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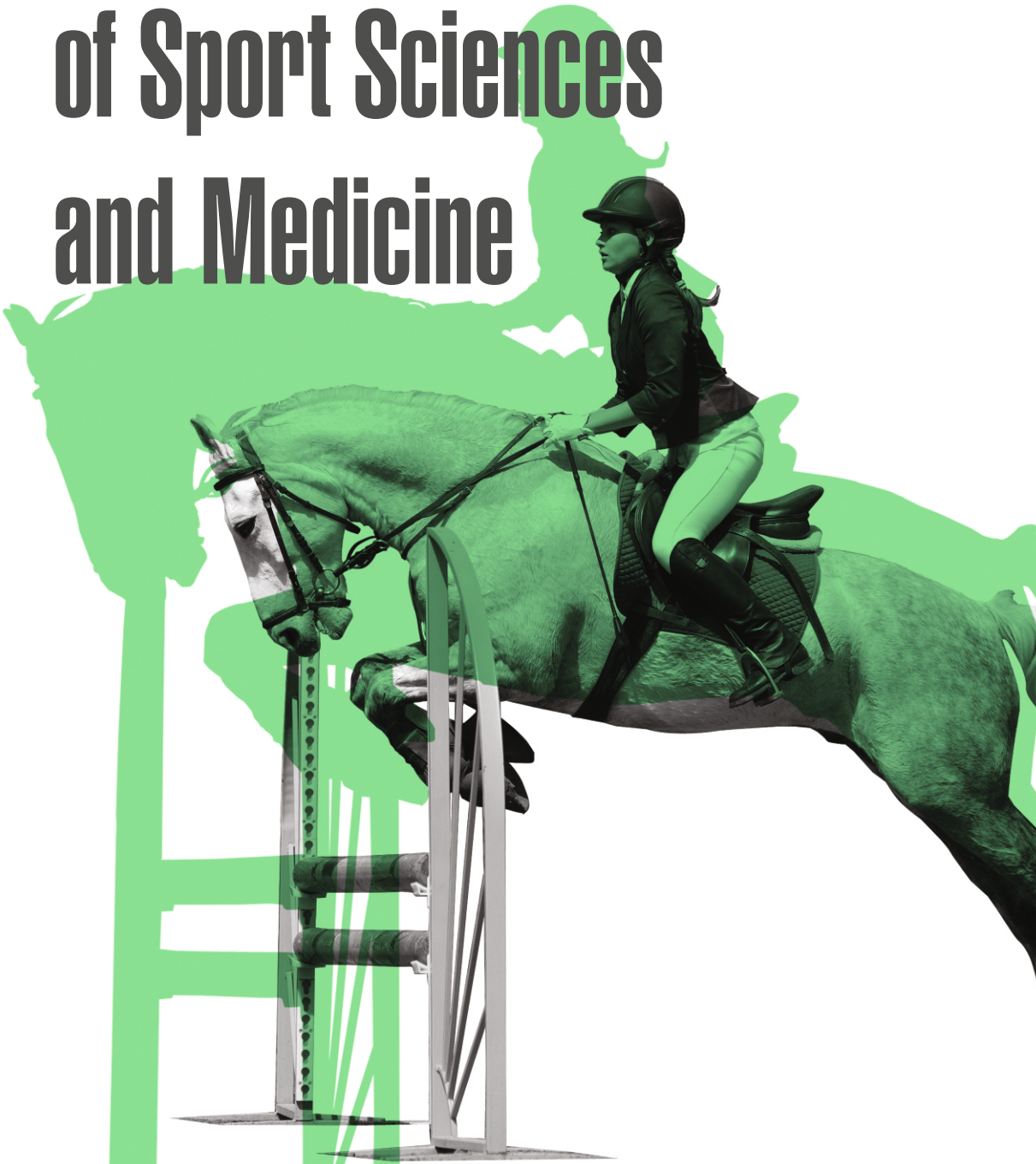

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Contents

RUNNING ANAEROBIC SPRINT TEST, LACTATE MINIMUM AND CRITICAL VELOCITY PROTOCOL IN SHUTTLE FUTSAL TESTING

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Abstract. The aims of this study were to investigate whether the running anaerobic sprint test, lactate minimum and critical velocity protocol can be applied in shuttle futsal testing, and to investigate if these protocols provide related variables. Seven male well-trained futsal players were evaluated. The lactate minimum test (Lac_{Min}) consisted of three phases: a) a hyperlactatemia phase using the running anaerobic sprint test (RAST); b) recovery phase; c) an incremental shuttle test for the lactate minimum speed (LMS) determination. Successful rate (SR) was calculated for feasibility analysis. Peak, mean and minimum power and fatigue index were obtained by the RAST application (six bouts – 35 meters). The critical velocity protocol (CV) was applied through three exhaustive shuttle tests (12, 13 and 14 km/h) with distances of 20 meters. Critical velocity (Cv) and anaerobic running capacity (ARC) were analysed by the linear (velocity vs.1/tlim) and hyperbolic (time vs.velocity) models. Fits of regression (R^2) were considered as the main result for feasibility analysis of CV. ANOVA showed a difference between linear (11.04 ±0.55 km/h) and LMS (9.67 ±0.50 km/h), and no significant correlation was observed between them. High SR (85.71%) was observed for Lac_{Min}, and high R^2 for CV (linear-R^2 = 0.99 ±0.04; hyperbolic-R^2 = 0.98 ±0.02).Overall, the RAST, Lac_{Min} and CV can be successfully applied in shuttle futsal testing, nonetheless, precaution is necessary since the test results were not related.

Key words: Aerobic-anaerobic transition, fitness testing, exercise evaluation

Introduction

Similar to soccer, but played in restricted spaces, futsal is an intermittent sport requiring both aerobic and anaerobic metabolisms during matches (Rebelo et al. 2011). Despite the fact that the scientific community have

been studying this sport in several aspects (Barbero-Alvarez et al. 2008; Castagna and Barbero-Alvarez, 2010; Castagna et al. 2009; Dogramaci et al. 2011), there is a lack of reports around the application of evaluation protocols for aerobic and anaerobic parameters determination.

Proposed by Zacharogiannis et al. (2004), the running anaerobic sprint test (RAST) is an Wingate Anaerobic Test adaptation (Bar-Or et al. 1977) for running. This test consists of six 35-m maximal bouts with 10 seconds recovery between efforts. Certain advantages are recognized by means of RAST application, such as the obtainment of parameters related to anaerobic power, low financial cost, necessity of only one evaluation day and easy application in the field. Additionally, RAST reliability and validation has already been investigated (Balciunas et al. 2006; Zagatto et al. 2009). Although this protocol has also been applied for military personnel (Zagatto et al. 2009), handball athletes (Roseguini et al. 2008) and well trained subjects (Deminice et al. 2013), its application in shuttle futsal testing is unknown. On account of the great anaerobic metabolism participation during futsal matches (Rebelo et al. 2011), the data from RAST may be valid for both controlling and prescribing training.

The so-called lactate minimum test (Lac_{Min}) (Tegtbur et al. 1993) was classically proposed in running and subsequently adapted to cycling (MacIntosh et al. 2002) and swimming (Ribeiro et al. 2003) exercises. This test is started by a short supramaximal exercise inducing hyperlactatemia followed by short rest period to allow the equilibrium between muscle and blood lactate concentration ([Lac]) (Faude et al. 2009). Subsequently the rest period, an incremental phase is initiated. In the first stages of low intensities, the [Lac] is expected to fall, and in the next stages of higher intensities to rise again. The lowest point of the "U-shaped" lactate curve is assumed as the lactate minimum speed (LMS), which is related to the intensity where the [Lac] is in equilibrium (Faude et al. 2009), or in other words the lactate threshold (Kindermann et al. 1979). Despite the interesting possibility of the LMS assessment in only one evaluation session, few scientific information is available regarding the Lac_{Min} in shuttle testing (Ribeiro et al. 2003). Additionally, there is no data about the application of this test in shuttle futsal testing.

Based on mathematical analysis, the critical velocity protocol (Lloyd 1966; Wakayoshi et al. 1992) is an analogous of the critical power concept proposed by Monod and Scherrer (1965). The critical velocity (C_V) and the anaerobic running capacity (ARC) are known as the aerobic and anaerobic estimates provided by this test. While the C_V is related to the maximum rate of work performed for a long time without fatigue, the ARC is recognized as the finite amount of work that can be used above C_V (Jones et al. 2010). In view of the mathematical approach beyond this test, several studies have applied linear and nonlinear (i.e. hyperbolic) mathematical models to assess the aerobic/anaerobic estimates (Bull et al. 2000; Copp et al. 2010; Gobatto et al. 2013; D. J. Housh et al. 1990; T. J. Housh et al. 2001). Also, this approach is an interesting way to ease the estimates obtainment, since the necessary mathematical knowledge required by this protocol may hamper the analysis of its results. Taking into account the necessity to improve both aerobic and anaerobic capacity of futsal players for better performance, and the relationship of critical velocity estimates with these capacities, the protocol adaptation in shuttle futsal testing is an interesting proposal.

Considering that the application of RAST, Lac_{Min} and critical velocity protocol in futsal may provide relevant information to improve athlete's performance, the aims of this study were to investigate whether these tests can be applied in shuttle futsal testing and to investigate if these protocols provide related variables.

Methods

Participants

Seven well-trained futsal male athletes (ages 22 ±2 years old, body mass79.4 ±13.9 kg and height 176 ±8 cm) were evaluated. Prior to the evaluate sessions, the athletes were asked to keep the same individual food/hydration habits and avoid hard physical activity, alcohol and caffeine ingestion. After a detailed explanation about the risks and objectives of the study, a written informed consent was signed by all participants. All experiments were approved by the Ethics Committee of the Methodist University of Piracicaba (no. 33/10) and performed in accordance with the ethical standards of the 1964 Declaration of Helsinki.

Design

For RAST, Lac_{Min} and CV applications and assessment of its variables, each athlete participated in four evaluation sessions separated by 24 hours between sessions. Every evaluation session was applied in an official futsal court and took place at the same time of the day (±1 h). Moreover, athletes wore the same running shoe and lightweight running kit for all tests. In the first session the athletes performed the RAST and Lac_{Min} test for anaerobic and aerobic variables assessment, respectively. The RAST was applied in the first phase of the Lac_{Min} test. In the following three evaluation sessions, the CV protocol was applied randomized. The aerobic and anaerobic variables provided by this protocol were analysed using both linear and hyperbolic mathematical models. Before each of the tests, the athletes performed 10 min of self-paced jogging as a warm-up.

Running Anaerobic Sprint Test

After weighed, the athletes performed six maximal bouts of 35 meters in a futsal court, with passive recovery of 10 seconds between bouts. Time (s) of each bout was recorded with a timer (Casio, HS – 30 W – N1). Peak power ($Peak_{power}$), mean power ($Mean_{power}$) and minimum power (Min_{power}) were calculated by: Power = (Body mass × $Distance^2$) / $Time^3$ (Zagatto et al. 2009). Maximum velocity (V_{maxR}) was calculated by: V_{maxR} = Distance / fastest bout. Fatigue Index (FI) was calculated according to Fitzsimons et al. (1993): FI = (100 × (total sprint time / ideal sprint time)) – 100; where Total sprint time (TT) = sum of all the sprint times and Ideal sprint time = number of sprints × fastest sprint time.

Lactate Minimum Test

The lactate minimum test consisted of three phases (Figure 1a): 1st phase – Hyperlactatemia induction – Hyperlactatemia induction was conducted by the RAST; 2nd phase – Passive recovery – After the hyperlactatemia induction, athletes performed a passive recovery for 8 minutes. 3nd phase – Incremental test – Right after the passive recovery, an incremental test was performed in stages of 3 minutes in shuttle exercise with distances of 20 meters. Velocity was controlled by a metronome considering as predictive loads the velocities of 7, 9, 10 and 12 km/h. Lactate minimum speed (LMS) was determined as the lowest lactate value of ''U-shaped'' curve between blood lactate concentration and load (Figure 1b). Capillary blood samples were collected before and at the third, fifth and seventh minute after RAST, and at the end of each stage of incremental phase. Each blood collection took approximately 20 seconds. Successful rate (SR) of the Lac_{min} was determined considering $R^2 \geq 0.80$ in a polynomial second order fit, according to Araujo et al. (2007).

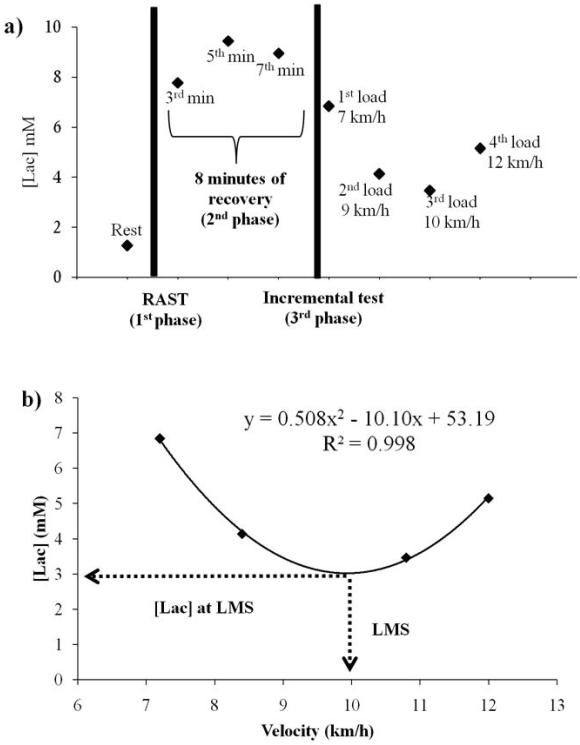

Figure 1. a) Three phases of the lactate minimum test and the respective [Lac] at each phase. b) Example of "U-shaped" curve of blood lactate concentration vs. velocity in the incremental phase

Critical Velocity Protocol

Athletes performed three exhaustive shuttle tests, with 20 meters of distance in 12, 13 and 14 km/h velocities controlled by a metronome. Individual time to exhaustion (tlim) was recorded in each test. Exhaustion criteria were considered as the non-maintenance of previously established velocity in two consecutive 20 meters or voluntary exhaustion. Critical velocity (C_V) and anaerobic running capacity (ARC) (aerobic and anaerobic variables, respectively), were obtained by two mathematical models. 1) linear model of velocity (v) vs. 1/tlim proposed by Hughson et al. (1984), with C_V ($C_{VLinear}$) related to intercept-y and ARC (ARC_{Linear}) to slope of regression (Figure 2a); and 2) hyperbolic model of time (t) vs. velocity (v) (Monod andScherrer 1965), with C_V ($C_{VHyperbolic}$) related to asymptote of x axis and ARC ($ARC_{Hyperbolic}$) to slope of regression (Figure 2b). R^2 data from both mathematical models were considered as the main result for the feasibility application analysis of the CV protocol.

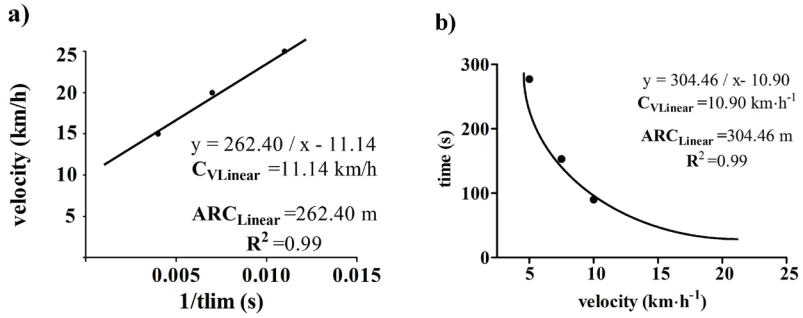

Figure 2. a) Example of the velocity vs. 1/time (1/tlim) model, with the $C_{VLinear}$ related to intercept-y and the ARC_{Linear} to the slope of regression. b) Example of the time vs. Velocity model, with the $CV_{Hyperbolic}$ related to asymptote of x axis and $ARC_{Hyperbolic}$ to the slope of regression.

Blood Sample

Capillary blood samples were collected from athlete's ear lobes in 25-µL heparinised capillaries. Blood samples were transferred to 1.5-mL micro tubes (Eppendorf) containing 200 µL of TCA (tricloroacetic acid). In order to analyse blood lactate concentration enzymatically, samples were stored at a –30°C temperature, shaken in a magnetic stirrer and centrifuged (3000 rpm). The homogenate was again mixed and immediately incubated for 20 minutes at 37°C. Samples were read in a spectrophotometer with a 340 nm wavelength. Blood lactate concentrations were then assayed using an enzymatic method (Engel and Jones 1978) and expressed in mM.

Statistical Analysis

Statistical analysis was carried out using a statistical software package (Statistic 7.0, Statsoft, Tulsa, USA). Mean and standard deviation were calculated for all studied variables. Before using a parametric analysis, the normal distribution and homogeneity of data were verified by Shapiro-Wilk and Levene tests, respectively. Results from Lac_{min} test and CV protocol were compared using ANOVA one-way for a paired sample. ANOVA one-way was also applied for comparison between bout times of RAST. Student t-test was applied for comparison of C_V and ARC between the mathematical models. Pearson product moment correlation was applied for relationship analysis. Confidence intervals were also calculated in relationship analysis (Pearson product moment) and standard deviation with $\alpha = 0.05$ ($\sigma/\sqrt{n}$). In all cases, statistical significance was set at $P < 0.05$.

Results

Descriptive results from RAST are shown in Table 1. No differences were visualized between bouts times (Bout 1 – 5.27 ±0.31 s; Bout 2 – 5.11 ±0.48 s; Bout 3 – 5.49 ±0.42 s; Bout 4 – 5.63 ±0.19 s; Bout 5 – 5.64 ±0.26 s; Bout 6 – 5.79 ±0.38 s). For 58% of athletes, the V_{maxR} was attained at Bout 1, 14% at Bout 2, 14% at Bout 3 and 14% at Bout 6.

Table 1. Peak Power ($Peak_{power}$), mean power ($Mean_{power}$), minimum power (Min_{power}), maximum velocity (V_{maxR}), fatigue index (FI) and total sprint time (TT) obtained from RAST

	$Peak_{power}$ (W)	$Mean_{power}$ (W)	Min_{power} (W)	$Peak_{power}$ (W/kg)	$Mean_{power}$ (W/kg)	Min_{power} (W/kg)	V_{maxR} (km/h)	FI (%)	TT (s)
Mean	662.98	528.93	413.52	10.48	7.91	6.00	24.67	8.50	33.27
SD	117.42	79.00	76.33	2.79	0.85	0.87	1.42	5.08	0.89
CI (α = 0.05)#	75.66–258.57	50.91–173.96	49.19–168.08	1.80–6.14	0.55–1.87	0.56–1.92	0.94–2.89	3.36–10.34	0.56–1.92

SD = standard deviation; CI = Upper and lower confidence limits of confidence interval for SD.

Lac_{Min} test results are shown in Table 2. After first phase, high [Lac] were visualized at the third (8.71 ±1.70 mM), fifth (9.07 ±1.33 mM) and seventh (9.63 ±1.61 mM) minute in the second phase. Only in one case the R^2 was lower than 0.80 (R^2 = 0. 67), resulting in the high success rate of 85.71%.

Table 2. Lactate minimum speed (LMS), blood lactate concentration at lactate minimum speed ([Lac] at LMS), R^2 of second polynomial and successful rate (SR) obtained from the Lac_{Min} test

	LMS (km × h^{-1})	[Lac] at LMS (mM)	R^2	SR (%)
Mean	9.67	4.36	0.90	85.71*
SD	0.50	1.57	0.10	---
CI (α = 0.05)#	0.32–1.10	1.01–3.46	0.06–0.22	---

* Data in absolute percent.
SD = standard deviation; CI = Upper and lower confidence limits of confidence interval for SD.

CV protocol results from the two mathematical models are shown in Figure 3. No differences were visualized for C_V ($C_{VLinear}$ = 11.10 ±0.55 km/h; $C_{VHyperbolic}$ = 10.70 ±0.65 km/h; P = 0.690) (Figure 3a) and ARC (ARC_{Linear} = 281.22 ±64.61 m; $ARC_{Hyperbolic}$ = 354.25 ±113.14 m; P = 0.198) (Figure 3b). A significant relationship was only visualized for C_V (r = 0.77; P = 0.04; CI = 0.04 – 0.96). High R^2 were observed both for linear (R^2 = 0.96 ±0.04) and hyperbolic (R^2 = 0.98 ±0.02) models (Figure 3c). Regarding the times of exhaustion in each effort, a rage between 100.7 and 333.1 seconds was visualized (Figure 3d).

ANOVA pointed differences only for LMS and $C_{VLinear}$(P = 0.004). In addition, the correlations between LMS and C_V were not significant (Figure 4a, 4b). Nevertheless, no relationship was visualized between ARC and all other RAST results.

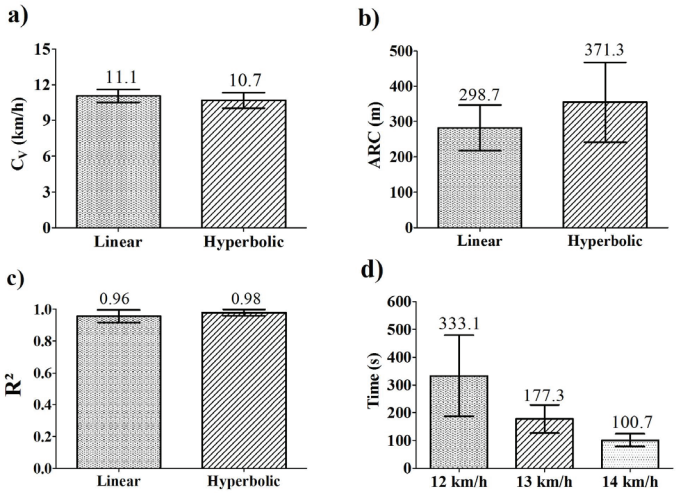

Figure 3. a) Results of aerobic estimate (C_V) obtained in the critical velocity protocol by two mathematical equivalent equations. b) Results of anaerobic estimate (ARC) obtained from the critical velocity protocol by two equivalent equations. c) Fits of regression (R^2) obtained by the two mathematical equivalent equations. d) Time of exhaustion from each effort in the critical velocity protocol

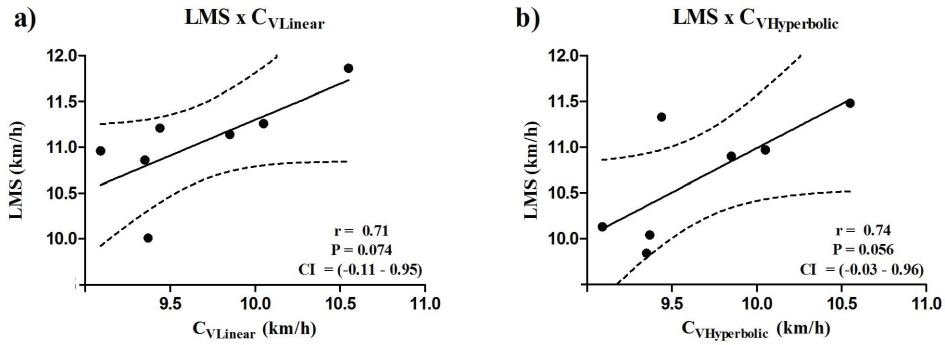

Figure 4. Correlations between Lac_{Min} test and CV protocol results. a) Correlation between LMS and $C_{VLinear}$. b) Correlation between LMS and $C_{VHyperbolic}$; LMS – lactate minimum speed; $C_{VLinear}$ – aerobic estimate from the linear model; $C_{VHyperbolic}$- aerobic estimate from the linear model

Discussion

This is the first study to investigate the RAST, Lac_{Min} and CV application for futsal players. We have shown that these evaluation protocols can be successfully applied in shuttle futsal testing without impairing the assessment of aerobic and anaerobic variables provided by these protocols. On the other hand, it is not possible to affirm that those variables can be interchangeably used, since the aerobic and anaerobic results were not related.

Some factors are necessary to ensure the Lac_{Min} application. Due to the fact that the incremental test (i.e third phase) is initiated with high [Lac], the kinetic of this metabolic product in the bloodstream is expected to fall in the firsts incremental stages and rise again in the subsequent stages. Thus, a "U-shaped" curve between intensity (i.e velocity) and [Lac] is visualized, which is necessary to identify the minimum point, or the lactate minimum speed (i.e. LMS). Moreover, Tegtbur et al. (1993) proposed that a second order polynomial fit is characteristic in the curve between intensity and [Lac] in this test. In this sense, the coefficient of determination (R^2) from the polynomial fit is an intuitive data to ensure the Lac_{Min} success application. In this way, studies have been using the "U-shaped" curve followed by a high coefficient of determination (R^2) as successful rate criteria for Lac_{Min} test application. Despite the relevance of this rate, its values are not shown. The only study that established a rate value for Lac_{Min} application was conducted by Araujo et al. (2007). They concluded that is necessary to assess $R^2 \geq 0.80$ for the Lac_{Min} test success application.

It is valid to state that depending on the type of exercise, the R^2 from the polynomial fit can be modified. In the present study, the Lac_{Min} was adapted in a shuttle exercise testing, making necessary constantly acceleration and deceleration by the futsal players in the incremental test. This dynamic could influence the production of lactate by muscle cells or its removal from the bloodstream. Considering the "U-shaped" is based on the [Lac], if the type of exercise influences in the blood lactate, the lactate curve could be right or left shifted. Consequently, the LMS could be also overestimated or underestimated, compromising the Lac_{Min} test application. Despite the fact that the above cited factors could impair the LMS determination, our results showed that only one athlete obtained low R^2 ($R^2 = 0.67$), resulting in 85.71% of success rate.

This result is favourable for the Lac_{Min} regarding its application in shuttle exercise. For futsal this data is even more interesting. Inside training and matches the athletes must constantly accelerate and decelerate in several situations (Rodrigues et al. 2011). Thus, the high success rate obtained by means of Lac_{Min} application in shuttle exercise highlights the futsal specificity in this test. Whether the Lac_{Min} adaptation for futsal was accomplished considering its classic proposal in continuous exercise (Tegtbur et al. 1993), then the futsal specificity would not be considered. Thus, based on our results, it is possible to suggest that at least for futsal, the Lac_{Min} application in shuttle exercise is more specific than in continuous exercise. Furthermore, training sessions based on the LMS obtained in shuttle exercise would be more effective for performance improvement.

Another interesting data was the successful application of the RAST inside the Lac_{Min} test. Usually the RAST is solely applied to assess parameters related to the anaerobic power. In the present study, we have applied this test for both assessments of its variables as well as to induce hyperlactatemia in the Lac_{Min} first phase. High [Lac] were observed in Lac_{Min} test second phase, concluding that the RAST was effective for its purpose in this study. Despite these important information, it is valid to highlight that the RAST inclusion in Lac_{Min} first phase is even more relevant. Considering that the Lac_{Min} application requires only one evaluation day, and that the RAST can be successfully applied in this test, the Lac_{Min} test becomes a complete evaluation protocol for futsal players. In other words, our results suggest that by means of Lac_{Min} application using the RAST, futsal coaches may assess both anaerobic (i.e $Peak_{power}$, $Mean_{power}$ and Min_{power}) and aerobic (LMS) variables in only one evaluation session.

Widely studied, the CV protocol has been applied in different exercises (Berthoin et al. 2006; Fukuda et al. 2011; Toubekis et al. 2011). In addition, the CV protocol analysis by different mathematical models has been performed using different ergometer for humans (Bull et al. 2000; D.J. Housh et al. 1990; T.J. Housh et al. 2001) as well as for rodents (Copp et al. 2010; Gobatto et al. 2013). However, it is well established that albeit mathematically

equivalent, the transformation from linear to a nonlinear model does not always promote similar estimates (Jones et al. 2010). Instead, in the present study no difference was visualized between estimates from linear and hyperbolic models (Figure 3a, 3b). Similar to Lac_{Min} test, in CV protocol studies use the R^2 in the respective mathematical model as a data related to its successful application. In this way, high R^2 values were visualized in both models (Figure 3c). These results suggest that independently of mathematical model, the aerobic and anaerobic parameters may be obtained in shuttle futsal testing.

Considering the comparison between the aerobic parameters from Lac_{Min} test and CV protocol, we have shown that only LMS and CV_{Linear} were different. Despite the fact that this absence of statistical difference between LMS and $C_{VHyperbolic}$ suggests that these two indicators match in similar physiological significance, it is worth noting that absolute results were differentiated by approximately 1 km/h (LMS = 9.67 ±0.50 km/h; $C_{VHyperbolic}$= 10.70 ±0.65 km/h). For training prescription these results can make great difference. These contradictory differences about LMS, $C_{VLinear}$ and $C_{VHyperbolic}$ are not surprising, since current knowledge establishes LMS and C_V in different physiological significance. C_V is actually described as the intensity of transition between intense and severe domain (Jones et al. 2010). On the other hand, Tegtbur et al. (1993) define LMS as an maximal lactate steady state intensity predictor. Even some studies contradict this (Carter et al. 1999; Jones and Doust 1998), other support the Tegtbur hypothesis (Knoepfli-Lenzin and Boutellier 2011; MacIntosh et al. 2002).

Regarding the relationship between RAST and CV results, while high $Peak_{Power}$, $Mean_{Power}$ and V_{MaxR} are related to anaerobic power, low TT could be related to a fatigue resistance, or in other words, anaerobic capacity. Theoretically, the ARC should be relative to a finite amount of work performed above C_V (Monod and Scherrer 1965). However, while the C_V is considered as the intensity transition between the heavy and severe intensity domains (Jones et al. 2010), several studies have criticized the physiological meaning of ARC (Dekerle et al. 2006; Zagatto and Gobatto. 2012; Zagatto et al. 2008). Supporting this idea, in the present study no relationship was observed between ARC and RAST results. This absence of relationship may be attributed to the questionable physiological meaning of ARC, since the RAST is considered a valid test for anaerobic parameters assessment (Balciunas et al. 2006; Zacharogiannis et al. 2004; Zagatto et al. 2009).

In spite of the fact that the present investigation provides relevant information regarding RAST, Lac_{Min} and CV application in shuttle futsal testing, it is impossible at this moment to discuss about the suitability and validity of these tests for this sport. Future investigations comparing gold standard protocols (i.e. maximal lactate steady state and maximal accumulated oxygen deficit) with RAST, Lac_{Min} and CV results in shuttle exercise could validate these protocols for futsal.

Conclusion

The results of this study provide novel information for aerobic and anaerobic assessment of futsal players using laboratory tests applied in the field. Despite the scientific contribution about RAST, Lac_{Min} and CV applications in shuttle futsal testing, the data from this study mainly contribute to approach science and practical application. Nowadays the futsal schedule is full of championships and tournaments, and many evaluation days for physical variables assessment are not welcome. Thus, in this study, we have showed relevant information to deal with this problem. We have demonstrated that futsal coaches may apply both Lac_{Min} test (including RAST) and CV protocol in one or three evaluation days, respectively, and obtain relevant information of both aerobic and anaerobic

metabolisms. Additionally, despite the CV protocol requires at least three evaluation days, it is possible to apply this test during the warm-up.

On the other hand, we also suggest that if one or another test was chosen, coaches must evaluate and re-evaluate using the same test, since the RAST, Lac_{Min} test and CV protocol provide aerobic and anaerobic results with different physiological meanings. Therefore, the present study concludes that the RAST, Lac_{Min} test and the CV may be successfully applied in shuttle futsal testing; however, coaches and researches should be aware that, depending on the test applied, different aerobic and anaerobic results can be obtained.

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ASSESSMENT OF IMPACT OF EARLY STROKE REHABILITATION ON HIP JOINT MOBILITY OF THE AFFECTED LEG IN PATIENTS AFTER CEREBROVASCULAR ACCIDENTS

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Abstract. One of the main priorities of stroke rehabilitation is regaining patients' independence in basic everyday activities. This paper is aimed at assessing impact of early stroke rehabilitation on hip joint mobility of the affected leg in patients after cerebrovascular accidents. The study included 30 subjects (13 men and 17 women) aged on average ±66.1, with hemiparesis, who were treated at the stroke unit and participated in a 4-week rehabilitation program. Measurements of passive and active motion ranges were conducted with a goniometer in both limbs: healthy and affected ones by stroke. There were statistically significant differences in motion ranges between healthy and affected limbs. Examination I revealed that affected limbs amounted to only 40% of physiological range, while in Examination II, the result reached 73%. The most significant motion limitations were noted in terms of bending, adduction and internal rotation, while the least significant in terms of external rotation and abduction. Exercises used during early stroke rehabilitation of hemiparesis patients considerably increased active motion ranges and maintained passive motion ranges in the hip joint of the affected limb. Patients with right-sided hemiparesis experienced much better improvement in hip joint motion of the affected limb. The 4-week period was insufficient to mobilize patients and help them regain full active mobility in the hip joint of the affected limb. These patients required further physiotherapy, until they fully regained functionality.

Key words: stroke rehabilitation, stroke, kinesiotherapy, physiotherapy, motion range, hip joint

Introduction

Stroke is a sudden clinical syndrome characterized by sudden, partial or overall disorder of brain functions, whose symptoms last for more than 24 hours or lead to death within this time, and have no other cause than vascular (The WHO 1988). Recently, the term 'cerebrovascular accident' (CVA) has been used increasingly frequently instead of the term 'stroke'. Nowadays, stroke is one of the most severe health problems, as it is the

3rd most common cause of death (4th in Poland) (Grochulska and Jastrzębska 2012). It also leads to severe and chronic disability, which results in social and economic problems (Członkowska et al. 2006; Kwolek et al. 2005). Stroke has numerous and severe consequences. It is estimated that 15–30% of stroke patients remain disabled for life (Schwamm et al. 2005), while 50% of them require 3rd person assistance due to limited physical and mental ability (Jaracz and Kozubski 2006). Stroke often results in hemiparesis, i.e. partial loss of muscle strength resulting from damage to the corticobulbar tract, usually near the internal capsule, which affect half of the body (side opposite to the brain damage) (Mazur 2007). Therefore, the key issue is an overall, holistic hospital and outpatients care (Mazurek et al. 2013), which relies heavily on comprehensive stroke rehabilitation (Członkowska et al. 2006). Rehabilitation must be treated as an important element of treatment, which should be implemented as soon as possible. According to Experts' Group, it should commence 1–2 day after the stroke, as soon as the patient stabilizes. It should tackle mobility deficit (mobilizing exercises) and higher nervous activities (Wiszniewska et al. 2012), which reduces disability, improves life quality, helps attain maximally improved motor skills, enables the patient to walk and reduces tonus (Członkowska et al. 2006; Kwolek et al. 2005). According to Flis and Bejer (2014), improved balance and learning to walk again is one of main aims of stroke rehabilitation.

Research indicates that treating acute stroke, especially at stroke units, correlates with better prognosis and significant reduction of mortality after stroke (Stroke Unit Trialists' Collaboration 2013).

According to Helsingborg Declaration, the aim of rehabilitation (to be attained by 2015), is regaining independence in basic everyday activities in 70% of patients within 3 months after stroke (Kjellstrom et al. 2007).

This paper is aimed at assessing impact of early stroke rehabilitation on hip joint mobility of the affected leg in patients after cerebrovascular accidents.

Material and methods

This study included 30 patients (13 men and 17 women) who suffered from stroke. They were rehabilitated in Regional Hospital in Kołobrzeg, Poland, at stroke unit in an increased medical care room, which provides stroke patients with the highest medical standards. 56.7% (n = 17) of subjects suffered from right-sided hemiparesis, while 43.3% (n = 13) – from left-sided hemiparesis. Patients were divided into two groups, based on the affected side. Group A included patients with right-sided hemiparesis, and Group B consisted of subjects with left-sided hemiparesis. 53.3% of subjects suffered from stroke caused by clots in brain arteries, 40% suffered from transient ischemic attack, while 6.7% suffered from embolism in cerebral arteries.The average age of subject was ±66.1 (34–85). On average, subjects spent 28 day at the stroke unit.

The study included measurements of active and passive motion ranges of hip joints of healthy and affected legs; measurements were made with goniometer (measurement accuracy: 1°). Measurements followed widely accepted standards (Rosławski and Skolimowski 2000).The following movements in the hip joint were measured: bending, straightening in horizontal axis, abduction and adduction around axis sagittalis, as well as external and internal rotation in vertical axis.

Rehabilitation process was continuous and employed Kabat Method of Exercise, known as Proprioceptive Neuromuscular Facilitation (PNF). Other methods and techniques were also used (Brunnstrom, Rood, Bobatch's methods) in various sets of exercises, depending on mobility and regained functionality of patients. Rehabilitation aimed at increasing motion ranges in peripheral joints in the affected limb. Subjects were rehabilitated every day with

kinesiotherapy for 45 minutes. Rehabilitation consisted of compiled, specialized techniques adjusted individually to patients.

To statistically analyze the results of the study, standard methods were used (arithmetic mean, standard deviation, coefficient of variation). Hypothesis related to significance of differences between mean deviations for particular motion ranges were verified with statistical tests: for two averages (Student's t-distribution), Student's t-distribution of differences between correlated pairs.

Results

Passive motion ranges in the hip joint of the affected and healthy limb in Group A and Group B were similar in Examination I and Examination II (statistically insignificant differences at λ = 0.05). Table 1 presents characteristics of active motion ranges in the hip joint of the healthy and affected limb in Examination I and II in Group A.

Table 1. Characteristics of active motion ranges of the hip joint in Examination I and II in Group A

MOTION	Examination I							Examination II							
	motion range [in °]						t1	motion range [in °]						t2	t3
	affected limb			healthy limb				affected limb			healthy limb				
	mean	SD	Vs	mean	SD	Vs		mean	SD	Vs	mean	SD	Vs		
Bending	34.50	7.33	21.23	120.7	9.95	9.24	27.89*	77.0	12.69	16.49	121.5	9.52	7.83	11.25*	19.73*
Straightening	6.00	2.30	38.85	17.8	1.39	7.85	17.50*	12.8	2.80	21.92	18.3	1.56	8.34	6.96*	16.00*
Abduction	20.40	6.00	29.48	42.4	1.45	3.43	14.26*	34.2	7.82	24.64	42.9	1.53	3.37	4.34*	10.42*
Adduction	9.24	4.05	43.97	25.4	2.37	9.37	13.73*	19.5	4.82	24.56	25.5	2.23	8.72	4.52*	13.95*
Internal rotation	24.50	3.43	13.99	42.3	3.39	8.02	14.73*	36.1	4.42	12.23	42.8	3.35	7.80	4.79*	15.61*
External rotation	14.30	4.17	28.73	41.7	1.41	3.39	24.92*	23.5	6.18	26.35	42.1	1.55	3.69	11.67*	9.49*

* Statistically significant differences (λ = 0.05).
Mean – arithmetic mean value; SD – standard deviation; Vs – Variation coefficient.
t1 – Significance of differences between affected and healthy limb in Examination I;
t2 – Significance of differences between affected and healthy limb in Examination II;
t3 – significance of mean differences between affected limbs in Examinations I and II.

Analysis of mean motion ranges in affected and healthy limb obtained in Examination I indicated very significant differences. The affected limb had noticeably worse results. It amounted to only 40% of physiological range of movement. The most significant motion limitations were noted in terms of bending, adduction and internal rotation, while the least significant in terms of external rotation and abduction. Differences between affected and healthy limb were statistically significant. Examination II proved a significant increase of active motion range in the affected limbs. Nonetheless, they were still lower in comparison to the healthy limb, amounting to on average 73% of the physiological range. Calculated differences between affected and healthy limb were statistically significant. Examinations I and II proved a noticeable improvement in active motion ranges in hip joint of the affected limb. The improvement was statistically significant.

Table 2 presents characteristics of active motion ranges in the hip joint of the healthy and affected limb in Examination I and II in Group B.

Table 2. Characteristics of active motion ranges of the hip joint in Examination I and II in Group B

MOTION	Examination I							Examination II							
	motion range [in °]						t1	motion range [in °]						motion range [in °]	t1
	affected limb			healthy limb				affected limb			healthy limb				
	mean	SD	Vs	mean	SD	Vs		mean	SD	Vs	mean	SD	Vs		
Bending	22.1	4.65	21.05	115.0	11.83	10.03	25.23*	42.4	7.50	17.7	116.1	11.2	9.65	18.93*	15.20*
Straightening	1.2	1.24	101.00	17.5	0.92	5.20	36.77*	5.8	1.53	26.5	18.4	1.39	7.6	21.15*	14.56*
Abduction	14.3	5.27	36.80	41.4	1.13	2.77	17.39*	23.7	6.57	27.7	41.9	1.07	2.56	9.49*	9.90*
Adduction	3.9	1.03	26.70	24.1	2.20	9.10	28.95*	11.2	2.89	25.7	24.4	2.27	9.32	12.48*	12.0*
Internal rotation	19.6	5.21	26.57	38.9	4.41	11.33	9.79*	27.8	4.37	15.7	39.8	4.23	10.06	6.86*	11.57*
External rotation	10.5	2.60	19.56	41.2	1.32	3.18	43.55*	15.1	2.79	18.3	41.6	1.86	4.45	7.71*	10.43*

* Statistically significant differences (λ = 0.05).
Mean – arithmetic mean value; SD – standard deviation; Vs – Variation coefficient.
t1 – Significance of differences between affected and healthy limb in Examination I;
t2 – Significance of differences between affected and healthy limb in Examination II;
t3 – significance of mean differences between affected limbs in Examinations I and II.

Examination I revealed very significant limitations of active motion of the affected limb. Active motion in the hip joint of the affected leg on average amounted to 24% of physiological range. The biggest mobility limitations were observed in terms of straightening, adduction and bending, while the least limited motions were external rotation and abduction. There were statistically significant differences noted. Examination II proved an increase of active motion range in the affected limb. Nevertheless, they were lower than healthy limb motion ranges. They amounted only to 45% of the physiological ranges (with statistically significant differences). The observed improvement of active motion in the hip joint in the affected limb was statistically significant.

Figures 1 and 2 present analysis of active motion ranges in the hip joint in the affected limb in Group A and B in Examination I and II. Based on Examination I, Group B faced greater limitation of active motion ranges in the hip joint than Group A. Examination II showed that despite improved active motion ranges in the hip joint in patients in both groups, the difference between groups persisted. Patients with right-sided hemiparesis experienced much better improvement in hip joints of the affected limb (Group A).

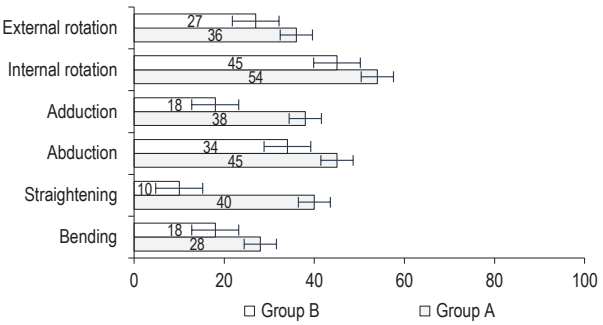

Figure 1. Comparison of active motion ranges in the hip joint in Group A and B in Examination I [%]

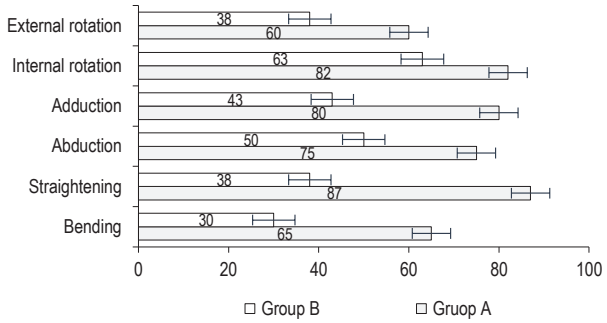

Figure 2. Comparison of active motion ranges in the hip joint in Group A and B in Examination II [%]

Discussion

According to the Helsingborg Declaration, shortly after stroke, all patients should have the right to rehabilitation without preselection (Postępowanie w udarze mózgu 2008). Guidelines for early rehabilitation of stroke patients assume everyone is treated from the beginning as if they were to fully regain lost functions (Nyka and Jankowska 2009).

Considering current medical advances, the role of early, continuous, comprehensive and easily available rehabilitation is obvious (Kwolek 2005; Mazurek 2013). 90% of stroke patients qualify for continued rehabilitation at a rehabilitation unit. Kwolek team's study (2005) showed that there are no explicit and irreversible counter indications for rehabilitation. Study by Grochulska and Jastrzębska (2012) revealed that after release from hospital, only approximately 50% of patients participated in rehabilitation at rehabilitation units; 17% continued the process of rehabilitation with a privately hired rehabilitation specialist, while every third stroke patient discontinued the process of rehabilitation for various reasons.

In practice, the rehabilitation process which started at the stroke unit should be professionally continued at a neurological rehabilitation unit, where early stroke rehabilitation is offered, which should last for 3–9 weeks. The continuation of the therapy should focus on perfecting the ability to walk and change positions, and on stimulating functionality. Patients who completed early stroke rehabilitation (2–3 months after stroke), should be able to walk on their own or with little assistance. Walk should include active bend of the hip joint. Poland faces the problem of insufficient number of rehabilitation beds; patients are often released with a list of rehabilitation recommendations which are difficult to meet in practice (Nyka and Jankowska 2009). Therefore, the key factor of successful rehabilitation is its comprehensiveness and easy availability. Unfortunately, study by Mazurek et al. (2013) showed that only a small proportion of neurology wards (14%) and rehabilitation wards (10%) in Poland offer comprehensive stroke rehabilitation.

The Expert Committee of the National Program of Prevention and Treatment of Stroke recommended short sessions of physiotherapy (e.g. 10–15 minutes) but with many repetitions (e.g. 6 times per day) so that in total physiotherapy lasts for at least 45 minutes daily (Członkowska et al. 2006). In Germany, the recommended minimum time of rehabilitation care of patients who were transferred from intensive care unit is 4 hours (Bundesarbeitsgemeinschaft für Rehabilitation 1995).

In this study a 4-week rehabilitation treatment was assessed. The examination of patients revealed that the 4-week period was insufficient to mobilize patients and help them regain full active motion in the hip joint of the affected limb. Patients required further rehabilitation. Kinesiotherapy should be the key element of such treatment (Jajor et al. 2013), as well as modern therapies and rehabilitation techniques for disabled patients. Karakiewicz et al. (2011) noted positive impact of computer programs as auxiliary therapy for improving cognitive functions of patients who suffered from ischemic stroke. It has been established that cognitive disorders constitute a considerable barrier and may negatively influence rehabilitation success rate (Luk 2012).

An alternative method of reducing disorders caused by neurological diseases is aquatic rehabilitation (Jajor et al. 2013). Water creates favorable conditions for the human body (Łubkowska et al. 2015; Nalazek et al. 2015). Due to its beneficial effects, water offers a positive environment to conduct therapy of neuromuscular diseases, such as stroke. Used for neurologic diseases, the aquatic therapy strengthens muscle groups, improves joint motion ranges, improves balance, lowers or strengthens tonus, and reduces pain (Becker 2009). Study of hemiparesis patients revealed that it was possible to speed up the process of teaching them to walk by strengthening muscles, improving blood flow and overall fitness (Chon et al. 2009; Nowotny-Czupryna 2001).

Conclusions

1. Hemiparesis patients who suffered from stroke and were included into early physiotherapy treatments showed considerable improvement of active motion ranges and maintained passive motion ranges in the hip joint of the affected limb.

2. Patients with right-sided hemiparesis experienced much better improvement in hip joint motion of the affected limb.

3. The 4-week period was insufficient to mobilize patients and help them regain full active mobility in the hip joint of the affected limb. These patients required further physiotherapy, until they fully regained functionality.

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DEFENCE EFFICACY IN PRACTICE AND COMPETITION. A CASE STUDY IN WOMEN'S VOLLEYBALL

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Abstract. The aim of this study was to compare the player positions, situations, techniques, and efficacy in defence between practice and competition for a women's professional volleyball team. The sample was a Spanish professional women's volleyball team. The defence actions carried out in three sessions of the competitive season and two in-season matches were studied (794 rallies in practice and 166 rallies in competition). The variables studied were: actions done, defence zone, player role, type of attack, court defence technique, game phase, situations, level of execution of the defence team system, block efficacy, defence efficacy, and result of the rally for the analysed team. Descriptive and inferential analyses of the data were done (Mann-Whitney U, and Chi-Square Test and likelihood ratio). Differences in defence systems and efficacies were found between practice and competition. A higher collective efficacy was found in competition, and higher levels of individual block and defence efficacies were found in practice. The results show the need to reconsider the way match analysis is done. Consideration should not only be given to the actions done with the ball when analysing players' performance.

Key words: team sports, performance, coaching, monitoring, volleyball

Introduction

In team sports, such as volleyball, the level of a team depends on the players' abilities and their coordination in executing team strategies and tactics. Matches are the situations in which teams demonstrate the level of achievement of their techniques, tactics, and strategies. In order to increase performance, teams must practice in an organised and systematic manner to master their skills, actions, and movements. Most of the research done in relation to performance analysis for team sports is focused on studying performance in competition. There are few studies that assess the way teams practice, and those focus on physical aspects (Häkkinen 1993; Gabbett 2008; Marques et al. 2008).

Practice is the key to achieve success in competition (Travassos et al. 2012). The reference that guides practice is competition. Therefore, the first step in planning is to know what the competition involves. The information that is available in relation to team sports' characteristics and performance indicators in competition shows that these are topics that are studied by researchers (Drikos and Vagenas 2011; Palao et al. 2004; Peña et al. 2013; Zetou et al. 2007). However, less information is known about reference values to monitor and guide practices in team sport (Thiess et al. 2004). The criteria given by experts to guide practices follow several pedagogical and biological principles (specificity, overload, progression, diminishing returns, variation, reversibility, individual differences, and moderation) (Martens 2012). Therefore, coaches try to create practice situations that involve their players and teams, that are adapted to their specific and individualised needs, that challenge them (competitive), and that are presented in progression and intensity (Nash et al. 2011).

The characteristics of each sport affect the way that they can be monitored and the implications on the players (Palao and Morante 2013; Van del Pol and Kavussanu 2012). Indoor volleyball is a team sport in which most of the actions are not terminal, there is a high number of ball contacts per time, the ball cannot be held, and the concepts of offense and defence are different than in other team sports (FIVB 2012). A team can score while on defence, through a block. Most of the studies in this sport assessed the offensive phase in competition (serve, reception, set, and attack). However, the defence is critical because it is the basis for neutralising the opponent's attack and trying to score. At least fifty percent of the points are achieved in actions that involve defence and/or counter-attack (Palao 2004). In defence, teams must adapt to the opponent's attack system under conditions that involve a time deficit (different possible zones and tempo attacks) and coordinate the players' actions (block and court defence). The success of this phase depends on different aspects, such as reaction, anticipation, and adaptation skills; displacement skills, players' motivations; and players' and teams' technique and tactics (Selinger and Ackerman-Blount 1986; Hernández-Hernández et al. 2004).

No studies have been found in the bibliography review that was carried out in relation to the way teams defend in volleyball competitions and practices regarding technical actions. The studies that compare practice and competition have been focused on physical aspects of the game (Edwards and Kurlander 2010; Gonzalez et al. 2005). For individual sports, such as golf, research shows that at higher levels, players' practice efficacy is also higher and they use highly structured and consistent routines in practice and in competition (Douglas and Fox 2012). Elite golfers presented higher efficacies and better mental states in competition than in practice. Douglas and Fox (2012) hypothesize that it could be due to their ability to cope mentally with the demands of the situation. To our knowledge, no information is available about these aspects in open skills done by players of a team sport, where the skills depend on the opponents' actions and the teammates. Research has shown that it is more difficult for players of team sports to feel a sense of personal accomplishment and they are less focused on task orientation (van del Pol and Kavussanu 2012). Further studies are needed to increase the knowledge about how teams practice and the specific relationship between the level of achievement in practices and competitions. This will allow us to obtain information about how successfully players and teams are practicing and how reference values from the competition should be adapted to establish real and challenging goals. In practice, coaches try to create challenging real situations using their own players (starters and reserve players). The aim of this study was to compare the player positions, techniques, situations, and efficacy in defence between practice and competition for a women's professional volleyball team.

Method

The sample was a professional women's volleyball team. The team was composed of eighteen players (average height of 1.85 ±0.07 meters and average age of 25.2 years) and a technical staff of three coaches, a strength and conditioning coach, and a statistician (combined average age of 31.5 years and 7.2 years of experience). Ninety-four percent of the team players played that season with their national team. Thirty-eight percent were Spanish players. The rest of the players were from the Dominican Republic, Belgium, Brazil, Russia, Poland, the United States, and Puerto Rico. This team won all the official competitions they played (National league, National Cup, and Top Team Cup (European Club Competition)). The defensive actions carried out in three practice sessions of the competitive season and two in-season matches played against the second-ranked team of the National Competition were studied (794 rallies in practices and 166 rallies in competitions). The second-ranked team of the National Competition finished that season in the third position in the CEV Women's Champions League (European Club Competition). The Research Ethics Committee of the University of Murcia (Spain) pre-approved the study.

An observational study (one-time, nomothetic, and multidimensional) was done (Anguera 2003). The variables studied were: actions done (block or defence), defence zone (court zone), player role (setter, opposite, middle blocker, outside hitter, or libero), type of attack (attack in zone 1, 2, 3, 4, 6, or one-leg slide attack), court defence technique (bump, overhead, acrobatic, or other), game phase (defence of side-out or defence of counter-attack), situation (practice or competition), level of execution of the defensive team's system, block efficacy, defence efficacy, and result of the rally for the team analysed (win, loss, or neutral).

The players' level of execution of the defensive team's system was established by comparing the criteria established by coaches and the position adopted by players. The head coach was interviewed, and he established the standard position of the defensive system for the different types of opponent attack (attack in zone 1, 2, 3, 4, 6, or one-leg slide attack). The head coach established the exact position that players must adopt against the opponent's attack (in Table 1, an example of the criteria set is described).

Table 1. Description of the defence position in an opponent attack in zone 4 (right side of the net)

Zone 1 player	Player in court defence. Player´s left foot on the side line and 3–4 meters from the net.
Zone 2 player	Player in block. Player must be a half meter from the antenna and/or with her inside arm in front of the attacker´s shoulder.
Zone 3 player	Player in block. Player must be close to the player of zone 2. No space between them is allowed.
Zone 4 player	Player in court defence. Player must be on the back row line and one to two meters inside the court laterally.
zone 5 player	Player in court defence. Player must in the long diagonal spike trajectory (3–4 meters from the end line and two meters inside the court).
Zone 6 player	Player in court defence. Player must be in centre of the court and 1–2 meters from the end line.

The efficacies of the block and defence were evaluated in relation to their success and the options that the actions gave the analysed team and the opponent. The statistical system of the Fédération Internationale de Volleyball (FIVB) was utilised, adapted from Coleman et al. (1969). Four levels to categorise the defence performance were differentiated: error (0), no attack options (1), limited attack options (2), and maximum team attack options (3). Five levels to categorise the block performance were differentiated: error (0), maximum team attack options (1), limited attack options (2), no attack options (3), and point (4). With the categories of defence and

block efficacy, an efficacy coefficient was calculated (sum of the attempts per category multiplied by the value of the category and divided by the total attempts (Coleman et al. 1969)).

The result of the rally was established by the way the rally ended (the analysed team won or lost). In practice, if in some exercise the coach did not let the rally continue (e.g. the coach did not let the ball be attacked after the court defence) or there was not a full opponent against the attack and the goal set by the coach was fulfilled, the result of the rally was categorised as neutral. If the goal was not achieved, the rally was categorised as lost.

All analysed periods, both in training and competition, were recorded from the same place (from a plane that was perpendicular to the net) with a digital video camera (HD 720 p 50Hz). The recording included the entire volleyball court and its adjacent areas where play could take place. The observation was done by one observer who was previously trained following the criteria established by Anguera (2003). The observer had a degree in sport science and was a former volleyball player. After training and during the analysis, the inter-observer and intra-observer reliability percentages of the studied variables were calculated between the observer, the head coach, and one of the researchers (Anguera 2003). The observer had an inter- and an intra-observer reliability above 0.85 for all the studied variables (Cohen's kappa). Descriptive and inferential analyses of the data were done using the SPSS 20.0 software (Mann-Whitney U for the continuous variables and Chi-Square Test and likelihood ratio for the categorical variables) with a level of statistical significance set at $p < 0.05$.

Results

Similar proportions of actions in the different game phases are carried out by the analysed team in practice and in competition. The team's actions done in the different game phases were significantly better in competition than in practice. Different proportions of defence actions related to the opponent's attack were found in practice and in competition. A significantly higher proportion of attacks from zones 2 and 3 and setter attacks were found in practice, and a significantly higher proportion of attacks from zone 2 (one-leg slide attack) and zone 4 were found in competition. The team's actions were carried out significantly better in competition than in practice. Regarding the actions where players contact the ball, similar proportions of technique are done against the different types of opponent attack by players in practice and competition, except for the acrobatic defence, where a higher use was found in competition. The actions done involving the players contacting the ball were significantly better in practice than in competition.

Table 2. Types of actions done in practice and in competition and number of correct actions by the team and individual

	Practice				Competition			
	total	%	correct	%	total	%	correct	%
	1	2	3	4	5	6	7	8
Game phase								
Defence of side-out	346	43.6	36*	10.4	78	47.0	25*	32.1
Defence of counter-attack	448	56.4	129*	28.8	88	53.0	54*	61.4
Attack zone								
Zone 1 (Back row)	29	4.0	4^{-}	13.8	7	4.4	3^{+}	42.9
Zone 2	158^{+}	21.8	14^{-}	8.9	13^{-}	8.1	8^{+}	61.5
Zone 2 (one-leg slide)	42^{-}	5.8	0^{-}	0.0	20^{+}	12.5	2^{+}	10.0
Zone 3 (quick attack)	191^{+}	26.3	10^{-}	5.2	26^{-}	16.3	9^{+}	34.6

	1	2	3	4	5	6	7	8
Zone 4	224⁻	30.9	63⁻	28.1	84⁺	52.5	38⁺	45.2
Zone 6 (Back row)	72	9.9	10⁻	13.9	10	6.3	5⁺	50.0
Setter attack	10⁺	1.4	0	0.0	0⁻	0.0	0	–
Technique								
Bump	333	70.7	299	89.8	21	63.3	16	82.3
Overhead	79	16.8	71*	89.9	62	21.4	51	76.2
Acrobatic	21⁻	4.5	16*	76.2	12⁺	12.2	5	41.7
Other	38	8.1	22*	57.9	3	3.1	0*	0.0

* Statistically significant at a level of $p < 0.000$ in relation to correct execution of the defence system by the team (Mann-Whitney U).
⁺ or ⁻ Statistically significant increase or decrease at a level of $p < 0.000$ (Chi-square Test).

The percentage of correct executions of the defence system was significantly higher in competition than in practice. The percentage of the team's players that properly adopted the position of the defence system was significantly higher in competition than in practice (Table 3).

Table 3. Players' level of execution of the defence system in relation to game phase and opponent's type of attack in practice and competition

	Practice		Competition	
	average	standard deviation	average	standard deviation
Execution of defence system				
Defence of side-out	66*	19	85*	13
Defence of counter-attack	75*	18	88*	15
Total	71*	19	86*	14
Attack zone				
Zone 1 (Back row)	68*	12	92*	14
Zone 2	67*	13	93*	12
Zone 2 (one-leg slide)	59*	16	77*	14
Zone 3 (quick attack)	64*	19	88*	10
Zone 4	78*	18	85*	11
Zone 6 (Back row)	74*	13	95*	9
Setter attack	44*	12	–*	–

* Statistically significant at a level of $p < 0.000$ in relation to the team´s correct execution of the defence system (Mann-Whitney U).

With regard to the execution of the defence system by the different players (Table 4), better execution of the defence system was found in competition than in practice, except in zone 3 (middle blockers) and zone 6 (outside hitters). For block efficacy, similar proportions of efficacy were found between practice and competition, except for in block points, where a higher proportion of occurrence was found in practice. The defence efficacy was significantly higher in practice for the defences that allowed maximal options and significantly higher in competition for the defences that did not allow attack options. From a general perspective, the efficacy coefficients of the block and defence were higher in practice than in competition. Similar tendencies were found regarding the result of the rally. A significantly higher number of the rallies were won by the team studied in defence in practice than in competition.

Table 4. Execution of the defence system position and efficacy of the defence actions by player in practice and competition

	Practice		Competition	
	n	percentage	n	percentage
Team player				
Zone 1 (Setter & Opposite)	539⁻	74.2	134⁺	89.9
Zone 2 (Setter & Opposite)	375⁻	51.7	136⁺	91.3
Zone 3 (Middle blocker)	591	81.4	113	75.8
Zone 4 (Outside hitter)	445⁻	61.3	109⁺	73.2
Zone 5 (Libero & Middle blocker)	552⁻	76.0	144⁺	96.6
Zone 6 (Outside hitter)	587	80.9	136	91.3
Block				
Error (0)	47	18.7	13	26.5
Max opp. attack options (1)	58	23.0	8	16.3
Limited attack options (2)	47	18.7	12	24.5
No attack options (3)	47	18.7	10	20.4
Point (4)	53⁺	21.0	6	12.2⁻
Efficacy Coefficient	2.00		1.76	
Court defence				
Error (0)	82	16.7	12	16.2
No attack options (1)	124⁻	25.3	42⁺	56.8
Limited attack options (2)	196	39.9	19	25.7
Max attack options (3)	89⁺	18.1	1⁻	1.4
Efficacy Coefficient	1.59		1.12	
Result of the rally				
Win	164 *	27.6	89 *	47.6
Loss	246 *	41.3	98 *	52.4
Neutral (positive for coach)	185 *	31.1	–*	–

* Statistically significant at a level of $p < 0.000$ in relation to situation and result of the rally (Mann-Whitney U).
⁺ or ⁻ Statistically significant increase or decrease at a level of $p < 0.005$ (Chi-square Test).

Discussion

Regarding proportions of the work done on the different defence actions between practice and competition, similar proportions were found in the use of different techniques, and different proportions were found in the work done to prepare for the opponents' attack types. These results coincide with proposals in the literature regarding creating competition-like situations in practice (Travassos et al. 2012). These results could be due to the reserve team creating similar practice situations to those of competition due to their characteristics or because the coach demands certain actions or ways of playing. Also, the results could be due to the types of attack technique depending mostly on the reserve players' characteristics. Therefore, players in both circumstances have the same tendency to resolve the game's situations using the same techniques. The only difference was found in the use of acrobatic techniques, which shows that players in competition try to resolve more difficult situations or they are more involved in the game (van del Pol and Kavussanu 2012). The differences found regarding attack type show how these aspects depend on the characteristics of the team and its strong points. In the case studied, the opponent teams attacked most often from zone 4, where half of the attacks are done. These results show that in order to adequately prepare matches, scouting opponents' tendencies is needed. This type of work is common in volleyball (Palao and

Hernández-Hernandez 2014). These tendencies are similar to the ones found in the literature (Palao et al. 2007). Teams must scout opponents, and after that, they must scrimmage in practice and have bench players simulate this type of attack in order to get specificity in their defence work (speed, positions, options, etc.) (Travassos et al. 2012).

The results show that collective efficacy is higher in competition than in practice. These results are similar to findings in elite female golfers (Douglas and Fox 2012). The reasons for these results are probably a combination of the following: starting teams know the level of the bench teams and adapt their effort to the situation, low motivation or involvement by starting players in practice, higher time in practice than in competition, absence of public, and/or importance of the situation (practice vs. competition). In team sports, it should also be considered that this finding could be influenced by aspects related to team dynamics, such as the fact that players from a team practice together every week, which results in a lack of variability in practice. It is important for coaches to introduce environments that provide variation and provide a challenge for the players in practice (coaching and training principles) (Nash et al. 2011). The opposite tendency was found in relation to the ball contact efficacy by the players. A higher efficacy was found in practice, which is related to a higher number of ball contacts on defence in practice than in competition. The reason for this is probably because in practice, coaches plan exercises with the goal of having players carry out a high number of repetitions. There, attackers (a teammate or a coach) seek out the defensive player, something that rarely occurs in competition. This may be the reason for the higher block and defence efficacies found in practice. Another possible cause is that practices are less challenging for players, due to less focus on task-orientation or feeling less involved in familiar situations (e.g. attack repertoire of their teammates and/or coaches) (van del Pol and Kavussau 2012) .

The criteria set by the head coach regarding team defensive positions were not achieved by his team on many occasions in competition (on average, less than half of the time). In practice, the levels were even lower. Additionally, a high level of fluctuation in the ability to adapt the defence system to the type of attack was found. The one-leg slide was the type of attack with the lowest values (10% in competition), and the attack for zone 2 was the attack with the highest values (60% in competition). These values show the number of times that all the team's players are in position for the defence system at the same time. When analysing this data by player, it is found that in practice, an average of 4–5 players out of six are in the correct defence system position, and in competition, an average of 5-6 players out of six are in the defence position system. These values show that the criteria established as ideal by the coach are difficult for the team to achieve. However, the type of criteria set by the coaches is similar to the one established by other elite coaches on a tactical level (Beniscelli et al. 2014). The results show that the goals set may be too challenging for the players. Further studies are needed to establish reference values of the achievement of the defence system proposed by the coaches in peak performance. These studies must assess the difference between the coaches' criteria and the level of their competitions and teams. In this analysis, it should be taken into consideration whether the purpose of the goal set by the coaches is to push the players to the limit, individually or collectively (Nash et al. 2011). Data from this study show that goals set for defence are achievable by players, but they are too hard for the team. In volleyball, defence is done under a time deficit. In volleyball defence, players do not know what they have to do and where they have to be until the ball leaves the hands of the setter and the hitter. For example, to contextualize these data, the goal set by the head coach that the block carried out at the side of the net should be done by two players is only achieved in 70% of the cases by women's national teams (Palao et al. 2004).

The present study monitors the defence utilizing information about the way the ball is contacted but also by analysing whether the player adopts the theoretical position established by the coach. The combination of the two aspects provides more information to coaches, which allows them to give more specific feedback to players. The position adopted by the players provides information about whether each player makes the proper decision (execution and timing) for their role and their interaction with the rest of their teammates (Beniscelli et al. 2014). This provides a better perspective of the team effectiveness in defence. For the analysed team, the results show that in competition, the player role that achieved the set position in the defence system was the middle blocker in the front row (zone 3). This type of analysis provides information to coaches which allows them to focus their attention on the aspects that need improvement in practice and in competition and it provides objective data for working with the players and monitoring their improvement. Volleyball is a sport where many actions occur in a short period of time. This makes it more difficult for coaches to give feedback to the players. Monitoring players' actions is done frequently in practice and competition (Palao and Hernández-Hernández 2014). However, these statistical systems are only focused on collecting and analysing the ball contact actions done by players in volleyball. New technologies have simplified the task of collecting and analysing player actions in volleyball, in addition to allowing data to be combined with video (Carling et al. 2008; Liebermann et al. 2002). A critical review must be done about the ways players' actions are analysed in volleyball in order to give players feedback about the actions that they do. In this way, game statistics must collect the data in the same way that coaches analyse the team's tactics (Beniscelli et al. 2014).

The aim of this paper was to study the practice done by a women's peak performance professional volleyball team in relation to defence. The data obtained are from a case study. Therefore, the generalization of the data is not possible, because it is obtained from the practice of one team and confrontations between two teams. However, the information provides a reference of the type of requirements that the competitions involve for the studied team in order to compare the specificity of their practice. Data from peak performance teams provide information about the way players and teams practice. This information is useful for coaches, researchers, sport pedagogists, psychologists, etc. to have a reference about how to monitor and analyse technical and tactical aspects in practice and in competition (Beniscelli et al. 2014; Nash et al. 2011). This is the first step to provide adequate feedback and communication in team sports to improve their performances (Eccles and Tran 2012; van del Pol and Kavussanu 2012).

Conclusions

Differences in the defence system and efficacy were found between practice and competition. In volleyball, the defence is conditioned by the attack system. Therefore, the study of the opponent's tendencies and the simulation of them in practice could be a solution to reduce these differences and increase the specificity of the practice. A higher level of efficacy in collective efficacy was found in competition, and higher levels of the individual block and defence efficacy were found in practice. The results show the need to reconsider the way match analysis is done. Traditionally, statistical analysis in volleyball is done by only taking into consideration the ball contacts done by players. Following that criteria, collective actions are not evaluated. Currently, the focus in volleyball game analysis is on individual executions.

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THE USE OF GROSS EFFICIENCY COEFFICIENTS IN CYCLISTS' ENDURANCE TESTS

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Abstract. The efficiency of energy conversion of aerobic metabolism to external work is of great importance to sports exercise. Despite this fact, gross efficiency (GE) is not commonly used as a parameter in the assessment of cyclists' exercise ability. It is also known that road cyclists traverse most of their route at a work intensity below the anaerobic threshold (AT). We tried to examine the relationship between the standard aerobic parameters used for defining the endurance of cyclists and GE, measured just below the anaerobic threshold. Fifty cyclists were subjected to a progressive test. Work done and the basic respiratory and circulatory parameters were measured. Gross efficiency was calculated at work intensity just below AT. We observed a very low correlation (R = –0.137) between GE (24.9 ±2.06) and maximal oxygen uptake (VO_2max) – 63.8 ±6,27 ml × kg^{-1} × min^{-1}. The strongest correlation (R = –0.258) was recorded between GE and the percentage of maximal oxygen consumption (58.9 ±7.0%) for the load prior to the occurrence of the anaerobic threshold. The weak, but existing correlation between GE and selected respiratory and circulatory parameters may suggest that GE provides unique and independent information about the examined athletes.

Key words: gross efficiency; cycling; anaerobic threshold

Introduction

Physiologists and trainers have long been interested in work efficiency (Gaesser and Brooks 1975). Moreover, there are articles in the scientific literature describing the gross efficiency (GE) coefficient in research on adaptation to effort. These studies, however, do not provide clear results. The variability of this parameter during a season (Hopker et al. 2010) and the dependence of this parameter on the diet in the days before the test (Dumke et al. 2007) have been observed. Work efficiency is defined as the ratio of external work done to the energy released in the metabolism necessary to ensure that external work could be done. Work efficiency is not a commonly used parameter in endurance tests. This is strange, because it seems that work done at a lower energetic cost should facilitate success in sport. During work at constant submaximal intensity, O_2 consumption is proportional to the load.

During the test, oxygen consumption increases progressively as the load increases. Using this relationship, work efficiency can be calculated by the following formula at any given moment (Herman 2007):

$$\text{Efficiency} = \frac{\Delta\text{intensity}}{\Delta VO_2 \times \text{caloric coefficient}}.$$

The way of calculating work efficiency is to use the conversion factors using oxygen consumption and taking the RQ coefficient into account. These conversion ratios were determined by Zunz in 1901 (McArdle et al. 2006). This method has its limitations. At more intensive work, the substantial part of adenosine triphosphate (ATP) used for performing muscle functions comes from anaerobic metabolism. To date it has been extremely difficult to properly estimate the share of anaerobic metabolism in bioenergetics. However, there are some works in which such attempts have been described (de Koning et al. 2013). It is a well-known fact that good cyclists have a high maximal oxygen uptake, as well as high oxygen uptake at the anaerobic threshold, high power at the anaerobic threshold (AT) and maximal aerobic power achieved in progressive tests. It is also known that road cyclists traverse most of the route at a work intensity of less than AT.

The aim of this study is to examine the relationship between the standard parameters used for defining the endurance of cyclists and the GE, measured just below the anaerobic threshold.

Materials and methods

The study included 50 cyclists performing progressive tests on a cycle ergometer in the Laboratory of Exercise (ISO 9001 Certificate) at the Department of Physiology and Biochemistry, University School of Physical Education in Wroclaw. The tests were performed over the years 2005–2014, and were carried out at the request of the cyclists and their sports clubs. Both the examined subjects and their clubs provided written permission for their results to be used in scientific studies.

The most important data characterizing the cyclists surveyed are shown in Table 1.

Table 1. Basic anthropological data and maximal oxygen consumption of examined cyclists

	Age [years]	Body mass [kg]	Body height [cm]	VO_2max [ml/kg]
Mean	19.50	68.40	178.20	63.80
SD	2.80	5.28	5.18	6.27

The height and weight of cyclists were measured using the Radwag tool before starting the exercise test. First, the subjects sat on an ergometer and remained at rest for 3 minutes. At this point, pre-exercise oxygen consumption was measured. Progressive tests were performed, without a prior warm-up, on the Monark cycle ergometer or on Excalibour, a product of Lode. The progressive tests started from a load of 50 W. Participants used a cadence of about 80–90 revolutions per minute. The load was increased every three minutes by 50 W, to the point where the subject could not keep up with the imposed work intensity. During the test and the subsequent 5 minutes the following parameters were recorded: oxygen consumption, CO_2 excretion and ventilation using k4b2 device. Simultaneously, participants' heart rates were recorded using a heart rate monitor produced by Polar. Maximal

oxygen uptake and anaerobic threshold were measured and calculated using a k4b2 device and computer program of the same name. The anaerobic threshold was measured indirectly through the determination of a ventilatory threshold (Beaver et al. 1986). A work efficiency ratio was calculated for the load, prior to the occurrence of the anaerobic threshold.

In calculating the efficiency ratio, two assumptions were made:

1. It is assumed that at this point of the test, the whole energy is coming from the oxidation of carbohydrates – muscle glycogen and glucose. The subjects had the respiratory exchange ratio (RER) very close to 1 at the load immediately preceding the anaerobic threshold. Moreover, according to the literature, the acceleration of fatty acid oxidation in the first few minutes of exercise is insignificant. The energy equivalent of oxygen at 21.14 kJ / l O_2 was assumed.
2. The oxygen consumption which was used in our calculations was measured at the last minute of the test load prior to the occurrence of AT, but decreased by the value of oxygen consumption before the workload. The moment of measurement was chosen individually for each test record. An example of chosen moments of oxygen consumption measurements for a participant is shown in Figure 1.

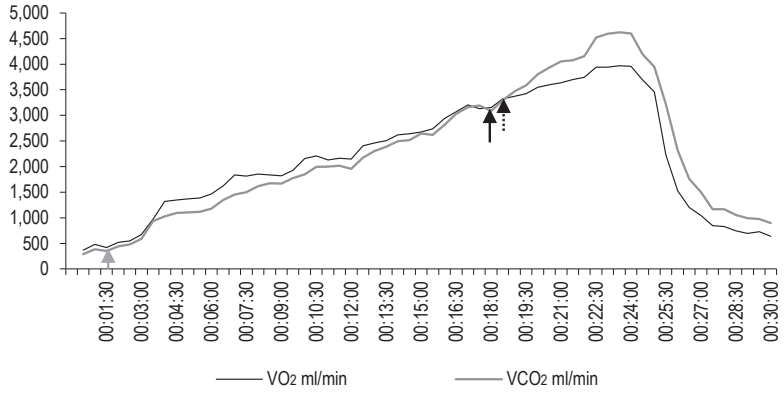

Figure 1. Example of a progressive test with marked points: resting oxygen uptake (grey arrow), oxygen uptake representing the determined GE (black arrow), oxygen uptake at AT (dotted arrow)

To calculate the gross coefficient, the following formula was used (Geasser and Brooks 1975):

$$GE = \frac{\text{Work done in one minute at load before the AT[kj]}}{\text{(oxygen consumption at load before the AT[L] – oxygen consumption without load [L] × 21.14 (kj/L)}}$$

A statistical analysis of the results was conducted using Excel (MS Office).

Results

The results of the analysis of respiratory gases and heart rate are shown in Table 2.

Table 2. Chosen respiratory and circulatory parameters of the examined cyclists

Parameter	Oxygen uptake without load VO_2 [ml]	Maximal Oxygen uptake VO_2 [ml]	VO_2 max [ml/kg]	VO_2 at anaerobic threshold [ml/kg]	$\%VO_2$max at anaerobic threshold	Heart rate at anaerobic threshold [b/min]
Mean	371.66	4352.38	63.80	48.73	77.22	165.48
SD	±89.60	±433.12	±6.27	±5.35	±5.78	±11.36

Respiratory, load and work efficiency parameters are given in Table 3.

Table 3. Load, work and respiratory parameters of examined cyclists

Parameter	Load before AT [W]	VO_2 before AT [ml]	Net VO_2 before AT [ml]	Energy calculated [kJ]	Work measured [kJ]	Work efficiency [%]
Mean	227.00	2970.61	2598.95	54.94	13.62	24.90
SD	30.66	365.33	359.10	7.59	1.84	2.06

The correlation coefficient between the VO_2max and gross efficiency was calculated. This relation was weak: R = –0.137.

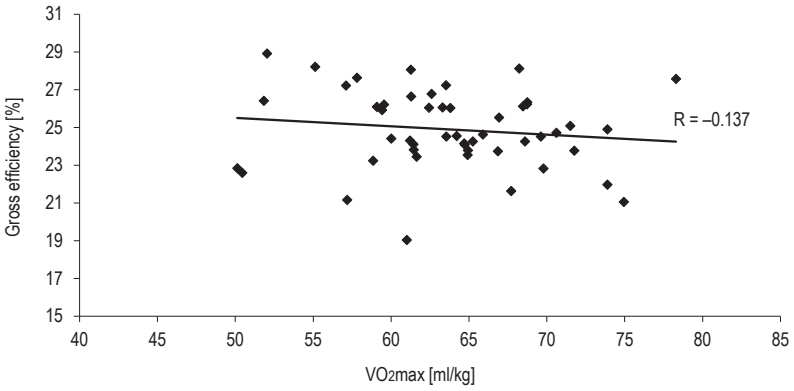

Figure 2. The relationship between VO_2max and gross efficiency in examined cyclists

The correlation coefficient between the percentage of VO_2max on the last load before AT and gross efficiency was also calculated. It was found that the compound is low, as R = –0.258. See Figure 3.

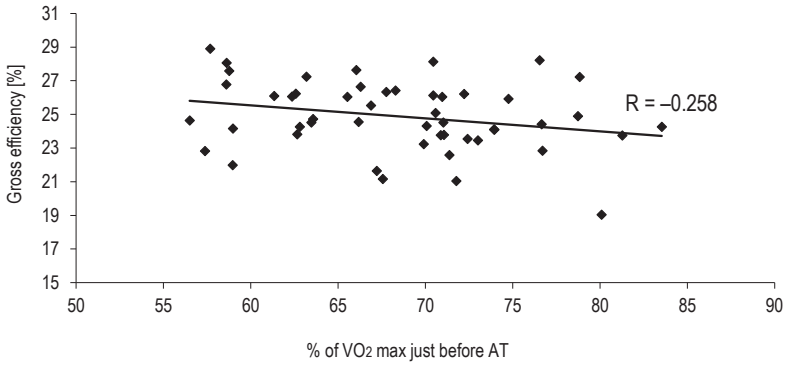

Figure 3. The relationship between % of VO_2max (ml/kg of body mass) measured on the last load before AT and gross efficiency in cyclists tested

Values of Pearson correlation coefficients for other physiological parameters and work efficiency were also calculated. All tested features were proven to be unrelated to GE. The results are shown in Table 4.

Table 4. The correlation coefficient between gross efficiency and chosen physiological parameters

Feature	HR on AT	%VO_2max on AT	Oxygen uptake without load
Pearson correlation to GE	0.037	–0.054	–0.019

Discussion

Road cycling is considered as endurance competition. Cycling races sometimes take several days, or many hours in the case of an individual stage or single race. As such, the economization of work is a very important factor that may determine the level of success in a race. Therefore, long-lasting work must be performed mostly with an intensity below the anaerobic threshold. Performing the work with such intensity allows the cyclist to overcome the majority of the distance, as well as to regenerate during the race after more intensive parts of the stage. Success in cycling comprises many factors, some of which are of interest to physiology. Parameters such as VO_2max, metabolic thresholds and maximum power demonstrate physical preparation for competition. Particularly important is the determination of these parameters among young athletes, as they have prognostic significance in the selection of competitors, particularly VO_2max (Zatoń et al. 2011). The issue of work efficiency is one that hitherto has not been widely addressed in the scientific literature. GE reflects the degree to which energy derived from aerobic metabolism appears in the form of external work. It can therefore be assumed that when GE is greater,

better results can be achieved during the competition. According to Moseley et al. (2004), world-class cyclists do not show higher work efficiency on an ergometer than amateurs. From this point of view, it can be assumed that this parameter is not particularly useful in the assessment of physical fitness. There are articles describing that the GE value varies in a given cyclist, and even changes in reverse proportion to changes in VO_2max. (Hopker et al. 2012). On the other hand, the findings of Hopker et al. (2010) suggest that intensive training improves gross efficiency. Studies of members of the same team showed that GE is higher in women than in men in cases of the same absolute intensities of work (Hopker et al. 2010). It was also found that GE is also affected by changes in diet. An increase in GE was noted when participants followed a 3-day high carbohydrate diet before the endurance test (Cole et al. 2014). Leirdal and Ettema (2011) found that an increase in pedaling frequency causes a loss of work efficiency at an intensity of 75% VO_2max, while Abbiss and Laursen (2005) indicate a high GE in trained cyclists working with high cadence. Gross efficiency is a parameter which may indicate the effectiveness of aerobic work. However, it is not ideal coefficient. As mentioned in the introduction, this coefficient as well as the entire indirect calorimetry has serious limitations. It would seem that the higher GE is, the better it is for the competitor. Meanwhile, GE increases with every increase in work intensity during a progressive test. This is due to the fact that the athlete is already doing more intensive work, but the rate of oxygen uptake which is needed to supply it increases slowly. In this case we have a paradoxical increase of GE. Numerator (labor intensity) increases and the denominator (oxygen consumption) remains temporarily unchanged. It can be assumed that women perform more anaerobic work, as shown during examinations made by the Hopker's team (2010). The problem of anaerobic metabolism and its influence on the calculation of GE is considered in an article by Scott (2005). Reger et al. (2013) found that at low intensities of exercise in untrained people, the corrected gross efficiency in some cases even exceeds the hypothesized values. These claims make the use of GE problematic as a parameter to adequately describe physical abilities.

Many scientists link high GE with better coordination of the contraction and relaxation of the muscles responsible for movement. The use of pressure sensors in the pedals and chain tension gauges in a cycle ergometer allows independent measurements of coordination without determining GE.

The present study has shown that there is a lack of correlation between the gross coefficient and physiological parameters most commonly used to measure physical abilities in cycling. In the examined group there was no correlation of GE to VO_2max, VO_2max per kg of body mass, or VO_2 on anaerobic threshold, etc. This result may support the thesis that GE is not a useful parameter in commonly applied physiological tests measuring the physical abilities of cyclists. On the other hand, it may mean, however, that GE provides new information about examined athletes that is unrelated to the other parameters. However, it is not easy to interpret this information. One would need to collect large amounts of data over a long period of time. Fortunately, it is not difficult to introduce work efficiency as an additional parameter in respiratory gas analyzing software.

Conclusion

Determining GE at characteristic points of a progressive test could provide new information about the athlete. GE values measured and calculated at the last moments below AT are not correlated with other physiological parameters. It can be concluded that the measurement of GE just below the anaerobic threshold gives new, independent information about the examined athlete. The usefulness of this new information, however, is debatable.

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PREDICTORS OF PATELLOFEMORAL PAIN APPLYING FULL WEIGHT BEARING KINEMATIC MRI

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[A] Study Design; [B] Data Collection; [C] Statistical Analysis; [D] Manuscript Preparation

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Abstract. Purpose. To determine the associations among PFM, trochlea groove morphology, femoral and patellar rotation and to determine which measures best predict patellofemoral pain (PFP).
Material & Methods. Knees of 51 female patients with PFP and 26 healthy female volunteers as control group were analysed with kinematic magnetic resonance imaging and full weight-bearing. The bisect offset (BSO), patellar tilt angle (PTA), femoral rotation angle (FRA), patellar rotation angle (PRA) were measured in steps of 10° between 0° to 50° of knee flexion. Static measures of Insall-Salvati ratio (ISR), sulcus angle (SAB & SAC) and lateral trochlear inclination at bone and cartilage levels (LTIB & LTIC) were performed and compared.
Results. The SAB & SAC were higher and the LTIB & LTIC were lower in patients compared to volunteers. BSO, PTA, PRA and medial FRA were higher in the PFP group at all flexion angles. A multiple logistic regression analysis demonstrated that increase of FRA and SAB by 1° increased the likelihood of PFP 5.6 times and 1.6 times respectively, decrease of PRA by 1° decrease PFP likelihood by 1.7 times.
Conclusion. These results revealed FRA, SAB and PRA to have best predictive value for patellofemoral pain. Current findings can help to assess the complexity of predisposing factors for PFP in practice.

Key words: patellofemoral pain, patellofemoral malalignment, kinematic MRI, femoral rotation

Introduction

Patellofemoral pain (PFP) is a common knee disorder characterized by a diffuse pain over anterior aspect of the knee and aggravated by squatting, running, jumping or other activities that increase patellofemoral joint compressive forces (Wilson 2007). This multifactorial condition often is diagnosed in physically active people and can be described as chronic problem reducing their athletic ability. Limited effectiveness of treatment is associated

with a different genesis of PFP. Local, trunk and distal factors that influence PFP are determined and studied (Wilson 2007; Witvrouw et al. 2014). Patellofemoral maltracking was found in 50% of patients and currently could be named as mostly accepted reason for PFP (Pal et al. 2013).

Patella alta is believed to be one of the possible causes for PFP and instability (Pal et al. 2013). Patients with patella alta are at 20–30% greater risk for PFP and patellar displacement but the influence of patellar height for patellar instability is still controversial (Ward et al. 2007; Stefanik et al. 2012; Biyani et al. 2014; Teng et al. 2014).

Femoral trochlea sulcus angle is a static factor for patellar stability. Flattened sulcus predispose patella to displace laterally as the quadriceps muscle contracts. Angle between 140–150° is believed to cause PFP (Insall et al. 1983). It has been reported that there is a mismatch between the bony and cartilaginous anatomy of the trochlea (Staubli et al. 1999; Shih et al. 2004) but possible influence on patellar instability was not evaluated. Harbaugh et al. (2010) and Teng et al. (2014) reported that the lateral trochlear inclination (LTI) was more important in predicting patellar lateral displacement, than sulcus angle.

It is widely accepted, that the unstable patella slides over the stable femur (Wittstein et al. 2006). However altered patellofemoral joint kinematics during weight bearing may be more associated with abnormal femur motion than patella motion. Greater lateral patellar tilt and displacement, greater amount of medial femoral rotation were associated with PFP (Powers 2010; Souza et al. 2010). We hypothesized that females with PFP might have greater medial femoral rotation when compared to the pain free individuals.

Different opinions exist regarding morphometric characteristics of the patellofemoral joint and their influence on patellar alignment and PFP (Powers 2000; Harbaugh et al. 2010; Varadarajan et al. 2010). The purpose of this study was to use full weight bearing kinematic MRI, to systematically examine relationships among patellofemoral malalignment; morphologic features of the trochlea groove, femoral and patellar rotation and to determine which measures are the best predictors for PFP.

Materials and methods

Fifty one females with PFP and twenty six pain free females aged between 18–40 years were included in the study. Before MRI study all subjects were informed as to the nature of the study and signed a human subject's consent form approved by the Vilnius Regional Biomedical Research Ethics Committee. Inclusion criteria were for at least two symptoms associated with PFP: painful stair ascent or descent, painful squatting, painful kneeling, painful prolonged sitting. Exclusion criteria were: age >40 years, previous knee surgery, traumatic patellar dislocation, any implanted pacemakers, cochlear implants, clips. The kinematic MRI examination was done with a 1.5 T MRI unit (Siemens Symphony, Erlangen, Germany) using body coil to allow flexion and extension of both knees. We used a Dynawell L-spine device to load patients with full weight and MRI machine table movement to let knees extend from 50° to 0°. Patients in supine position were asked to press upon the Dynawell L-spine device using both legs with equal force. The table was moved automatically to extend knees by 10°. Sagittal and axial images of the patellofemoral joint were acquired with a transmit-receive surface body coil and a fast gradient-echo pulse sequence. Sagittal images were acquired to double check the knee flexion angle. Scanning parameters: repetition time (TR) 2.84 milliseconds, echo time (TE), 1.05 milliseconds; flip angle 8°, field of view 30 × 30 cm, matrix 256 × 128, slice thickness, 3 mm; number of slices 30, excitations 1.

Images with maximum patellar width were selected for evaluation of medial femoral rotation, patella rotation, lateral patella tilt and lateral patella displacement. Medial/lateral femoral rotation (FRA) was measured as the

angle formed by the line joining the posterior femoral condyles and the line parallel to the horizontal orientation of the field of view (Figure 1a). Patella rotation (PRA) was measured as the angle formed by the line defining the maximum patella width and a line parallel to the horizontal orientation of the field of view (Figure 1b). Medial/lateral patella tilt (PTA) was measured as the angle formed by the line joining the maximum width of the patella and the line joining the posterior femoral condyles (Figure 1c). Positive values for femoral rotation indicate medial rotation, negative – external. As with femoral rotation, medial patella rotation was defined as positive and lateral patella rotation as negative. Medial/lateral patellar displacement (Figure 1d) was measured using the bisect offset (BSO) index as described by Brossman et al. (1993). A line was drawn parallel to posterior femoral condyles, while another perpendicular line was drawn through the deepest trochlear point. This line intersects the line connecting the widest patellar points. Measurements were made with Leonardo workstation (Siemens, Erlangen, Germany). The femoral and patella rotation angle, patella tilt angle and the bisect offset measurements were collected from images acquired with full weight bearing from 50° to full extension. Femoral rotation, patella rotation and lateral patella tilt measurements were reported in degrees, lateral patella displacement (bisect offset) was expressed in percent.

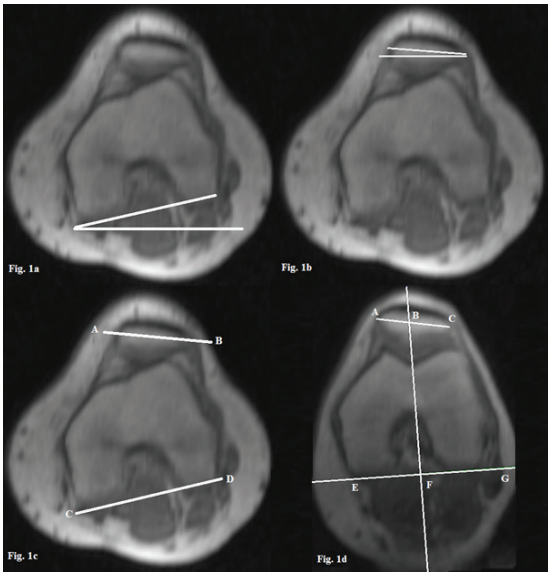

Figure 1. Descriptions of analyzed patellofemoral kinematic parameters. (a) femoral rotation (FRA) – angle between posterior femoral condyles and external field of view; (b) patellar rotation angle (PRA) formed by a line connecting the widest patellar points and external field of view; (c) patella tilt angle (PTA) formed between lines connecting the widest patellar points and posterior femoral condyles; (d) Bisect offset (BSO). EG line parallel to posterior femoral condyles, BF line perpendicular to EG line bisects AC line connecting the widest patellar points A and C. BSO is BC/AC × 100

Insall-Salvati ratio (ISR) was measured from sagittal images. Ratio was calculated by dividing the distance from the tibial tuberosity to the inferior pole of the patella by the length of the patella measured by the distance from the apex of the patella to its most posterior superior point (Figure 2).

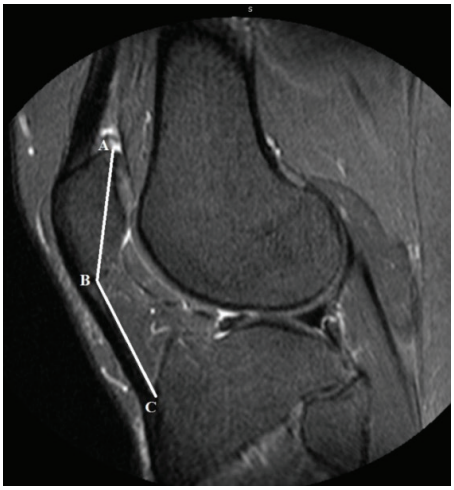

Figure 2. Insall-Salvati ratio was calculated by dividing the length of the patella tendon (BC) by the length of the patella (AB)

Measurements for sulcus angle and lateral trochlear inclination were made at first proximal axial image where cartilage completely covered trochlear groove. Sulcus angle is defined as the angle connecting highest points of the medial and lateral trochlear facets and the deepest point of the trochlear groove. Sulcus angle at bone level (SAB) and sulcus angle at cartilage level (SAC) were measured (Figure 3). Lateral trochlear inclination (LTI) is the angle of the lateral ridge of the trochlear groove with respect to the posterior condyles. LTI was measured at the bone level (LTIB) and cartilage level (LTIC).

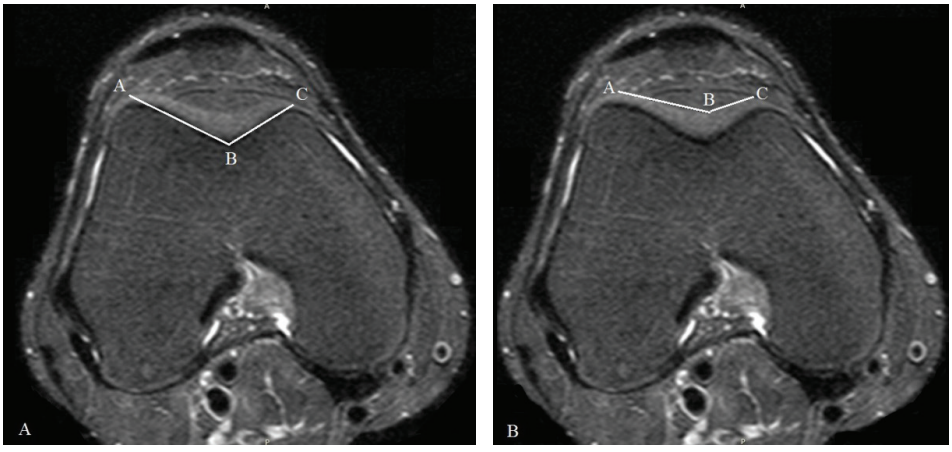

Figure 3. (A) Sulcus angle at the bone level (SAB) is the angle formed by the highest point of the medial and lateral anterior femoral condyles and the deepest point of the femoral trochlear groove at the bone level, (B) sulcus angle at the cartilage level (SAC) is the angle formed by the highest point of the medial and lateral anterior femoral condyles and the deepest point of the femoral trochlear groove at the bone level at the cartilage level

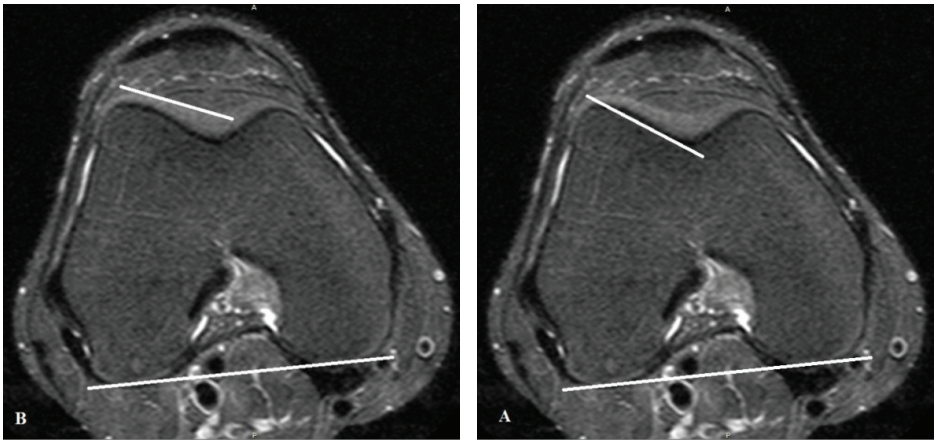

Figure 4. (A) Lateral trochlear inclination angle at bone (LTIB) level is the angle of the lateral ridge of the trochlear groove bone with respect to the posterior condyles, (B) lateral trochlear inclination angle at cartilage level (LTIC) is the angle of the lateral ridge of the trochlear groove cartilage with respect to the posterior condyles

Statistical analysis was performed using SPSS version 20 for Windows (SPSS Inc., Chicago, IL). Student's t-test for independent samples was used to compare means between PFP and pain free groups at all angles of KMRI. Multiple logistic regression was used to determine the effect of trochlea geometry and patella alignment MRI variables on patellofemoral pain. Level of significance was set at $p < 0.05$.

Results

Seventy seven females participated in this study. Fifty one had a diagnosis of PFP (mean ± standard deviation; age: 25.84 ±5.04 years), twenty six subjects were asymptomatic (mean ± standard deviation; age: 26.35 ±4.77 years).

The descriptive statistics of the trochlea geometry, patellar height in PFP and control groups are presented in Table 1.

Table 1. Comparing the trochlea geometry and patellar height indices in PFP and control groups, mean ± standard deviation

	Pain-free	PFP	p
SAB	135.9 ±8.2	143.0 ±12.6	0.004
SAC	146.4 ±9.2	153.1 ±10.9	0.009
LTIB	21.3 ±4.1	17.4 ±6.9	0.003
LTIC	17.4 ±4.2	13.9 ±5.9	0.004
ISR	1.1 ±0.2	1.3 ±0.2	<0.0001

SAB: sulcus angle bone; SAC: sulcus angle cartilage; LTIB: lateral trochlear inclination bone; LTIC: lateral trochlear inclination cartilage; ISR: Insall-Salvati ratio.

The means, standard deviations of the variables describing patellar alignment and femoral rotation measurements for both groups are presented in Table 2.

Table 2. Comparing the patellar alignment and femoral rotation indices in PFP and control groups, mean ± standard deviation

		Knee flexion angle					
		0°	10°	20°	30°	40°	50°
BSO	pain-free	57.2 ±4.8*	55.4 ±5.2*	53.8 ±5.2*	52.3 ±4.7*	51.3 ±4.8*	50.2 ±4.9*
	PFP	70.1 ±11.7*	65.5 ±9.8*	61.2 ±7.7*	57.2 ±6.1*	55.1 ±4.7*	53.9 ±4.4*
PTA	pain-free	10.1 ±2.7*	8.5 ±2.4*	7.5 ±2.6*	6.6 ±2.6*	5.3 ±2.8*	4.1 ±3.1*
	PFP	13.5 ±4.3*	11.8 ±4.3*	10.4 ±4.2*	9.0 ±4.3*	8.2 ±3.9*	6.9 ±3.9*
PRA	pain-free	4.8 ±5.7*	3.8 ±5.6*	2.4 ±5.6*	1.2 ±5.7*	–0.2 ±5.3*	–1.2 ±5.1*
	PFP	0.5 ±6.6*	–0.6 ±6.7*	–1.6 ±6.5*	–2.9 ±6.1*	–4.2 ±5.3*	–5.0 ±4.9*
FRA	pain-free	10.2 ±2.6*	7.0 ±2.6*	4.9 ±3.1*	3.2 ±3.3*	1.7 ±3.9*	0.7 ±4.0*
	PFP	18.1 ±3.7*	13.2 ±3.7*	10.7 ±3.8*	8.7 ±3.7*	7.3 ±3.4*	5.8 ±3.0*

BSO: bisect offset; PTA: patellar tilt angle; PRA: patellar rotation angle; FRA: femoral rotation angle, PFP: patellofemoral pain; * $p < 0.05$ comparing pain-free and PFP groups.

As shown in Table 1 SAB was by 7.1° and SAC was by 6.7° higher, while LTIB and LTIC were significantly lower in women with PFP compared to healthy women. ISR in females with PFP was 1.3 and it was by 0.2 (18%) higher than in controls.

In the PFP group compared to the pain-free group, BSO and PTA were higher at all flexion angles ($p < 0.01$). Females with PFP demonstrated greater lateral patellar rotation and greater medial femoral rotation at all flexion angles: PTA was significantly lower in PFP group compared to controls ($p < 0.01$), while FRA was significantly higher in PFP group compared to controls ($p < 0.001$).

A multiple logistic regression (backward based on Wald statistic) analysis was performed on PFP status as outcome and 7 predictors: SAB, LTIB, IS, BSO, PTA, PRA and FRA. Model Nagelkerke R^2 was 0.88. The Table 3 shows regression coefficients, Wald statistic, odds ratio and 95% confidence intervals for odds ratios.

According to Wald criterion SAB, FRA and PRA reliably predicted PFP status.

Table 3. Odds ratios of factors predicting PFP derived from multiple logistic regression analysis

Variable	Coefficient (B)	p	Odds ratio	95% CI for odds ratio
SAB	0.5	0.039	1.6	1.0–2.6
LTIB	0.7	0.077	2.0	0.9–4.6
ISR	–15.2	0.060	0.0	0.0–1.9
FRA	1.7	0.005	5.6	1.7–18.6
PRA	–0.5	0.008	0.6	0.4–0.9

SAB: sulcus angle bone; LTIB: lateral trochlear inclination bone; ISR: Insall-Salvati ratio; FRA: femoral rotation angle, PRA: patellar rotation angle.

Odds analysis demonstrated that increase of FRA by 1° increased the likelihood of PFP 5.6 times, increase of SAB by 1° increased the likelihood of PFP by 1.6 times. Decrease of PRA by 1° decrease PFP likelihood by 1.7 times.

Discussion

In our study females with PFP had shallower femoral sulcus at subchondral bone level as well at cartilage level compared to the healthy volunteers. Majority of investigations demonstrated that increase in the sulcus angle is indicative of compromised patellar stability and PFP (Powers 2000; Varadarajan et al. 2010). Our findings were consistent with Powers et al. (2000) results who reported a substantial loss of the bony groove depth in subjects with PFP as the knee extended beyond 27° with approximately 9° higher SAB at full extension in subjects with PFP compared to healthy volunteers. In our study subjects' with PFP SAB was by 7.1° higher and SAC was by 6.7° higher compared to the controls.

Teng et al. (2014) reported higher SAB values in asymptomatic controls and in women with PFP compared to our results, as well as smaller difference between healthy and in females with PFP. Balcarek et al. (2010) reported 154.6 ±11.6° SAB in patients with patellar dislocation, which was by 8.4° higher than in healthy women. Examination of 566 knees (59% of them were female) in patients who either had knee osteoarthritis or were at high risk (older than 50 years, overweight, or had a previous knee injury) for knee osteoarthritis revealed SAB at 130.4°±8.7° (Stefanik et al. 2012). Our results showed lower SAB than reported by Balcarek et al. (2010) because his data was collected from patients treated for lateral patellar instability, which is associated with shallower sulcus. On the contrary, data presented by Stefanik et al. (2012) showed deeper sulcus for patellofemoral osteoarthritic patients, because they were selected with risk factors that predispose osteoarthritis despite sulcus depth.

In our study females with PFP had higher lateral trochlea inclination at subchondral bone level as well at cartilage level compared to the healthy volunteers. Carrillon et al. (2000) were the first to describe the use of the lateral trochlear inclination on MRI. They reported mean values of 6.2° in subjects with a history of patella dislocation and 16.9° in control subjects ($p < 0.001$). Teng et al. (2014) reported mean LTIB values of 14.9° ±5.4° in women with PFP and 17.9° ±8.3° in asymptomatic controls. In our study LTIB in women with PFP was 17.4 ±6.9° and in controls 21.3 ±4.1°. Our results are consistent with the results of other investigators in that a lower lateral trochlear inclination angle (i.e., flattened lateral trochlea) was associated with the compromised patellar stability and PFP.

Our study demonstrated greater patella height in PFP subjects compared to pain free subjects using ISR. Our results were consistent with Pal et al., (2013) who reported greater patella height in chondromalacia patella subjects compared to pain free subjects using the ISR. Pal et al. (2013) reported that average patella height for PFP subjects was even 30% greater than the pain free subjects using the Insall-Salvati index ($p < 0.001$).

Based on values of BSO, patellar lateralization was confirmed in both groups at all angles of KMRI. Despite it, the subjects with PFP demonstrated greater statistically significant patellar lateralization at all angles of flexion compared to healthy women. This finding coincide with results of Souza et al. (2010). The largest difference between groups was evident at full extension (70.1% versus 57.2% of the patella lateral to the midline), which was consistent with Powers (2000) results and coincided with the contention of Fulkerson (2002) that patellar subluxation typically occurs during terminal knee extension.

The patellar tilt data showed that the patella was laterally tilted throughout the range of motion in both groups. The subjects with PFP demonstrated a greater magnitude compared with the subjects without PFP at all knee flexion angles with the largest difference between groups was evident at full extension. The subjects with and without PFP demonstrated an overall pattern of increasing lateral tilt as the knee extended, which was consistent with other authors (Biyani et al. 2014; Teng et al. 2014).

Patella rotation significantly differed between groups. The progressive internal rotation of the patella with knee extension was observed in both groups, but in women with PFP group internal patellar rotation was evident from 10° of knee flexion angle while in control group internal patella rotation occurred at 40° and 50° of knee flexion. Our results are in agreement to data of Souza et al. (2010). They reported about slight lateral rotation of patella across all knee flexion angles and there was a tendency for the patella to rotate medially as the knee extended in PFP and control groups. For pain free group patellar rotation demonstrated grater positive values (i.e. greater medial rotation). Differences might have occurred because of different patient positioning. We used supine, while Souza et al. (2010) used upright scanning position. The pattern of motion we observed is in contrast to what has been reported by Powers et al. (2000) during non–weight-bearing conditions.

Women with PFP demonstrated greater medial femoral rotation compared to the control group at all knee flexion angles. The largest difference between groups was observed at 0° of knee flexion, where the subjects with PFP had 180% of the amount of medial femoral rotation compared to the control group (10.2° ±2.6° vs. 18.1° ±3.7°). The maximum medial rotation exhibited in our PFP group (18.1°) was higher than previously reported by Powers et al. (13°) and Souza et al. (12.2°), who used a similar weight-bearing protocol to that employed by the current study. Greater medial femoral rotation may be predisposed by skeletal abnormalities such as femoral anteversion or hip muscle weakness, which was not evaluated in the present study. Another possible reason for greater medial femoral rotation could be “screw-home mechanism”, which occurs at end stage of extension and knee joint locking (Wittstein et al. 2009; Dietrich et al. 2014; Izadpanah et al. 2014).

Conclusions

This kinematic magnetic resonance imaging study revealed femoral rotation angle, sulcus angle at bone level and patellar rotation angle to have best predictive value for patellofemoral pain. Presented results can help to assess the complexity of predisposing factors for PFP in practice.

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FUNDAMENTAL SIGNIFICANCE OF PHYSICAL ACTIVITY FOR SENIORS' HEALTH

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Abstract. Physical activity is a basic component of geriatric prevention. Lower physical activity of seniors is a cause and effect of many chronic conditions, e.g. type 2 diabetes, obesity, diseases of musculoskeletal system or cancer.
This paper analyzes Polish and international literature in terms of significance of physical activity for keeping and improving health of seniors. Numerous studies carried out at large research facilities all over the world proved that taking up physical activity by seniors is one of the key factors for ensuring better health. It is, however, important to precede workout with medical examination. After that, suitable exercises, their frequency, duration and intensity need to be determined.
The conclusion of this paper is as follows: regular physical activity improves effectiveness of preventive measures and treatments related to diseases such as cardiovascular disease; it also reduces mortality rate and prolongs the period of physical and mental activity of seniors.

Key words: physical activities, seniors, lifestyle, healthy behaviors

Introduction

At every stage of human life, the need for physical activity helps maintain one's health (Kaczmarczyk and Trafiałek 2007; Kostka and Bogus 2007). Improving one's fitness level gained at the adolescence and maintaining it throughout the middle age results in better fitness in old age. Physical activity is a basic component of geriatric prevention. Beneficial results of workout depend on the regularity of exercise. Lower physical activity in seniors is both a cause and effect of many chronic conditions, e.g. type 2 diabetes, obesity, diseases of musculoskeletal system or cancer (Knoops et al. 2004; Sumic et al. 2007).

Usually, the process of aging (with its prevailing stereotypes) discourages seniors from physical and social activity. This is further enhanced by ceased professional activity, limitation of social contacts, sense of loneliness and lower motivation for being active. An important element of the workout program is educating and convincing

seniors to be physically active, encouraging them to continue being active and praising even the slightest successes on their path to better fitness (Corner et al. 2004; Fiatarone et al. 1994; Polak et al. 2007).

Assessing health of seniors before workout

Numerous studies proved effectiveness of workout (regular physical exercise) in terms of preventing disadvantageous results of the aging process and sedentary lifestyle (Kostka et al. 2001; Pitsavos et al. 2008). Seniors aged 65+ often suffer from chronic illnesses and disabilities. Usually they require medical attention and social help. These unfavorable phenomena may be prevented, but general practitioners are unwilling to encourage seniors to take up everyday physical workout. The role of the doctor must include: effective persuasion of patients to be physically active, detailed examination, and finally designing an individual and safe workout routine. During a standard appointment, doctors should examine the patients thoroughly in order to determine whether they are healthy enough to engage in physical workout. 'Being healthy' means lack of illnesses which could prevent from participation in workout (Sygit 2008). Physical activity is aimed at reducing risk of certain chronic degenerative diseases and improving metabolism, Vo_2 max and better functioning on a daily basis (Kliginan 1999; Kostka et al. 2001).

During medical check-ups, the doctor needs to determine possible counter indications related to cardiac stress tests and subsequent workout, as well as training limitations of their senior patients. Factors to be considered include: patient's previous activity level, current activity (frequency, duration, intensity of training), acute and chronic illnesses (with special consideration given to chronic obstructive pulmonary disease, cardiovascular disease and severe mobility limitations due to joint diseases). To obtain full set of data on a patient, a family history needs to be verified (incl. cardiovascular disease, respiratory disease and determining risk factors for the coronary artery disease). During the verification of the family history, the doctor should consider all systems and organs. Risk factors that could limit cardiac stress tests also need to be determined (Borowiak and Kostka 2004; Fiatarone et al. 1994).

Unfortunately, workout does sometimes result in adverse effects, including deaths, but usually they result from ongoing cardiovascular disease. Rules for qualifying and counter indications for cardiac stress tests and trainings for seniors are the same as for younger patients (Chipperfieid 2008; Psaltopoulou et al. 2008).

Assessing functions of the circulatory system

Strict counter indications for cardiac stress tests are: new changes in the ECG, acute myocardial infarction, unstable myocardial ischemia, atrioventricular block and acute congestive cardiac failure. Conditional counter indications are: high blood pressure, cardiomyopathy, valvular heart disease, complex ventricular extra beats and metabolic decompensation (Sygit 2008).

The American College of Sports Medicine (ACSM) recommends cardiac stress tests on a treadmill before proceeding to intense workout (over 60% of the maximal oxygen uptake) for men over 40 and women over 50 years old. The test should also be performed with seniors with cardiovascular disease risk factors, irrespectively of their ailments and expected intensity of workout. Cardiac stress test is also necessary when the patient is 65+ and leads a sedentary life. Cardiac stress test on a treadmill is also helpful to plan workout intensity. If treadmill is not available, normal pulse recovery test (Kasch's test), presented in Table 1, must suffice to assess patient's functions (Kliginan 1999).

Table 1. Kasch's Pulse Recovery Test

Function	Heartbeat (beats per minute) in patients aged 50–60	Heartbeat (beats per minute) in patients aged 66
Men		
– Excellent	72–82	72–86
– Good	89–97	89–95
– Above average	98–101	97–102
– Average	105–111	104–113
– Below average	113–118	114–119
– Poor	122–128	122–128
– Very poor	131–150	133–152
Women		
– Excellent	74–92	73–86
– Good	97–103	93–100
– Above average	106–111	104–114
– Average	113–117	117–121
– Below average	119–127	123–127
– Poor	129–136	129–134
– Very poor	142–151	135–151

The test assumes that the better oxygen function of a patient the quicker they regain the initial heartbeat after workout. Before commencing the test, pulse and blood pressure need to be measured. Next, patients spend 3 minutes walking up and down (using both legs) on a 30-cm step at the rate of 24 up-and-downs per minute. To facilitate the correct rate, a metronome may be set at 96 beats per minute. Pulse and blood pressure must be measured 1 minute after completion of the test. Functions of respiratory system may be measured with forced vital capacity of lungs and forced expiratory volume in 1 second.

Measurement of musculoskeletal system functions should include muscle strength (hand grip strength) and joint movement ranges. Grip strength (measured with a dynamometer) helps predict functional limitations. Simple measurement of strength and endurance of muscles consists of holding tight the dynamometers as long as possible. Thus, data for comparative assessment of subsequent trainings is obtained. The other strength and function indicator is Squat-Stand Up Test, which is very easy to conduct (Kliginan 1999; Sygit 2008).

Designing a training plan

Designing a workout plan is similar to prescribing medicine, planning a surgery or determining treatments. It is a compromise between expected benefits and possible side effects. After thorough consideration given to all factors, doctors and patients should work together to develop an optimal workout plan. The most important aspects are: determining the aim of exercises (e.g. osteoporosis prevention, reducing body mass, preparing for a marathon) and patient's preferences. One should consider expanding current forms of activity because selecting workout which is pleasurable for a patient guarantees persistence (Borowiak and Kostka 2004; Fiatarone et al. 1994).

The American College of Sports Medicine presented its exercise recommendations for healthy seniors and other adults. Thus, a basic exercise plan was created; it should be presented to a patient, with consideration given to their health level and aims of particular exercises (Kostka et al. 2001; Lampinen et al. 2006).

During initial tests, similarly to planning the trainings, one should consider 5 basic physical ability aspects: circulatory system functions, strength and endurance of muscles, agility, body composition and sense of balance.

Many seniors have low proportion of lean body mass and weakened muscle strength. Benefits of strength training for these patients are often ignored, therefore the American College of Sports Medicine highlights the importance of this type of training in its newest recommendations. Considering all of the above-mentioned factors, both doctors and patients should determine the ideal physical activity level. The minimal aim should be to maintain current fitness level, and the optimal - to improve it. The type and intensity of exercise may change along with changes in patient's functions (Kostka 2009; Sumukadas et al. 2007).

Selecting exercise types

Workout plan should include type, frequency, duration and intensity of exercises aimed at improving all aspects of physical fitness. Type of exercise often depends of availability of facilities and sports equipment, but patients' preferences and expectations should not be ignored, e.g. golf lovers should be encouraged to do certain exercises on the treadmill and strength trainings. The doctor should balance health benefits of particular types of exercise and physical limitation of the patient. For example, marching, cycling and swimming have the same beneficial effects on the circulatory system functions. Improved calcification of bones is obtained, however, by marching because this type of activity ensures full strain on the whole musculoskeletal system, while swimming works best for patients with limited joint mobility.

Alternative workout is the best compromise between numerous forms of training. Patients can engage in various forms of physical activity in a week. Alternative training effectively combats boredom, engages more muscle groups and reduces strain injuries of the musculoskeletal system (Blair et al. 1995; Chipperfieid 2008; Onder et al. 2002).

Determining frequency, duration and intensity of workout

In order to motivate a senior to be persistent in their trainings, the workout plan may be diversified. It must be remembered that results depend on the intensity of exercise. Although more frequent, longer and more difficult exercises require better preparation, the relation between results and effort are almost linear. Sense of satiety is a natural and desirable mechanism which prevents the patient from over-training and injuries. It is hard to believe how little physical activity is enough to conform to recommendations of the Center for Disease Control and Prevention and the National Institutes of Health. Doctors and physiotherapists often design workout plans with two options: minimal and optimal. Patients are supposed to exercise according to the former option when they are very busy, and fulfill the latter whenever they have more time for exercise (Aria et al. 2007).

Recommendations for exercise intensity are usually given in ranges (e.g. target heartbeat: 120–145 per minute, muscle fatigue after 8–12 repetitions in a series). Expected norms of heartbeat in all age groups, found in literature, have little usability in the population of seniors, and often are erroneous (the recommended 70–85% of max. heart beat often means difference of 15-20 heartbeats per minute in practice). Physiological response occurs when stimuli are stronger than the current activity level. Many people do not appreciate physical activity, seeing it as uncomfortable, risky and unjustified. M.E. Tinetti roved, however, that strength training is effective and safe even for 90-year-olds. Their study recommended changing frequency and intensity of workout once the improved functions were obtained. When designing a workout plan, it is essential to monitor or teach patients how to monitor their progress (Tinetti 1986).

Determining workout aims requires knowledge about progress equivalents for metabolic exercise. A table was published which presents different types of physical activity and their metabolic equivalents. We encourage doctors to familiarize themselves with this list and use it during designing workout plan for their patients, according to their health and geographical conditions.

In order to determine the intensity of aerobic exercise, Borg Rating of Perceived Exertion is often used (Table 2) (Tinetti 1986; Sygit 2008).

Table 2. Borg Rating of Perceived Exertion

Value	Exertion
6–7	Extremely light
8–9	Very light
10–11	Light
12–13	Somewhat hard
14–15	Hard
16–17	Very hard
18–20	Extremely hard

This scale may also be used in relation to strength and stretching exercises. Physiotherapists often recommend exercise that are 'somewhat hard' or 'hard' to perform (13–15 points on the Borg scale) to healthy and young individuals, while 'light' and 'somewhat hard' (11–13 points) to seniors. Once functions have improved, patient should increase intensity or duration of workout. During strength training one must remember to exercise until muscles are fatigued, which occurs after 8–12 repetitions. For seniors, it is better to perform more repetitions (12–15) with lower weights. Weight should be increased when patient is able to easily repeat the exercise 13 times; then, the whole process is repeated (Tinetti 1986).

Conclusions

Aging of Europe and Poland's population is probably the biggest medical and socio-political challenge of the coming years. It is predicted that by 2050 seniors aged 60–79 will constitute a quarter of the EU population. Maintaining satisfactory health and functions of seniors, including prolonged professional life and reducing medical costs, are priorities for the European Commission (Gębska-Kuczerowska 2002; Kostka et al. 2009).

Regular physical activity, counteracting the effects of hypokinesis, has a number of beneficial effects for seniors. It is a universal medicine used in prevention and treatment of age-related illnesses (coronary artery disease, hypertension, obesity, hypercholesterolemia, diabetes, and osteoporosis). It results in increased sensitivity to insulin, improved glucose tolerance and lower risk of diabetes. Regular physical activity in seniors results in lower incidence of infections and normalizes lipid values (Gębska-Kuczerowska 2002; Polak 2007).

Workout plays a significant role in more optimistic perception of life quality. Number of studies proved that regular workout by seniors resulted in higher assessment of life quality, better mobility in everyday life, being able to take care of oneself, doing household chores, lower risk of depression and less frequent pain and anxiety incidence in seniors over 65. Beneficial impact of workout is especially notable in seniors with disabilities and mobility limitations. Regular workout reduces mortality rate, but also prolongs the period of self-reliance and independence from others in everyday life, as well as improves quality of life of seniors. Physical and mental health and regular

physical activity impact senior's life quality more than cardiovascular disease or hospitalization (Lampinen 2006; Petrella 1999; Sumic et al. 2007).

To summarize, regular physical activity improves effectiveness of preventive measures and treatments related to cardiovascular disease; it reduces mortality rate and prolongs the period of physical and mental activity of seniors (Korner et al. 2004; Polak et. al. 2007).

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EFFECT OF INTEGRATED YOGA PROGRAM ON ENERGY OUTCOMES AS A MEASURE OF PREVENTIVE HEALTH CARE IN HEALTHY PEOPLE

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Abstract. The aim of this study was to measure the changes in stress, general health index and disorderliness in human energy pattern through Integrated Yoga Practices (IYP). Ninety four healthy volunteers (male 55 and female 39), age (mean ± sd 26.70 ±8.58) were assessed before and after four weeks of IYP. The experiment was conducted four times and the assessment was done by utilizing the Electro Photonic Imaging (EPI) technique. Comparisons were made to ascertain whether energy homeostasis diverges based on genders. The parameters considered for analysis were Activation Coefficient (AC), Integral Area (IA) and Integral Entropy (IE). Reduction in stress levels (AC), increase in general health index (IA) and decrease in disorderliness (IE) on the left side parameters were found reproducible in all four experiments. The results also revealed a highly significant reduction in stress levels and highly significant improvement in the health indices at the psycho-physiological level. The subgroup analysis of both male and female demonstrated a significant reduction in stress levels and significant improvement in health index (psycho-physiological). Baseline comparisons between males and females showed significant difference in general health index at both psychophysiological and physiological levels. In conclusion, IYP regulates, improves and prolongs energy homeostasis of an organism. Therefore, it helps in prevention of ill health and also preserves health. The EPI outcomes are reproducible. Further, the present study also found that the energy pattern differs with gender. Hence, it is suggested that studies with male and female participants may be conducted separately.

Key words: Integrated Yoga Program IYP, Electro Photonic Imaging Technique EPI, Gas Discharge Visualization GDV, Stress, General Health Index and Disorderliness

Introduction

Health and its care have become a global concern. The fast pace of life, sedentary lifestyle, immoderation in diet, activities, recreation and sleep are the factors responsible for stressful living which ultimately manifest in diseases (Bijlani et al. 2005; Sivananda 2008a; Smaldone et al. 2007; Waxman 2005) like obesity, diabetes mellitus, heart diseases, hyperlipidaemia, respiratory infections and cancer (Segasothy and Phillips 1999; Sharma and Majumdar 2009). They affect daily work and quality of life of individuals (Van Nieuwenhuizen et al. 2015).

Thus, there is a need for change in lifestyle in most populations to prevent ill health and promote good health. Since energy is the foundation of electrophysiological and biochemical processes, it is necessary to measure and correlate the energy through available technology known as electro photonic imaging technique (EPI).

Yoga, an ancient Indian lifestyle-related discipline has been scientifically proven and shown to improve physical, mental, and emotional wellbeing (Buffart et al. 2012; Gard et al. 2014) through all its components which include Kriya (cleansing techniques), Asana (yogic postures), Pranayama (breathing practices), Dhyana (meditation) and diet. These techniques correct energy imbalances, and restores energy homeostasis in humans (Lynton at al. 2007). This energy which is subtle known as Prana (Srinivasan 2014). It is considered to be the vital energy that regulates all cellular processes and keeps a person healthy. As per the Ayurvedic texts, Prana (Traditional Chinese Medicine counterpart, Qi), is believed to be responsible for health of every cell in the body (Sancier and Hu 1991). Availability of cellular electrons is closely related to the health of cells (Szent-Gyorgyi 1978). We conceptually tried to relate Prana (the fundamental febric of subtle energy) with electrons (the fundamental aspect of matter) and expect that both will converge closely. Through this, we tried to derive our operational definitions of various abstract constructs. The conceptual relationship between Prana and electrons seems to be quite evident, however, more empirical evidence is needed to support this concept. We operationally define Prana as the intensity of electro photonic emission patterns as obtained in a form of EPI-gram. Homeostasis of Prana is operationally defined as uniformity of electro photonic emission patterns in a form of EPI-gram as obtained by EPI instrument. Electron availability is operationally defined as the intensity of electro photonic patterns obtained from EPI-grams.

However, when this homeostasis level of Prana is disturbed, it leads to pain and somatic diseases later as postulated in yoga (Srinivasan 2014; Srinivasan 2013). All the animate beings require steady conditions inside for their survival, such as internal temperature, body pH, metabolic rate and energy expenditure versus energy consumption; similarly, energy (Prana) homeostasis is required for healthy functioning of all systems within the body. The health and disease concept of yoga enables us to better understand the root cause of diseases and disorders (Vyadhi) which are believed to emerge from the disrupted mind (leading to Adhi). The disturbed mind leads to stress and further creates imbalances in Prana, finally manifest as disease or disorder at the physical level (Nagarathna and Nagendra 2009), especially in those systems and organs which have either deficient or disturbed Prana. This understanding of disease manifestation suggests that if this hindrance in energy (Prana) could be prevented or corrected, then we could probably succeed in preventing diseases and also reverse the progress of manifested diseases.

Earlier research on short-term lifestyle modification and stress management education program based on Yoga has shown remarkable improvement in subjective well-being scores of the subjects (Sharma et al. 2008). This could therefore make a considerable contribution to early prevention as well as management of lifestyle diseases. The present evidence convinced us to attempt research on yoga based lifestyle-related program in healthy subjects to prevent ill health and promote health.

Therefore, the present single-arm prospective study was undertaken to study the potential effect of an integrated yoga program on energy parameters, namely; Activation Coefficient (a measure of stress), Integral Area (a measure of general health), and Integral Entropy (a measure of disorderliness) as measured through EPI technique. The study also attempts to find out the reproducibility of EPI outcomes and also to check whether energy outcomes differ gender-wise.

Material and Methods

Subjects

A total of 152 volunteers were assessed before and after four weeks of a one month Yoga Instructor Course (YIC) at Swami Vivekananda Yoga Anusamdhana Samsthana (S-VYASA, Yoga University), Bengaluru, Karnataka, India. All volunteers were selected from four batches of YIC (Months – May 2014, n = 43, June 2014, n = 52, July 2014, n = 38 and August 2014, n = 19).

Inclusion criteria

Healthy volunteers, age ranging 18 to 60 years, both male and female, willing to participate in the study and having post hoc Integral Area value between –0.6 to +1 (IA, normal health index range in European Popultion in the EPI technique) were included in the study.

Exclusion criteria

Volunteers who had cuts in the fingers, missing fingers, having any health-related issues and substance abuse were excluded from the study.

Ethical consideration

The study protocol was approved by the Institutional Ethics Committee. A written informed consent was obtained from all the volunteers who were willing to participate in the study before the assessment, and the confidentialities of their data and information were maintained.

Yoga intervention

Residential Integrated Yoga Program (IYP) for four weeks.

The program comprises of Kriya (cleansing techniques), Asana (Physical postures), Pranayama (Breathing practices), Dhyana (meditation), Bhajan (devotional songs), Krida Yoga (Yoga games), spiritual discourses and lectures on yoga and philosophy. The program starts daily at 4.30 am till 10.00 pm and the diet is vegetarian (yogic food).

Assessments

EPI technique

Electro Photonic Imaging (EPI) technique also known as Gas Discharge Visualization (GDV) has been used in a number of studies as a scientific device to evaluate stress, general health and disorderliness based on a measure of stimulated optoelectronic emission of humans (Korotkov et al. 2010; Korotkov et al. 2012; Deo et al. 2015; Kushwah et al. 2015).This emission takes place when the finger tips are exposed to a short electric pulse of high voltage (10 kv), with high frequency (1024 Hz) and low current in micro amps for less than a millisecond (Ciesielska 2009). Emission is captured in the form of an image by a CCD-camera placed under a dielectric plate in the EPI system (Hacker et al. 2005). Further, the acquired 10 EPI images are divided into various sectors, which

correlate with diverse organs and systems within the body (Korotkov et al. 2012; Hacker et al. 2011; Korotkov 2011) This correlation of EPI image sectors with different organs of the body is mostly based on empirical findings and also supported by both acupuncture and meridian system of Sujok (Korotkov 2002). Recently, meridian system has been scientifically supported by a newly found circulatory system called Bonghan system. It is a thread like structure found on the superficially inside blood or lymph vessels, on the surface of internal organs, and also in the brain ventricles (Soh 2009). It provides a possible connection between the EPI sectors from finger tips' images and with the organs and systems within the body. EPI assessment is done in two ways; namely, with filter and without filter (Korotkov et al. 2012). A filter is a plastic film specially designed to be used in between the finger tips and the dielectric plate to eliminate the sympathetic response which results in sweat and cooling sensations of fingers and to register the information which is more of physiological in nature. Measurements using filter provides physiological and without filter provides psycho-physiological information (Korotkov 2002).

EPI Parameters

1. Activation Coefficient (AC), 2. Integral Area, left and right side (IAL and IAR) and 3. Integral Entropy, left and right side (IEL and IER).

AC parameter is an estimation of stress level acquired by comparing the reading with and without filter. Hence, it is the difference between sympathetic and parasympathetic responses. It ranges from 0–10 where 2–4 is an indication of normal quiescent state. Below 2 – is a state of relaxed and calm people. This could be because of the two possible reasons, deep meditation or chronic depression. AC above 4 indicates exited state and towards higher levels of stress. IA, left and right parameter is a magnitude of general health index of a person being investigated and ranges from [–0.6 to +1] and is an indicative of good health condition. IE, left and right parameter is a determinant of disorderliness in the human energy system. A range of [1 to 2] indicates a healthy pattern of entropy in an organism (Korotkov 2002; Cioca et al. 2004; Kostyuk et al. 2011).

Further, the EPI provides a non-invasive, objective and painless method, which is used for quick evaluation of health abnormalities in the human energy system (Korotkov 2011; Korotkov et al. 2010). Therefore, it is gaining high significance in the field of medicine and energy dimensions. From the reliability point of view, EPI parameters have a variation of 4.1% on a daily average, whereas, on 10 minute average it varies only 6.6% shows high reliability of the technique (Korotkov 2011). In the present study, EPI Pro and EPI Compact devices, produced by Kirlionics Technologies International, Saint-Petersburg, Russia were used in the assessment processes.

Procedure

The experiments were carried out four times on four different YIC programs in order to find out the reproducibility of EPI outcomes. All subjects were assessed before and after four weeks of their YIC course. The readings were taken from all 10 fingers in two ways, namely without filter and with filter. In order to obtain a reliable and reproducible data, an established guideline (Alexandrova et al. 2002) was followed. The data was collected after three hours of food intake. The subjects were asked to remove all metallic items which they do not wear for 24 hours in a day. Further, they were also provided an electrically isolated surface to stand on during the measurements and were instructed to place the finger on the dielectric glass plate at 45° angle. A distance of 3 feet between the EPI camera and the computer system was maintained; the calibration of the instrument was performed routinely, and an alcoholic solution was used to clean the glass plate after the assessment of each individual.

Temperature and humidity measurements

To check the variability in the environmental condition during measurement time, we used a Thermo/ Hygrometer – Equinox, EQ 310 CTH. This dimension is necessary to quantify and check as the variation in this environmental factors influence the electro photonic emission pattern, especially if the changes are greater than ±2.5% (Korotkov 2011). The average temperature observed during all four experiments was (mean ± sd) pre 29.10 ±1.06°C and post 29.20 ±2.39°C and humidity pre 59% and post 59%.

Data extraction and analysis

The GDV diagram program was used to extract the raw data from the EPI system into Excel. This program provides all parameters which were taken into consideration for analysis, namely Activation Coefficient, Integral Area and Integral Entropy. Further, data analysis was carried out using 'R statistical package for data analyses' (R Development Core team 2014) and Microsoft Excel program. Paired sample t-test was used for evaluating pre and post readings and independent sample t-test for cross sectional comparisons between male and female subgroups.

Results

Out of 152 volunteers, a total of 94 healthy subjects (male 55 and female 39, age, mean ± sd 26.70 ±8.58) who were eligible as per the inclusion and exclusion criteria were only considered in the analysis. Table 1 presents the participants' characteristics of subgroups as males and females and as a whole. There is no difference in between the age and BMI of both the genders.

Table 1. Participants' Characteristics

Variables	Male (n = 55)	Female (n = 39)	Total (n = 94)
Age (year)	26.93 ±9.12	26.36 ±7.87	26.70 ±8.58
Height (cm)	169.16 ±9.96	159.31 ±6.08	165.07 ±8.19
Weight (kg)	65.05 ±12.99	57.79 ±10.12	62.04 ±12.36
BMI (kg/m^2)	22.70 ±3.92	22.78 ±3.82	22.73 ±3.86

The observations in all four experiments (psycho-physiological level) showed a decreasing trend of AC, increase in IA, left and right and decrease in IE left. Whereas, IE right was found increasing in three of four experiments and decreased only in one experiment. This suggests that there exist a reproducibility of stress reduction and health improvement through Integrated Yoga Practices. Table 2 presents results from all four groups combined into one, where the decrease in AC value turned highly significant ($p < 0.001$, $d = 0.59$). The results at the psycho-physiological level showed a highly significant increase in both IA, left and right (IA left $p < 0.001$, $d = 0.39$ and IA right $p < 0.001$, $d = 0.48$). The IE left values decreased from higher to lower (IE left 1.88 ±0.17, to 1.84 ±0.15, $p = 0.07$, $d = 0.18$), but not significantly. The mean values of IE right side shifted towards higher, but marginally not significantly (IE right 1.85 ±0.24 to 1.88 ±0.17, $p = 0.30$, $d = 0.1$). Whereas, the results at the physiological level were found very stable except IE Left, which showed a shift of a marginal increase within the normal range.

Table 2. Pre-post changes at both psycho-physiological and physiological levels (n = 94)

Levels	Variables	Pre mean ± sd	Post mean ± sd	t-value	p-value
	AC	3.28 ±1.21	2.56 ±0.60	5.75	<0.001***
Without filter	IAL	–0.002 ±0.24	0.11 ±0.15	–3.78	<0.001***
	IAR	–0.01 ±0.21	0.10 ±0.16	–4.57	<0.001***
	IEL	1.88 ±0.17	1.84 ±0.15	1.86	0.070
	IER	1.85 ±0.24	1.88 ±0.17	–1.05	0.300
With filter	IAL	0.39 ±0.16	0.39 ±0.12	–0.14	0.890
	IAR	0.39 ±0.15	0.39 ±0.13	–0.04	0.960
	IEL	1.91 ±0.15	1.95 ±0.15	–1.92	0.060
	IER	1.94 ±0.15	1.94 ±0.15	–0.21	0.830

Abbreviations: AC – Activation Coefficient; IAL – Integral Area Left side; IAR – Integral Area Right side; IEL – Integral Entropy Left side; IER – Integral Entropy Right side. Significant level, *p < 0.05, **p < 0.01, ***p < 0.001.

Table 3. Pre and post results of sub groups at both psycho-physiological and physiological levels

Levels	Variables	Pre male mean ± sd (n = 55)	Post male mean ± sd (n = 55)	t-value	p-value	Pre female mean ± sd (n = 39)	Post female mean ± sd (n = 39)	t-value	p-value
	AC	3.09 ±1.06	2.58 ±0.55	3.25	0.002**	3.55 ±1.36	2.52 ±0.66	5.13	<0.001***
Without filter	IAL	0.07 ±0.19	0.13 ±0.13	–1.96	0.050*	–0.11 ±0.25	0.07 ±0.16	–3.36	0.002**
	IAR	0.04 ±0.19	0.12 ±0.15	–2.71	0.009**	–0.08 ±0.21	0.08 ±0.16	–3.78	<0.001***
	IEL	1.88 ±0.17	1.83 ±0.16	1.66	0.100	1.88 ±0.17	1.85 ±0.14	0.90	0.370
	IER	1.85 ±0.22	1.90 ±0.18	–1.10	0.270	1.84 ±0.27	1.85 ±0.17	–0.27	0.790
With filter	IAL	0.42 ±0.13	0.42 ±0.11	0.25	0.800	0.35 ±0.20	0.36 ±0.13	–0.31	0.760
	IAR	0.43 ±0.12	0.41 ±0.11	0.91	0.360	0.35 ±0.19	0.37 ±0.15	–0.58	0.570
	IEL	1.92 ±0.14	1.95 ±0.16	–1.19	0.240	1.89 ±0.15	1.95 ±0.14	–1.53	0.130
	IER	1.96 ±0.15	1.91 ±0.15	2.35	0.020*	1.92 ±0.16	1.99 ±0.14	–2.35	0.020*

Abbreviations: AC – Activation Coefficient; IAL – Integral Area Left; IAR – Integral Area Right; IEL – Integral Entropy Left side; IER – Integral Entropy Right side. Significant level, *p < 0.05, **p < 0.01, ***p < 0.001.

Both groups demonstrated significant reduction in stress levels and significant improvement in general health index after IYP at the psycho-physiological level. However, integral entropy parameter at (NF) level did not show any change. At physiological level, IE right side decreased significantly in the male group, whereas it significantly increased in the female group. Other parameters at the physiological level in both the groups did not reveal significant changes.

The baseline comparisons between both groups showed higher mean values of AC in females than males (AC, females 3.55 ±1.36 and males 3.09 ±1.06, p = 0.06). The magnitude of mean values of IA, left and IA right side (NF) readings were found significantly higher in males (IA left p < 0.001 and IA right p < 0.01) than females, whereas, no significant difference was found from IE left and IE right values between the groups. Further, the magnitude of IA left and IA right values (WF) were significantly higher in males than females (IA left p = 0.04 and IA right p = 0.02). However, no significant difference was found from IE left and IE right (WF) in between the genders.

Table 4. Cross sectional results (between males and females) at both psycho-physiological and physiological levels

Levels	Variables	Pre male mean ± sd (n = 55)	Pre female mean ± sd (n = 39)	t-value	p-value	Post male mean ± sd (n = 55)	Post female mean ± sd (n = 39)	t-value	p-value
	AC	3.09 ±1.06	3.55 ±1.36	1.88	0.060	2.58 ±0.55	2.52 ±0.66	–0.47	0.640
Without filter	IAL	0.07 ±0.19	–0.11 ±0.25	–3.67	<0.001***	0.13 ±0.13	0.07 ±0.16	–2.06	0.040*
	IAR	0.04 ±0.19	–0.08 ±0.21	–2.93	<0.010**	0.12 ±0.15	0.08 ±0.16	–1.26	0.210
	IEL	1.88 ±0.17	1.88 ±0.17	–0.12	0.900	1.83 ±0.16	1.85 ±0.14	0.36	0.720
	IER	1.85 ±0.22	1.84 ±0.27	–0.24	0.810	1.90 ±0.18	1.85 ±0.17	–1.29	0.200
With filter	IAL	0.42 ±0.13	0.35 ±0.20	–2.10	0.040*	0.42 ±0.11	0.36 ±0.13	–2.28	0.020*
	IAR	0.43 ±0.12	0.35 ±0.19	–2.38	0.020*	0.41 ±0.11	0.37 ±0.15	–1.66	0.100
	IEL	1.92 ±0.14	1.89 ±0.15	–0.78	0.440	1.95 ±0.16	1.95 ±0.14	–0.11	0.910
	IER	1.96 ±0.15	1.92 ±0.16	–1.23	0.220	1.91 ±0.15	1.99 ±0.14	2.90	0.005**

Abbreviations: AC – Activation Coefficient; IAL – Integral Area Left; IAR – Integral Area Right; IEL – Integral Entropy Left side; IER – Integral Entropy Right side. Significant level, *p < 0.05, **p < 0.01, ***p < 0.001.

Post of male and female data indicated improvement in all parameters except IE right (WF), which showed a significant shift towards higher values in the females group, though this increase was in the normal range of the entropy parameter.

Discussion

Compared with the previous research in the field of yoga, the present study is first of its kind to measure the effect of Integrated Yoga Program (IYP) on healthy volunteers, makes an attempt to find out whether EPI parameters differ gender-wise and tries to establish the reproducibility of the EPI outcomes by conducting four different experiments.

The results from all four experiments (psycho-physiological level) were found reproducible except for IE right side which exceptionally increased in three of four experiments. There was a highly significant decrease in activation coefficient and highly significant improvement in integral area, left and right side (psycho-physiological level) after four weeks of IYP. Similar changes were also observed from subgroups of male and female. Further, the baseline comparisons between the genders have also demonstrated the significant difference in IA, left and right side from both without filter and with filter readings.

Psycho-physiological level

Activation coefficient (stress parameter)

A number of studies have evidence of the phenomenon that regular practice of integrated yoga reduces stress in various populations (Buffart et al. 2012; McDermott et al. 2014; Michalsen 2008; Rao et al. 2008; Yoshihara et al. 2014). The results from the present study also show that integrated yoga practice on a regular basis reduces stress significantly ($p < 0.001$) in healthy people. This may be due to the yoga practices which work on autonomic nervous system (Streeter 2012) and restore balance between sympathetic and parasympathetic responses. Development of a coherence zone between both SNS and PNS responses may regulate, unify and correct the imbalances in the flow of Prana in the body. This may be confirmed by the uniformity throughout the EPI image glow area which increases

after the yoga practice. Earlier, this phenomenon was noticed in a pilot study by other researchers. It was found that during progression of relaxation, the sensitive stress marker Salivary Alpha Amylase (sAA) (Van Stegeren 2006) decreased, whereas, the EPI image glow area increased (Hacker 2011). It suggests that significant reduction in AC leads to prevention of any abnormality in the Pranic energy distribution which could lead to prevention of diseases.

Integral Area (IA, general health index)

It is well known that yoga components, i.e., physical postures, breathing techniques, meditation, cleansing techniques, and diet practices improve health and well-being in individuals (Jagannathan et al. 2014; Cabral et al. 2011; Gomes-Neto et al. 2014; Buffart et al. 2012). The present study also showed a highly significant increase in IA left ($p < 0.001$) and right ($p < 0.001$) which suggest improvement in general health of the participants. It may be due to reduction in stress level leading towards harmony and improved Pranic circulation, indicating improvement in psycho-physiological health.

Integral Entropy (IE, disorderliness)

The integrated practices of yoga improve and regulate the vital energy called Prana (Sharma et al. 2014). Keeping harmonious homeostasis of this energy is a key essence of yoga practice, which keeps one healthy and promotes positive health (Nagarathna and Nagendra 2009). Loss of homeostasis of the energy produces entropy, which is otherwise known as disorderliness in the human energy systems (Korotkov 2002) and high or low entropy may lead to diseases in the body. The shift of IE left higher to lower values and IE right toward higher may be an adjustment towards balance in both. It indicates better energy homeostasis through IYP, which is an indication of prevention of ill health.

Physiological level

Present study results at the physiological level have demonstrated the strength of regular practice of yoga, which helps in sustaining the homeostasis level of energy by keeping both mind and body in harmony. That is a unique outcome from the study suggesting that yoga is a boon for the health. The finding showed that the mean values of IA left, right and IE right was same before and after the IYP. Although, the IE left showed a shift of an increase within the normal range, but was negligible and not significant.

Gender-wise comparisons

Subgroup analysis of males and females showed a clear significant difference of energy parameters at the baseline. One of the previous studies reported that women experience more stress than men (Matud 2004). The findings of our present study are also similar, showing that magnitude of the stress parameter is higher in females than males as found from the baseline comparisons of both males and females. After the intervention, both male and female groups showed a significant reduction in stress level. It is a well-known fact that high-stress levels affect the health of individuals. According to a report by American Psychological Association, women are more prone to the stress-related health problems such as hypertension, depression, anxiety, and obesity (Herscher 2014) than men. The present study findings showed significantly lower level of the IA values in females than males at both physiological and psycho-physiological levels in baseline comparison. This suggests that females are more

susceptible to develop health issues than males. After the IYP, IA values showed significant improvement in both the groups, but the magnitude of improvement was more in females than males as compared with pre scores. Studies have reported that socio economic and cultural factors influence the health of females, whereas the work responsibilities influence males (Annette 2001; American Psychological Associantion 2015). Baseline comparisons of the IE, left and right values at both psycho-physiological and physiological levels indicated no difference between males and females. However, after the intervention IE right side (WF) decreased significantly in the male group indicating reduction in disorderliness, whereas, an exception of significant increase was observed in IE right values in the female group, but it was within the normal range. Moreover, these findings suggest that gender has an influence on energy patterns which needs to be studied separately with more data to substantiate the findings.

Strength

The findings of reproducible EPI outcomes, highly significant reduction in stress, highly significant improvement in general health indices (psycho-physiological level) and the baseline comparisons of males and females, which showed significant difference in general health indices (psycho-physiological and physiological level) provide the strength for the study.

Limitations

Absence of a control group may have posed a threat to the internal validity of the study; however, we estimate that this would at the maximum obscure the measured magnitude of the effects but not the direction of effect. A further confirmatory study may be done to better estimate the effect sizes.

Suggestions for future study and Implication of the study

From the findings of significant difference in energy trend between the males and females, it is suggested that males and females should be studied separately. Further, it is also suggested that future study should attempt to follow the subjects after the completion of study in order to find out prolonging effects of yoga practices. Moreover, IYP can be implemented for the prevention of ill health and promotion of health in individuals.

Conclusions

Present study achieved the reproducible results of stress, general health and disorderliness parameters in all four experiments at the psycho-physiological level except IE right side. Outcomes of the study also suggest that the energy parameters differ gender-wise and hence needs to be studied separately with more data to substantiate the findings. Further, the findings from the investigations also suggest that IYP can be used to regulate, improve and sustain the energy homeostasis of an organism. This, in essence, is important in the field of prevention and sustenance of health.

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FACTORS ASSOCIATED WITH PHYSICAL ACTIVITY IN PEOPLE WITH DIABETES

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Abstract. Background: Diabetes mellitus is a chronic disease related to the occurrence of numerous metabolic disorders. Their common feature is hyperglycaemia, caused by insufficient insulin secretion or its malfunction. The World Health Organization states that 346 million people worldwide have diabetes. The studies in adults with type 2 diabetes clearly demonstrate that the change of lifestyle behaviours effectively improves glycemic control. The modifications of lifestyle habits, such as regular physical activity and healthier dietary habits prove to be beneficial for patients. The aim of this study was to determine the factors affecting the level of physical activity in people with diabetes mellitus.

Methods: Research material consisted of the data gathered from a diagnostic survey, which was conducted in a form of a questionnaire. The study included 60 people with type 1 or type 2 diabetes.

Results: Unfortunately, the results show that not all of them were active enough, which is so crucial for stabilizing the disease.

Conclusions: The diagnosis of diabetes in the respondents resulted in more time being spent by them on physical activity, which resulted in the improvement of diabetes control and the normalization of body weight according to BMI, thus increasing the effectiveness of diabetes treatment and reducing complications. The frequency of the physical activity undertaken by the respondents prior to the disease was not related to gender, however, after the diagnosis, it was dependent on gender.

Key words: physical activity, diabetes mellitus, Body Mass Index, lifestyle

Introduction

Diabetes mellitus is a chronic disease related to the occurrence of numerous metabolic disorders. Their common feature is hyperglycaemia, caused by insufficient insulin secretion or its malfunction. Ninety percent of these disorders are related to type 2 diabetes – reduced insulin secretion by pancreatic islet cells or insulin resistance (Simmons et al. 2009). This type of diabetes has become epidemic in both developed and developing countries and is associated with rapidly occuring changes in lifestyle (Zhang et al. 2013). Type 1 diabetes is a chronic autoimmune

disease characterized by progressive and selective destruction of pancreatic beta cells in genetically predisposed individuals during childhood or adolescence. It is triggered by the interaction between genetic and environmental factors (Bason et al. 2013).

The World Health Organization (WHO) states that 346 million people worldwide have diabetes (Roshan and Stanton 2013). In Europe, the index of morbidity related to diabetes ranges 3–6% (Zatońska et al. 2011). In Poland, it reaches more than 5%, which stands for 2 million people. It is also worth noting that 10% of the Polish population have hyperglycaemia, a pre-diabetic illness, which accounts for additional 4 million people. According to the predictions made by the International Diabetes Federation (IDF), the occurrence of diabetes worldwide will rise from 6.4% in 2010 to 7.7% in 2030, and a pre-diabetic state – from 7.8% in 2010 to 8.4% in 2030 (Sicree et al. 2009). The risks related to diabetes and a pre-diabetic state (such as impaired fasting glucose) include various diabetic complications: microvascular (retinopathy, nephropathy and neuropathy) and macrovascular (coronary heart disease and vascular diseases, including stroke) (Reyden et al. 2007; van den Brom et al. 2013). For example, in 2004 3.4 million people died of the complications associated with a high blood glucose level, and this number will double in the years 2005–2030 (Zatońska et al. 2011). 50% of people with diabetes die from cardiovascular diseases. The complications of diabetes mellitus develop early, before any diagnosis can be made. About 50% of patients already have one chronic complication at the moment of diagnosis (Pranoto et al. 2014).

The disease is closely related to lifestyle behaviours, especially unhealthy and irregular eating habits and low physical activity. The occurrence of diabetes in people with abnormal body weight is 2–4 times higher (Zatońska et al. 2011). Until recently, type 2 diabetes was a disease of older people. However, in the past years it was also diagnosed in children, which is mostly due to the rising prevalence of obesity in this group. All risk factors for either pre-diabetes condition or the development of full-blown diabetes can be divided into non-modifiable risk factors, such as genetic factors, age and gestational diabetes, and modifiable risk factors: obesity, nutrition, physical activity or, for example, low birth weight or exposure to intrauterine diabetic environment (Pranoto et al. 2014). The studies in adults with type 2 diabetes clearly demonstrate that the change of lifestyle behaviours effectively improves glycemic control (Wittmeier et al. 2012). The modifications of lifestyle habits, such as regular physical activity and healthier dietary habits prove to be beneficial for patients (Daniele et al. 2013). Evidence suggests that regular physical activity can have positive effects on adults, for example improved disease self-management, weight loss, higher fitness, reduced medication usage and the improvement of HbA1c/fasting glucose (Plotnikoff et al. 2013). Therefore, the aim of this study was to determine the factors affecting the level of physical activity in people with diabetes mellitus.

Materials & Methods

Research material consisted of the data gathered from a diagnostic survey, which was conducted in a form of a questionnaire. The study included 60 people with type 1 or type 2 diabetes. It involved 38 women and 22 men aged 18 to 70 years, who had filled in the survey in the period from January to February 2012. Prior to the study, the respondents acquainted themselves with the aim of the research and agreed to voluntary and anonymous participation.

All of the respondents completed the questionnaire containing 20 questions. It included the section with demographic and social data, such as age, gender, education, place of residence, as well as the part concerning

physical activity levels in people with diabetes and the factors affecting it. Physical activity levels were assessed based on its frequency. Physical exercise undertaken 6–7 days a week was considered as high, 4–5 days – moderate, and 2–3 days – low.

Data were also collected to determine the nutritional status of a respondent at the time of the study. It was assessed using Quetelet index: BMI (Body Mass Index) = [weight (kg)] / [body height (m)]^2. The data were classified through division into categories based on the nutritional status of the patients. The interpretation of the results was based on the criteria provided by the WHO in 2003 (Gertig 2006).

One of the considered parameters assessing the metabolic control of diabetes is glycated hemoglobin – HbA1c (the normal value given by the Polish Diabetes Association in 2007: ≤6.5%). Its value is used to evaluate the degree of metabolic control and the risk of chronic complications of diabetes (Sieradzki 2006). We also examined fasting blood glucose levels (the normal value in patients with diabetes provided by the Polish Diabetes Association in 2007: ≤110 mg/dl).

The study also determined the blood pressure of the patients. They were checked according to the guidelines of the European (2007) and Polish (2011) Society of Hypertension (Grodzicki et al. 2012). The data received from the respondents were statistically analysed. χ^2 test was conducted to analyse selected nonparametric values.

Results

Analysis of the education level of the respondents showed the prevalence of those with secondary education – 47% of the women and 46% of the men. The study involved far less people with vocational and primary education (8 and 5%, respectively). In terms of occupation, the students (45% female) and the white-collar workers (41% of men and 34% of women) constituted the most numerous populations. The unemployed were the smallest group in the study (women – 3%, men – 4%).

The study showed that most of the respondents had type 1 diabetes mellitus (I): 92% of the women and 86% of the men. The percentage of the patients with type 2 diabetes mellitus (II) was quite low (8 and 14%, respectively). The subjects injected insulin in order to regulate the blood glucose level, using pens (76% of the women and 68% of the men) or insulin pumps (respectively 16% and 18%). 8% of the women and 14% of the men received medication in a form of an insulin pill.

The aim of this research was to evaluate the physical activity of the patients. We evaluated how many times per week the subjects took exercise and divided them into groups in relation to the frequency of these activities (Figure 1).

Most of the surveyed exercised 2–3 times a week. The results show that not all of them were active enough, which is so crucial for stabilizing the disease.

The evaluation of BMI values showed that a significant part of the respondents had normal weight (86% of the women and 69% of the men). However, the study group also included women and men with underweight and obesity class (3% and 4%, respectively) and overweight (8% and 23%). Sixty percent of the subjects who engaged in moderate physical activity had a normal nutritional status. Twelve percent of those with low physical activity and 8% of those who exercised intensely had a normal nutritional status as well. Overweight and obesity appeared far less frequently in the individuals who took part in various and intense physical activities (2% and 3%, respectively).

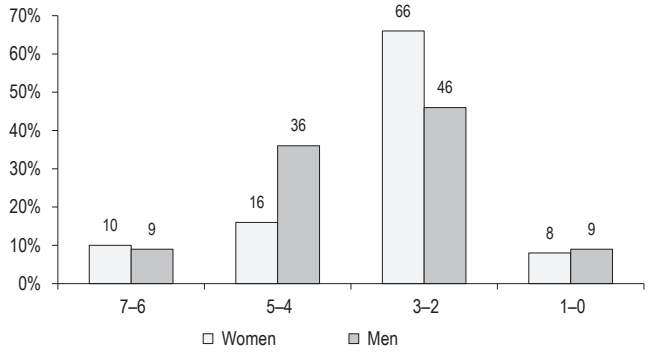

Figure 1. Frequency of physical activity per week in the study group

Prior to the diagnosis of diabetes, 15% of the respondents had exercised regularly, 57% had exercised occasionally and 28% had not exercised at all. After the onset of the disease the number of the respondents who exercised regularly more than tripled, whereas 43% of them stated that they still had been exercising occasionally. The data show that after the incidence of diabetes all of the subjects from the study group began to participate in physical activities, but in many cases they were still insufficient.

A form of physical activity favoured by both sexes was cycling (24%) (Figure 2).

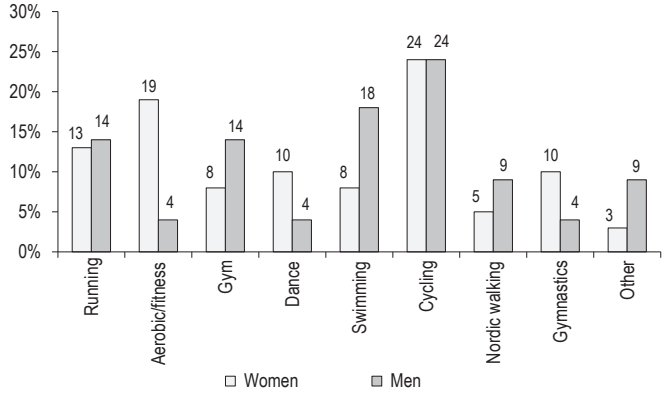

Figure 2. Preferred forms of physical activity in the study group

The male population preferred spending their free time swimming (18%). A large percentage of the women (19%) took aerobic/fitness exercises, while slightly lower percentage of them preferred dance and gymnastics (10%). Gym exercises were also quite popular among the men (14%).

The site of drug injection prior to exercise is crucial for blood glucose levels afterwards. Most of the respondents answered that before exercise they injected insulin in the abdomen (58% of the women) and thigh (36% of the men) (Figure 3).

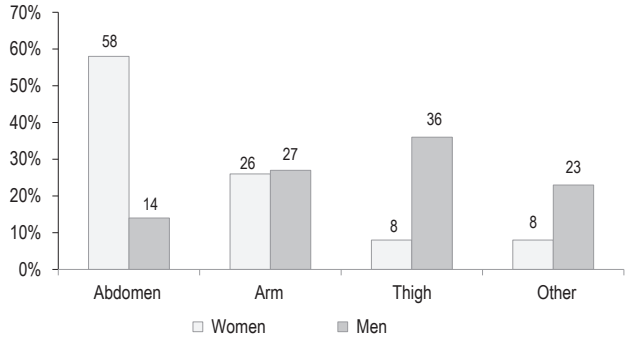

Figure 3. Sites of insulin injection prior to exercise

These are the regions which endure the most strain and determine the subsequent decrease in blood glucose levels. The respondents also pointed to other sites of insulin application such as buttocks and shoulder. Some of the subjects took insulin orally.

Most subjects (90% of women and 77% of men) declared that the administration of insulin into the body regions involved in exercise is important for glycemic control during physical activity. The patients also evaluated the effect of exercise on the blood glucose level. As many as 92% of the women and men reported that the blood sugar concentration decreased during physical activity. Less than 10% of the women and men claimed that they did not notice the effect of exercise on blood glucose levels. Eighty two percent of the women and 72% of the men observed that a low level of glucose persisted for over an hour after exercise, increasing the risk of unexpected hypoglycemia. Considerably fewer respondents felt it for less than an hour, and 5% of the women and 14% of the men had hypoglycemia for up to 30 minutes after physical activity.

The glycated hemoglobin levels of the subjects varied. HbA1c levels were within normal limits in 58% of the women and less than 23% of the men. The increased levels of this parameter were observed by more than half of the studied males (68%), while 9% of the male respondents reported higher values of HbA1c. The blood sugar concentration observed before exercise reached analogical levels. A significant part of the respondents (57%) had normal blood sugar levels (Figure 4).

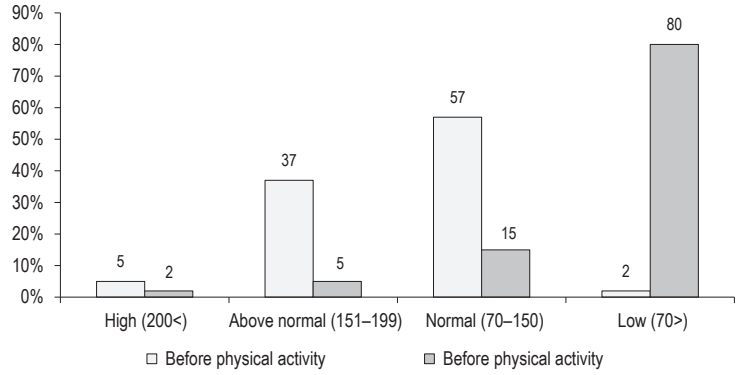

Figure 4. Blood glucose levels before and after exercise

37% of the subjects reported increased glucose levels. 80% of the survey participants stated that after physical activity blood glucose stayed at low levels.

Majority of the study group had normal blood pressure (85% of the women and 77% of the men). 10% woman and 9% men had low blood pressure. The mental state associated with physical activity was assessed in all of the subjects. 95% of the women and 91% of the men reported feeling better after taking exercises. To determine the relationship between gender and physical activity before and after the onset of the disease, as well as the improvement of a mental state due to exercise in each gender, chi-square test ($\chi 2$) was used. It was found that gender and the frequency of physical activity prior to the disease were independent, with the probability of type I error equal to 0.05. After the onset of the disease, the frequency of physical activity and gender were dependent, with the probability of type I error equal to 0.05. It was observed, however, that gender and the improvement of a mental state due to exercise were independent, with the probability of type I error equal to 0.05.

Discussion

The diagnosis of diabetes should be followed by a change in lifestyle habits. In comprehensive diabetes care, besides treatment and medication, much emphasis is placed on a proper diet, education and physical activity (Sierakowska-Sitkiewicz and Karnafel 2008). Health habits play a significant role in the proper functioning of a patient with diabetes. Physical activity can prevent the premature development of diabetic complications, such as cardiovascular diseases, and reduce the unpleasant symptoms associated with the disease. Yet, for most people with diabetes it may be difficult to change habits (Centis et al. 2014). In addition, there is still a lack of knowledge on how to promote physical activity in people with type 1 diabetes mellitus (Quirk et al. 2014).

The survey which was conducted as a part of our study among people with diabetes brings optimistic results. One hundred percent of the respondents were aware of the significance of physical activity as an essential part of the therapeutic program for diabetics. They practiced regularly, whereas prior to the diagnosis nearly 30% of them did not participate in any physical activity at all.

A proper amount of physical exercise results in the improvement of the health status of a patient. According to the recommendations of the Polish Diabetes Association for the clinical management of patients with diabetes

(2007), the best therapeutic effects of physical activity can be achieved when patients exercise regularly, preferably daily or at least 2–3 times a week. These recommendations were followed by the majority of respondents: 60% of them exercised 2–3 times per week, and more than 30% engaged in physical activities even more frequently.

The study also showed that glycemic control is an important determinant of physical activity. Our research indicated that most of the respondents observed the improvement in diabetes control as a result of regular exercises.

The respondents agreed that the sites of insulin injection prior to exercise were related to the blood glucose levels observed afterwards (85%) and that physical activity increased the effectiveness of diabetes treatment. 93% of the respondents reported the improvement of their mental state thanks to physical exercises.

Numerous previous studies report the beneficial effects of physical activity on the prevention and treatment of the disease. Quirk et al. (2014), reviewing 23 publications issued in the years 1964–2012, demonstrate the potential health benefits for diabetics due to physical activity: a decrease in the levels of glycated haemoglobin (HbA1c), triglycerides and total cholesterol and the reduction of BMI.

More recent studies provide rich evidence that exercise facilitates controlling and maintaining normal blood glucose levels (Techmańska 2006). The study also reports numerous benefits of regular physical activity, including the reduction of body fat and blood sugar glucose, lowering blood pressure, decreasing the risk of diabetes complications, reducing the need for insulin, the maintenance of normal body weight, improvement of the blood circulation throughout the body, reducing the levels of "bad" cholesterol, etc. It is also reported that physical activity increases insulin sensitivity.

The study conducted by Zdrojowy and Sutkowska (2005) shows that in patients with diabetes who participate in sport activities, daily insulin requirement is reduced to up to 40%. A large number of other authors also indicate the beneficial effects of physical exercises leading to the reduction of the stress and discomfort caused by the chronic disease and the overall improvement of mental state (Younk et al. 2009; Edmunds et al. 2007).

However, in the case of patients with well controlled diabetes, physical activity may lead to hypoglycaemia, if glucose depletion coincides with high levels of insulin and a lack of food intake. The risk of hypoglycemia occurring due to intense physical activity persists even for several hours afterwards – the fact that was also reported by our respondents. Therefore, physical exercise, which is considered an integral part of diabetes treatment, should be adapted specifically to the condition of a patient. Good information increases the benefits and safety of physical activity in patients with diabetes.

Efficient glycemic control may even allow diabetics to take part in professional sports and achieve great international successes. The most outstanding Polish athlete suffering from type 1 diabetes mellitus is Michał Jeliński, a rower competing in heavy weight quadruple sculls, the Olympic gold medallist from Beijing (2008), a four-time world champion (2005, 2006, 2007, 2009) and 2010 European champion (Raczyńska et al. 2011). Another world-class rower with diabetes is Steve Redgrave, a five-time Olympic gold medallist (Los Angeles 1984, Seoul 1988, Barcelona 1992, Atlanta 1996, Sydney 2000). Another great athlete struggling with diabetes is an American swimmer, Gary Hall – a winner of five gold, three silver and two bronze medals at the Olympics. The participation of patients treated with insulin in competitive sports depends on developing individual insulin treatment schemes, adjusting insulin doses and adapting diet to the intensity and duration of physical activity (Techmańska et al. 2006).

These successful athletes prove that people with diabetes do not have to be excluded from professional and social life and they are capable of pursuing their personal goals.

Conclusions

1. The diagnosis of diabetes in the respondents resulted in more time being spent by them on physical activity, which resulted in the improvement of diabetes control and the normalization of body weight according to BMI, thus increasing the effectiveness of diabetes treatment and reducing complications.

2. The frequency of the physical activity undertaken by the respondents prior to the disease was not related to gender, however, after the diagnosis, it was dependent of gender.

3. The improved mental state observed by the subjects due to participation in various forms of physical activity is independent of gender.

4. The injection of insulin in the body regions involved in exercise plays an important role in the reduction of blood glucose levels. In the women, the abdomen was the most frequent site of insulin injection prior to physical activity, while in the case of the men, it was the thigh.

5. If the sites of insulin injection are selected in accordance to the type of exercise, an extended period of the lowered blood glucose levels is observed by the diabetic subjects.

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INFLUENCE OF PHYSICAL ACTIVITY ON REDUCTION OF DELAYED ONSET MUSCLE SORENESS

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Abstract. The purpose of this study was to determine if physical activity of different intensity has an effect on reduction of delayed onset muscle soreness. Eighty women divided into two groups participated in the study. Subjects from Group 1 participated in the training of upper libs, whereas subjects from group 2 – in the training of lower limbs. Tests of power of upper limbs – the active overhang on the bar (Gr. 1) and power of lower limbs – the vertical jump test (Gr. 2), visual analog scale of pain (VAS) and the International Physical Activity Questionnaire (IPAQ) were used as investigative tools. The majority of studied women were characterized by the high level of physical activity. Physical activity level had strong positive correlation ($r = 0.54$; $p < 0.001$) with the reduction of pain. Taking into account the partition according to the kind of physical activity, there was observed some significant correlation between the diminution of delayed onset muscle soreness and the level of moderate activity and walking (relocating). Physical activity level positively correlated with the reduction of delayed onset muscle soreness. Moderate physical activity and walking proved to be the most beneficial from the reduction of delayed onset muscle soreness point of view.

Key words: DOMS, physical activity, post-exercise recovery, muscle damage, IPAQ

Introduction

Delayed onset muscle soreness, in short DOMS, is developed usually from several to a dozen or so hours after the intense exercise. Its culminant intensity appears between the second and the third day after the activity and can last even for 5–7 days. Most often it occurs in people not practicing sport, who proceeded with physical effort of greater intensity than activities performed on an everyday basis and at sportsmen who return to trainings after a long break. Greater threat with the damage of fibers is caused by the eccentric exercises because, in their

progress, the tension per motor unit is far higher than during concentric efforts (Wilmore and Costill 2004; Czarkowska-Pączek and Przybylski 2006).

The effect of delayed onset muscle soreness on physical activity is not fully explained. It is accepted that it is characterized by the fall of muscular power, limitation of mobility in joints and disturbances of co-ordination of motor units' muscles during their contraction. Too early renewal (repetition) of the training can be connected with the activation of compensatory mechanisms of above-disturbances, and what is more, with the risk of repeated damage of tissues. On the other hand the repetition of exercises of similar character leads to organism's adaptation and contributes to diminution of damages extensiveness and myalgia (Bednarek et al. 2013; Augustyn et al. 2013; Halson 2008).

In the counteraction of DOMS results different strategies of conduct are proposed, however, their efficiency is not always confirmed, some of them are not effective (Punduk et al. 2014). As Cheung et al. (2003) suggest non-steroidal anti-inflammatory medicines are of high efficiency. Massage gives diverse effects (depending on the length of application and put-upon techniques). Zainuddin et al. (2005) suggest that the massage can lower pain complaints by about 30%, but it does not influence functions of the muscle. In turn, the efficiency of stretching, local cryotherapy, homeopathy and ultrasounds is limited. It is also shown that moderate physical activity is the most efficient kind of conduct during the occurrence of DOMS symptoms, though its effect can be temporary (Cheung et al 2003). The influence on the previously mentioned temporary analgesic effect can be the reason here, despite the lack of influence on the renovation of muscles after micro damages (Zainuddin et al. 2006). What is more, badly chosen conduct, despite the immediate analgesic effect can outright retard the full restoration of muscle structure (Coudreuse et al. 2004).

In the absence of univocal evidence of influence of the physical exercise of given intensity on DOMS, the main cognitive objective of this study was the estimation of influence of different intensity physical activity on reduction of delayed onset muscle soreness of upper and lower limbs.

Material and methods

There were 80 women, aged 18–28 years, not attending any organized sports or recreational activities, who partook in the research. The subjects were randomly divided into two groups. Group 1 consisted of women who had the training of upper limbs applied. Group 2 comprised of participants who participated in the training of lower limbs. Groups did not significantly differ in respect of the age and body mass or height (Table 1). The research was not-invasive and the approval of the Bioethics Committee of Medical University of Warsaw was not required.

Table 1. Research group profile

Groups	Number of people [n]	Age [years]	Body mass [kg]	Body height [cm]	BMI [kg/m^2]
Group 1 (training of upper limbs)	40	22.03 ±2.62	56.23 ±5.56	167.93 ±5.29	19.91 ±1.82
Group 2 (training of lower limbs)	40	24.68 ±1.07	57.3 ±4.99	165.9 ±5.12	20.85 ±1.91

All women taking part in the research were interviewed before participating in the study. The questionnaire referred to present diseases of circulatory system, respiratory system and past traumas within upper/lower limbs

and the spine, making the execution of tests impossible. Women not burdened with above-mentioned diseases and trauma qualified to the research.

Women from Group 1 were subjected to test of power of shoulders (measurement 1), which was an active overhang on a bar, and then there was a training of shoulder muscles. It consisted of series of minimum five active overhangs – similarly as during the test, during 60 to 80% of the first test (i.e. the time of maximum ability). Every series was finished with a rest of the time equal to minimum twice the time of the overhang. Women from Group 2 performed the test of power of lower limbs, which was a vertical jump (measurement 1) and the training of lower limbs muscles in five series of squat jumps of 60–100% of maximum abilities (the first series till the refusal, series 2–4 of 60–80% ability, the fifth series till the refusal). After the training both groups had the measurement of pain intensity taken (measurement 1). Then tests of shoulders power (Group 1) and powers of lower limbs (Group 2) were repeated and the level of pain intensity was rated (visual analog scale of pain – VAS) after 24 (measurement 2), 48 (measurement 3), 72 (measurement 4) and 96 hours (measurement 5).

To estimate the efficiency of muscles burdened with the training tests of physical fitness were applied, for Group 1 – the test of power of shoulders (from the International Physical Fitness Test) consisting of the active overhang on the bar, (where the result was determined by the time of holding in the overhang, with the head above the bar) and for Group 2 – the test of power of lower limbs (the vertical jump), consisting of the squat jump – (where the result was determined by the height of lifting of the center of gravity) (Bielski 1996). The intensity of the pain was rated with the use of visual analog scale – VAS (Korzeniowska and Szałek 2010). Reduction of pain was established by the difference between maximal intensity of pain and value obtained in the last measurement.

For the purpose of qualifying the level of physical activity, the researched women filled, on the last day of the research (96 hours after the training), the International Physical Activity Questionnaire – the short version, consisting of seven questions. They referred to undertaken activity in last seven days. The physical activity level was rated in three categories (vigorous, moderate and walking). The result is expressed in agreed upon MET estimates (IPAQ 2012; Biernat et al. 2008).

Standard statistical tools such as the arithmetical mean together with the standard deviation were used in the research. Differences between performances of each measurement were counted by means of paired t-Student test and dependences between the variable were estimated by means of Pearson correlation. Level $p \leq 0.05$ was accepted as of minimum significance.

Results

The greatest regress of agility test data ($p < 0.001$), in both groups, was noted between the first and the second measurement (24 hours after the exercise). Progress of results was observed instead between the fourth and the fifth measurement (in Group 1 the difference was statistically significant $p < 0.001$). In Group 1 the result of the last test was indeed higher than of the first one. In Group 2 results of the first and last test were similar (Figure 1).

The highest level of pain (measured with the VAS) was noted in the third measurement, which took place 48 hours after the exercise, both in women realizing the training of upper limbs, as well as the lower ones. On the following days (measurement 4 and 5) the intensity of complaint was indeed lower ($p < 0.001$) in both groups. People from Group 2 were characterized by the lower average level of pain in all five measurements (Figure 2).

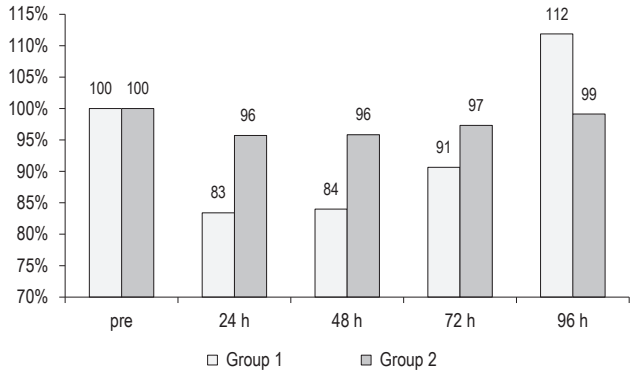

Figure 1. Results of physical fitness tests (of upper limbs – Groups 1 and lower limbs – Groups 2).

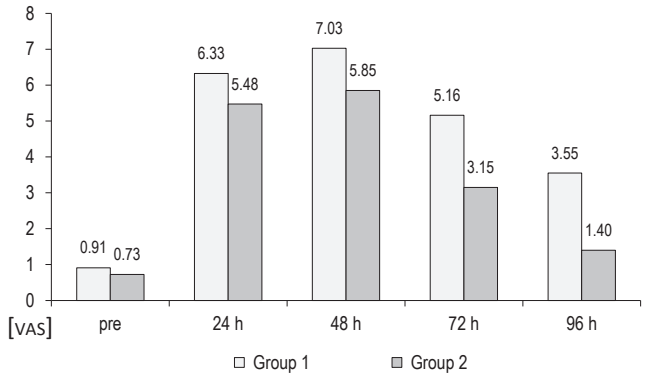

Figure 2. Intensity of muscle pain

The majority of researched women (20 from Group 1 and 24 from Group 2) were characterized by the high level of physical activity, IPAQ measured. To the category of sufficient physical activity 29 were classified (18 from Group 1 and 11 from Group 2), and to inadequate – 7 women (2 from Group 1 and 7 from Group 2). The average level of general physical activity was similar in both groups. The significant difference ($p < 0.001$) was noted only with reference to vigorous physical activity (Table 2).

Table 2. Level of physical activity measured by IPAQ

	Vigorous physical activity [MET]	Moderate physical activity [MET]	Walking [MET]	Sitting [min. per day]	Sum [MET]
Group 1	959*** ±971	1019 ±1691	1851 ±1443	327 ±338	3829 ±3040
Group 2	282 ±451	1374 ±1197	2131 ±1988	321 ±245	3788 ±2554

*** $p < 0.001$.

The physical activity level measured with IPAQ, expressed in MET estimates, strongly and positively correlated ($r = 0.54$; $p < 0.001$) with the reduction of pain (with the difference between the maximum and minimum-level of pain measured with the VAS) (Figure 3). Taking into account the partition according to the kind of physical activity, some important correlation between the diminution of delayed onset soreness of burdened muscles and the level of moderate activity and walking was observed. Similar dependences were not observed in the case of vigorous activity and akinesis (Table 3).

There were no significant correlations between the level of physical activity and fitness tests.

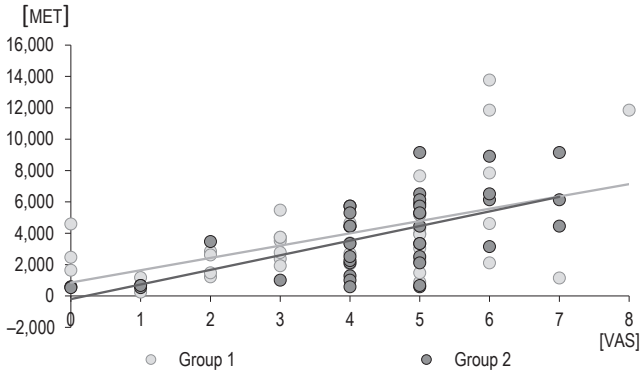

Figure 3. Correlation between reduction of pain and overall physical activity

Table 3. Correlation between reduction of pain and physical activity

	Vigorous physical activity	Moderate physical activity	Walking	Sitting	Sum
Group 1	–0.052	0.471**	0.537***	0.057	0.500***
Group 2	0.105	0.514***	0.481**	–0.292	0.634***

** $p < 0.01$; *** $p < 0.001$.

Discussion

The occurrence of muscular fatigue has a composite basis conditioned with the kind of physical activity. Mechanisms concerning its formation differ depending on types of muscle fibers. Exercises with a component of eccentric contractions generate greater power in comparison to concentric and isometric types; moreover, it correlates with smaller and later fatigue with relation to remaining two kinds of exercises (Wilmore and Costill 2004; Czarkowska-Pączek and Przybylski 2006).

The genesis of delayed muscle soreness was not exactly proved, however there are several opinions on the subject. It was assumed that it was related to too high level of injurious metabolites in skeletal muscles – especially the lactate. The lack of correlation in time of both from these factors caused challenging of this assumption (Wilmore

and Costill 2004; Bednarek et al. 2013). Among many authors there is a conviction that the reason of DOMS is multifaceted. The starting point of its appearance is the inflammation in response to the microdamage of muscle fibers, during the eccentric physical exercise. Symptoms that accompany the inflammation (i.e. the swelling and pyrexia of tissues) increase sensation of pain in muscles. In turn, the level drop of calcium in endoplasmic reticulum and the inflammatory swelling of tissues lead to the stiffness of muscles felt after finished physical activity. Prostaglandins, which are chemical mediators of the inflammation, among other things, are responsible for this mechanism. As the result of lowered level of nociception in muscles, strong sensation of pain is observed in response to occurring mechanical impulse – e.g. the muscle contraction (Bednarek et al. 2013; Augustyn et al. 2013; Halson 2008).

Some interest in methods of aiding post-exercise biological renovation and reduction of delayed onset muscle soreness can be noticed in the available literature, especially in the area of sports-medicine (Best et al. 2008; Lee et al. 2013; Bae et al. 2014). Kawczyński et al. (2013), studying football competitors before the game and after it, showed the differentiation of DOMS symptoms of dominating and non-dominating lower limb muscles. Results of this research suggest the variability of the occurrence of DOMS symptoms, for the dominating side of body, despite the use of similar physical effort (Kawczyński et al. 2013).

To improve the post-exercise restitution and minimization of DOMS symptoms several physiotherapeutic applications were used. Classical massage was most often used. Its beneficial effect on delayed onset muscle soreness e.g. of biceps of shoulder and quadriceps of thigh (burdened by participants of own research) is confirmed. Massage was not only analgesic, but it also considerably accelerated the restoration of tired muscles efficiency (Willems et al. 2009; Boguszewski et al. 2013; 2014).

Results of Lee's et al. (2013) research, with reference to manners of DOMS minimization, gave some interesting information. In this research speed of the reduction of DOMS symptoms at women and men were compared, referring at this to the risk of ACL injury. Authors subjected the estimation of the ligament elasticity before and during the occurrence of DOMS symptoms. On the ground of results obtained, authors suggest that women are more subject to injury of anterior cruciate ligament and they return to full efficiency after exercises more slowly. Therefore, thesis was put forward, that in women the time of convalescence after the hard physical exercise is prolonged (Lee et al. 2013).

Bae et al. (2014) evaluated the influence of kinesiology taping (KT) on the reduction of delayed onset muscle soreness of shoulder biceps. Based on the thermal result the of the pain level, it was observed, that pain complaints diminished considerably in the researched group after 24 hours from the exercise. Quicker decrease of pain in the group with the KT application was noted. The researchers suggest that KT causes subjective diminution of pain (Bae et al. 2014).

Own research proved that active rest, even without the use of physiotherapeutic applications, could accelerate the post-exercise regeneration. From the practical point of view, combination of different means of renovation seems to be the best solution. Research carried out by Imtiyaz et al. (2014) confirms beneficial influence of vibratory training combined with massage. According to the researchers, the application of massage helps more quickly to restore the muscles power (which were earlier subjected to exercise), and the vibration of muscles causes earlier minimization of pain in comparison to control group (Imtiyaz et al. 2014).

There is no sufficient evidence to prove the efficiency of different kinds of therapy on DOMS reduction. Due to different investigative tools used in research, it is difficult to compare the results. Proper and new manners

of treatment and rehabilitation of diseases and dysfunctions (in compliance with foundations of Evidence-Based Medicine) are constantly being sought after. It seems legitimate to continue the research on DOMS phenomenon and efficiency of different means of post-exercise renovation.

Conclusions

1. Physical activity level positively correlated with the reduction of post-exercise muscle soreness. This confirms the beneficial influence of active rest even after very burdening eccentric exercises.

2. Moderate physical activity and walking proved to be the best in relation to reduction of delayed onset muscle soreness. Exercise of little intensity can be one of biological rejuvenation elements.

3. Obtained results are basis for continuation of research (with the use of other investigative tools) with the participation of more diverse experimental groups.

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THE EFFECT OF CORE STABILITY AND FUNCTIONAL EXERCISES ON SELECTED SPEED AND STRENGTH PARAMETERS IN EXPERT FEMALE FOOTBALLERS

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Abstract. Designed to strengthen the deep (stabilizer) muscles which stabilize joints and ligaments, core stability exercises are important for the development of motor skills in athletes. In this research, we aimed to determine how a two-year program of core stability and functional exercises influenced the strength and speed of female football players. The tested athletes (n = 17) were members of Olimpia Szczecin MKS, a first division football club from Poland. Their mean age was 19.8 ±1.4 years, while the mean duration of sport experience was 6 years. We analyzed their running speed, as well as the maximal strength of eight major muscle groups: rectus abdominals, abdominal oblique, shoulder girdle, chest, upper limbs, quadriceps, biceps and gastronomies. The effects of training on motor speed and strength were measured twice, prior to each of the two seasons. The functional training resulted in significant changes in the strength of various muscle groups: quadriceps (Δ17.1 kg; $p < 0.05$), abdominal oblique muscle (Δ9.1 kg; $p < 0.05$), shoulder girdle (Δ3.6 kg; $p < 0.05$) and chest (Δ3.5 kg; $p < 0.05$). There was also a significant reduction in the time of the 30 meter sprint ($p < 0.05$) (Δ0.1 s; $p < 0.05$). In summary, functional training had a positive effect on the strength and running speed of the tested female footballers.

Key words: core stability, functional training, motor effects, football

Introduction

Football places high demands on players in terms of their motor performance, essential for the effective execution of technical and tactical tasks. The necessary motor skills can be improved by core stability exercises which involve strengthening of the deep(stabilizer)muscles responsible for stabilizing the joints and ligaments. Importantly, any malfunction in the deep muscles also negatively affects the superficial muscles that are directly responsible for body movements. As a result, poor coordination between these two groups of muscles may result in injuries and disorders in the muscle tension distribution, directly affecting motor performance. Dealing with this

deficiency in neuronal-muscular coordination and in economy of movement is yet another role of core stability exercises (Sharmann 2002; Boyle 2004; Paterno et al. 2004).Systematic core stability exercises have been used in relation to back pain and rehabilitation and to decrease the risk of injury (Beam 2002; Clark 2001; Duncan et al. 2000; Haynes 2004; Wilson et al. 2005).The number of recent studies has identified the importance of a strong core in relationto improve sport performance (Nesser et al. 2008; Sato and Mokha 2009; Sharrock and Cropper 2011). In a review on the efficiency of core stability exercises, Reed and Ford 2012) indicated that most reports reveal a significant effect of stability exercises on the strength of legs and the height of vertical jumps. Nesser et al. (2008) attempted to analyze the effects of core stability exercises and motor performance in footballers to determine connections between core stability and the individual elements of fitness. Correlation analysis showed a significant effect ($p < 0.05$) of total core muscle strength on 20 and 40 yard sprint times, 10-yd shuttle run, squats and countermovement vertical jump. The obtained results showed a significant effect of core stability exercises on the performance of athletes. Furthermore, Sato and Mokha (2009) analyzed the influence of core strength training on running kinetics, lower extremity stability, and performance in runners. They observed that core stability exercises did not significantly influence kinetic efficiency and lower extremity stability, but did influence running performance (5000 m). On the other hand, Ścibek et al. (2001) investigated the effect of Swiss ball training on core stability and subsequent swim performance. Their results reported enhanced core stability, which did not transfer into improved swim times. Similarly Stanton et al. (2004) have reviewed running performance, economy, and core strength in high school-aged touch football and basketball athletes. Groups from this study completed core training, and groups that underwent training experienced improvements in core strength but did not show improvements in running performance. Tse et al. (2005) tested rowing performance and core endurance in college-age rowers. After training period (2 days per week for 8 weeks) core endurance training program improved selected core endurance parameters in athletes, but the effectiveness of the core intervention on various functional performance aspects(vertical jump, broad jump, shuttle run, 40-m sprint, overhead medicine ball throw, 2,000-m maximal rowing ergometertest) was not supported.

According to previous research, relationships between core strength/stability and sport performance is not clear. Therefore, the purpose of this study was to identify a relationship between core stability and functional exercisesandmotor performance. The effect of core stability exercises on motor skills is very interesting not only from the general scientific point of view, but also in terms of direct application in football training. Its significance in sports theory and practice is the main premise behind this research on the strength and speed of female football players, with the following specific objectives:

1. Determination of changes in strength over a two year period in football training supported by core stability and functional exercises.
2. Determination of changes in 30 meter sprint times resulting from the core stability and functional training program.

Material and Methods

The research was carried out on 17 female players of the first division football club MKS Olimpia Szczecin. The mean age was 19.8 ±1.4 years, with a mean sporting career of 6 years. All the tested players were included in the same training plan, including 5 training units in a week-long micro-cycle of the season, always finishing with a match. The preparation period lasted 3 months in which the players were subjected to a program of 3 stability

and functional exercises a week, 20 minutes each session (Stein 2008). During the season, stability and functional exercises were performed twice a week, and theoffseason workout period included one training unit with key exercises. The measurements of strength and speed were performed prior to the start of the preparation period before each season. The measurements of speed were made on 8 January 2014 and 5 January 2015, while maximal strength was measured on 9 January 2014 and 6 January 2015. The procedures followed in the study were approved by the Ethics Committee of the Regional Medical Chamber in Szczecin (Approval number 02/KB/V/2015).

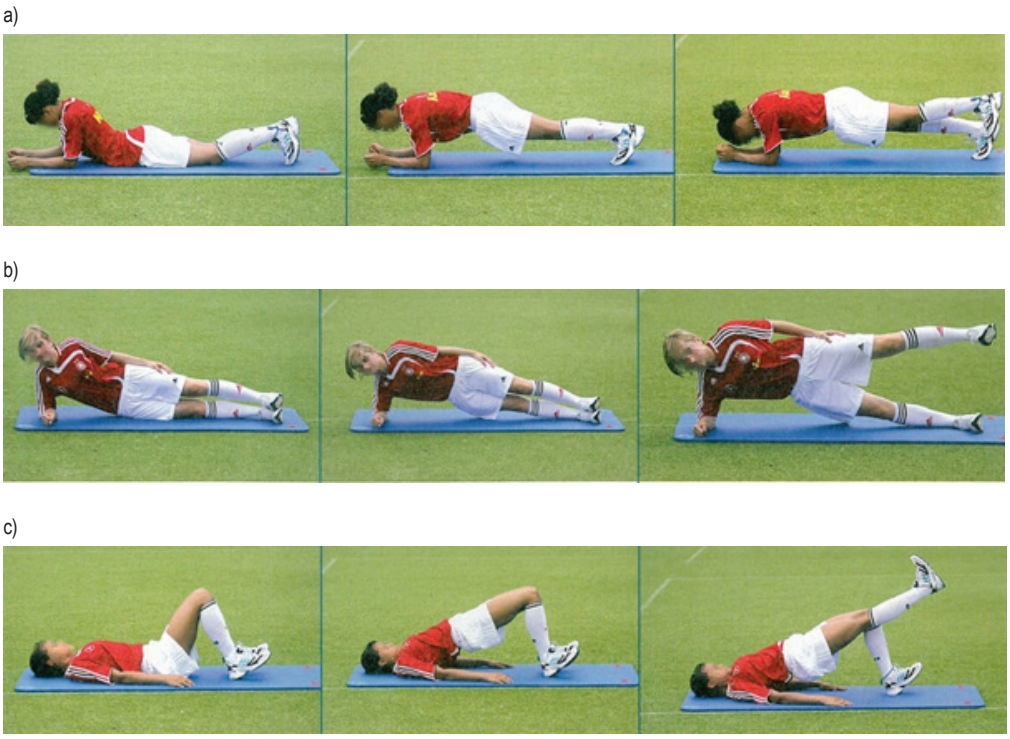

Figure 1. Representative examples of functional and core stability exercises (Stein 2008)

The measurement of speed was performed on a straight section of running track (30 meters) with the use of photo-cells (TS – F5) placed at the beginning and the end of the track. The photo-cells were mounted at a height of 1.20 m. The tested football players started their sprint without any audio or visual signal; they themselves decided when to start running. Each participant ran twice, and the better result of the two was recorded. The interval between the repetitions was 4 minutes, which allowed for a full recovery before the second attempt.

The examinations of abdominal strength were performed at a gym by measuring the level of maximal strength (apparatus for measuring – Technogym) of eight muscle groups: rectus abdominal muscle, abdominal oblique muscle, shoulder girdle, chest, upper limb muscles, quadriceps, biceps and gastrocnemius muscle. The determination of maximal strength was carried out in three training units, and the players used trial and error to lift a maximal load.

Each test wasfully assisted by the other participants. After the general warm-up program, participants performed a specific warm-up including submaximal intensity performance for all tested exercises, at levels of 50, 75, and 85% of the 1RM (one repetition maximum) for each participant. The relevant repetitions for each selected intensity were 12, 8, and 3 respectively. Two sets were performed for each selected intensity. After that, resistance was gradually increased from a critical value 5% below the expected 1RM. After each successful performance the intensity was gradually increased by 2% until failure in lifting of the same load was observed. Interval between repetitions was 3 minutes. For the final estimation of 1RM, 3–6 trials were used. Failure was de-fined when participants failed to perform the full range of motion of the selected exercise on at least 2 attempts. The full range of motion was defined by lifting the bar without any additional load. All testing procedures were closely supervised.

The measurements of strength and speed were preceded by an appropriate warm-up at a moderate intensity, finishing with dynamic stretching. The obtained results were recorded and written down in files. The participants wore sport shoes and clothes. In addition, the players were asked to perform at maximal effort during the tests. The collected material was subjected to basic statistical analysis with the use of the Statistica 10 software. The results were described with the methods of descriptive statistics. The differences between the results were evaluated with a Student's t-test for dependent variables. The level of significance was established at $p < 0.05$.

Results

The study was based on the measurements of the time of sprint over 30 m, as well as the maximal strength of eight major muscle groups: rectus abdominis muscle, abdominal oblique muscle, shoulder girdle, chest, upper limb muscles, muscles, quadricepsfemoris, bicepsfemoris and gastrocnemius muscle.

Table 1. Mean maximal strength and results of the Student's t-test (n = 17)

Musclegroup	Measurement	$\bar{x} \pm SD$	Student's t-test
Quadriceps femoris	1 st measurement	141.8 ±36.4	3.40*
	2 nd easurement	158.8 ±34.6	
Abdominal oblique muscle	1 st measurement	43.8 ±7.8	4.73*
	2 nd measurement	52.9 ±13.1	
Chest	1 st measurement	30.9 ±9.2	2.70*
	2 nd measurement	34.5 ±6.6	
Shoulder girdle	1 st measurement	52.9 ±8.7	2.30*
	2 nd measurement	56.5 ±10.9	
Biceps femoris	1 st measurement	55.0 ±8.5	1.85
	2 nd measurement	57.6 ±11.1	
Rectus abdominis muscle	1 st measurement	50.2 ±12.1	0.73
	2 nd measurement	51.5 ±10.9	
Gastrocnemius muscle	1 st measurement	178.2 ±23.0	1.29
	2 nd measurement	170.9 ±28.8	
Upper limbs	1 st measurement	36.8 ±6.6	1.56
	2 nd measurement	38.5 ±7.5	

* $p < 0.05$.

There were significant changes in maximal strength in 4 muscle groups: quadricepsfemoris (Δ17.1 kg, 141.8 kg vs. 158.8 kg, $p < 0.05$), abdominal oblique muscle (43.8 kg vs. 52.9 kg, $p < 0.05$), shoulder girdle (52.9 kg vs. 56.5 kg,

$p < 0.05$) and the chest (30.9 kg vs. 34.5 kg, $p < 0.05$) (Table 1). In the rest of the studied muscle groups: biceps femoris, rectus abdominis muscle, chest, gastrocnemius muscle, and upper limbs muscles, we found no significant changes in the studied strength parameters.

Analysis of 30 m sprint results also showed a positive effect of stability and functional training on speed. The results of the first and second measurement showed a significant reduction in sprint time over 30 m in the analyzed group of female footballers (4.32 s vs. 4.22 s, $p < 0.05$).

Table 2. Mean sprint time over 30 m and the Student's t-test results (n = 17)

	Measurement	$\bar{x}$ ±SD	Student's t-test
30 m sprint time	1st measurement	4.32 ±0.23	2.13*
	2nd measurement	4.22 ±0.25	

* $p < 0.05$.

Discussion

In this study we observed an improvement in motor skills over the duration of the stability and functional training. This trend concerned quadriceps femoris, abdominal oblique muscle, shoulder girdle and the chest, as well as in the sprint time. Our observation confirmed previous study results that systematic core stability and functional exercises have positive effects on motor performance (Nesser et al. 2008; Sato and Mokha 2009; Sharrock and Cropper 2011). However, the lack of statistically significant changes in maximal strength in the rest of the categories (biceps femoris, rectus abdominis muscle, gastrocnemius muscle, upper limbs) was probably due to the method of implementing the core stability and functional exercises. According to its author (Stein 2008), the program is governed by the 'trunk before limbs' principle. Only the well-developed muscles of the abdomen and back create a necessary 'corset' for high performance of the arms and legs. Thus the stable trunk and coordination obtained are very significant in football and other sports; allowing for a more efficient energy transfer and directly helping to maintain correct posture and silhouette. Otherwise, if a player first improves the stability of the limbs while neglecting the trunk (lumbar-pelvis-femoral complex), this may lead to adverse compensatory habits and, in consequence, overloading and injuries (Clark 2001; Haynes 2004). In this study, the point of departure in the annual scheme of training was to stabilize the trunk first, and then the upper and lower limbs, leading to an observed lack of statistically significant changes in the maximal strength of the muscles: gastrcnemius, biceps femoris and the upper limbs.

The comprehensive program of core stability exercises resulted in efficient motor performances in football, a sport which requires the work of the entire body. During various actions in the match, the body functions as the comprehensive system of elements connected by joints and tissues. There are practically no movements in this sport that involve only selected muscles. As the natural football form of movements involves almost all joints and groups of muscles, footballers benefit from stability and functional training.

It should be mentioned that despite the lack of statistically significant changes in some muscle groups, we observed a considerable improvement in maximal strength of the biceps femoris (by 2.6 kg), upper limbs (by 1.7 kg) and rectus abdominis muscle(by 1.3 kg) (Table 1).Probably, continuationof the stability and functional exercise by the studied players would lead to a number of further improvements in the results of measurements.

The results of our study suggest that the improvements in sprint speed were mainly due to the improved neuro-muscular coordination and caused alterations in thetransfer of energy. Movements performed with maximal speed become more economical and so sprint speeds increased. Speed, treated as a motor ability, improves also due to proper strength training, and hence the observed improvement in the sprint test (Kotzamanidis et al. 2005). The general strength training during the preparation period, properly supported by core stability and functional exercises, is a solid foundation for increasing speed parameters.

The positive influence of the functional and core stability exercises on motor performance in this study may be due to a long-term, systematic training program. Our study's procedures when compared to the ones of Scibek et al. (2001),Stanton et al. (2004) and Tse et al. (2005) had different designs regarding the total duration of the intervention program (2 years vs. 6–8 weeks). Similarly, Barnes (2002) using various methods of strength training for runners, observed the importance of core strength development as the foundation for long-term dynamic muscular strength training and to maximize the propulsive forces developed by the power-producing legs.

In our opinion the functional and core stability exercises are necessary for optimal sport performance and should not be dismissed. Determination of the role of core strength/stability requires additional research and sport-specific means of determining its effectiveness.

Conclusions

The results of this study allow for the following conclusions:

1. Core stability and functional exercises implemented during the two-year program of football training are conducive to improvements in maximal strength in the analyzed muscle groups.
2. Core stability exercises and functional training has a positive effect on the sprint speed of female football players.

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AN OBJECTIVE ASSESSMENT OF MEN'S PHYSICAL ACTIVITY DURING COOPER TEST BASED ON THE DIRECT MONITORING BY ACCELEROMETER ACTIGRAPHWGT3X

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Abstract. Physical activity should play an important role at every age and on every stage of human life. It affects health, well-being and the quality of life. The authors of the paper have shown the use of accelerometer as a device for testing physical activity. They used a group of runners, who during a promoting project of physical activity called "Cooper Test for all", applied accelerometer ActiGraph WGT3X. It was placed on the person's waist. The use of accelerometer valuably complements the survey methods aimed at physical activity levels.

Key words: physical activity, accelerometer ActiGraph WGT3X, cooper test

Introduction

Physical activity (PA) accompanies us our whole lives, to a smaller or larger extent and in different areas, while being "an integral component of a comprehensive process of adaptation in the history of human evolution'' (Malina 1988). Furthermore, PA blends in individual lifestyle, acting as its priority and a connecting component, essential in health promotion (Drabik 1996). As the results of clinical and epidemiological studies on health population show numerous diseases are more prevalent or develop much more in the group of people who use little physical activity or do not take it at all, than in those who regularly perform moderate or vigorous physical activity (Vuori 2004).

One of the most effective methods of developing overall strength in physical education and recreation is the continuous method (cross-country, cross-country skiing and ice skating, rowing, longer marches and field walking or running, cycling). This method is used especially in its monotonous variant, but also in the diversified variant.

Forms of cyclic movement structure prevail. The most effective means for shaping children's and young people's fitness is running, but in case of adults and elderly people those are only marches.

Running, especially in the fresh air, is, from the physiological point of view, the most comprehensive form of exercise, because it can involve almost the whole body, all its systems, especially – which is important for the prevention of cardiovascular disease – it increases the effort of the heart and circulatory system, as well as it improves ventilation of lungs, contributing to the improvement of metabolic mechanisms (metabolism) and supply body in oxygen. Systematically practiced cross-country courses also have a beneficial effect on strengthening muscles and skeletal system (Bielski 1996). Nowadays, a continuous 12-minute run (Cooper test), a run over a distance of one mile, a long endurance run used in Eurofit test are considered as relevant strength tests in population research (Osiński 2001). Cooper test is the most popular and recommended by many scientists. According to current trends, all tests should be focused on diagnosis of regularities of the basic course of functional processes and should be useful in the creation of healthy behaviors. Control should also facilitate the design of further work and thus, become a pretext teach how to shape your body, improve health. Generally speaking – how to live in physical culture.

The method of data collecting through questionnaires is simple but very subjective; it often gives inaccurate results. Respondents have usually trouble with defining exact walk distance and this is often the only physical activity which people perform every day. The final conclusions of all research questionnaires should be drawn very carefully. Objectification of the level of undertaken physical activity can happen in this case thanks to small-sized mobile devices operating on the basis of accelerometry (e.g. ActiGraph). The device mentioned above, worn by respondents, for example, on their waist, is stimulated proportionally to the movement of the entire body and it allows the measurement of physical activity during several-day periods, as well as in minutes or even seconds (Dwyer et. al. 2007). Accelerometers have become the most accurate, available and widely used devices to monitor physical activity (Esliger and Tremblay 2007; Troiano and Freedson 2010). Accelerometers are widely accepted as important devices for an objective measurement of physical activity and ActiGraph is the most commonly used brand (Kelli et al. 2013). Several studies have documented validity and reliability of activity accelerometers and their ability to track physical activity (Bassett et. al. 2000; Silcott et et al. 2011).

Aim of the study

The main purpose of the article was to analyze physical activity in a group of men during Cooper test. The aim of the study was to analyze, compare and contrast parameters, such as: BMI (body mass index), Mets (metabolic equivalent of work), kcals (energy balance), number of steps.

Material and Method

The study was conducted during a promotional project of physical activity called "Cooper Test for All" on the professional athletics track with tartan surface, in the stadium located at the University of Rzeszów, Faculty of Physical Education. All participants proceeded to trial in the morning. The study involved six randomly selected men who were participants in the project mentioned above. The number of respondents was dictated by the fact that authors had only one accelerometer. The necessary condition for participation in the test was the age between 20 and 50 on the day of the event. The respondents were at the following ages: 29, 39, 41, 42, 42 and 49 years old. The average weight of the group was 80.8 kg and it ranged between 71 and 98 kg. The average body height was 175.1 cm, the tallest man was 180 cm tall and the two shortest men – 170 cm tall each.

Table 1. Data of participants with their running distance

Number	1	2	3	4	5	6
Age	29	39	41	42	42	49
Body height [cm]	180	170	178	170	175	178
Weight [kg]	89	71	98	71	74	82
BMI	24.16	25.88	24.57	27.47	30.93	24.57
Profession	Electrician	Medical lifeguard	Soldier	Teacher	Computer specialist	Company Chairman
Covered distance [m]	2,625	3,190	2,140	2,680	2,950	2,645

Source: the authors' research.

To assess the level of resistance, the authors applied 12-minutes KH Cooper test (continuous run). In many physiological studies significant correlation between the effect of 12 minutes run and body aerobic endurance was identified. The test was conducted according to the instructions of Drabik (1989). This trial had already been popularized in the educational school system and it is quite easy to conduct. The distance can be covered not only by running, but also marching in this test. Within 12 minutes one has to cover the longest possible distance. Therefore, also motivation constitutes a very important question.

Table 2. Criteria of Cooper test (20–50+ years old)

Age	Sex	Criteria				
		very good	good	average	bad	very bad
20–29 years old	M	2,800 + m	2,400–2,800 m	2,200–2,399 m	1,600–2,199 m	1,600 – m
	W	2,700 + m	2,200–2,700 m	1,800–2,199 m	1,500–1,799 m	1,500 – m
30–39 years old	M	2,700 + m	2,300–2,700 m	1,900–2,299 m	1,500–1,899 m	1,500 – m
	W	2,500 + m	2,000–2,500 m	1,700–1,999 m	1,400–1,699 m	1,400 – m
40–49 years old	M	2,500 + m	2,100–2,500 m	1,700–2,099 m	1,400–1,699 m	1,400 – m
	W	2,300 + m	1,900–2,300 m	1,500–1,899 m	1,200–1,499 m	1,200 – m
50+ years old	M	2,400 + m	2,000–2,400 m	1,600–1,999 m	1,300–1,599 m	1,300 – m
	W	2,200 + m	1,700–2,200 m	1,400–1,699 m	1,100–1,399 m	1,100 – m

Source: Cain et al. (2013).

According to the interpretation of the results in the Cooper test (Table 2), four persons from the group of participants achieved very good results according to their age group, while two others recorded good results in the body efficiency test proposed by Cooper (1970).

Body mass index (BMI) for each participant was also calculated on the base of data obtained in the study. According to the interpretation, three respondents had normal weight (BMI = 24), and three others were overweight (BMI = 25 – 30). The respondents did both sedentary work (computer specialist, teacher, electrician, president of the company) and work requiring high physical activity (soldier, paramedic).

Accelerometer ActiGraphWGT3X was placed on the person's waist to evaluate selected parameters of physical activity in the group of respondents. Accelerometer measured acceleration in three planes and also all obtained data were calculated into one value called the vector value being the square root of the square sum of activity measurements for each vector. This tool also calculated the number of steps taken by the subjects during Cooper test (Hussey et. al. 2007; Midorikawa et. al. 2007).

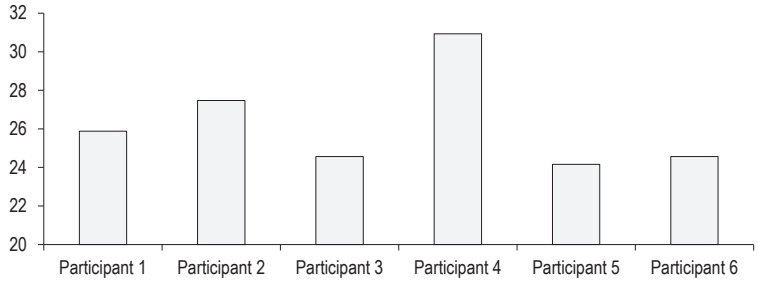

Figure 1. Body mass index BMI of men

Source: the authors' research.

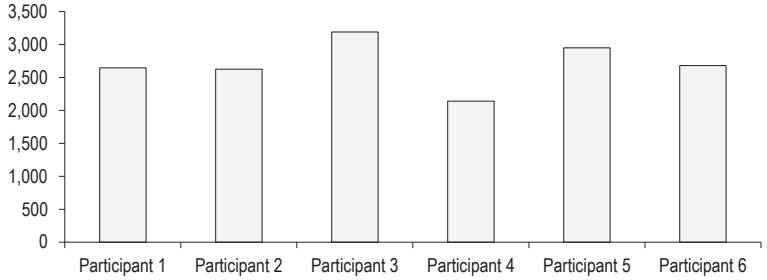

Figure 2. Distance covered during Cooper test [m]

Source: the authors' research.

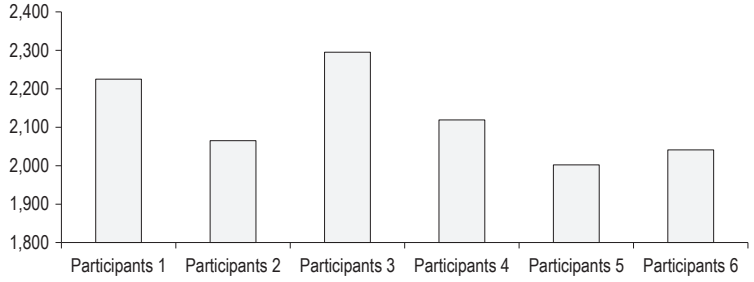

Figure 3. Number of steps made by respondents during Cooper test

Source: the authors' research.

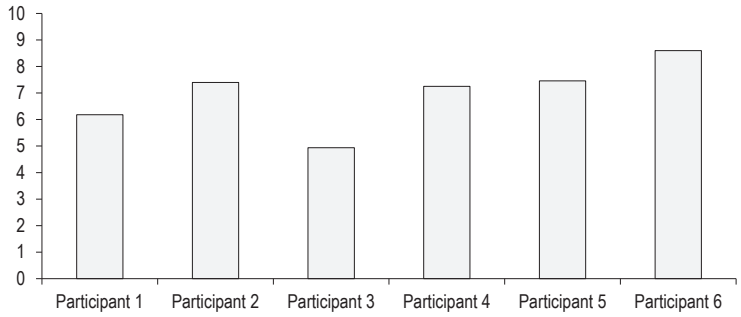

Figure 4. METs values of the energy balance of respondents

Source: the authors' research.

The use of accelerometer allowed the researchers to determine movement from a quantitative and qualitative perspective by recording changes in the acceleration of body and their subsequent conversion to energy expenditure expressed in kcal, as well as to calculate the energy balance in the individual respondents expressed in MET (Herbert and Czarny 2013; Osiński 2003).

Methods of statistical analysis

Statistic StatSoft 10 Programme was used by authors for statistical analysis. Nonparametric tests were used for comparison of selected quantitative traits. The choice was dictated by the small size of the study group and the fact that the condition of normal distribution of all studied variables was not met. Compliance of those distributions with normal distribution was verified with the use of Shapiro – Wilk test. The correlation was obtained from the Spearman's rank correlation test and determined factors of correlation are significant with <0.05. The result of this test can range between –1 and 1, while extreme values indicate a very strong correlation between variable A and variable B. However, when the result is equal or close to 0 it indicates that there is no direct relationship between these variables. A positive test value meant that where the value of one variable is increased the value of the other variable adopts higher values as well and vice versa, when the value of one variable is decreased also other values decreased. Negative Pearson r factor indicated that with the increase in the value of one variable the value of the other variable decreased and vice versa, if one value decreased the value of the other variable increased. The result of this test can range between –1 and 1 and extreme values are ideal to show a complete correlation between variable A and variable B. The result equal or close to 0 indicates no relationship between these variables. The authors adopted the following interpretation of the results of the Spearman's rank correlation in the paper:

- 0.9–1.0 – very strong correlation,
- 0.7–0.9 – strong correlation,
- 0.4–0.7 – average correlation,
- 0.1–0.4 – weak correlation,
- below 0.1 – no or very weak correlation.

Data of parameters generated by accelerometer were exported to Excel spreadsheet whereby authors have illustrated it with the use of graphs.

Results and Discussion

Accelerometers seem to be ideally suited for capturing short activity (i.e. Sampledat e.g. 30H) which are beneficial to human health (Freedson et. al. 2005; Janz et. al. 2010). Statistical analysis of the collected data showed a statistically significant correlation between body mass index BMI, covered distance and energy expenditure expressed in kcal and also the number of steps that a participant made during its trial and the energy balance expressed in MET.

Table 3. Spearman rank order correlation

Variable	Spearman rank order correlations p < 0.05000						
	BMI	age	distance [m]	kcals	METs	axis 1 counts	step counts
BMI	1	–0.338240	–0.898650	–0.231910	–0.289890	0.463817	0.376851
Age	–0.338240	1	0.115954	0.289886	0.173931	0.086966	–0.173930
Distance [m]	–0.898650	0.115954	1	–0.142860	–0.085710	–0.657140	0.028571
kcals	–0.231910	0.289886	–0.142860	1	0.892857	0.607143	–0.821430
METs	–0.289890	0.173931	–0.085710	0.892857	1	0.500000	–0.750000
Step Counts	0.376851	–0.173930	0.028571	–0.821430	–0.750000	–0.392860	1

Source: the authors' research.

In Table 3 the analyzed seven parameters, for which the Spearman correlation test was done, are presented. This test showed a high correlation between six variables analyzed. To check whether results obtained in the study correlate the values of one variable are presented in order from the smallest to the largest and it has been checked whether the other parameters listed will work similarly.

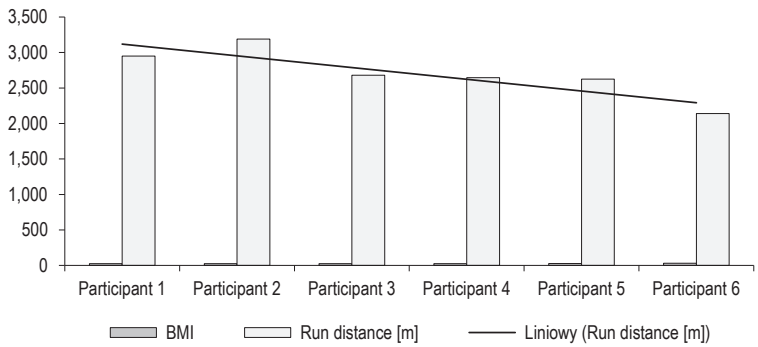

Figure 5. Summary of body mass index from the smallest to the largest with run distance

Source: the authors' research.

BMI and the distance surveyed in order from lowest to highest BMI values were put together (Figure 5). It turned out that the higher value of body mass index BMI examined the shorter distance they covered during the trial. Spearman's rank order test showed that there was a strong correlation here, exhibiting statistical significance.

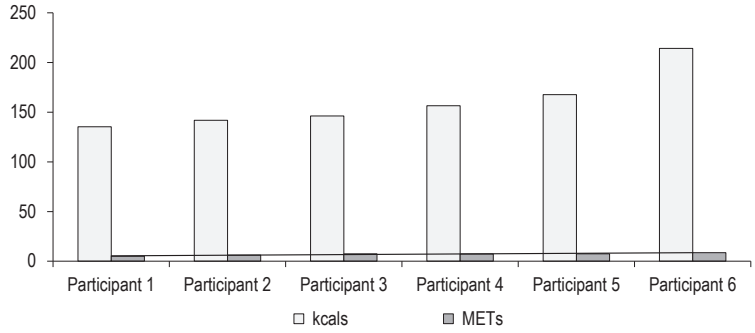

Figure 6. Summary of the energy balance expressed in MET from the smallest to the largest with the energy [kcals]

Source: the authors' research.

Analysis of survey results also showed a strong correlation between balance and energy expenditure of the respondents. Along with an increase in the first variable significantly increased the value of the other one. This relationship also proved to be statistically significant.

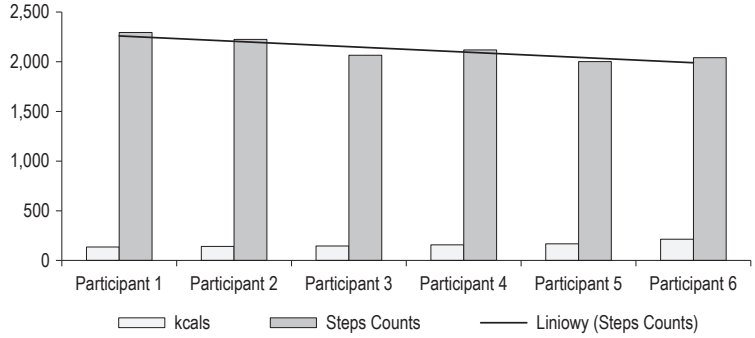

Figure 7. Statement of energy expenditure expressed in kcals with the number of steps taken during Cooper test

Source: the authors' research.

Based on the results of the analysis, it can also be concluded that there is a strong and statistically significant correlation between energy expenditure and the number of steps taken by the respondents during the 12 minutes run. It turned out that with the increase in energy expenditure the number of steps taken during the Cooper test decreased. This test in the most of articles is regarded as the basic test of the efficient use of aerobic energy sources (Cooper 1970; Raczek 1981; Sharkey 1990). According to the data presented in the tables, test results were very good and good. Furthermore, the interdependence between the Cooper test result (your distance) and BMI seems to be interesting. We can observe very good results at a high BMI from Cooper tables (BMI – 30.96 – distance 2,950 meters). It is assumed that from 1,000 to 2,000 kcal should be consumed by physical exercise per week, what accounts for about 300 kcal per unit of training (Nowak and Nowak 2010; Rütten et. al. 2003).

In the case of above studies in the 12-minute run, participants burned between 140 and 210 kcal what gives the average of 175 kcal. In studies of Grzywocz and Skowronek (2012) a group of surveyed people during one-hour-long training – jogging and fitness- burned an average of 478 kcal. The average was in this case less than 100 calories per 12 minutes. Additionally, according to the assumptions of Paffenbarger et al. (1990) for an adult of 70 kg the minimal energy expenditure is 2,000 kcal × wk –1 (approximately 300 kcal × day –1). Significant reduction in risk of myocardial infarction could be achieved with an effort of about 2,000 kcal per week. Physical activity related energy expenditure >1,000 kcal/week (4,200 kJ/week) is associated with a 30% reduction in total mortality (for Zadarko et. al. 2011). It can therefore be assumed that the significant part of the assessment of the effectiveness of appropriately selected loads in health training is the heart rate and calories burned.

According to scientific findings (Biernat et. al. 2007) 1 MET is 3.5 ml O2/kg of body weight per minute. It was determined that strenuous exercise requires 8 MET every minute of its duration, moderate effort requires 4 MET and walking (walking, fast walking) 3.3 MET. Calculating the total energy expenditure and thus, establishing participants' level of physical activity requires the multiplication of the frequency and the duration of exercise by its intensity expressed in MET units. In this study, the effort was between 4.5 and 8 MET (within 12 minutes of the test). In the study by Topolska et al. (2011) the average was 34.65 MET hours/week, while the research in eight countries of the European Union on physical activity were as follows: Belgium – 67.0 MET hours/week, Finland – 70.2 MET hours/week, France – 63.8 MET hours/week, Germany – 84.5 MET hours/week, Italy – 19.6 MET hours/week, Netherlands – 56.4 MET hours/week, Spain – 39.3 MET hours/week and UK – 27.6 – MET hours/week.

Schneider et al. (2004) compared 13 different models of pedometers in a 24-hour period. They found that some of them underestimate number of registered steps (error up to 25 %), while others greatly overestimate it (error up to 45%). In this case, accelerometers equipped with piezoelectric motion sensors register every motion much more accurately than pedometers. The daily number of steps reaching over 10,000 is recommended for an active lifestyle, over 12,000 for better shape of body weight (Leermakers et. al. 2000), while it is recommended for children to take up to 12,000–16,500 steps per day (Bohannon 2007) .In the case of this study it is the interval between 2,000 and 2,300 meters within 12 minutes.

The measurements of various vital signs, including human physical activity, with the use of portable devices is an increasingly common method for monitoring these signs in the world today (Lawrence et. al. 2005).

Conclusions

1. ActiGraph model WGT3X is a useful device for monitoring physical activity (measured number of steps and mets metabolic equivalent), as well as energy expenditure (kcal).

2. This analysis provided quantitative estimation of an activity of persons participating in the Cooper Test. The authors agree that it is necessary to further analyze different parameters.

3. This study showed a statistically significant correlation between energy expenditure and the number of steps made by respondents during the 12-minutes run.

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OPTIMIZATION OF THE EFFORT PREPARATION PROCESS AMONG THE SHORT TRACK FEMALE COMPETITORS IN A YEAR CYCLE

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Abstract. The aim of conducted research was an attempt to define the dynamics of aerobic and anaerobic endurance changes in the short track female competitors training during a year cycle which is dependent on the energy characteristic of training burden. Nineteen female competitors of OMKŁS Opole club and KU AZS PO Opole, were put through the examination. Eight of them were members of National Team and Olympic Team (Vancouver 2010), moreover, the competitors participated in the World Cup, World Championship, European Championship. The other examined competitors were members of National Team. With the help of terrain and laboratory tests, an official record was made on every lap time, final time of every trial, HR max and HR medium as well as the concentration of lactate in blood in fourth minute after an effort. In the thirtieth minute, after an effort, HR and lactate concentration were registered in order to define the course of restitution. Anaerobic and mixed parameters were examined by the Wingate test in 7.5% load formula of body weight. The results of researches proved that a selection of applied training burdens was not conductive to the adaptation of process according to the Mathews, Fox model (1976). In the short track, a training burden should reflect the specific of an effort in this discipline, emphasising an anaerobic energy type in a year cycle of preparations.

Key words: physical effort adaptation, aerobic endurance, Wingate test

Introduction

The search of training solutions, helpful in raising training effectiveness during the short track, requires the accurate assessment of endurance changes, which are the effect of applied training stimuli. The second crucial element, on the road to optimization sport training, is to define interrelation between the endurance level and the size as well as the structure of training burdens. The fundamental purpose of conducted researches was the attempt to define the dynamics of aerobic and anaerobic endurance changes in the short track female competitors training during a year cycle, which is dependent on the energy characteristic of training burden. In accordance with accepted in sport training rule, it was assumed that the structure of training burdens is characteristic for training periods,

assigned in a year cycle training, and it remains in strict interrelation with tasks that result from sport rivalry (Bompa and Haff 2010; Dovalil et al. 2002; Moravec et al. 2007). Considering lack of scientifically proven conceptions how to solve this problem in Polish competitors' training, the division of training tasks was put into practise, which was applied to Canadian short track competitors (Speed Skating Canada's Long-Term Athlete Development Plan, www.speedskating.ca). According to assumptions of long standing training system in Canada in a year cycle training, the basic tasks were guided on the sport rivalry ability, optimization of the functions of energy systems and movement system as well as fast ride improvement and endurance shaping. The second aspect of training burden classification, beside sport training periodization, is the energy characteristic that defines dominant metabolism type, produced during diverse exercises (Sozański 1999). The basic purpose of training process in sport is to achieve the highest adaptation level, which is reflected in increasing the rate of efficiency and progression of sport results. Taking the criterion of the direction of change of bioenergy in the body, the authors divided the means and methods of training into four categories, which were used in the analysis of research results (Dick 2002; Sozański 1999; Płatonow 1999):

- Burdens realized in the aerobic changes area, which intensity do not exceed the anaerobic changes level.
- Burdens realized in the aerobic and anaerobic changes area. We can distinguish subcritical intensity burdens (intensity below VO_2max level) and overcritical (exceed VO_2max level) among them.
- Burdens realized in lactic acid anaerobic changes area, while the best activity in anaerobic metabolism zone is registered.
- Burdens realized in lactic acid anaerobic changes area, whose intensity correspond with maximal anaerobic power level.

In the first phase of the researches, the specific features of polish female short track competitors course in a year cycle was established. In the general preparation period the basic training task was focused on shaping aerobic endurance. This kind of direction appears in majority of sport disciplines that have similar energy of start effort to short track (Bartkowiak 1999; Banister et al. 1999; Bassett and Howley 2000; Ingham et al. 2002; McKenna et al. 1988). In this period, the biggest volume of training work was realized by using low and very low burdens intensity, which constituted adequately 28% and 24% of total training burden. According to Laursen and Jenkins (2002), Dick (2002) works, the acceptance of such intensities does not constitute the base for considering the training stimulus as sufficient enough to the development of aerobic endurance. As a result of the inclusion of measures related with the beginning of training on the ice during the preparation of specialized period, the training burdens structure has slightly changed. The necessity to solve a new task by changing the structure of training burdens, also caused changes that head towards the endurance of tested competitors. The participation in total training burdens of measures that form the aerobic endurance (regeneration and developing) remains at level (53%), which is similar to general preparation season. In terms of volume, the third ones become measures of mixed (aerobic-anaerobic) character, and their share in total training burden constitute 24% of the whole burden of this period. The structures of burdens during specialized preparation season, with a dominant role as measures of aerobic metabolism character, indicate a delayed competitors entry in the starting period. Similar conclusions were reached in Steinacker (1993) researches. The work, executed in the second intensity range (aerobic, developing range), does not stimulate aerobic endurance of skaters. The frequency of heart rate, at the threshold of AT, reduce after a period of general development and specialized preparations. Such an organism reaction indicates a failure to achieve the desired training effect. The same interrelations are described by Londree (1997), Shave and Franco (2006).

In the works of Wang and Ruon (2007), Wang (2007), Zhang et al. (2007), the authors pay attention to the function that perform the preparation in the aerobic endurance area during the short track competitor training. Lack of sufficient level of specialized endurance, constitute a serious limitation on the possibility of forming anaerobic, lactic acid endurance (Zhang et al. 2008). This area of an effort adaptation was exposed to particularly strong impact on pre-competition period. This period contains a large increase in burdens, almost in all ranges of intensity, including primarily specialized training as well as control competitions. According to training plan assumptions, a contribution of aerobic burdens (supporting and aerobic range) decreases to 40% of total training volume, which is accompanied by a 30% increase of anaerobic burdens. Such a burden structure is typical of the specialized preparation period in other sports. The level of basic rate of skater's aerobic endurance, which is HRat, clearly increases at the end of pre-competition period. The observed dynamics of HRat parameter, indicates the significant training impact on aerobic endurance development of competitors, in the third intensity range. It is confirmed in Laursen and Jenkins (2002) as well as Shave and Franco (2006) researches. The nature of the relationship between dynamics of aerobic and anaerobic endurance parameters and the energy structure of executed training burdens proves that the tasks and assumptions which were supposed to be done, were not fulfilled during training.Conducted research showed that anaerobic, both lactic acid and non-lactic acid stimuli have typically significant influence on sport result in the short track.

Materials and methods

The researches involved 19 female competitors aged 18–23 years, training in the OMKŁS Opole club and KU AZS PO Opole, whose training experience was 7–10 years. Eight of them were members of the National Team, including Olympic Team (Vancouver 2010), furthermore they participated in the World Cup, World Championship and European Championship. The others examined competitors were members of the National Team. The examined group was realizing an annual training plan, taking into account current results and participation in competitions. The training plan consisted of five periods: general preparation period, specialized preparation period, pre-competition period, competition period and deconditioning. During the researches period, competitors were participating in trainings which took up to 180 minutes per day, realizing up to 11 training units per week except competition period and temporary period. In order to determine the interrelations between examined variables, the Pearson product-moment correlation matrixes were calculated. The characteristic of interdependencies between particular parameters in each of the four training periods was based on the correlation analysis between anaerobic as well as aerobic efficiency and the size of training burdens, realized in various training periods.

Table 1. Register of parameters with the assignment to the specific type of tests, effort trials and results of control competitions

Parameter	Type of a test or an effort trial
HRmax – maximum frequency of heart rates LAmax – maximum concentration of lactate after an effort, time (s) gained during tests 60%, 80% and 100% Vmax	Test 3 × 7 laps, break 20 minutes
WTOT – total work HRmax – maximum frequency of heart rates LAmax – maximum concentration of lactate after an effort	Cycle Ergometer Test 3 × 60 (s), break between tests 20 minutes
Time gained from the sport distances 500 m, 1,000 m, 1,500 m	Results of control competitions

Terrain trials and laboratory diagnostic methods, evaluating the competitors' endurance in short track:

1. Interval effort test performed on ice 3 × 7 laps.

The test consisted in three times skating on the 777 meters of ice (7 laps) with increasing speed according to the programme: I repetition – 70% speed on the life record level in the distance of 1,000 meters; II repetition – 85%, III repetition – 100%. The break between repetitions was 20 minutes. During every effort the HRmax, HRmedium, concentration of lactate in blood in the fourth minute after an effort, the time of each lap and the final time of the whole test were registered. In the thirtieth minute after an effort, HR and concentration of lactate were registered in order to define the restitution course. The test of Canadian trainer, Iv Nado, is commonly applied by trainers all over the world.

2. Interval test 3 × 60 s. performed on Cycle Ergometer.

The test consisted in making an effort (3 times in 60 s.) with 20 minutes break between repetitions. The number of spins was determined by the average number of spins, made by the subject during Wingate test. The size of the burden was as follows: I effort 60% average number of spins, II effort 80% average number of spins and III effort 100% average number of spins registered in Wingate test. Burden 7.5% body mass.

The indicators registered during the test:

- $HR_{max,}$ HR_{medium}, HR w 4 minutes after effort,
- HR before each test, HR in 30 minutes after three tests,
- LAsp1, LA4 – concentration of lactate before an effort and in the fourth minute after finish,
- LAsp2, 3 LA30 – concentration of lactate before the second and the third effort and in the thirtieth minute after finishing the test.

The test was conducted in order to evaluate the endurance in laboratory conditions which reflect the effort on ice while skating 1,000 m. So far, the research concerning application of this test in diagnostics of the short track competitors were not published.

3. Time results from the control competitions in which subjects took part at 500 m, 1,000 m and 1,500 m. Control competitions took place in each of defined training periods.

Results

The analysis of a year cycle structure which consist of five training periods showed that the skaters did the greatest work as regards the volume. In the I range of intensity (aerobic support area) – 27%, then in the III range (aerobic-anaerobic area) – 21%, and subsequently in the II range (aerobic, developing area) – 18%, in IV range (anaerobic lactic acid area) – 15%, in VI range (anabolic area) – 10% and in V range (anaerobic non-lactic acid area) – 9%. The greatest work of total volume in a training year cycle, the competitors did during the pre-competition period – until 33%, then during the competition period – 25%, during the period of general preparations – 22%, during the period of specialized preparations – 14%, and during temporary period – 6%.

Figure 1 shows the characteristics of the training burdens dynamics in a year cycle of sport training (five periods of training). The highest values characterize the burdens in I and III intensity range – during the pre-competition period for the I range, and during the competition period for the III intensity range. The lowest values were registered in V and VI intensity range, adequately in the first and the second training period.

Figure 2 shows the dynamics of training burdens volume in different intensity ranges. The highest values gained in IV training period (competition period) – III range of burdens intensity and during third pre-competition

period – I range of training burdens intensity. The lowest values were registered in the first and the second training period – V range of training burdens intensity.

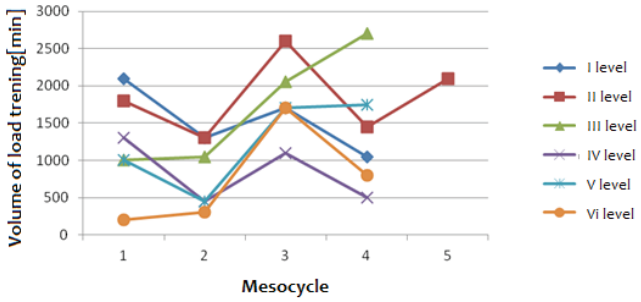

Figure 1. The burdens dynamics in mesocycles of a year cycle sport training in short track (1 – II–II mesocycle, 2 – IV–V mesocycle, 3 – VI–IX mesocycle, 4 – X–XII mesocycle, 5 – XIII–XIV mesocycle)

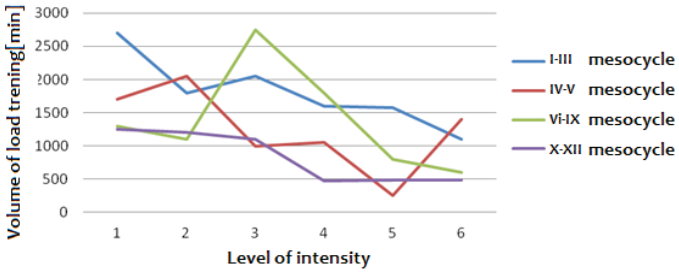

Figure 2. Burden dynamics in different intensity ranges in next mesocycles of sport training in a year cycle

Figures 3–6 show the volume of carried out burdens of different intensity ranges in the skaters' year cycle training.

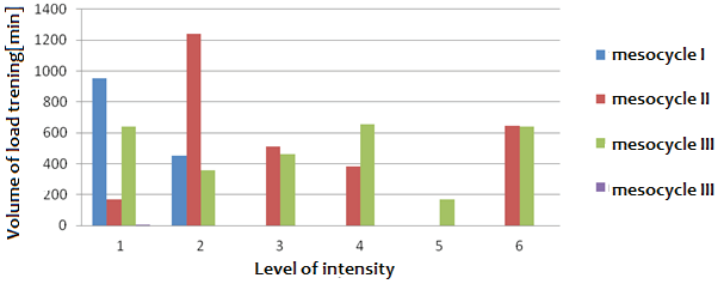

Figure 3. Training burdens volume carried out in different intensity ranges during three mesocycles of general preparation period

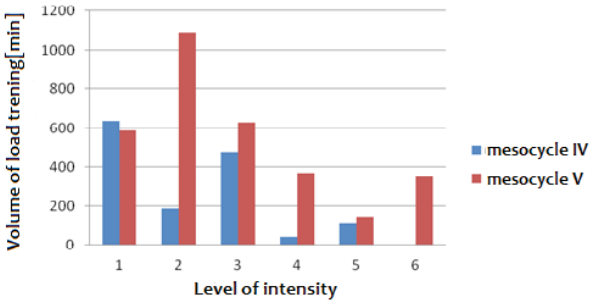

Figure 4. Training burdens volume carried out in different intensity ranges during two mesocycles of specialized preparation period

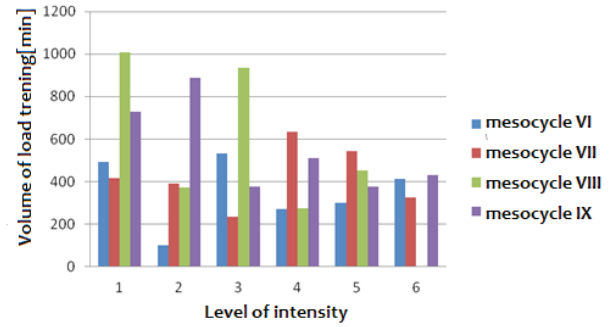

Figure 5. Training burdens volume carried out in different intensity ranges during pre-competition period

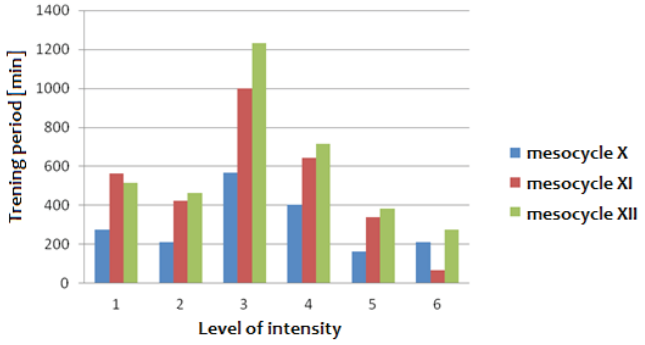

Figure 6. Training burdens volume carried out in different intensity ranges during three mesocycles in competition period

Discussion and conclusion

The competition period is a goal of all-year competitor's preparations (Bompa and Haff 2010). The short track characteristic feature during this period is a training burdens structure with a great contribution of anaerobic measures which constitute 31% of total training volume. The basic assignment of this period in a year cycle is to achieve and maintain the top physical condition, which guarantees a high disposition during main competitions of season (Bompa and Haff 2010; Sozański 1999). All training activities are subordinated to described task. A characteristic feature is reducing the burdens carried out in support and aerobic range (from 52% to 28%), as well as increase of volume measures from 30% during general training period up to 64% during competition period, carried out in intensity areas with the share of anaerobic metabolism (mixed range and anaerobic, lactic acid and non-lactic acid). Such dynamics of changes in the structure of training burdens is characteristic of sport disciplines with a significant share of anaerobic metabolism during start effort (Bangsbo et al. 1991). Lack of desired increase in aerobic endurance during the general preparation period, as a response to the highest burdens volume in a year cycle with predominant share in the energy of aerobic metabolism effort, authorise to propose a thesis on interrelation between training burden and its effect which reflects competitors' preparation in short track. Excessive increase of low intensity burdens is not conductive to aerobic endurance development. Moreover it can indirectly influence on lowering its level. This is a result of disturbance in the optimal relation between stimulus of varying power impingement on different metabolic areas of athlete's organism (Gabryś 2008). In the testing group, the most effective in shaping aerobic endurance were the stimuli with the power corresponding with AT intensity threshold, even slightly above the threshold. The effectiveness of such a solution in shaping the aerobic endurance was proved by Zając and Cholewa (1996) in their work. The authors indicate the extensive interval method as the most effective in shaping aerobic endurance, which was the basic training measure in pre-competition period in connection to significant share of trainings on the ice. Such work intensity level stimulates the metabolism of free fatty acids (Raczyński et al. 1994). The result is a body fat loss and increase in active body mass as well as lowering the pace of muscle glycogen consumption. On the one hand, the lower body mass in relation to active mass is conductive to train for speed and endurance, which is typical in short track (Hoffman et al. 2009; Nemoto et al. 1990). On the other hand, during such a training, the economy of energy reserve usage is being increased which constitute a competitor's protection from a sudden decrease of physical effort ability (Buglione et al. 2011; Costa et al. 2012; Szymański et al. 2010). According to Bomp and Haff (2010) the basic factor determining high effort adaptation during endurance sports like short track, is not training volume, but adequate diversity of trainings and various intensity ranges. The thesis is confirmed by the results of researches by many authors (Bartkowiak 1999; Colwin 2002; Maglischo 2003; Ratel 2011; Zieliński et al. 2011). Guo (2006), Wang (2007), Zhang et al. (2008) who paid attention to the preparation role of short track competitors as regards anaerobic endurance. Also own researches indicate that there are permanent tendencies in the changes characteristics of indicators size of this area in a year cycle. Anaerobic, lactic acid capacity in tested group showed a range of changes inconsistent with the expected changes. Lack of statistically significant changes of this indicator, including pre-competition and competition period, points to the insufficient size of burdens aimed at shaping the sphere of preparations. The only indicator that informs about changes in preparations to anaerobic lactic acid efforts of tested competitors group is the growing size of lactate concentration in blood, which can be interpreted as an increase in the capacity of anaerobic energy source (Laursen and Jenkins 2002). The comparative analysis of the changes in the parameters values registered in the laboratory and specific tests indicated an increase in efficiency of the effort performed with

the intensity based on aerobic-anaerobic metabolism and adaptation to the effort performed with maximum intensity through an increase in the activation of anaerobic glycolysis (Capelli 1999; Di Prampero 2003). There is a downward trend in concentration of lactate in blood after exercise made with 60% intensity. After exercise made with 80% intensity, the LAmax value in blood submits to statistically insignificant hestitations depending on training period. During exercise of maximum intensity there is statistically crucial increase in the LAmax value ina year cycle. The specificity of effort in a short track distances considerably influence the characteristics of the changes in sizeof anaerobic, not lactic acid endurance indicators. This area of endurance performs an important function of making effort in maximum two laps. This is the half of the shortest distance (500 meters), thus the anaerobic not lactic acid endurance in limited range is used during sport fight, especially while achieving a high sport condition i.e. in competition period (Zhang et al. 2009). In a year-long training cycle the anaerobic lactic acid endurance, that is evaluated in changes of values rates in laboratory and terrain tests (on ice), is characterized by periodic changes. The maximal power is characterized by twofold values increase – during preparation and competition period. During the pre-competition and competition period the highest increase in anaerobic, not lactic acid capacity is achieved. The general preparation and specialized preparation periods are the part of year cycle training in which the training burdens structure do not possess a positive transfer on desired development of parameters of short track competitors' anaerobic not lactic acid endurance. The construction of a year cycle training is determined of the optimal calendar of competitions. At the selection of competitions the preparation of a competitor is taken into account (Bompa and Haff 2010; Moravec et al. 2007). The basic criterion for participation in the competitions is the motor preparation taking into account the capacity and the power of particular systems of energy metabolism (Gabryś 2008). The foregoing issue should be considered from two points of reference. The first is the opponent and a state of his or her preparation, the second is the level of self-preparation and the relation between the preparation areas, which undergo some changes in a training year cycle (Cai et al. 2008; Tong and Cai 2008; Wang 2008). On the basis of analysis of the literature as well as own research results, it can be concluded that the selection of training burdens that was used during the test of short track competitors preparations did not favour the process of adaptation according to Mathews, Fox (1976) model. In can be concluded that in a short track the training burdens should be selected in a way as competition burdens. The main energy supply security system is the anaerobic system. The training which should be responsible for increasing the efficiency indicators that determine the sport score in a short track such as VO_2max, maximal power, VO_2max on the AT threshold and a result of competition, would have to be a training focused on the anaerobic efficiency. The aerobic training could be a connective element of main trainings, moreover it could also be a method for quick regeneration. When analysing the correlation between the results from the 3 × 7 laps test (20 minutes break) and the training burdens in subsequent periods of training, the authors came to the following conclusions:

1. During all-purpose period, the increase of burdens in the second range results in the growth of HRmax parameters during running on the ice with 60% and 80% intensity. The increase of burdens in IV intensity range results in the growth of HRmax during running on the ice with 100% intensity. Otherparametersdid not show statisticallycrucialinterrelations.
2. During specialized preparation period, the increase of burdens in the second range, results in the growth of HRmax during running on the ice with 80% and 100% intensity. The increase of burdens in V intensity range, results in lowering of acidification (LA) after running with 100% intensity. The application of burdens

anabolic (6 range), results in lengthening the skating time with 60% and 80% intensity. Other parameters did not show statistically crucial interrelations.

3. During pre-competition period, the change in training burdens did not show statistically crucial interrelations with the parameters of applied physiological tests.
4. During competition period, the change in burdens in IV range results in lowering of acidification (LA) after skating with 100% intensity. Other parameters did not show statistically crucial interrelations.

Analysing the correlation results between tests results on the Cyclo Ergometer 3 × 1 minute (break between tests 20 minutes) and training burdens in subsequent training periods, the authors came to following conclusions:

1. During all-purpose period, the increase of burdens in the sixth range results in the growth of LA after first trial with 60% intensity. Other parameters did not show statistically crucial interrelations.
2. During specialized preparation period, the increase of burdens in the first range results in the growth of HRmax after first section with 60% and 100% intensity. Training burdens in IV range result in lowering of LA in third section with 100% intensity. Training burdens in V range result in lowering of LA in first trial with 60% intensity, whereas the increase of training burdens in sixth range results in lowering of spins speed in three intensities and lowering of HRmax in the second trial. Other parameters did not show statistically crucial interrelations.
3. During pre-competition period parameters did not show statistically crucial interrelations.
4. During competition period, increase of burdens in fifth range results in lowering of HRmax after first trial with 60% intensity.

Analysing the correlation between results from control competitions and training burdens in subsequent periods, the authors came to following conclusions:

1. During all-purpose periodan increase of burdens in the sixth range results in lengthening of time on 1,000 meters and 1,500 meters.
2. During specialized preparation period, an increase of burdens in the sixth range results in lengthening of time on 1,500 meters.

During pre-competition and competition period, despite the competitors were gaining better results on three distances, the change of parameters of training burdens did not show statistically crucial influence on the sport score.

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CHANGES IN MOTOR SKILLS OF BOYS WHO TRAINED SPORTS SWIMMING IN AN ANNUAL TRAINING CYCLE

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Abstract. This paper presents an empirical approach to the changes in motor skills of children who trained sports swimming at the initial stage of school education in an annual training cycle. The research included 94 boys aged 7 (1st grade of elementary school); 57 of them belonged to the Swimmers group and 37 belonged to the Control group. All boys attended elementary schools in Szczecin, Poland. Motor skills were assessed with 8 tests of the EUROFIT Test Battery. The study resulted in the following conclusions:

I. Dynamics of changes in terms of overall balance, static strength, functional strength (between Examination I and II) was greater in the Swimmers group.
II. In terms of upper limb movement, agility, explosive strength, torso strength, and agility run, differences between results of both examinations were similar in the Swimmers and Control groups.
III. Progressive changes in motor skill of subjects were a positive phenomenon in the physical development of children. Thus, swimming trainings significantly impacted dynamics of positive changes in motor skills of boys at the early stage of school education.
IV. Regular participation in sports classes (including swimming classes) had positive impact on motor skill development of children, which is of utmost importance at that age.

Key words: selection, motor skills, swimming

Introduction

Effects of trainers' work depend largely on a correct selection process for sports swimming, and on professional, multi-step selection at a later stage (Eider 2014). It is easier and more effective to cooperate with athletes who possess qualities of the 'champion model' – Olympic and World Championship medalists. During many years of swimming trainings, focus should be placed on those characteristics of the body which are stable and developed by training (Opyrchał et al. 2005; Eider 2015).

Competitive swimming is an Olympic sport, trained by numerous athletes in Poland (Sprawozdanie 2012). Szczecin, Poland, is one of the cities that have strong traditions and achievements and where Municipal Swimming Club (MKP) operates. Every year, the club wins numerous medals in swimming competitions in various age categories, including juniors, adolescents and seniors. The most awarded swimmers from Szczecin are the Olympic medalists, Melbourne 2007 World Champions, Mateusz Sawrymowicz (1,500 m freestyle) and Przemysław Stańczyk (800 m freestyle) (Eider and Eider 2012).

Competitive swimming is one of the Olympic sports which need early selection (at the age of 5–7 years) and specialization (Volbekiene 2007; Vranešić-Hadžimehmedović et al. 2012). The biggest sports events – the Olympic Games – offer as many as 102 medals for swimmers; there are 17 competitions for women and 17 for men (Janicka and Lewandowski 2012). Thus, for various reasons, National Swimming Associations in majority of countries are interested in training future representatives – hopefully medalists – who would promote their countries 'through sport'.

Szczecin is home to many Polish representatives, including participants of the Olympic Games, World and Europe Championships. Among Olympic athletes one can list: Dorota Brzozowska – Moscow 1980, Marta Włodkowska – Barcelona 1992, Przemysław Stańczyk – Athens 2004, Beijing 2008, Katarzyna Baranowska – Beijing 2008, Mateusz Sawrymowicz – Beijing 2008, London 2012, and Oskar Krupecki – London 2012. Among Melbourne 2007 World Championship medalists there are: Mateusz Sawrymowicz (1500 m freestyle) and Przemysław Stańczyk (800 m freestyle). All of these athletes were members of Municipal Swimming Club in Szczecin. It is the largest and most awarded swimming club in Zachodniopomorskie voivodship. Every year, it achieves high ranks in national competitions in various age categories. (Ankieta 2013). Many medals were won by swimmers during Junior and Senior Europe Championship (25 m pool). The following seniors won gold medals: Katarzyna Baranowska – Trieste 2005, Helsinki 2006, Mateusz Sawrymowicz – Debrecen 2007, Szczecin 2011 (Drozd 2007; Eider 2009).

The aim of this study was to determine what changes in motor skills occurred in 7-year-old boys who trained swimming at the Municipal Swimming Club during a 1-year training cycle.

Material and research methods

Subject group consisted of 94 boys aged 7 who attended four elementary schools in Szczecin. The Swimmers group was 57-strong; boys trained at the Municipal Swimming Club (MKP) in Szczecin. The Control group consisted of 37 boys who attended the same elementary schools. The Control group members were selected based on the age of the Swimmers group members, with 3 months' precision; all subjects attended the same grade (1st of elementary school). Children from the Control group did not participate in any sports/recreation classes.

All subjects took part in two examinations (Table 1), carried out in the 2009/2010 academic year among 1st graders of Elementary Schools no. 51, 55, 56 and 62 in Szczecin (five swimming groups and four control groups). Examination I was conducted in September 2009, immediately after selection of Swimmers and Control groups (1st graders), while Examination II took place in June 2010, i.e. at the end of the 1st grade. The analysis included only those children who participated in both examinations.

Physical ability tests were conducted in gyms where they were preceded by standard warm-up for all children (7–8 minutes). The tests were as simple as possible and required minimal equipment.

Motor skills were assessed with 8 tests of the EUROFIT Test Battery (Grabowski and Szopa 1991):

- General balance – Flamingo Balance Test – keeping balance while standing on one leg on a beam of certain dimensions.
- Speed of upper limb movements – Plate Tapping Test – touching quickly two purposefully placed plates with the preferred (stronger) hand.
- Flexibility – Sit-and-Reach Test – sitting and reaching forward as far as possible.
- Explosive leg power – Standing Broad Jump Test – broad jump from a standing position.
- Static strength – Handgrip strength test – gripping forcefully a dynamometer.
- Torso strength – Sit-Up Test – lying on the back and doing max. number of sit-up within 30 seconds.
- Functional strength – Bent Arm Hang Test – total time of maintain the hang position with bent arms on a bar.
- Agility run – 10 x 5 m Shuttle Run Test – running with max. speed and changes of direction.

Table 1. Number of boys in Swimmers and Control groups during examinations

School	Group	Class number	Examination	
			I	II
El. Sch. 51	Sw	1a	10	10
	Sw	1b	10	10
	C	1c	6	6
	C	1d	8	8
El. Sch. 51	Sw	1a	14	14
El. Sch.56	Sw	1a	13	13
	C	1b	13	13
El. Sch. 62	Sw	1a	10	10
El. Sch. 56	C	1c	10	10
Total			94	94

El. Sch. – Elementary School, Sw – Swimmers, C – Control.

Research results

Flamingo Balance Test – general balance

In both groups (Sw, C), Examination I and II revealed that average balance test results were insignificantly lower in the Swimmers group. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 2). In the Swimmers group, it was on average 2.8 attempts, while in the Control group it was 1.9 (p = 0.0004) (Figure 1).

Table 2. Descriptive characteristics of Flamingo Balance Test (general balance) in the Swimmers and Control groups

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw	C	Sw	C	Sw	C
Boys	n	57	37	57	37		
	min–max	4.0–9.0	4.0–9.0	2.0–7.0	2.0–9.0		
	mean	8.0	8.0	4.0	6.0		
	$\bar{X}$(SD)	7.5 (1.1)	8.0 (1.1)	4.7 (1.2)	6.1 (1.3)		
	ss	0.074		<0.0001		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

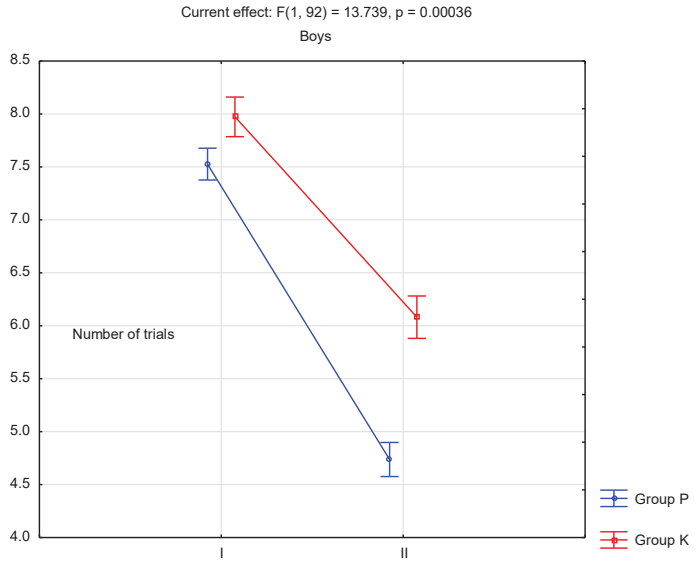

Figure 1. Changes in results of Flamingo Balance Test (general balance) in Swimmers (Sw) and Control (C) groups

Plate Tapping Test – speed of upper limb movements

Examination I revealed that average results of upper limb movement results were significantly lower (shorter time) in the Swimmers group. Examination II revealed statistically better results of boys from the Swimmers group. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 3). In the Swimmers group, it was on average 1.4 s, while in the Control group it was 1.3 s (p = 0.280) (Figure 2).

Table 3. Descriptive characteristics of Plate Tapping Test (speed of upper limb movements) results in the Swimmers Group (Sw) and Control group (C)

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw	C	Sw	C	Sw	C
Boys	n	57	37	57	37		
	min–max	16.6–29.9	22.1–32.4	15.5–28.3	21.1–31.9		
	mean	26.3	26.2	24.8	25.0		
	$\bar{X}$(SD)	25.5 (3.4)	26.7 (2.3)	24.1 (3.2)	25.4 (2.3)		
	ss	0.062		0.036		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

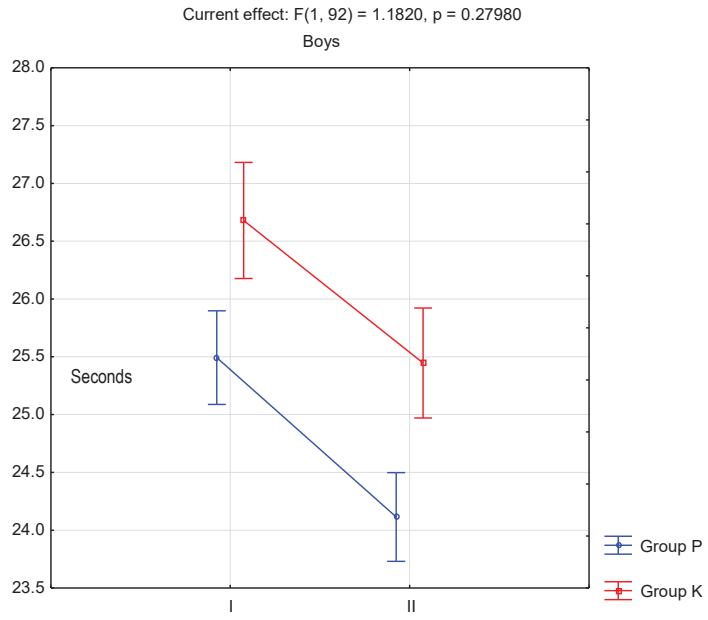

Figure 2. Changes in the results of Plate Tapping Test (speed of upper limb movements) in the Swimmers group (Sw) and Control group (C)

Sit-and-Reach Test – flexibility

Swimmers group displayed statistically significantly better results in Examination I and II in terms of torso flexibility. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 4). In the Swimming Group, it was on average 5.1 cm, while in the Control group it was 4.5 cm (p = 0.241) (Figure 3).

Table 4. Descriptive characteristics of Sit-and-Reach Test (flexibility) results in Swimmers (Sw) group and Control (C) group

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw	C	Sw	C	Sw	C
Boys	n	57	37	57	37		
	min–max	–16.0–12.0	–18.0–11.0	–10.0–17.0	–15.0–15.0		
	mean	2.0	–4.0	5.0	2.0		
	$\bar{X}$(SD)	–0.6 (6.6)	–3.5 (6.5)	4.5 (6.2)	1.0 (6.2)		
	ss	0.032		0.011		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

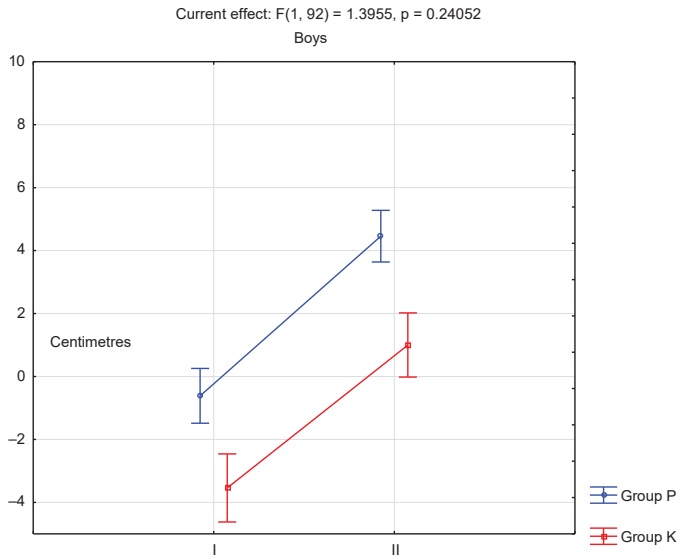

Figure 3. Changes in results of the Sit-and-Reach Test (flexibility) in Swimmers (Sw) group and Control (C) group

Standing Broad Jump Test – explosive leg power

Swimmers group displayed statistically significantly better results in Examination I and II in terms of standing broad jump. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 5). In the Swimming Group, it was on average 12.2 cm, while in the Control group it was 14.2 cm (p = 0.271) (Figure 4).

Table 5. Descriptive characteristics of Standing Broad Jump Test (explosive leg power) results in the Swimmers (Sw) group and Control (C) group

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw	C	Sw	C	Sw	C
Boys	n	57	37	57	37		
	min–max	65.0–165.0	68.0–123.0	75.5–167.0	74.0–137.0		
	mean	115.0	96.5	126.0	111.5		
	$\bar{X}$(SD)	113.8 (17.9)	96.4 (16.5)	126.0 (16.9)	110.6 (15.5)		
	ss	<0.0001		<0.0001		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

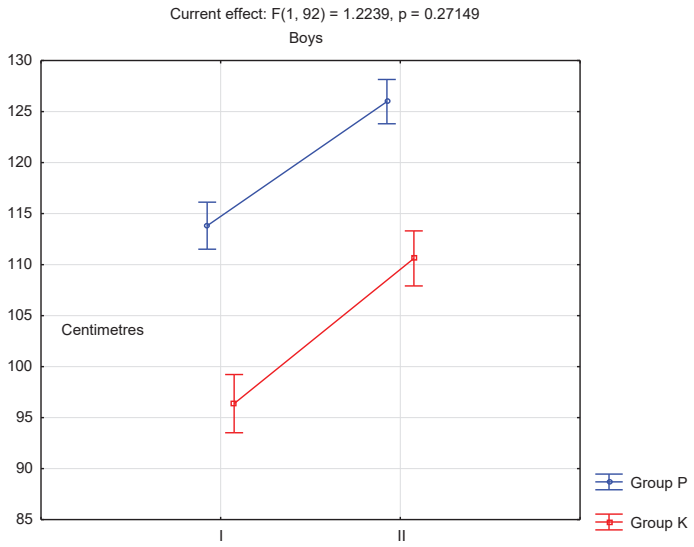

Figure 4. Changes in the results of Standing Broad Jump Test (explosive leg power) in the Swimmers (Sw) group and Control (C) group

Handgrip strength test – static strength

Examination I revealed that in both groups (Sw, C) handgrip strength was identical. In Examination II statistically insignificantly better result was obtained by the Swimmers group. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 6). In the Swimmers group, it was on average 1.1 (psi – measurement in pounds per square inch), while in the Control group it was 0.8 (psi – measurement in pounds per square inch) (p = 0.010) (Figure 5).

Table 6. Descriptive characteristics of Handgrip Strength Test (static strength) results in the Swimmers (Sw) and Control (C) groups

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw	C	Sw	C	Sw	C
Boys	n	57	37	57	37		
	min–max	0.5–5.0	1.0–5.0	1.5–6.0	2.0–5.5		
	mean	2.5	2.5	3.5	3.5		
	$\bar{X}$(SD)	2.6 (0.9)	2.6 (0.8)	3.7 (1.0)	3.4 (0.7)		
	ss	0.967		0.175		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

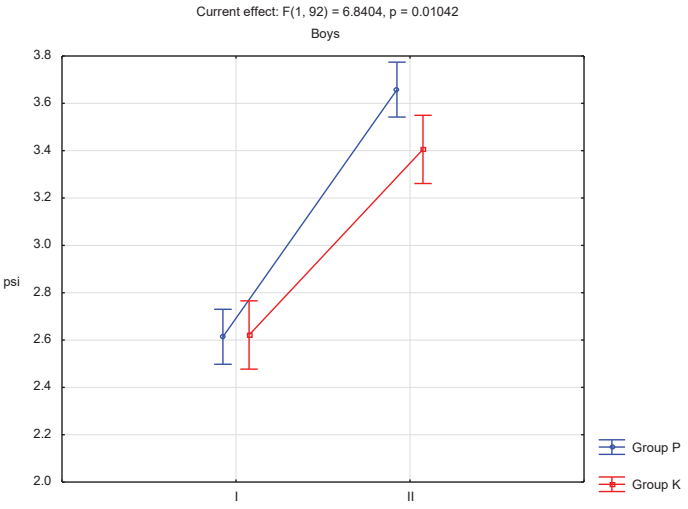

Figure 5. Changes in Handgrip Strength Test (static strength) results in the Swimmers (Sw) and Control (C) groups

Sit-Up Test – torso strength

Swimmers group displayed statistically significantly better results in Examination I and II in terms of sit-up test. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 7). In the Swimmers group, it was on average 7.4 (n), while in the Control group it was 6.5 (n) (p = 0.148) (Figure 6).

Table 7. Descriptive characteristics of Sit–Up Test (torso strength) results in the Swimmers (Sw) and Control (C) groups

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw	C	Sw	C	Sw	C
Boys	n	57	37	57	37		
	min–max	0.0–20.0	0.0–21.0	5.0–29.0	2.0–26.0		
	mean	13.0	10.0	20.0	17.0		
	$\bar{X}$(SD)	12.4 (4.9)	9.8 (5.3)	19.8 (5.1)	16.3 (5.6)		
	ss	0.020		0.002		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

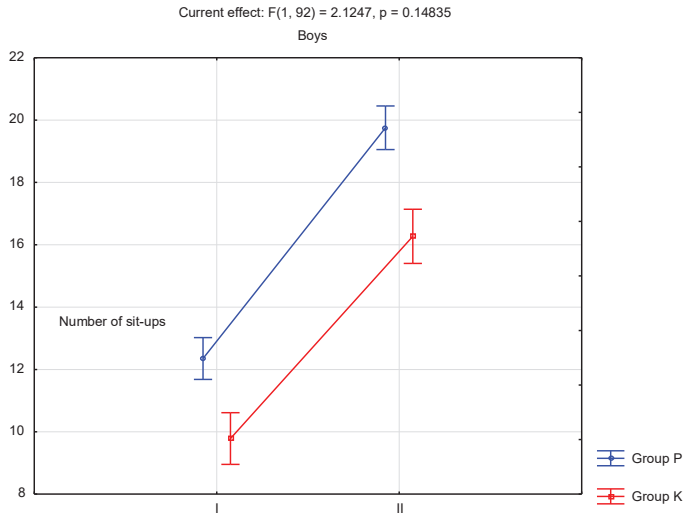

Figure 6. Changes in Sit-Up Test (torso strength) results in the Swimmers (Sw) and Control (C) groups

Bent Arm Hang Test – functional strength

Swimmers group displayed statistically significant better results in Examination I and II in terms of bent arm hang. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 8). In the Swimmers group, it was on average 3.9 s, while in the Control group it was 2.3 s (p = 0.0009) (Figure 7).

Table 8. Descriptive characteristics of Bent Arm Hang Test (functional strength) results in the Swimmers (Sw) group and Control (C) group

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw (seconds)	C (seconds)	Sw (seconds)	C (seconds)	Sw	C
Boys	n	57	37	57	37		
	min–max	2.1–28.7	0.7–20.5	4.9–34.8	2.7–17.6		
	mean	10.7	6.9	13.7	8.1		
	$\bar{X}$(SD)	11.7 (5.8)	6.8 (4.5)	15.6 (6.2)	9.1 (4.1)		
	ss	<0.0001		<0.0001		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

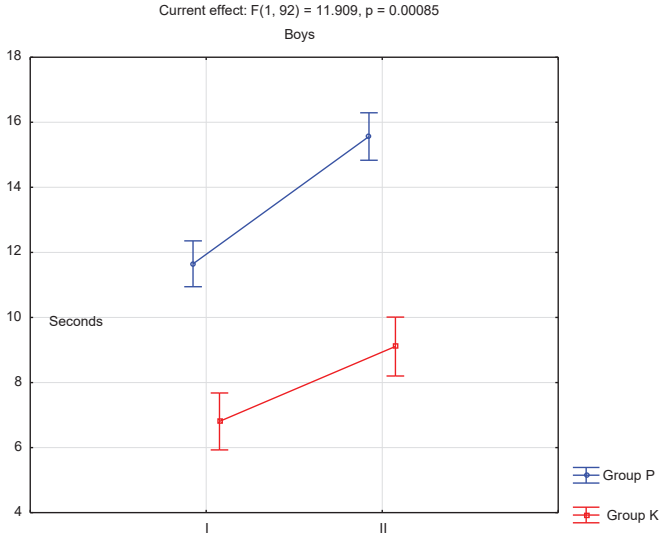

Figure 7. Changes is Bent Arm Hang Test (functional strength) results in the Swimmers (Sw) group and Control (C) group

10 × 5 m Shuttle Run Test – agility run

In Examination I the average results of the shuttle run were statistically insignificantly better in the Swimmers group, while in Examination II the statistical difference was significant. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I (Table 9). In the Swimmers group, it was on average 2.7 s, while in the Control group it was 2.2 s (p = 0.259) (Figure 8).

Table 9. Descriptive characteristics of 10 x 5m Shuttle Run Test (agility run) results in the Swimmers (Sw) group and Control (C) group

	Distribution type	Examination I		Examination II		Examination I vs. examination II	
		Sw (seconds)	C (seconds)	Sw (seconds)	C (seconds)	Sw	C
Boys	n	57	37	57	37		
	min–max	18.5–33.0	21.3–35.5	17.4–29.7	20.0–32.9		
	mean	26.2	27.2	23.7	25.1		
	$\bar{X}$(SD)	26.4 (3.2)	27.5 (3.2)	23.7 (2.9)	25.3 (2.8)		
	ss	0.071		0.016		<0.0001	<0.0001

Sw – Swimmers, C – Control, min – minimum value, max – maximum value, $\bar{X}$ – arithmetic mean, SD – standard deviation, ss – statistical significance.

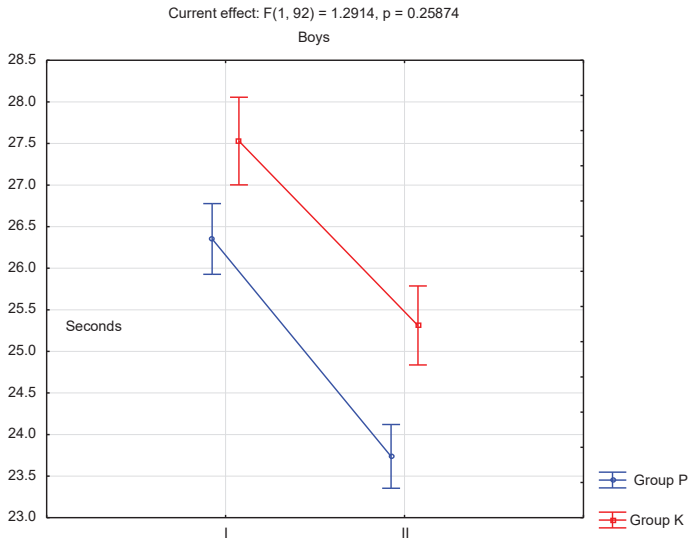

Figure 8. Changes in 10 x 5m Shuttle Run Test (agility run) results in the Swimmers (Sw) group and Control (C) group)

Discussion

The research revealed changes in both groups (Sw, C) in terms of all eight tests. Examination II proved statistically significant improvement of results in both groups (Sw, C) in comparison to Examination I. Comparing the Swimmers and Control groups, the dynamics of changes between Examination I and II was greater among Swimmers only in balance, static strength and functional strength tests. In groups (Sw, C), differences between results of Examination I and II were similar in terms of speed of upper limb movement, agility, explosive strength, torso strength and agility run. Pietrusik's research (1981) confirmed that boys in Swimmers groups displayed significant improvements in final results of all physical ability tests. Pietrusik (1997) believes that better motor skills '...of girls and boys from the Swimmers groups in the final examination do not result from unique motor predispositions, but rather from specialized swimming exercises performed by children during the swimming training process' (Pietrusik 1997: 33). The Swimmers group did not attain better dynamics of changes in all tests than their peer Control group (i.e. speed of upper limb movement, agility, explosive strength, torso strength, agility run). Progressive changes in motor skill of subjects were a positive phenomenon in the physical development of children. During both Examinations (I and II), subjects attended elementary school 1st grade, i.e. the first grade of the early school age (Osiński 2011). Przewęda (1981: 164) described this period, saying that '...school takes over the role of a provider of factors that influence children and it needs to fulfill their biological motor needs'. According to Przewęda (1981: 164), children display a great 'need to blow off steam by physical activity, to satisfy their great hunger for activity.' Parents of children at early school age serve as 'stimulators' of development. It is their duty to provide children with additional sports classes. Based on child's interests, sports predispositions, family (sports) traditions, often it is the parent who choose a particular activity for the child, e.g. sports club, dancing club etc. Participation in organized, regular sports classes results in the development of motor (physical) skills of children (Torrance et al. 2007; Chalcarz et al. 2008; Wilk, Eider 2014).

Conclusions

1. In both groups (Sw, C) there was a statistically significant improvement of results of all motor skill tests in Examination I and II.

2. In Examination I and II, the Swimmers group displayed higher motors skills than Control group in terms of: overall balance, upper limb movement speed, agility, explosive strength, torso strength, functional strength and agility run (Figures 1, 2, 3, 4, 6, 7, and 8).

3. Dynamics of changes between Examination I and II was the greatest among Swimmers in the following tests: overall balance, static strength, and functional strength (Figures 1, 5, 7). It was similar in the remaining 5 tests: upper limb movement speed, agility, explosive strenght, torso strength, and agility run (Figures 2, 3, 4, 6, 8).

4. Progressive changes in motor skill of subjects is a positive phenomenon in the physical development of a child.

5. Swimming training resulted significantly in positive changes in terms of motor skills of boys who were at the initial stage of swimming trainings, compared to their non-training peers.

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