 4 walks); 66% report walking outdoors for 15 minutes once a month or more;
- 36% drive their car at least once a day, and an additional 42% drive once or twice a week;
- 48% went to one or more meetings in the previous month (average of 2 meetings a month);
- 68% have face-to-face contact with their children once or more per week, with a further 16% reporting such contact two or three times a month; 50% have telephone contact with children more than once a week, plus 28% at least once a week; mail from children is infrequent, with 51% reporting they never get mail (not surprising given the frequency of face-to-face contact);
- there is considerably less reported contact with grandchildren, with 24% reporting face-to-face contact with grandchildren once a week or more, and 22% reporting telephone contact once a week or more (mail contact is also infrequent, with 56% indicating they never receive mail from grandchildren);
- 85% report having someone to confide in;
- AAP scores are shown in Table 1. A decrement in activity levels among the oldest old relative to the average population aged over 70 is evident in all domains. Domestic chores and household maintenance are the scales containing the most physically demanding activities, and a decrement among the oldest old relative to the population aged over 70 is unremarkable. Perhaps more noteworthy is the similar decrement in social activities among the oldest old. It is of interest that the scale in which activity is best preserved among the oldest old is service to others, a domain reflecting altruistic activities. This finding is consistent with the view of Erikson (1982) that generative behaviours are well-maintained, even in advanced age.

4.1.5. Decision-making, Satisfaction, and Self-worth

- If they became dependent on others, 70% would like to stay at home with outside help;
- 75% of those who are married report that they make all major decisions equally with their partner/spouse; those not in a marital relationship indicate they make all major decisions themselves;

- over 90% indicate that they feel they are a person of worth;
- 98% are satisfied with their location of residence;
- 89% are satisfied with their health and physical condition;
- 96% are satisfied with their financial situation; 98% report their income takes care of their needs, 95% say that money takes care of most of their large annual expenses, and 92% say they have enough to buy little extras;
- 97% are satisfied with their friendships, 97% with their marriage, 95% with their family life, 97% with the way they handle problems, and 95% with life in general.

4.2. STATISTICAL ANALYSIS ON PREDICTORS OF HEALTHY AGING

The simple descriptive analyses on the community dwelling oldest old subset of the sample presented in Section 4.1 are complemented by the following more detailed statistical analysis of the whole sample of people aged 85 years and over. The object of this analysis was to examine the relevance of a number of potential predictive factors of healthy aging. For the purpose of this initial exploratory analysis, an empirical definition of "healthy aging" was employed that drew on that used in the MacArthur studies of successful aging (e.g., Berkman et al. 1993). The following criteria were used to define "healthy aging":

1. no cognitive impairment (i.e., MMSE $>$ 23);
2. no ADL disability;
3. no more than one disability in eight activities reflecting physical performance (pushing or pulling heavy objects, stooping or kneeling, lifting a 10 pound weight, reaching above shoulder level, handling a small object) and gross mobility (climbing stairs, walking half a mile, doing light housework);
4. self-rated health good or better.

High functioning individuals were classified as those fulfilling any three of these four criteria. Using this classification, a group of 72 (23.5%) of the 307 participants were identified as high functioning. No attempt was made to subdivide the remaining participants, who were classified as "not high". This classification was then used as the dependent variable in an analysis designed to identify those pre-existing factors at Wave 1 that were associated with this outcome.

Data analysis followed the approach used by Andrews et al. (2002). First, univariate analyses were conducted to evaluate the relative importance of a large number of potential risk or protective factors for healthy aging. This screening exercise identified three groups of conceptually related predictors from Wave 1, which were designated health and lifestyle (e.g., arthritis, alcohol consumption, exercise), social (e.g., marital status, social contact), and economic (e.g., net assets, receipt of pensions and superannuation). The second stage of analysis then used a logistic regression model, controlling for age and gender, in which these groups of predictors were entered in separate blocks, to correct for mutual associations.

Table 2 shows the results of this analysis. Odds ratios and 95% confidence limits are shown for significant predictors only. The chi-square for the overall model was $\chi^2_{(9)} = 59.58$, $p < .001$.

Table 2. Factors at Wave 1 associated with healthy aging at Wave 6: logistic regression analysis.

Wave 1 predictor	Odds ratio	95% Confidence limits
Health and lifestyle factors		
Arthritis	0.45*	0.23–0.88
Number of IADL problems	0.39**	0.21–0.72
Frequency alcohol consumption		
Alcohol never	1.00	
Alcohol occasional	1.89	0.74–4.83
Alcohol regular	2.87**	1.33–6.17
Adelaide Activities Profile		
Domestic chores	1.02*	1.01–1.03
Household maintenance	1.02*	1.00–1.04
Social factors		
Index of social contact	1.02*	1.00–1.03
Number of social group memberships	1.21*	1.04–1.49
Economic factors		
Financial needs met (self-report)	2.26*	1.19–4.28

*$p < .05$. **$p < .01$.
All estimates adjusted for age and gender.

The Wave 1 health and lifestyle factors significantly associated with healthy aging status at Wave 6 were: no arthritis, regular alcohol consumption, fewer IADL disabilities, and greater activity in domestic chores and household maintenance. The Wave 1 social factors associated with healthy aging status at Wave 6 were more frequent social contact and membership of more social groups. The only Wave 1 economic factor associated with healthy aging status at Wave 6 was a self-report that the level of assets was sufficient to meet then current financial needs.

5. Discussion

These results from the ALSA are preliminary and the present analysis is very much "work in progress". More in depth analyses of these findings and their significance is currently being undertaken and further waves of data collection are planned that will contribute to the possibility of further longitudinal and outcomes analysis.

The present findings do illustrate, however, that survivors beyond 85 years old are a remarkable group, a significant proportion of whom exhibit the hallmarks of successful aging. There is a high level of general satisfaction with life, family, and community along with a positive sense self worth and purpose.

A number of predictors of achievement of what we defined as "healthy aging" were identifiable from data obtained 9 years earlier in the baseline data collected from ALSA participants. These predictors were: health and lifestyle factors including no arthritis, regular alcohol consumption, fewer IADL disabilities, and greater activity in domestic chores and household maintenance; social factors including more frequent social contact and membership of more social groups, and an economic factor of self-report that the level of assets were sufficient to meet then current financial needs.

The findings of this study suggest that there is considerable potential for fruitful investigation of the determinants, accompaniments, and outcomes related to maintenance of good health, function, and well-being among those surviving to very advanced age.

Rather than being dismissed as unlikely to benefit from interventions aimed at maintaining their personal sense of worth and contribution to family, community, and society there appears to be good evidence that investment in such strategies, as the numbers and proportion of the very old continues to grow disproportionately in many populations, would be worthwhile at individual and societal levels.

While the present study makes no claims of representativeness or generalizability the findings do point to the prospect of a generally more positive vision of what is achievable with survival into very advanced ages, the potential for the very old in populations to still have a voice within their families and communities, to continue to contribute meaningfully socially and economically and to enjoy their additional years to a much greater extent than seems to be commonly assumed. Further analysis of existing data sets including the oldest old and new research that includes these exceptional survivors is clearly warranted.

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CHAPTER 20. NEEDS, PROVISION, AND FINANCING OF CARE FOR ELDERLY

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1. Introduction

This chapter will approach issues related to the care of the oldest-old—the type of care needed, providing and financing such care—from a historical perspective. In addressing these three topics, four processes will be kept in mind: Aging, advancement of knowledge, replacement of generations, and continuous changes to social organization and health care systems.

I would like to put forward two ideas. The first is regarding care. With the increase in human longevity and number of older people, particularly the oldest-old, we are developing our knowledge about individual aging and its heterogeneous nature, and as a result are seeking ways to intervene to maintain autonomy for as long as possible. Two types of services contribute to this goal: Acute care (ambulatory and hospital) and long-term care (LTC). Long-term care is quite specific because it must fit into the life of the person and his or her family in order to ensure that health care and assistance are provided on a continuous basis. It is from this perspective that home care is now being promoted and traditional institutional mechanisms questioned. LTC has acquired its own legitimacy and visibility even though it is still often perceived as an "unproductive social necessity" (Feldman and Kane 2003).

Second, is the issue of financing. The levels and methods of financing chosen must contribute to maintaining the health and social integration of older people. Moreover, the challenge varies according to the demographic trends and the systems already established in each country.

Our discussion of the issues of acute health care and LTC services for the oldest-old will be based mainly on the Québec system. This Beveridge system, financed by taxes, puts an emphasis on LTC and is currently undergoing important changes (Trahan and Caris 2002).

I will first examine the needs of the oldest-old and their caregivers, both in terms of quality and quantity of services. The effect of age in relation to other variables such as vital status and health status will also be presented. I will then present a number of ongoing changes in the methods of assessing the population's needs, planning and organizing services for frail older persons. Finally, I will discuss various problems with financing LTC based on existing systems and demographic, economic and health trends.

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2. What Type of Care?

2.1. THE PROCESS OF DISABLEMENT OR FRAILTY

The oldest-old are associated with frailty, multiple acute and chronic diseases, physiological deficiencies, cognitive deficits, and disabilities that concur with social isolation, nutritive deficiencies and, for many, economic hardship (Béland et al. 2002). These health and social problems are part of the disablement process, while the probability of accumulating one health problem after another increases with frailty. Verbrugge and Jetté (1994) argue that the *disablement process describes (1) How chronic and acute conditions affect functioning in specific body systems, general physical and mental actions, and activities of daily life, and (2) the personal and environmental factors that speed or slow disablement, namely, risk factors, interventions, and exacerbators*. Lebel et al. (1999) define frailty as the risk that an older person has at a given time of developing or aggravating functional limitations or disabilities given the combined effects of deficits and modulating factors. Thus, frailty has a dynamic and evolutionary character which was revealed by longitudinal studies on the health of older persons and the measurement of transitions.

Only a fraction of elderly persons have this geriatric profile at a given time (about 20% according to Bergman, Béland, and Perreault 2002) and this fraction increases with age. However, it should be noted that the oldest population is replaced very quickly, since life expectancy at 80 years old is generally less than 10 years. We already know of several factors that differentiate the cohorts that constitute the older population of today from those of tomorrow, such as living conditions, education, lifestyle, financial security at retirement, and family composition. These factors will influence both the health status and the approach to caring for tomorrow's oldest-old. Behaviors related to seeking formal assistance—most often in addition to help from families—are already changing and differ according to characteristics such as education and income (Attias-Donfut 1999; Carrière et al. 2001; Spillman and Pezzin 2000). For instance, the higher the income, the less help received from children. New mixed models (formal-informal) are emerging. Also, it appears that the use of special equipment has helped to decrease the need for human assistance, at least in the United States (Manton, Corder, and Stallard 1993).

Moreover, LTC research has also shown that expectations for the frailest elderly can be raised (Feldman and Kane 2003). Careful training of nursing home staff to provide behavioral interventions can lead to dramatically improved results for patients with urinary incontinence. Even modest exercise training and nutritional supplementation can improve the function of residents who were thought to be beyond rehabilitation. Preventive (e.g., adjustment of homes to prevent falls and injuries) and rehabilitative programs are gradually being established, and the institutional model is increasingly questioned because some of its practices (physical and chemical restraints) are seen to contribute to a loss of autonomy and the onset of depression.

2.2. RANGE OF SERVICES

The needs of the oldest-old are numerous and complex. In order to meet these needs, services include not only traditional curative health care and dependency care (help and assistance in activities of daily living) but also a wider range of services aimed at supporting prevention and rehabilitation.

In the new Québec policy for the development of services for frail older persons, 6 types of care are defined: (1) information, prevention, and screening; (2) help for the individual; (3) help for informal caregivers; (4) basic professional services; (5) specialized gerontogeriatric, psychogeriatric, and rehabilitation services; and (6) palliative care.

Help for the individual comprises help given for personal activities, assistance with personal care (hygiene, meals, mobility, and taking medications daily), help with household chores (meal preparation, housework, washing, grocery shopping, and other errands) and help with community activities (budgeting, writing letters, filling out forms, or doing administrative tasks). Help provided to caregivers (family and friends) includes continuous monitoring of the elderly person or respite care, such as a weekend break or week-long vacation, which allows time for relaxation and recharging, and emergency relief in a crisis situation.

Basic professional services comprise various types of nursing care that are preventive, curative and palliative including such activities as evaluation, treatment, teaching and follow-up. Such basic services are also comprised of medical, rehabilitation, adaptation, psychosocial, pharmacy and nutritional services.

All of these services must be available throughout Québec and accessible regardless of a person's living environment, whether a private household or private residence for seniors or a nursing home. However, presently, this accessibility remains unequal due to financial constraints and the slow progress in implementing integrated networks of services.

2.3. CARE RECEIVED

Expenditures provide an overall indicator of the intensity of the use of acute health and LTC services. However, it is difficult to establish a common terminology since there are so many differences between the systems of different countries. Information systems are in fact often based on the place of service rather than on the type of service. In addition, the recent shift towards providing certain hospital care (post-acute and sub-acute) in the home or in nursing homes further blurs these boundaries (Stone 2000). Because LTC systems are more highly decentralized, nationwide information is often lacking and hard to interpret (Jacobzone 1999).

In the Organization for Economic Co-operation and Development (OECD) System of Health Accounts, nursing care given in nursing facilities or in the home is included in the definition of health care. Services for older persons and disabled persons such as day care, rehabilitative services, home care and in-kind benefits, as well as expenditures linked to care in an institution (for example, covering operating costs of residential homes for older persons) are included in the definition of social expenditures. However, it is not possible to determine social expenditures on this basis for certain countries, such as Canada (OECD 2002). Another OECD publication includes nursing care in dependency care (OECD 1998). Comparison of these two sources is surprising since the picture presented is similar for some countries but is different for others.

2.4. EXPENDITURE PROFILES BY AGE

The Québec data on LTC expenditures presented here includes nursing care in nursing homes or in the home, and human or technical (e.g., prosthetic) assistance services received by older persons with decreasing autonomy or disabled persons. Estimated hospital care (post-acute and sub-acute) provided in the home, which is increasingly common, was excluded; on the other hand, drug expenditures for residents are included in the expenditures of nursing homes. The universe of LTC expenditures is thus similar to that found in other studies (Economic Policy Committee of the European Commission 2001 for public expenditures and OECD 1998).

Public expenditures on acute health and LTC represent 4.7% and 1.6%, respectively, of Québec's GDP. Although total expenditures on acute health and LTC (6.9% and 2.1% of GDP) are not represented, their age profiles are similar to those of public expenditures. The expenditures on acute health and LTC increase with age but differently, the latter concentrated among the oldest-old (Figure 1). As has been observed in European countries, (public) health expenditures occur at all ages and increase from the age of 40 to the 85–89 age group (with a few exceptions in Europe). On the other hand, expenditures on LTC are very low until age 65 when they begin to increase rapidly. In Québec, as in European countries where LTC is developed and reaches at least 2% of GDP, expenditures for LTC are higher than other health expenditures in the 85 or older age group (Economic Policy Committee of the European Commission 2001: graphs 4.1 and 4.3 and Table A5–4).

This substantial increase in LTC expenditures reflects the fact that the rate of institutionalization increases greatly with age. In Québec, as in most of the countries for which information is available, institutionalization expenditures make up most of public expenditures on LTC (Jacobzone 1999). The oldest-old are those who most need these services and from the age of 85 onwards, expenditures on LTC appear to be greater than expenditures on acute health care.

Cohorts that will become the oldest-old in a few decades should have benefited from significant access to medical care over their lives and one could hypothesize that they might have greater recourse to that care than current cohorts. However, this hypothesis is not confirmed by the Québec data of the past 20 years. In fact, when consumption of all types of services (health and LTC) is examined, very little change in the age profile is observed (Rochon 2002).

2.5. AGING AND LIFE EXPENDITURES

The age profile of expenditures, however, cannot account for the evolution of needs as individuals age. It represents the consumption of a group of persons who are the same age but who do not have the same health status or the same number of years to live (Fuchs 1984). When the same individuals are followed over time, it is observed that, regardless of their age at the moment of death, the highest consumption of acute and LTC takes place in the last years of life (Roos, Shapiro, and Tate 1989).

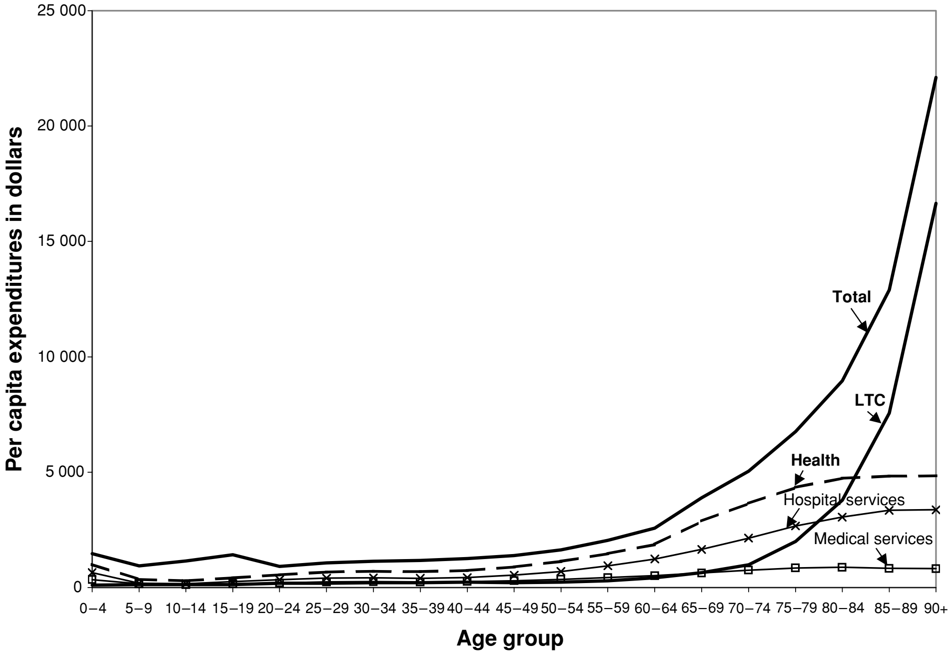

Figure 1. Per capita public expenditures on acute health and long-term care by age, Québec, 1999.
Source: Rochon M., Ministère de la Santé et des Services sociaux (unpublished data).
Note: Public expenditures represent nearly 100% of hospital and medical services expenditures but 60% of expenditures of other types of institution (in Québec, a contribution is required for food and accomodation, and is geared to the individual's income) and home care, a third of drugs (excluding drugs provided by the institutions to their patients) and very few services by other health professionals (e.g., dentists).

American data on health expenditures, including nursing homes and home care services, shows that when we compare individuals with the same vital status, or the same number of years to live, age has a different effect from that indicated by the profile in Figure 1 (Spillman and Lubitz 2000). Indeed, in a cohort of deceased persons (in the same period), there is a decrease in acute health expenditures with age and, in contrast, an increase in nursing home expenditures, plus a slight increase in total costs in the last 2 years of life. Only persons who die at age 90 or more incur, at the end of their lives, LTC expenditures greater than acute health care expenditures (defined as Medicare expenditures). Nevertheless, the composition of expenditures changes gradually, with increasing LTC expenditures, as people die at an advanced age. These results are confirmed by data from another Canadian province (McGrail et al. 2000).

Another recent American study that simulates the life of a fictitious cohort (synthetic cohort) from age 70 onwards, based on 6 years of observation, provides an entirely different perspective of longevity because it allows us to clearly identify the effect of health status on the expenditures of individuals (Table 1 from Lubitz et al. 2003). If the 2% of persons who already live in a nursing home by age 70 are excluded, better functional health at age 70 is associated with increased life expectancy but with similar life expenditures and time spent in an institution. Thus, 28% of people who do not have any functional limitations at age 70 can expect to live more than 14 years, including 8.7 years or 61% without limitations or with minor limitations, while 18% of persons who need help in activities of daily living can expect to live 12 years including only 4 years (35%) without limitations or with minor limitations. Their life expenditures are nevertheless similar, ranging from US$136,000 to US$145,000, as is their length of stay in an institution of 0.7 years. Life expenditures are similar, regardless of the initial health status, because each health status is associated with a different annual cost (bottom of Table 1), and it is the length of time spent in each of these states (top of Table 1) which is the determining factor.

Unpublished data also indicate a similar pattern of life expenditures by type of service (physician and outpatient hospital, inpatient hospital, nursing home, prescription drugs, and others) or by source of payment (Medicare, out of pocket, Medicaid, private insurance, and other). Similar results were obtained using self-reported health status instead of functional status (Lubitz et al. 2003).

Good health is thus associated with an expanded length of life and, more importantly, with a longer length of life in good health and a shorter length of life in poor health. As cohorts reach the oldest-old ages in good health, this could thus translate into a reduction of (absolute and relative) morbidity. Increases for acute care and LTC needs would then be less substantial than suggested in Figure 1, as there will be a shifting in the age at which LTC needs are greater than acute care needs.

3. How Should Care be Provided?

All health systems are confronted with increased costs and the utilization of services (e.g., medical services, drugs, etc.). Moreover, these systems developed at a time when health issues and diagnostic and therapeutic means were quite different from those of today. The hospital has become a high-tech place where each stay represents considerable costs, is intended to be short-term and where the frail older person is viewed as a bed-blocker. Reforms have been carried out in many countries, resulting in the transfer of post-acute and sub-acute care from the hospital to the home, thus increasing the pressure on home care resources and the complexity of services received there. In Sweden, for example, resources have been transferred between sectors, but the increase in resources in the community has not always kept up with needs and has led to a greater emphasis on prioritizing patients (Lagergren 2002).

Moreover, in Québec as in other countries, the decline in institutionalization rates has contributed to the growth in the need for home care services, making it even more difficult for existing resources to meet needs. New resources have been developed through the social economy to support persons with difficulty in instrumental activities of daily

Table 1. Life expectancy at age 70 and expected expenditures from age 70 until death in different functional states by functional state at age 70, United-States.

	Functional state at age 70				
Functional states	**No limitation**	**Nagi limitation**	**IADL limitation**	**ADL limitation**	**Institutionalized**
			Population as %		
Total	28	40	12	18	2
			Years in functional state		
Total	14.3	13.7	12.8	11.6	5.3
No limitation or Nagi only	8.7	7.8	5.3	4.0	0.3
IADL or ADL limitation	4.9	5.2	6.8	6.8	0.6
Institutionalized	0.7	0.7	0.7	0.7	4.5
Total (%)	100	100	100	100	100
No limitation or Nagi only (%)	61	57	41	35	6
IADL or ADL limitation (%)	34	38	53	59	10
Institutionalized (%)	5	5	5	6	84
			Health care expenditures (1998 US$)		
Total	136 000	138 000	140 000	145 000	226 000
No limitation or Nagi only	44 000	43 000	29 000	23 000	2 000
IADL or ADL limitation	60 000	63 000	79 000	89 000	8 000
Institutionalized	32 000	32 000	32 000	33 000	216 000
Total (%)	100	100	100	100	100
No limitation or Nagi only (%)	33	31	21	16	1
IADL or ADL limitation (%)	44	46	56	61	3
Institutionalized (%)	23	23	23	23	96
			Mean health care expenditures per year		
Total	9 000	10 000	11 000	13 000	43 000
No Limitation or Nagi Only	5 000	5 000	6 000	6 000	7 000
IADL or ADL Limitation	12 000	12 000	12 000	13 000	14 000
Institutionalized	45 000	45 000	45 000	45 000	48 000

Source: Lubitz et al., 2003, and unpublished data.

Relative standard errors were less than 10% except for years lived and expenditures incurred in non-institutional states for persons institutionalized at age 70, representing about 25%. Hierarchical classifications were used to define functional states (e.g., Nagi limitation means at least one Nagi limitation but no other limitation). Multistate life-tables methods and microsimulation were also used to estimate life expectancy. Data are from the Medicare Current Beneficiary Survey from 1992 through 1998. The response rate is approximatively 70%. The data is based on 16,964 persons and 50,477 person-years.

living (IADLs). Nevertheless, it seems clear that in-home care services are not increasing as rapidly as needs, and public services focus primarily on personal assistance and professional care (nursing, rehabilitative, psychosocial) (Trahan and Caris 2002).

Current problems in LTC reflect the lack of answers to three interrelated questions. What is the population's level of service needs? What are the resources needed to respond to them? How can resources be distributed and coordinated more efficiently?

3.1. ASSESSMENT OF NEEDS, PROCESSES, AND OUTCOMES

Several tools have been developed and implemented in recent years to respond to these questions and to improve care for frail older persons living in an institution or in the community. In particular, computerized evaluation and follow-up tools are shared by all workers involved in the care of a person. Examples of broad-ranging tools include the Resident Assessment Instrument (RAI) for nursing home residents and the Outcome and Assessment Information Set (OASIS) for home health care (Feldman and Kane 2003). In Québec, a multiclientele tool, including the Functional Autonomy Management System (SMAF), is being systematically used in institutions and now at home (Hébert et al. 2001a). Plans exist to integrate more narrowly focused tools designed to recognize additional problems (e.g., cognition, depression, and caregiver's needs).

These tools allow for a standardized assessment of the needs of frail older persons and promote the establishment of individualized service plans and networking for more efficient use of existing resources. Fragmentation of services seems to generate substantial costs in many systems. These processes require the collaboration of several types of professionals attached to different places of service delivery.

The adoption of common evaluation tools at the national level helps us to better understand the population's service needs, especially if the tools accurately reflect the impact of cognitive deficits. Information generated by these systems can be used to improve the methods of organization of services as well as workers' practices. Moreover, at the international level, these common tools facilitate comparisons between different methods of management for similar clientele (Hirdes, Carpenter, and Challis 1999).

The research also focuses on the efficiency or cost-effectiveness of the different methods of intervention and places of service delivery. Thus, in the United States, the introduction of geriatric nurse practitioners has dramatically reduced nursing home residents' use of acute care in hospitals (Feldman and Kane 2003). In Canada, for the same level of dependency, the public costs of health care and LTC (including hospitalization costs) are lower in the home than in an institutional setting (Hollander 2001). Care management methods can only be assessed by taking into account all the care (health and dependency) incurred by frail older persons. This assessment method often favors the improvement of LTC services.

The data generated by these systems, combined with other data such as unit cost of services, can also be used to allocate human, material and financial resources based on the population's needs (Feldman and Kane 2003; Hébert et al. 2001b). Moreover, in some countries, as for example in the United States, the quality of services can also be assessed through the implementation of these mechanisms (Clauser and Bierman 2003).

3.2. QUALITY OF HUMAN RESOURCES AND ALTERNATIVE ENVIRONMENTS

The quality of services, particularly in alternative environments, human resources training and staff retention are concerns shared by many countries. Training programs for professional and paraprofessional staff, including evidence-based guidelines and protocols, are necessary.

Denmark provides an interesting example in this respect. Having recognized the fact that assistance to older persons arrived too late to have a preventive effect and that the services provided encouraged dependency, the so-called Aging Package was adopted in 1987. It included a halt on the construction of nursing facilities and sheltered housing, permanent home help free of charge, and a new common basic training scheme for all staff members working in social assistance and nursing care. New types of residences were created to allow people to grow old in their own homes. The same teams work at the homes or in residences for older persons, and services are available 24 h a day, regardless of where the older person lives. About 10% of people aged 70 or over live in special units for the elderly. Moreover, 20% of people aged 65 or over and 40% of people aged 80 or over receive home help services (Schroll 1999). However, the proportion of older persons who live in nursing homes is still high (5%) and increases sharply with age. Thirteen percent of 80–89 year olds and 41% of those aged 90 or over live in nursing homes (Witsoe-Lund and Ibenfeldt-Schultz 2002). A great number of people suffering from dementia live in nursing homes. Nevertheless, other living arrangements have been explored and have now become widespread, in particular sheltered facilities or units which include 6–9 people. Better outcomes in terms of well-being and a decrease in drugs consumption have been obtained there (Witsoe-Lund and Ibenfeldt-Schultz 2002).

Sweden has the highest institutionalization rate of the older population (8%). However, if the 2.7% of people who live in intermediate-type residences (residential homes which offer community living and various types of services) are excluded, only 5% of older persons in Sweden cannot stay in their own homes due to their health conditions, and live in a relatively medicalized institution (Johansson 2002; Lagergren 2002).

In Germany where new LTC insurance was introduced in the mid-1990s, the institutionalization rate of older persons is similar (5%) and private residences for older persons are expanding rapidly. In Québec, as everywhere else in North America, an assisted-living movement has emerged, based on a variety of private formulas (rarely financed with public funds) and the institutionalization rates, which have been decreasing, now hover around 4%. This rate will probably decline even more if new alternative resources are developed and home resources increase.

The health care system has changed and become more and more accessible over the last 50 years and this will have to continue for the next 50 years for the LTC system, as the problems facing the oldest-old become increasingly visible. Both the preservation of the health of older persons and their principal caregivers and the greater participation of women in the labor market will increase pressure for developing and improving services.

4. How Should Care be Financed?

The challenge of funding services differs among societies due to reasons related to the history of the development of their social protection system. The cost of an LTC program varies according to the objectives set, the mechanisms selected, and the public and private costs already assumed. Objectives must be defined as complementary to health care and financial social assistance programs. The place of service seems to be crucial in determining the public LTC cost because the family is more involved in a non-institutional setting (Hébert et al. 2001b). Moreover, the choice of cash or in-kind service is tricky but a combination of both methods is certainly desirable since it helps to attain the objectives of autonomy and quality of care according to the person's level of dependency.

4.1. SYSTEMS AND METHODS OF FINANCING

Every country's health system has its own history and organizational mode. In Europe, the health and social protection systems developed on the basis of two models. The Bismarck model covers workers and their families against social risks while the Beveridge model covers the entire population. In the first case, contributions are deducted from the payroll (shared between employers and employees) whereas in the second case, the financing of services is ensured by taxes and universal rights (to education, health services and so on). Traditionally, Beveridge systems have integrated LTC into social protection measures (Joël and Dufour-Kippelen 2002). Scandinavian countries have gone the furthest in this direction and devote the largest proportion of their national budget to dependency care.

Anglo-Saxon systems, which belong to the second tradition, have significant differences: less recognition of universal rights and more emphasis on the market. In Canada and the United States, financing methods and access to care differ greatly. The American insurance system is based on the workplace and a universal program which covers older persons, Medicare. The latter program covers only a small share of expenses in institutions (11%)—predominantly for-profit nursing homes—and Medicaid, a means-tested public insurance program, helps low and medium income people get access to nursing homes (Norton 2000). According to some authors, from half to two-thirds of nursing home residents are covered by Medicaid (Norton 2000; Wiener and Tilly 2002). In Canada, the Canada Health Act ensures universal access to medically required services. LTC in institutions is quite developed but the growth of home care services is insufficient. In Québec, the institutionalization rate is similar to that of the United States (4% compared to 5%) but access is based on needs, and services are free of charge although a contribution, tied to income, is required for food and accommodation. This contribution represents 17% of the expenditures of public residential and LTC institutions.

Furthermore, in both countries, different types of residences have appeared for older people, such as assisted living. Services were offered to meet the needs of people with a mild loss of autonomy and different lifestyle choices (autonomy and security of group living). In the

United States, the increase in the use of formal services by the disabled population can be partly explained by this phenomenon (Spillman and Pezzin 2000).

In every country, private LTC insurance is limited and does not seem to represent a true alternative (Joël and Dufour-Kippelen 2002). In the United States, about 10% of the elderly have purchased this type of insurance which pays for about 8% of nursing homes and home care expenditures (Finkelstein and McGarry 2003; Marks 2003).

4.2. TRANSFER OF RESOURCES BETWEEN SECTORS

It should be mentioned that the history of the development of institutional mechanisms in many countries has been associated in the past with economic hardship among older people rather than with their state of health. Thus, in Québec, while the LTC institutional component was the LTC hospital for chronic care patients, a network of residential centers was created to offer decent accommodation to older persons at a reasonable cost. However, this network has gradually changed its role because of the aging of its residents and the sharp increase in the number of older persons within the population. As a result of the increase in older persons' income, accessibility criteria based on income have been replaced by increasingly rigorous and standardized processes of assessing functional autonomy. In addition, this network has been merged with older hospitals for chronic care patients, resulting in a single network of public residential and LTC institutions, which accounts for its highly institutional nature.

In Germany, the recognition of the dependency risk served to ensure accessibility to care, which was compromised by unequal access to the benefits of local income security programs operated by cities, towns, districts, and states (Von Kondratowitz, Tesch-Römer, and Motel-Klingebiel 2002). In Japan, a new scheme was created to relieve overcrowding in hospitals.

4.3. CONTRIBUTION OF OLDER PERSONS TO THE FINANCING OF PUBLIC EXPENDITURES

Several mechanisms affect the allocation of the burden of expenditures; the public-private share is not the only way to describe this allocation. What an older person pays in the form of direct contribution is only one part of his or her total contribution. In systems where government financing is substantial, a significant part of public financing can indeed come from older people (Rochon 1999). Even a Bismarck-type system, such as the French system, already use state revenues in order to extend coverage and make up for deficits in health insurance funds, which requires a resort to taxation to ensure that older persons contribute to the financing of care.

In Scandinavian and Anglo-Saxon countries like Canada, the contribution of older persons to the financing of health expenditures can be considerable. In Québec, the average contribution of an older person to the financing of government expenditures was estimated to be 73% of that of a working-age person (20–64 years old) and this proportion is increasing. However, in the case of health and social services expenditures, the contribution is only 52% because of the existence of a health services fund (Fonds des services de santé) financed by deductions from the wage bill (Rochon 1999). Consequently, older people, who represent 13% of the population, finance approximately 6% of public expenditures for health and dependency. The positive aspect of this approach is that the financial burden is shared among all population age groups, broadly based on their economic resources.

The burden sharing feature of the Canadian taxation system might also greatly help the financing of additional public expenditures. Net tax expenditures related to private pension plans (tax exemption for contributions and investment income) are quite substantial in Canada, representing more than 3.5% of GDP. However, simulations conducted by Mérette (2002) show that by the time population aging exerts great pressure on the share of wealth devoted to public expenditures, these net tax expenditures will decrease, generating revenues of about 1% of GDP. These two taxation-related mechanisms (tax expenditures and method of financing health and dependency expenditures) should therefore ensure that the burden of increased expenditures will be better divided among cohorts.

Furthermore, besides intergenerational transfers, income redistribution among cohorts is also an issue. Cohorts of richer older persons will be asked to contribute more, and it is the specific conditions in each country which will influence the choice of modality. In countries like the United States, the concern is that the most vulnerable people do not have access to the resources required by their state of health (Stone 2000).

4.4. DEMOGRAPHIC AND ECONOMIC CHALLENGES

Moreover, although all Western societies are experiencing a marked increase in their oldest-old population, the rate of increase and relative size are far from uniform (Jacobzone, Cambois, and Robine 2000). In 2000, Sweden had the highest proportion of people aged 80 or over, much higher than that in Canada for example (5.1% compared to 3.0 %). However, Canada is going to experience a more rapid increase in this population (increases of 41% in Sweden and 95% in Canada in the next quarter century). Among OECD countries, Japan will have the highest increase in its oldest-old population (174% during this period) and its proportion of the oldest-old will exceed that of Sweden by 2025 (United Nations 2003).

The challenges of providing and financing LTC services to the oldest-old population are different, both in terms of the increase in this population's needs and the capacity for financing. The decrease in the size of the working-age population can alter the potential for economic growth (OECD 1998). In countries where the LTC workforce is poorly trained, badly paid and mobile, there is concern that it will be difficult to provide LTC at home or in an institution when the workforce increases less rapidly than the need for services (Stone 2000).

4.5. BABY BOOM COHORTS

In most Western countries, the first cohorts of baby boomers—i.e. those born generally between the mid-1940s and the late 1950s—are the last to have seen a continuous increase in their cohort size at birth, and their transition to each stage of their life cycle thus marks a challenge and a breaking point. The challenge comes from the level of resources that need to be increased relatively quickly, and the breaking point is due to the fact that they are followed by cohorts made up of fewer people, working-age cohorts with some risk of collective impoverishment.

The challenge posed by population aging in the coming decades can thus be illustrated by the stages of life that these baby boom cohorts will go through: end of working life, needs for acute health care, and then needs for LTC. Problems related to dependency and frailty come last; and the preceding stages, both in terms of the individuals' lives and the way in which society will manage each of these stages, will influence the level of success of society in adapting to its population aging.

In addition, baby boomers are currently faced with their parents' aging and the role of caregiver. It is not known what lessons they will draw from this experience nor the therapeutic possibilities for dementia and osteoarthritic problems which will exist when they reach the oldest-old age. Being better educated, they will understand their health status to a higher degree and most often will adopt self-care strategies. They will no doubt be more demanding about accessibility and quality of care in order to preserve their quality of life for as long as possible. What choices will they make when they are no longer able to ensure this quality? New laws on the protection of demented persons, living wills, and assisted ending life are possible considerations.

4.6. A COHERENT SET OF SOCIAL PROTECTION PROGRAMS

For pension payment, it is longevity that matters but for acute and LTC, it is the length of time spend in each health state and the complementarity of formal and informal services that matter. Thus, there are many uncertainties about both the increase in needs and the capacity for financing. Countries are certainly not facing the same challenges in terms of formal services and demographic changes (Jacobzone et al. 2000).

The next two decades will be decisive in terms of evolution of the collective wealth and the capacity for financing social protection systems. Proper coverage of end-of-life dependency risk is desirable in the coming re-engineering and this will probably happen gradually. A society which needs to retain a skilled workforce should make caregivers' lives easier by implementing various types of measures to reconcile work and family. Responsibilities between the individual and the collectivity in the organization and financing of acute and LTC will be reviewed in many countries. It should be mentioned that even if the costs of formal care increase, the total costs (direct and indirect) for society will not necessarily increase (Hébert et al. 2001b).

However, a country's situation may have both positive and negative aspects. Japan is facing the largest increase in its old-age dependency ratio but it also has a very low level of taxation. The aim of the reforms considered is therefore to increase the tax base (Tax Commission 2003). Canada must deal with a very large increase in the number of older people but its situation of government revenues is favorable because of its rather distinctive taxation system and the maturing of private and public pension plans.

Moreover, government debt level is another factor which may hamper the increase in the financial resources needed for the development of public health care and LTC. As debt is negative saving, its reimbursement is a form of capitalization and contributes to intergenerational transfers.

In the Beveridge systems, demographic changes gives rise to the problem of adapting a set of public programs for the older population and to arbitration mechanisms between government sectors (education and health, for example). The more limited the financial resources, the more intense intersectional competition will be.

Finally, in many countries, future pressure on the LTC systems, which are generally decentralized, could lead to a questioning of the distribution of responsibilities and of the tax revenues between government levels (Joël and Dufour-Kippelen 2002; Robson 2001).

5. Conclusion

Depending on the country, LTC systems are more or less developed and coordinated with the health care systems. They are also faced with different qualitative problems. Advancement of knowledge has shown the reversible nature of several functional states. Preventive and rehabilitative programs are important components of LTC. Quality of care, human resources training, and efficiency of acute and long-term services organization are also significant issues. The range of public services must aim at improving the health status and slowing the rate of decline of frail elderly. Ultimately, LTC must be coordinated very closely with acute health care services and distinguished from social assistance mechanisms based on insufficient income.

The place of the family and the role of institutions for frail elderly also vary according to the country. It is assumed that these will change with new cohorts of better-educated people and women who are more integrated into the labor market. Institutions, seen to contribute to loss of autonomy, could be transformed or replaced by alternative settings. More home services, public or private, are needed. On the one hand, cost sharing between frail individuals and their families, as well as various social protection programs are destined to change. A coherent set of social protection programs for elderly is needed. Universal coverage of end-of-life dependency risk is desirable in the coming re-engineering and this will probably happen gradually.

The next two decades will be decisive in terms of the impact of a declining workforce on the evolution of the collective wealth and the capacity for financing social protection systems. In this context, financial contribution of growing numbers of elderly by several fiscal policies is highly recommended. In several countries like Canada, baby boomers could also be wealthier, especially women.

Some Beveridge social protection systems have better integrated LTC. This type of care is more predominant in the last years of life of very old people. But, it is likely that there will be a shift in the age at which LTC needs become important as better initial health corresponds to higher active life expectancy and lower frail life expectancy. Thus, beyond a certain age, longevity does not have an impact on total expenditures nor on length of time spent in an institution.

Clinical advances are possible for the oldest-old as they have been at other ages throughout the 20th century. Tomorrow's cohorts of older people will benefit from an enhanced understanding of the problems encountered in the oldest-old age and from the improved efficiency of the current care management systems (better outcomes for a given cost).

The fatalism of the 1960s and 1970s has given way to an era of unprecedented optimism about human longevity. This expanded life brings new challenges such as maintaining older people's health and the quality of acute and long-term care services intended for them as well as adapting social protection systems.

The challenge posed by population aging in the coming decades can be illustrated by the stages of life that the first cohorts of baby boomers will pass through. Problems related to dependency and frailty come last and the preceding stages, both in terms of the individuals' lives and the way in which society will manage each of these stages, will influences society's level of success in adapting to its aging population.

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