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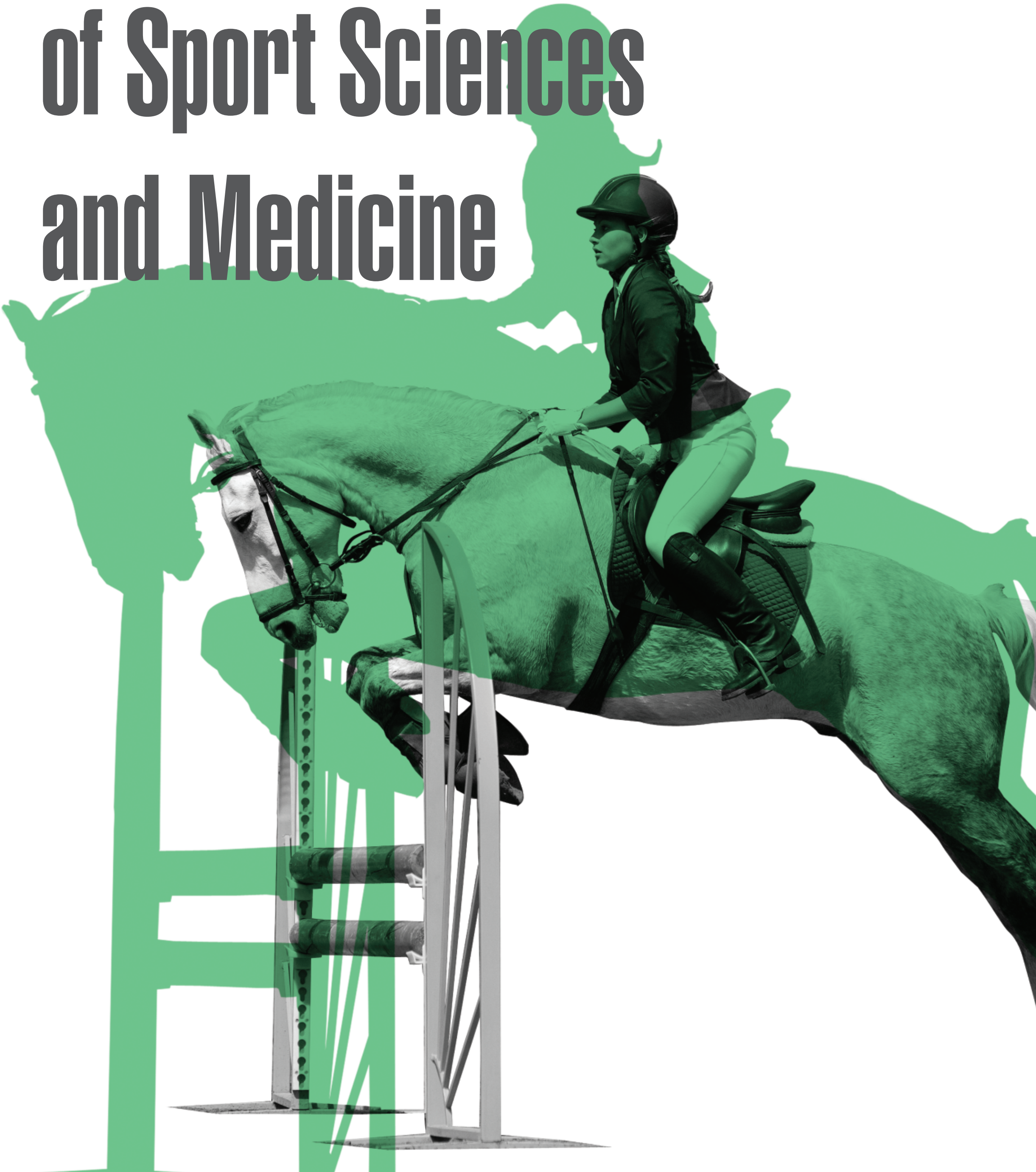

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Contents

SPECIALIZED MOVEMENT ON THE ROWING ERGOMETER AND POST-WORKOUT CHANGES IN SELECTED PERIPHERAL BLOOD PARAMETERS – A CASE REPORT

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Abstract Rowing is a sport discipline, which requires extreme physical strength and endurance and appropriate aerobic and anaerobic capacity as well. However, when the workout intensity and load is very high, exercise is associated with temporary changes in cellular metabolism and the immune system. The study included one male rower aged 28 years – the highly-skilled and experienced athlete. We determined basic cardiorespiratory fitness measures, complete blood count, and 24 clinical chemistry parameters including relevant biochemical and haematological parameters and matrix metaloproteinases activities. Maximal exercise on the rowing ergometer induced 2-fold increase in absolute counts of all leukocytes subsets. There was observed an increase in C-reactive protein concentrations as well. MMP-9 activity increased 1.3-fold compared to the baseline value. Exhaustive exercise caused significant changes in creatinine and urea serum levels, but the most prominent changes were found in total and direct bilirubin concentrations. Maximal exercise induced also a decrease in the iron and magnesium levels. No changes in ALT, GGT and ALP activity were observed, while increase in CK, AST and LDH activity in post-exercise time and the decrease during the recovery was found. Therefore acute specialized movement on the rowing ergometer is not the cause of muscular damage, but rather indicate efficient adaptation to the physical exercise. Moreover, it seems that maximal exercise induces an inflammatory response characterized by greater count of all subpopulations of leukocytes, elevated levels of CRP and MMP-9 serum activity.

Key words rowing, biochemical markers, haematological markers, matrix metalloproteinases

Introduction

Physical exercise is aimed to significantly disturb the current homeostasis in athletes' skeletal muscles resulting in collagen type IV regulation and enhancement of basement membrane, which leads to improvement of skeletal muscle mass and strength. However, under certain conditions, when the workout intensity and load is very high, exercise can cause a damage of skeletal muscles and tendons. Acute physical activity may lead to sarcomere damage, inflammatory responses and activation of satellite cells in order to replace the lost muscle fibres. The degradation of the extracellular matrix (ECM) structure often occurs in the damaged skeletal muscle and connective tissue. This kind of disturbances lead to the activation of collagen degradation enzymes – tissue matrix metalloproteinases (MMPs) as well. MMPs, including MMP-9, are also present in many types of leukocytes, including monocytes and lymphocytes (Baumert, Lake, Stewart, Drust, Erskine, 2016; Lo Presti, Hopps, Caimi, 2017).

Rowing is a sport discipline, which requires extreme physical strength and endurance and appropriate aerobic and anaerobic capacity as well. Minimising the influence of injuries and overtrained states and maximising the training efficiency are the main aims for coaches in preparing elite athletes for competitions. There are groups of well described metabolic parameters measured in blood, that are very useful tools in athletes' physical condition assessment, for example, creatine kinase activity, lactate dehydrogenase, and blood lactate concentration (Banfi, Colombini, Lombardi, Lubkowska, 2012; Chamera et al., 2015; Chamera et al., 2014). Intensive, long-term endurance training and participation in sporting competitions lead to the damage of muscle fibres and release of the inflammation factors and cellular enzymes into the peripheral blood.

Ever-changing environmental conditions typically found during on-water rowing testing cause significant standardisation problems. For this reason, we use the rowing ergometer, which simulates properly the action of on-water rowing in our research (Akça, 2014; Sforza, Casiraghi, Lovecchio, Galante, Ferrario, 2012).

Therefore, the aim of this study was to analyze the relationship between high-intensity physical exercise and changes in selected haematological and biochemical parameters levels of the highly-skilled rower, which was tested on a rowing ergometer.

Methods

Study design

To investigate body metabolism response to acute exercise in elite rower, we designed an experiment to evaluate these processes. We determined cardiorespiratory fitness measures ((maximum oxygen uptake (VO_{2max}), maximum heart rate (HR_{max}) and anaerobic threshold (AT)), complete blood count, and 24 clinical chemistry parameters, including relevant biochemical and haematological variables and matrix metalooproteinase 9 activity. The study was performed in the biochemistry, physiology and genetic laboratories of the Centre for Human Structural and Functional Research, Szczecin, Poland.

Participant

The study included one male rower aged 28 years. The participant was top-athlete, multiple medallist of high-profile competitions with 13 years of training experience. The rower trained 9 hours a week. The characteristics of the study participant are presented in Table 1. The participant was non-smoker, free of any health problems and was not taking any drugs, supplements or medications known to affect metabolism for 2 weeks prior to the test. He had no history of any metabolic syndrome or cardiovascular diseases. The participant was under no dietary restrictions.

Table 1. Subject characteristics

Parameter	Value
Age (years)	28
Height (cm)	194.0
Weight (kg)	98.9
Fat mass (kg)	13.4
Body mass index (BMI) (kg/m^2)	26.3
VO_{2max} (mL/kg/min)	57.4
HR_{max} (beats/min)	192.0
AT (beats/min)	146.0

VO_{2max} – maximum oxygen uptake, HR_{max} – maximum heart rate, AT – anaerobic threshold.

The Local Ethics Committee at the Szczecin approved the study protocol. Participant provided written informed consent.

Procedures

Aerobic capacity evaluation

The progressive exercise test until exhaustion was carried out on Concept2 model D rowing ergometer (Concept2, Morrisville, VT, USA) according procedure described previously by Nowak et al. (2017).

Blood sampling

Blood samples from the athletes' elbow vein were obtained three times: (1) at rest (in the morning, the day before testing, after an overnight fast), (2) immediately after the exercise test (5 min after completing the test), and (3) after a 17-h recovery period (after an overnight fast). For the safety reasons the test protocol required the participant to be after a light breakfast. Therefore, blood sample collected after the exercise test was not fasting blood.

Venous blood samples were collected into S-Monovette tubes containing clot activator and dipotassium EDTA (SARSTEDT AG & Co., Nümbrecht, Germany) for serum and anticoagulated whole blood preparations, respectively. The tubes for serum preparation were centrifuged at 2000 × g for 10 min at room temperature. The part of serum collected for zymographic assays was stored at – 80°C.

Biochemical, haematological and zymographic analyses were performed before the progressive test (pre-exercise), after the test (post-exercise) and at the end of recovery period (17 hours after completion of the test). The biochemical and haematological analyses were performed immediately after blood collection.

Complete blood count

Blood samples were taken for the analysis of red blood cells (RBCs), white blood cells (WBC), mean corpuscular volume (MCV), haemoglobin (HGB), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), total platelets level (PLT) and haematocrit (HTC) in a haematology analyser ABX Micros 60 (Horiba ABX, Warsaw, Poland).

Biochemical analyses

Biochemical tests have been carried out with the use of an Auto Chemistry Analyser BM-100 (BioMaxima SA, Lublin, Poland) in case of clinical chemistry variables or an Ion Selective Analyser BM ISE (BioMaxima SA, Lublin, Poland). Blood serum was used to determine metabolites (creatinine, urea, uric acid and bilirubin, both total and direct), albumin, total protein, C-reactive protein (CRP), lipid profile (triglyceride (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein (LDL-C) levels), enzymes activities (aminotransferases: aspartate (AST) and alanine (ALT), gamma-glutamyltransferase (GGT), alkaline phosphatase (ALP), creatine kinase (CK), lactate dehydrogenase (LDH)) and selected ions, namely iron, magnesium, phosphorus (Auto Chemistry Analyser BM-100, BioMaxima, Poland) and calcium (Ion Selective Analyser BM ISE, BioMaxima, Poland). All studied parameters were determined using a diagnostic method according to the appropriate manufacturer's protocol (BioMaxima SA, Lublin, Poland). Moreover, the CRP level was determined using two different turbidimetric assay kits according to the manufacturers' protocols (BioMaxima SA, Lublin, Poland and Quimica Clinica Aplicada SA, Amposta, Spain) to confirm the results obtained during the study. All analyses were verified with the use of multiparameteric control serum, as well as control serum of a normal level (BioNorm) and a high level (BioPath) (BioMaxima SA, Lublin, Poland).

Gelatin zymography

The serum samples collected were centrifuged at 1600 × g for 15 min at 4°C and were diluted 40-fold. To each sample a loading buffer (Tris-Base containing 10% glycerol, 2% sodium dodecyl sulphate (SDS) and 0.05% bromophenol blue (pH 6.8)) was added. Then, samples were loaded in a 7.5% polyacrylamide-SDS gel containing 0.1% gelatin and separated by electrophoresis at 110 V for 2 h at 4°C. Thereafter, gels were washed three times for 60 min with 2.5% Triton X-100 to remove SDS. Gels were then incubated for 48 h at 37°C in catalytic buffer (50 mM Tris-HCl, 10 mM $CaCl_2$, 200 mM NaCl, pH 7.5) and stained with 0.1% Coomassie brilliant blue G-250 in methanol : acetic acid : water (9 : 2 : 9, v : v : v) mixture for 1.5 h. Finally, gels were destained with methanol : acetic acid : water (1 : 1 : 8, v : v : v) mixture for 3 h. Proteolytic activity of MMPs was visualized as clear bands on a dark blue background. The bands were identified basing on the molecular weights of MMPs: 72 kDa and 92 kDa corresponding to MMP-2 and MMP-9, respectively. Proteolytic activity was determined using an imaging system (ChemiDoc™ XRS+ System, Bio-Rad, USA) and a software package (Image Lab™ Software, Bio-Rad, USA).

Results

Maximal exercise on the rowing ergometer induced changes in absolute counts of all leukocytes subsets. Athletes' total leukocyte count was 2-fold increased after maximal exercise (Table 2). Elevation of circulating lymphocytes and neutrophils was the main reason for the change in total white cells count. There was no increase in haemoglobin concentration and haematocrit (Table 2). There was observed an increase in C-reactive protein concentrations after maximal exercise as well (Table 3).

Table 2. Selected haematological parameters determined before (pre-exercise) and after the progressive exercise test on rowing ergometer until exhaustion (5 minutes post-exercise) and during recovery (17 hours after the test)

	Pre-exercise	Post-exercise	Recovery time
WBC (10^9/L)	4.10	8.30	5.90
RBC (10^{12}/L)	4.63	4.79	4.72
HGB (mmol/L)	8.70	9.00	9.20
HTC (%)	45.00	46.00	46.00
PLT (10^9/L)	172.00	201.00	164.00
MCV (fL)	97.00	97.00	97.00
MCH (fmol)	1.88	1.88	1.94
MCHC (mmol/L)	19.40	19.40	20.00
Lymphocytes (%)	39.10	48.50	33.70
Lymphocytes (10^9/L)	1.60	4.00	1.90
Monocytes (%)	5.70	6.90	5.00
Monocytes (10^9/L)	0.20	0.50	0.20
Neutrophiles (%)	55.20	44.60	61.30
Neutrophiles (10^9/L)	2.30	3.80	3.80

Table 3. Serum selected metabolite levels determined before (pre-exercise) and after the progressive exercise test on rowing ergometer until exhaustion (5 minutes post-exercise) and during recovery (17 hours after the test)

	Pre-exercise	Post-exercise	Recovery time
Creatinine (µmol/L)	111.00	132.00	104.00
Urea (mmol/L)	6.50	7.10	6.90
Uric acid (µmol/L)	280.00	261.00	218.00
Total bilirubin (µmol/L)	11.32	8.46	6.91
Direct bilirubin (µmol/L)	17.56	15.47	9.11
CRP (mg/L)	0.10	2.80	2.50
Albumin (g/L)	49.00	52.20	46.90
Total protein (g/L)	60.18	66.60	60.22

Exhaustive exercise caused significant changes in creatinine, urea and bilirubin levels. The most prominent changes were found in total and direct bilirubin concentrations in participant (Table 3). The activity of gelatinases (MMP-2 and MMP-9) were examined by gelatine zymography assays. MMP-9 activity increased 1.3-fold compared to the baseline value and then decreased below the baseline value in the recovery time. No detectable activity of MMP-2 was determined (Table 3 and Figure 1). CK activity in rowers' serum was far higher than in general population, however post-exercise increase did not remain at that high level in the recovery time. No changes in ALT, GGT and ALP activity in athletes' serum were observed, while increase in AST and LDH activity in post-exercise time and the decrease during the recovery period in rower was found (Table 4). It was also noted that maximal exercise induced a decrease in the iron and magnesium levels and post-exercise raise in the phosphorus level (Table 5). No changes in the lipid profile of the participants (Table 6).

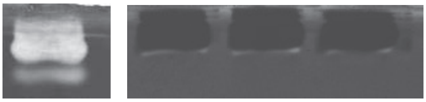

Figure 1. Zymographic profile showing relative serum activity of MMP-9 (92 kDa) and MMP-2 (72 kDa) in athlete determined by gelatine zymography before (pre-exercise) and after the progressive exercise test on rowing ergometer until exhaustion (5 minutes post-exercise) and during recovery (17 hours after the test). St – standard, L1 – pre-exercise, L2 – post-exercise, L3 – recovery time

Table 4. Serum enzyme activities determined before (pre-exercise) and after the progressive exercise test on rowing ergometer until exhaustion (5 minutes post-exercise) and during recovery (17 hours after the test)

	Pre-exercise	Post-exercise	Recovery time
Amylase (U/L)	62.30	70.20	67.40
AST (U/L)	46.40	64.40	35.40
ALT (U/L)	33.60	40.80	31.80
CK (U/L)	502.60	578.00	304.90
GGT (U/L)	13.40	14.70	13.20
LDH (U/L)	365.00	353.00	99.00
ALP (U/L)	61.48	66.64	55.51
MMP-9 (relative activity coefficient)	1.00	1.31	0.67

AST – aspartate aminotransferase, ALT – alanine aminotransferase, GGT – gamma-glutamyltransferase, LDH – lactate dehydrogenase, CK – creatine kinase, ALP – alkaline phosphatase, MMP-9 – matrix metalloproteinase 9.

Table 5. Serum selected ions determined before (pre-exercise) and after the progressive exercise test on rowing ergometer until exhaustion (5 minutes post-exercise) and during recovery (17 hours after the test)

	Pre-exercise	Post-exercise	Recovery time
Iron (µmol/L)	29.20	34.90	24.60
Magnesium (mmol/L)	0.75	0.69	0.62
Calcium (mmol/L)	2.53	2.58	2.37
Phosphorus (mmol/L)	0.96	1.55	0.93

Table 6. Serum lipid profile determined before (pre-exercise) and after the progressive exercise test on rowing ergometer until exhaustion (5 minutes post-exercise) and during recovery (17 hours after the test)

	Pre-exercise	Post-exercise	Recovery time
TG (mmol/L)	0.43	0.77	0.42
TC (mmol/L)	4.76	5.04	4.80
LDL-C (mmol/L)	2.32	2.28	2.27
HDL-C (mmol/L)	2.25	2.41	2.30

TG – triglycerides, TC – total cholesterol, HDL-C – high-density lipoprotein cholesterol, LDL-C – low-density lipoprotein cholesterol.

Discussion

Exhaustive exercise is associated with temporary change in cellular metabolism and the immune system (Desgorces, Testa, Petibois, 2008; Reihmane, Jurka, Tretjakovs, 2012). We observed some changes in blood parameters responses to a characteristic rowing maximum exercise in athlete, which was tested.

First of all, we noted that white blood cell total count was twice as high as baseline values with no significant increase in haemoglobin concentration and haematocrit. This suggest lack of dehydratation effect on haematological parameters in athlete examined. Moreover, it was found, that C-reactive protein concentration was elevated, which suggests induction of an inflammatory response. This hypothesis is supported by transient increase of the serum activity of another protein linked with inflammation state, such as MMP-9. Previously Danzig and Madden with co-workers has shown that the degree of the muscle damage and the intensity of exercise are important factors that positively influence the release of MMP-9 (Danzig et al., 2010; Madden, Byrnes, Lebin, Batliner, Allen, 2011). Further, Reihmane et al. showed that maximal exercise-induced MMP-9 release correlated with the increase in pro-inflammatory cytokine – interleukin-6 (IL-6) level suggesting a close relationship between inflammatory and proteolytic processes in tissues (Reihmane et al., 2012). In general, MMP-9 is considered to be the marker of skeletal muscle remodelling and regeneration (Lo Presti et al., 2017). However, it remains unclear which tissues were the original source of this enzyme after exhaustive exercise in our study? Since we observed 2-fold increase in leukocyte count this may reflect accelerated release of MMP-9 into the circulation from neutrophiles rather than an increased extracellular matrix damage (Koskinen, Hoyhtya, Turpeenniemi-Hujanen, 2001). Moreover, MMPs are the major components of neutrophilic granules (Chen, Fan, Poon, 2006), which supported hypothesis, that neutrophils could be the major source of increased MMP-9 activity.

The progressive exercise test on rowing ergometer until exhaustion induced also increase of bilirubin serum level. In these conditions, the primary source of bilirubin in peripheral blood is the red blood cells haemolysis. The greater destruction of erythrocytes is mainly caused by mechanical factors and the harmful effects of free radicals (Witek et al., 2017). The main reason for this were elevated body temperature, metabolic acidosis, hypoglycaemia and hemoconcentration which all took place during physical exercise (Reeder, Wilson, 2001; Robinson, Cristancho, Boening, 2006). Yusof et al. suggested that intravascular haemolysis observed during long-term exercise results from the injury of older erythrocytes, which are less elastic (Yusof et al., 2007). On the other hand, Hwang et al. have described anti-inflammatory properties of bilirubin, expressed through a negative correlation with the concentration of C-reactive protein (Hwang, Lee, Kim, 2011). Therefore, some researchers tried to explain out of range levels of bilirubin concentration in the highly-skilled athletes by the training adaptation (Witek et al., 2017). Moreover, in the recovery period, decrease in the serum iron concentration was noticed. Given the foregoing, this decline was not related to dehydratation state of athlete after the training. It seems, that the main reason of iron level lowering is the accelerated breakdown of red blood cells.

Another metabolite – serum creatinine level has been related to muscle mass and renal function. The maximal effort caused raise of this parameter value suggesting a decrease of renal function. However, since creatinine is a by-product of muscle contraction the post-exercise increase of this parameter could be due also to muscle tissue damage (Colombini et al., 2014). It is known, that acute exercise could initiate amino-acid metabolisms in highly trained subjects (Desgorces et al., 2008). Initiation of this metabolic pathway could provide an explanation for post-exercise increase of the urea level. This clinical variable could be good diagnostic marker for the evaluation of physical fitness and condition of athletes as well (Nowak, Buryta, Kostrzewa-Nowak, 2016).

CK is frequently described as the best indirect marker of damage of muscle tissue, especially after resistance exercise (Callegari et al., 2017). In our investigation, CK and LDH activity were at the very high levels in the post-exercise period of time, considerably exceeding the reference values established for general population. However, this state did not persist during the recovery time, which suggested that specialized movement on the rowing ergometer did not cause the muscular damage and athlete was well adapted to the acute effort. Great elevation in enzymes activity could be partially explained by research of Amorim et al., who found significant negative correlation between CK activity and the eGFR indices of renal function (Amorim et al., 2014). Similar changes in the AST serum level, which seems to be another marker of skeletal muscle damage (Banfi et al., 2012), supported this hypothesis.

Conclusions

Specialized movement on the rowing ergometer causes changes in selected clinical parameters in high-level athlete. The observed increase in CK and ASAT activity did not maintain at the end of recovery, which suggest that specialized movement on the rowing ergometer is not the cause of muscular damage. This observation is supported by decrease in the activity of another skeletal muscle damage marker – lactate dehydrogenase at the recovery time. Moreover, it seems that maximal exercise induces an inflammatory response characterized by greater count of all subpopulations of leukocytes, elevated levels of CRP and MMP-9 serum activity.

In conclusion, the different changes in biochemical and haematological parameters are part of the adaptive mechanisms to acute physical exercise. Therefore, monitoring of these parameters permit the alignment of the training process to the athletes' condition and could directly improve the athletes' performance.

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DEVELOPMENT OF EQUESTRIAN SPORTS AT STATE STUD FARMS IN VARMIA AND MASURIA BETWEEN 1947 AND 1975

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Abstract The regaining by the Polish People's Republic of territories that prior to the outbreak of World War 2 had remained under the rule of East Prussia set the stage for re-development of equestrianism in and reintroduction of horse breeding to a region that was now Polish Varmia and Masuria. This was a two-stage process whose success depended largely on the perseverance and commitment of one man, Mr. Adam Sosnowski, administrator at the State Horse Breeding Farms. The process was initiated in 1947 when a state stallion station in Ketrzyn and three studs named Garbno, Liski, and Rzeczna were started. Another eight were soon set up through the joint effort and collaboration of managements of local state farming cooperatives, or PGRs, mostly on the grounds of former Prussian horse breeding sites with appropriate technical infrastructure and solidly established stock breeding traditions. Over the years to come, equine breeding farms in Varmia and Masuria underwent numerous reforms and organizational changes, structurally always remaining part of the Polish Ministry of Agriculture. They provided a good foundation for propagating recreational horse riding among members of the general public and, most importantly, helped equestrian sports to return to and develop in the area.

Key words equestrian sports, breeding, studs, horses, Varmia and Masuria

Introduction

For hundreds of years horse breeding and horse riding remained tightly intertwined with the history of warfare and human conflict. It is therefore understandable that for a relatively long period of time people perceived the ability to breed and ride the horse as an advantage critical to their own survival. These sentiments were no different among inhabitants of Varmia and Masuria (Donhoff, 1988; Kamzolov, 2002), where the leader in equine breeding was the Royal Stud in Trakehnen (Grodzicki, Pacyński, 1966). For over 200 years since its establishment in 1732, the stud enjoyed wide prestige, a fact well illustrated by a steady demand for the fine Trakenher horse it produced and an unfaltering popularity of an on-site museum exhibiting paintings and pottery with images of the most successful mounts.

Professional training of young stallions in East Prussia started in 1823. The first official horse race was held a dozen or so years later, in Konigsberg (Królewiec), where by 1875 the Royal Horse Racing Federation had already been in full operation (Knoblauch, 1939, p. 16). After the post-WW2 border shift, Polish breeders who had arrived in the region relied on the Prussian experience, organizing in what was then officially called 'the Regained Territories' the first Polish studs and stallion stations (Grodzicki, Pacyński, 1966). The stimulus to resume horse breeding came primarily from the fact that a number of Trakenhers survived the war but were scattered across the country, and that the necessary infrastructure remained at many breeding sites relatively intact (Josse, 1959; Pacyński, 1960; Jegielski, 2002; Jastrzębska, 2002; Kamzolov, 2002; Wójcik, Skrzypczak, 2014; and others).

The emergence of equestrian sports in this area dates back to the middle 1850s (Wójcik, 2010). It was around that time that a clear relationship between stock breeding and equestrianism was observed, the latter positively correlating with cavalry training. This is one of the reasons why Prussian cavalry officers were obliged to take part in flat and hunt races (Pruchniewicz, 2003, p. 291). In the years to come, the military use of the horse was to become an invaluable contributor to the propagation of horse riding among members of the general public (Pruski, Grabowski, Schuch, 1963, p. 607). The Prussian military initiated a number of ventures that aimed at improving the manner in which the horse could be used. Manèges were built to allow introduction of elements of the Haute Ecole to everyday training in order to develop obedience and other desirable qualities that a well-trained cavalry horse should demonstrate in the battlefield. These efforts to harmoniously cultivate the inborn predispositions of the horse lay at the foundation of the gradually emerging dressage. Literature on the subject contains references to a dressage contest held in Bratislava as early as in 1873 (Wójcik, 2010, p. 19). Soon the principles of the new equine discipline spread to other European countries.

Yet it was not dressage but jumping that attracted decidedly more enthusiasm. Apart from the military, it was practiced also by the aristocracy and rich landowners. A good example was Prince Friedrich Karl of Prussia, member of the German equestrian team for the 1912 Summer Olympics in Stockholm, where the first Olympic show jumping event was held (Łysakowska, 2000). In the history of the region, Prince Friedrich came to be remembered as the first equestrian Olympian, one whose successes in the arena led to an increased popularity of horse riding and an official decision to begin construction of a hippodrome in Insterburg in 1919 (Knoblauch, 1939). Before long the new arena and the thriving horse breeding industry of East Prussia elevated the region to the forefront of European equestrianism (Lehndorff, 1980, p. 113).

High command of the Prussian army attached great importance to the quality of the military horse. Rigorous specifications for equine breeders to comply with were formulated and a variety of tools to test and further improve the condition of the supplied stock were devised. One of them was the Military Horse Championship initiated in France in 1900, a bravery test to fathom the usability of the horse for patrolling missions and other cavalry operations (Urban, 2003, p. 165). It triggered the appearance of yet another equestrian sport, today known as eventing, whose complexity is perhaps best expressed by its French name: '*Concours Complet d'Equitation'*, i.e. the comprehensive equestrian contest. From the start, Trakenher horses proved successful in this extremely difficult discipline, as the first official contest held in Lucerne in 1927 was won by a Prussian aristocrat, Prince Friedrich Sigismund (Łysakowska, 2000, p. 28).

Goal and methodology

This paper intends to outline the background and the context of the development of equestrian sports in Varmia and Masuria and the establishment of Polish state studs and stallion stations in the region. Research data used in it were sourced from publications by German authors (Knoblauch, 1939; Lehndorff, 1980; Schute, 1987; Donhoff, 1988), a Belarusian author (Kamzolov, 2002), and Polish authors (Josse, 1959; Pacyński, 1960; Urban, 2003; and Wójcik, 2010), their analysis reveling various stages in the growth of horse reproduction sites and their impact on the popularity of recreational horse riding and the quality of sports results achieved by members of stud-based riding sections in the region. A substantial amount of essential information on equestrian competition was also obtained from official records of Liski and Rzeczna Studs and local press, as well as master's theses and doctoral dissertations.

Equine breeding traditions in Varmia and Masuria

Horse breeding had flourished in the region when it was still East Prussia, with Trakehnen Stud being a jewel in the crown of the local equine breeding industry (Kamzolov, 2002). In time, the establishment was expanded to include an indoor manège, a race track, and a jockey school (Kamzolov, 2002). Among another six breeding sites administered by the government in Konigsberg were two stallion stations, in Rostenburg (today's Kętrzyn) and in Braunsberg (Braniewo), both initially overseen by a senior stable master, later on by a renowned hippologist, Gustaw Rau (Wójcik, 2010). Every year they supplied large numbers of fine horses to their principal customer, the Prussian army.

But horses were bred successfully also on country estates of the local aristocracy and gentry. The elite of the Prussian society of the time, who customarily considered the horse an indispensable element of everyday life, had set up a network of twenty-seven private stud farms such as, for example, Geissels (Gisiel), Prokelwitz (Prakwice), and Gr. Bestendorf (Dobrocin), all located near Mohryngen (Morąg), the birthplace of writer Walther Harich (1888–1931), author of 'Der Aufstieg' saga, or the already mentioned Rastenburg Stud, which prided itself on producing three superb mounts: Fasan, Nurmia, and Kurfust. Together with their riders, these splendid animals won medals during the 1936 Olympic Games in Berlin, bringing well deserved glory to the region. Not far from Braunsberg, home to Richard Schirmann, keen advocate of tourism for schoolchildren, thrived a stallion station and Korbsdorf Stud. In another corner of East Prussia, Preußsich Holland (Pasłęk), horses were bred in Jankendorf (Jankowo), Slobitten (Słobity), Schodien (Gładysze), and Behlendorf (Bielica) (Josse, 1959, p. 76; Wójcik, 2014, p. 334). Finally, one must not forget a land estate near Bartenstein (Bartoszyce) owned by Mr. von Kuenheim (Grodzicki, Pacyński, 1966, p. 7), and a stud farm in Loyden (Lojdy) belonging to a German landowner by the name of Negeborn.

Summing up, after World War 1, East Prussia exported horses to 14 countries in Europe, North America, and Asia (Kamzolov, 2002, p. 110), and the Prussian town of Insterburg repeatedly hosted German national equestrian teams training for three consecutive Olympiads: in Amsterdam (1928), Berlin (1936), and Helsinki (1940) (Kamzolov, 2002). Without the necessary facilities and years of experience neither of these would have been possible.

State studs and stallion farms in Olsztynskie Province

1947 was a breakthrough year for Polish horse breeders and equestrians in Varmia and Masuria. This is when, on the initiative of dr. Witold Pruski, head of the Horse Breeding Department of the Polish Ministry of Agriculture and Agricultural Reform, and in collaboration with Adam Sosnowski of the Sopot Branch of the Polish State Horse Breeding Farms, the first stage of restoration of horse breeding in the region began, a process which soon gave impetus to the development of equestrian sports in Olsztyńskie Province. In April 1947, former Prussian Rastengurg estate was reopened as Polish Kętrzyn Stallion Station (Wójcik, Skrzypczak, 2014, p. 241). A month later, three other sites began to operate, Garbno, Liski, and Rzeczna Studs respectively (Josse, 1959, p. 74). In the beginning, none of these ventures exhibited a strictly horse breeding or equestrian orientation per se. Their initial role consisted mainly in rounding up horses of all breeds scattered across the country and receiving equines that had either been imported or repossessed.

For a number of years Liski Stud was a leading enterprise in the region. Its staff had been obligated to learn to ride, and their horsemanship skills were demonstrated to the general public at a variety of events held either on site or in the vicinity. Since other stud farms did the same, together they became a natural basis for the local equestrian movement, which, in the course of time, transformed into a fully-fledged sport (Wójcik, 2010).

Braniewo (formerly Braunsberg) had had years of experience and offered technical facilities that survived the war in a relatively unscathed condition. This is where, in 1951, an official equestrian contest was organized as part of a Polish-Soviet comradeship festival. Solely amateur and primarily propagandist in character, the competition attracted teams of riders from many newly-established state studs. Events like this integrated local horse breeders and laid the foundation for the emergence of equestrian sports structures in the future.

Meanwhile, with considerable support from Mr. Witold Podczasi, former Hohenzollerns' manor by the name of Kadinen was transformed into Kadyny State Stud (Francuz, 1966, p. 3). The underlying idea here, too, was that Trakenher horse should be brought back to places where the breed had originated in order to assure optimal conditions for its further growth, and, as was already mentioned, Varmia and Masuria boasted centuries-long tradition in this respect.

Another important development that came about in 1951 was the foundation of the Central Stud Farms Management Agency, headed by Stanisław Arkuszewski, former Polish cavalry officer and former director of the Polish State Horse Breeding Farms. Mr. Arkuszewski then helped to constitute the Equestrian Section of the Central Physical Education Board, and chaired it for several years, so a prospect of reactivation of equestrian sports gradually opened up. Indeed, a host of propagandist horse-riding competitions were soon held all across the country. At the time there were 10 stud farms in Varmia and Masuria, and another 44 studs and 14 stallion stations in other parts of Poland (Grabowski, 1973), with a stock of 2,768 mares and 1,885 stallions in total (Grabowski, 1982, p. 84). Generally speaking, the first half of the 1950s was characterized by an intense growth in popularity of equestrian recreation, which shortly led to the emergence of equestrian sports. Olsztyńskie Provice, with a well-developed network of horse-breeding establishments and good quality of breeding stock, lent itself remarkably well to equestrianism. It is no coincidence then that riders from Varmian and Masurian stud farms, i.e. Henryk Choczilewski (Liski Stud), Edward Perzyna (Braniewo Stud), and Stanisław Przybylak (Plękity Stud), were selected to join the Polish national equestrian team (APO, WKKF, No. 444/22, p. 57). The early 1950s was also a period when equestrian sports picked up the much needed momentum. Masurian horses did very well both in driving and under saddle, even though it was not until the beginning of the 1970s that the Polish government finally sanctioned saddle horse breeding and introduced a clear breeding policy to go with it. That certainly did not stop other nations, such as Austrians, Belgians, Swedes, Italians, and the Dutch, going from strength to strength astride their Varmian-Masurian mounts in equestrian arenas all over the globe (Wójcik, 2010).

Role of horse breeding industry in the development of equestrians sports

The equestrian movement in Varmia and Masuria was initiated by chief state stud administrators, who were, as a rule, keen enthusiasts of horsemanship. In the pioneering years following the end of WW2, it was through their perseverance that the finest stock would be presented to audiences gathered for in-house stud fests and picnics, and the best horsemen among the grooms put on shows of riding prowess. In this way approval of local government officials was won, allowing inter-stud competition to begin. Since no formal equestrian sport structure existed at the time, the competition, chiefly in jumping, had to be organized by state stud managers themselves. In 1952, two local riding teams and their horses, one form State Stallion Station in Braniewo, the other from State Stallion Station in Kętrzyn, made their debut at a national-level equestrian contest in Wrocław (Habinowska, 1986, p. 71). Years of hard selective work paid off in 1955, when Henryk Choczilewski of Liski Stud won the first bronze medal in jumping at the Polish National Championships in the post-war history of the region. This extraordinary success would not have been possible without his splendid mount, Bosman, well prepared for the occasion by a local zootechnician and horse trainer (ASOSG, p. 121). National championships that came along in the following years brought new triumphs. Ultimately, in 1956 the original between-stud-farm-rivalry transformed into regular sports competition, the first local contest of the kind to be held on April 29, 1956 (Wójcik, 2010, p. 231).

In-house riders competed on the best horses bred on their own stud farms. These were, for example, Bosman, Boksana, Bolgamie, and Chloe at Liski Stud; Czarnków, Czarownik, War, and Kulnar at Rzeczna Stud; Wareg, Wolbórz, and Pregor at Kętrzyn Stallion Station; and Narwik, Balador, and Klejnot at Braniewo Stallion Station. The situation was similar in less renowned, rural sites such as Plękity, Kadyny, Warniki Łozaj, Popielno, and Kroplewo, although their horses, originating from breeding stock of lesser quality, were bound to achieve successes of much less spectacular a caliber. Nonetheless, pairs from all these stud farms participated with great enthusiasm in regional and zonal competitions. They were soon joined by equally enthusiastic contestants from breeding establishments located in the neighboring provinces, participation in these events having become an excellent form of advertisement and evaluation of the quality of breeding.

Due to systematic advances in horsemanship and passionate involvement of horse riding staff of Liski Stud, national-level competitions came to Varmia (i.e. to Bartoszyce) in 1960 (ASKL, p. 2; Już pierwsze zgłoszenia..., 1960, p. 2). The inaugurating contest brought together riders and 94 horses from 13 clubs from all across the country, including members of the Polish national equestrian team (Marian Babirecki, Andrzej Kobyliński and Andrzej Orłoś), training for the Olympic Games in Rome at the time. A large number of spectators arrived in the town hosting the event, many of them Polish buyers intending to purchase the finest horses. It should be noted that, at the very same time, Venice, Italy, was the venue of the European Junior Championships in jumping, where Poland was represented by two brothers, Antoni and Tomasz Pacyński, both Liski Stud in-house riders. Their performance in this prestigious competition brought much splendor to the region and the country because Antoni, astride a local horse named Bolgami, won a silver medal in individual contest, and his excellent disposition contributed significantly to the Polish team winning a silver medal (Chachuła, Bucholc-Ferenstein, 1981, p. 167). For the record, these were not the only Polish triumphs in European Championships.

Two years after the Venice success, in view of the ever improving results in horse breeding and sports competition in the region, Polish Equestrian Association decided that the next Polish Championships should be held in Olsztyn. Out of 77 participants, as many as six were local equestrians. They performed very well, and the good impression they had made was seen as a promise of major successes in the future. In 1963 Varmia and Masuria finally became the venue of an international equestrian contest. While it was in progress, the executive board of Polish Equestrian Association arrived in Olsztyn for a two-day session (June 16–17, 1963). This is how they commented on their choice: *Varmia and Masuria is a region that excels in horse breeding, not only in Europe, but* *also in the world. That is exactly why we decided to locate the international equestrian contest here. Western Europe prides itself on Aachen, we intend to be the best in Eastern Europe* (*Głos Olsztyński*, 1963, p. 6).

For over ten years to come annual competitions under the auspices of the International Federation for Equestrian Sports helped promote the horse breeding industry and the equestrian movement which local breeders so ardently supported. Not surprisingly, further triumphs soon followed. In 1964, representing Rzeczna Stud, Michał Siemion on Condylus won a bronze medal at the Polish Championships in dressage. It was not long before two other riders from the same facility, Bernard Kuleta and Henryk Hucz, began to score successes, too. Rzeczna Stud produced excellent stock, too: a mare named Drobnica, ridden by Jan Kowalczyk, member of the Polish national equestrian team, was well known at arenas around the world. Other horse athletes that made local equestrian history were Bojgard, Deptak, and Wodnik.

In 1966 Varmia and Masuria's horse breeding industry attracted attention of the central government in Warsaw. Between July 4 and July 8 that year all state studs and stallion stations in the region were visited by members of the Equine Breeding Commission, an advisory body to the Research Council for the Animal Husbandry Union. The visit ended in an official session, chaired by dr. Jan Grabowski, during which the researchers adopted a four-item resolution that began with the following sentence: '*The quality of horse breeding in Masurian studs is high and the breeding policy purposeful*' (*Koń Polski*, 1966, p. 42). Local breeders and equestrians received this complimentary opinion with great satisfaction. That it was well deserved was confirmed two years later when a Liski Stud rider, Marcin Pacyński on Legat, won a bronze medal in team eventing in France during the Junior European Equestrian Championships (Gaj, 1987, p. 262). By that time Masurian mounts were already in high demand, the finest of them often used by breeders of the Wielkopolski horse. Many that proved themselves in competition got sold to Canada, Germany, and the USA. Polish riders would often be competing against some of them in European and Olympic arenas around the world (Wójcik, 2010, p. 80).

In 1970, Olsztyn hosted the Polish Equestrian Championships for the second time. Although six local pairs successfully represented the region, only one of them, Antoni Pacyński (Liski Stud) on Leonidas, winners of the silver medal in dressage, was numbered among top pairs of the event. Antoni's brother, Tomasz Pacyński (Kadyny Stud) on Sztorm came in third (Wójcik, 2010, p. 291). Popularity of equestrianism in Varmia and Masuria in the 1970s soared. Horsemen from local studs enjoyed recognition in national and European arenas. A good example was Tadeusz Czermiński of Rzeczna Stud, who in 1974 won a bronze medal in four-in-hand driving in team competition (Czermiński, 1998, p. 107), and repeated his success the following year, at the 1975 European Championships in Sopot (*Koń Polski*, 1975, p. 18). Incidentally, Prince Philip, Duke of Edinburgh, who was a contestant in the Sopot driving contest, must have found the quality of the local horse population of interest because immediately after the championships were over he paid a visit to Rzeczna Stud (Wójcik, 2012, p. 195). Before the 1975 season came to an end, equestrians from Olsztyn had won as many as five medals at Polish championships, which was, and still is, by far the best result achieved by a single horse-riding club in the post-war history of Polish equestrianism.

However, an achievement that calls for particular acknowledgement is the fact that a tiny village of Liski produced riders who managed to qualify for Olympic-level competition. Antoni Pacyński on Cirrus[1] competed in the 1968 Summer Olympics in Mexico. Of a group of 20 riders training for the next Olympiad in Munich (1972), as

[1] A. Pacyński came in 38th in individual competition, and 10th, together with Jan Kowalczyk, Marian Kozicki, and Piotr Wawryniuk, in team competition (cf. Urban, 2013, p. 367).

many as three represented small local riding clubs: Stefan Grodzicki (Liski Stud), Henryk Hucz (Rzeczna Stud), and Tomasz Pacyński (Kadyny Stud) (Wójcik, 2010, p. 330). Ultimately, only Stefan Grodzicki and his mare, Biszka, made to the national Olympic team.[2]

Successes of these and of many other equestrians from Varmia and Masuria (for example Polish championships contestants) are still vividly remembered and appreciated. Some equestrian careers of the time have for years been held up to new generations of horsemen and horsewomen as examples to follow (see competition results in Table 1).

Table 1. Results of competitors from Warmińsko-Mazurskie breeding centers in the Polish Senior Equestrian Championships (1955–1975)

Competition	Dressage Competition	Jumping Competition	The Three-Day Event
1	2	3	4
1955	**Sopot**	**Sopot**	**They were not played**
Champion	Marek Roszczynialski (Ariol) – Stubno	Maciej Świdziński (Argun) – Moszna	–
I vice champion	Tomasz Tokarczyk (Bej) – Racot	Władysław Byszewski (Besson) – Moszna	–
II vice champion	Bernard Gellert (Bałagan) – Racot	**Henryk Choczilewski (Bosman) – Liski**	–
1957	**Poznań**	**Poznań**	**Łobez**
Champion	Wojciech Zbanyszek (Dystanz) – Łobez	Marian Kowalczyk (Pregor) – Poznań	Marek Roszczynialski (Ariol) – Łobez
I vice champion	Romana Orłowska (Bagalpur) – Poznań	**Antoni Pacyński (Bosman) – Liski**	Jan Kowalski (Czar Walca) – Sieraków
II vice champion	Feliks Drozd (Bałagan) – Racot	Jan Kubiak (Erotyk) – Kwidzyn	Only two riders he finished the competition
1960	**Wrocław**	**Wrocław**	**They were not played**
Champion	Marian Babirecki (Volt) – Kwidzyn	Stanisław Kubiak (Wareg) – Kwidzyn	–
I vice champion	Marian Kowalczyk (Mitrydat) – Poznań	**Antoni Pacyński (Bolgami) – Liski**	–
II vice champion	Andrzej Orłoś (Botwid) – Kwidzyn	Marian Kowalczyk (Pregor) – Poznań	–
1964	**Gniezno**	**Gniezno**	**Łobez**
Champion	Marian Babirecki (Volt) – Moszna	Andrzej Orłoś (Bao Day) – Kwidzyn	Marian Babirecki (Volt) – Moszna
I vice champion	Janusz Nowak (Britus) – Poznań	Franciszek Ciebielski (Hrabia) – “Legia” Warszawa	Andrzej Orłoś (Dysproz) – Kwidzyn
II vice champion	**Michał Siemion (Condylus) – Rzeczna**	Janusz Nowak (Britus) – Poznań	Only two riders he finished the competition
1967	**Poznań**	**Radom**	**Poznań**
Champion	Marian Kowalczyk (Sekt) – Poznań	Jan Kowalczyk (Drobnica) − “Legia” Warszawa	**Bernard Kuleta (Wodnik) – Rzeczna**
I vice champion	Marian Babirecki (Grigorij) – “Legia” Warszawa	**Stefan Grodzicki (Biszka) – Liski**	Zbigniew Madejczyk (Demon Schagya) – Bogusławice
II vice champion	Janusz Nowak (Istambuł) – Poznań	Antoni Pacyński (Remus) – “Służewiec” Warszawa	Stefan Kumorek − (Nalot) “Podhalanin” Wadowice

[2] S. Grodzicki came in 16th–20th individually, and 12th in team competition (cf. Urban, 2013, p. 367).

1	2	3	4
1968	**Poznań**	**Nie rozgrywano**	**Poznań**
Champion	Marian Kowalczyk (Sekt) – Poznań	–	Zbigniew Ciesielski (Skok) − "Legia" Warszawa
I vice champion	Wojciech Mickunas (Dżemila) – Poznań	–	Wojciech Mickunas (Dżemila) – Poznań
II vice champion	Marek Skrzypczyk (Herszt) – Bogusławice	–	**Bernard Kuleta (Wodnik) – Rzeczna**
1969	**Kwidzyn**	**Kwidzyn**	**Racot**
Champion	Marian Kowalczyk (Sekt) – Poznań	Jan Kowalczyk (Blekot) − "Legia" Warszawa	Wojciech Mickunas (Dżemila) – Poznań
I vice champion	Gerard Fröllich (Gładzysz) – Kwidzyn	**Stefan Grodzicki (Biszka) – Liski**	Mirosław Szefer (Nalot) – "Podhalanin" Wadowice
II vice champion	Wojciech Mickunas (Dżemila) – Poznań	Stefan Stanisławiak (Scheda) – Racot	Stefan Kumorek (Bałagan) – Klikowa
1970	**Olsztyn**	**Olsztyn**	**Książ**
Champion	Marian Kowalczyk (Sekt) – Poznań	Jan Kowalczyk (Blekot) – "Legia" Warszawa	Zbigniew Madejczyk (Bursz) – Bogusławice
I vice champion	**Antoni Pacyński (Leonidas) – Liski**	Piotr Wawryniuk (Poprad) – Poznań	Gerard Fröllich (Gładzysz) – Kwidzyn
II vice champion	Tomasz Pacyński (Sztorm) – Kadyny	Marian Kozicki (Bronz) – "Legia" Warszawa	Wojciech Mickunas (Giecz) – Racot
1971	**Warszawa**	**Warszawa**	**Starogard Gdański**
Champion	**Antoni Pacyński (Leonidas) – Liski**	Piotr Wawryniuk (Poprad) – Poznań	Zbigniew Ciesielski (Damaszek) − "Legia" Warszawa
I vice champion	Marian Kowalczyk (Sekt) – Poznań	Marian Kozicki (Bronz) – "Legia" Warszawa	Jacek Wierzchowiecki (Mistral) – Poznań
II vice champion	**Stefan Grodzicki (Tarnów) – Liski**	**Stefan Grodzicki (Biszka) – Liski**	Wojciech Mickunas (Giecz) – Racot
1972	**Warszawa**	**Warszawa**	**Biały Bór**
Champion	**Antoni Pacyński (Porfir) – Liski**	Marian Kozicki (Bronz) – "Legia" Warszawa	Wojciech Mickunas (Armator) – Racot
I vice champion	**Stefan Grodzicki (Tarnów) – Liski**	Jan Kowalczyk (Blekot) – "Legia" Warszawa	Jan Skoczylas (Cyrjak) – "Podhalanin" Wadowice
II vice champion	Krzysztof Tomaszewski (Haust) – Łąck	**Stefan Grodzicki (Biszka) – Liski**	Jan Kłym (Plutokrata) – "Legia" St. Miłosna
1973	**Warszawa**	**Warszawa**	**Poznań**
Champion	Jerzy Pawłowski (Diogenes) – Kwidzyn	Jan Kowalczyk (Blekot) – "Legia" Warszawa	Jacek Wierzchowiecki (Gniew) – Poznań
I vice champion	**Stefan Grodzicki (Tarnów) – Liski**	**Stefan Grodzicki (Biszka) – Liski**	**Józef Zagor (Kosa) – Rzeczna**
II vice champion	**Antoni Pacyński (Porfir) – Liski**	**Henryk Hucz (Bertyn) – Rzeczna**	Jan Kłym (Plutokrata) – "Legia" St. Miłosna
1974	**Kwidzyn**	**Warszawa**	**Kwidzyn**
Champion	**Antoni Pacyński (Porfir) – Liski**	Jan Kowalczyk (Blekot) – "Legia" Warszawa	Marek Małecki (Sirca) – Moszna
I vice champion	**Stefan Grodzicki (Tarnów) – Liski**	Rudolf Mrugała (Farsa) – Moszna	Krzysztof Aftyka (Odynit) – "Legia" St. Miłosna
II vice champion	Krzysztof Tomaszewski (Haust) – Łąck	Wiesław Dziadczyk (Via Vitae) – Kozienice	Józef Kutysz (Orlik) – "Legia" St. Miłosna
1975	**Biały Bór**	**Sopot**	**Biały Bór**
Champion	Krzysztof Tomaszewski (Haust) – Łąck	Jan Kowalczyk (Darlet) – "Legia" Warszawa	Piotr Skwira (Borta) – Nowielice

1	2	3	4
I vice champion	**Stefan Grodzicki (Kobryń) – Liski**	**Antoni Pacyński (Postawa) – Liski**	Mirosław Ślusarczyk (Dariusz) – "Legia" St. Miłosna
II vice champion	**Antoni Pacyński (Porfir) – Liski**	**Henryk Hucz (Bertyn) – Rzeczna**	Krzysztof Aftyka (Czad) – "Legia" St. Miłosna

Source: own study based on Wójcik (2010).

Recapitulation and conclusions

Based on the study of the process of establishment and operation of equine breeding sites in Varmia and Masuria the following conclusions can be formulated:

1. Long tradition of horse breeding in former East Prussia exerted dominant influence on horse breeding efforts continued in Varmia and Masuria after the region had become part of Poland.
2. First Polish stud farms and stallion stations in the region were started in 1947 at four locations, Liski, Rzeczna, Garbno, and Ketrzyn, using the remaining Prussian infrastructure and Trakenher and East Prussian stock that survived the war.
3. Equestrian sports began to emerge soon after horse breeding facilities resumed operation, and were a direct reflection of the improving quality of the breeding stock. Outdoor picnics and fests organized by state stud managements initially played the role of horse bravery tests. To see how stock breeding and horse training endeavors of individual establishments compared, inter-stud horse riding contests were introduced. In time, these led to the creation of an official system of regional equestrian competition, which in turn allowed in-house stud riders to compete at higher levels (zonal, national, and international).
4. Equestrianism helped promote the horse breeding industry, and the results achieved in equestrian competition were strongly correlated with the quality of the stock.
5. Between 1947 and 1975, local equestrians won:
   - 24 medals at Polish championships,
   - 5 medals at European championships,
   - 1 medal at world championships.
6. National competition, but most importantly, participation in European championships, world championships, and Olympic games, confirmed high quality of horse breeding in the region.
7. Over the years, in-house state stud riders and their horses competed at a number of Polish and European championships and, on one occasion, world championships (Tadeusz Czermiński's four-in-hand, Switzerland, 1974). The ones that contributed the most to the promotion of regional horse breeding and horse riding endeavors were Antoni Pacyński on Cirrus and Stefan Grodzicki on Biszka, who took part in Olympic-level competition (Mexico, 1968, and Munich, 1972).

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THE EFFECT OF VISUAL SPEED SWIMMING CONTROL IN SWIMMERS' THRESHOLD TRAINING

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Abstract Controlling swimming speed is an important factor as far as accomplishing swimming training tasks is concerned. The aim of this study was to determine the importance of visual information about control of swimming speed in threshold training for swimmers. Six swimmers took part in this experiment. The study consisted of two exercise tests in which the participants swam 10 × 100 m. Individually designated task time corresponded to intensity of 95–100% of anaerobic threshold (AnT) intensity. AnT was determined in a progressive test prior to the experiment. In the first exercise test participants did not receive information regarding their swimming speed. In the second test visual information regarding their swimming speed was transmitted in real time using the Swimming Pace Control System device. The effect of visual control of swimming speed in threshold training for swimmers was determined by measuring the time needed to complete the test distances, heart rate and lactate concentration. Visual information used in swimming speed control in real-time statistically significantly reduces the differences between the assumed and actual time needed to complete the test distance ($p = 0.057$). Visual control of swimming speed resulted in an appropriate level achievement of intensity for threshold training, which was measured by swimming time (inaccuracy $\bar{x}$6.97 ±1.38 s), heart rate ($\bar{x}$162.7 ±15.9 beat/min), and lactate concentration ($\bar{x}$4.70 ±1.78 mmol/l). Comparing the increase in lactate concentration and exercise test with visual information, statistically significant differences are not observed ($p = 0.710$, $p = 0.947$). However, among 33.33% of the subjects, lactate concentration after training without visual information did not meet the standards (4 to 5 mmol/l) of threshold training (8.85 mmol/l and 14.57 mmol/l). Additionally, value of standard deviations of lactate concentration after threshold training with visual information amounted to 37.87% mean of lactate concentration, and in the condition without information 84.00% mean of lactate concentration. The results indicate the need to use concurrent visual information provided in real-time allowing you to control the swimming speed in swimming training.

Key words controlling, swimming speed, visual information, threshold training

Introduction

Speed control in sports training is a multi-faceted issue (Micklewright et al., 2012; Szczepan, Zatoń, Klarowicz, 2016). Speed measurement determines the absolute intensity of physical exercise. However, determining the relative intensity is dependent on the swimmer's current training level.

Speed control facilitates stabilization of an athlete's technique. This, in turn, lowers the physiological cost of physical exercise and improves exercise economy (Barbosa et al., 2005; Wilmore, Costill, Kenney, 2008). Speed stability allows the athlete to conserve the energy needed to perform the exercise and pass longer distances.

Maintaining a given speed is essential in improving athletes' technique during different exercise intensities, and high-intensity exercise in particular. High-intensity exercise often results in reduced motion precision, thus making it more difficult to perform with optimum technique.

Exercising with a given intensity determines the improvement of projected exercise capacity. This increases the chance for faster adaptation to the physical activity which is being performed (Costill et al., 1991; Bishop, Edge, Davis, Goodman, 2004; Glaister, 2005). Moving at a given speed within designated intensity zones, for example, above or below the anaerobic threshold, is used in the process of adaptation to appropriate lactate concentration (Pérez, Llana, Brizuela, Encarnación, 2009; Scruton et al., 2015). Inexperienced athletes often cannot maintain proper speed, thus failing to maintain proper intensity. In this case, speed control can help with precisely maintaining speed.

Controlling swimming speed allows the swimmer to accomplish a training task with a given intensity. Exercise intensity are categorized into five zones. The first and second training zones (aerobic) involves effort at speeds beneath the anaerobic threshold (AeT). The third training zone (aerobic/anaerobic) is performed at an intensity between the anaerobic threshold and maximum oxygen uptake (VO_{2max}). The fourth (anaerobic) training zone involves effort at VO_{2max}. The fifth (anaerobic) zone is above the VO_{2max} (Bompa, Haff, 2009). Effort in last two zones produce significant concentrations of blood lactate, in which the threshold is termed as the onset of blood lactate accumulation (OBLA) (Bishop et al., 2004).

Threshold intensity is associated with the anaerobic threshold (AnT), which can be determined by ventilation or acidosis (Sharkey, Gaskill, 2013). Reaching the anaerobic threshold indicates the exercise intensity at which lactate utilization processes are slower than its production. Anaerobic threshold occurs during prolonged physical activity of increasing or variable intensity.

Threshold training is employed in a number of sports and used to develop many capacities. This training improves aerobic capacity, leading to greater efficiency (Larsen 2003; Diebel, Newhouse, Thompson, Johnson, 2017), developing cardio respiratory fitness through an increase in cardiac output and stroke volume (Hellsten, Nyberg 2015), an increase oxygen consumption, minute ventilation, and lung surface diffusion (Bassett, Howley, 2000). In addition, such training affects the development of slow-twitch fibres through an increase in the number of mitochondria and myoglobin concentration, and enhances the activity of oxidation enzymes (Ponsot et al., 2006). Such training helps in deferring the occurrence of anaerobic threshold in favour of higher muscle power (Rizzato et al., 2017).

During the threshold training, it is important to maintain a constant intensity that can be controlled using a predetermined time/speed. In addition, when speeding on a given distance, the speed should be constant. The stable threshold speed prevents excessive production of lactate in the blood and enables the implementation of the assumed goals of training.

The arguments raised suggest that using effective means of speed control during a swimming threshold workout is advisable. Hence, relaying information regarding elapsed time and swimming speed to athletes – that is, the intensity of their exercise – is a major role of the coach. This kind of information is often relayed verbally. However, it is not feasible in certain conditions. In an aquatic environment, interference in the process of information exchange occurs. Some examples are ambient noise, head submerged in the water, and swimming caps. They interfere with the exchange of information between coach and athlete.

Attempts to improve the flow of information between swimmer and coach have been undertaken. Zatoń, Szczepan (2014) showed a device for wireless verbal communication with a swimmer which employed radio waves. Turner, Smith, Coleman (2008) used an audio system which informed about swimming pace. Visual information, which also helps improve the performance of motor activities, has additionally been used (Anderson, Magill, Sekiya, Ryan, 2005; Andrieux, Proteau, 2016). Gonzalez et al. (2002) and Pérez et al. (2009) relayed information regarding elapsed time using a chronometer placed at the bottom of the pool. Zatoń, Kędrak, Rejman (2016) used a trolley with mirrors which moved along the edge of the swimming pool as a means of improving breaststroke.

The aim of this study was to determine the importance of visual information about control of swimming speed in threshold training for swimmers. It was assumed that visual control of swimming speed would allow an appropriate level of intensity for threshold training to be achieved, which was measured by swimming time, heart rate, and lactate concentration.

Materials and research methods

Participants

Six healthy swimmers – members of the University swimming team – took part in this experiment: age $\bar{x}$19.67 ±4.23 yo, height $\bar{x}$183.83 ±10.65 cm, weight $\bar{x}$69.83 ±9.87 kg, duration of training $\bar{x}$6.43 ±0.79 yr, 100 m freestyle personal best $\bar{x}$58.33 ±4.13 s. The relatively small size of the study group was associated with the pilot nature of this study. Each of the participants gave informed consent in writing. The Ethics Committee of the University approved the conduct of the study. Participants were asked to maintain a normal diet and avoid any strenuous physical activity during the study period (Thoma, Nelson, Silverman, 2015).

Procedure

Before the main tests, participants performed a warm-up, swimming 200 m in an anaerobic threshold. Intensity and warm-up was supervised by an exterminator. 2.5 minutes after the warm-up in the water, the blood lactate concentration and heart rate were measured.

The study consisted of two main exercise tests that started 5 min after warm-up. The main exercise tests were performed at a 24-hour interval. In both trials a water start was used. In the first and second exercise test the participants performed threshold training.

Due to the numerous interpretations of the threshold training intensity, the work intensity was adjusted to 95–100% intensity of the anaerobic threshold (AnT). AnT was determined according to methodology of Binder's et al. (2008) in a progressive test performed prior to the experiment.

The flow time (corresponding to the flow velocity) during the test tests was calculated using the formula. In the applied threshold training, subjects flowed 10 × 100 m front crawl with a speed corresponding to 95–100% intensity AnT. Between the repetitions, a 60-second break was used.

The study participants were tasked with swimming all ten repetitions in a time as close as possible to the individually designated time determined prior to the experiment. In the first exercise test, those participating in the threshold training did not receive any information regarding their swimming speed. In the second exercise test, visual information regarding swimming speed was transmitted in real time.

In this test the participants followed a beam of light moving across the bottom of the swimming pool, which was emitted by the Swimming Pace Control System (SPCS) (Creosiv, PL) device (Figure 1). SPCS device enables delivery of visual information about swimming speed in real time. System submerged at the bottom of the pool is equipped with LEDs and software informing the swimmer of the appropriate distance and swimming speed. A beam of light from the SPCS device covered the distance precisely within the time which had been designated for each participant prior to the experiment. A validation test of SPCS was completed with an accuracy of ±200 ms (Szczepan, Zatoń, 2017).

Figure 1. Swimming Pace Control System (SPCS) device before installation at the bottom of the swimming pool

Measurement

Measurements of time/speed, heart rate and lactate concentration were taken.

Measurement of time t(s) needed to complete the test distances was performed electronically, with an accuracy of 0.01 seconds. The Colorado start system (Colorado Time System, USA) was used for this purpose. After each test, time differences between the time designated for a given test subject and the actual time needed to complete the test distance in both variants (with visual speed control and without) were calculated.

Lactate concentration La (mmol/l) was determined using the enzymatic method (Hydrex, Italy). Arterialised fingertip blood was used in this assessment. Blood was diluted with a cold isotonic solution containing NaCl and NaF. Lactate concentration during the research tests was measured three times: (A) before the test – 2.5 min after the warm-up, (B) midway – halfway through the test and (C) after the test – 3 min after completing the test when the lactate concentration had a maximum value (Goodwin, Harris, Hernández, Gladden, 2017).

Heart rate Hr (beat/min) was recorded before (resting) and after (post-exercise) each test using POLAR sport tester (Polar Electro, Finland).

Statistical analyses

The statistical analyses used Student's T-test for paired values. Statistical analyses were performed in Statistica 9.0 (StatSoft, USA). Using t-test was a proper way to determine differences between variables (Thoma et al., 2015). To check whether a given distribution of the quantitative variable is normal, the difference between the observed distribution and the ideal one was checked. An insignificant result ($p > 0.05$) allowed assuming that the observed distribution has a normal shape.The absolute value (accuracy) between the assumed and actual time needed to complete the test distance in both situations (with visual speed control and without) was analysed.

The significance of the increase in lactate concentration prior to the test (A), midway (B), and after the test (C) in two condition was also calculated.

Additionally, the significance in the increase of lactate was calculated as well.

Results

In condition with visual information performed task was significantly more accurate in time ($p = 0.057$) compared to the condition without information, as evidenced by a decrease in the time difference.

It is interesting that after summing up all the differences in time for ten replications, the subjects obtained an inaccuracy equal to Σ = 41.80s (with visual information) and Σ = 89.70s (without visual information). Inaccuracy in time was a measure of sum of absolute values of differences between the scheduled time and elapsed time (Table 1).

Table 1. Inaccuracy in time in two conditions (with and without visual information)

	visual speed control Δt (s)	no visual speed control Δt (s)
	sum of inaccuracies	
	7.90	23.70
	6.10	7.40
	7.00	7.20
	9.20	23.20
	6.10	21.90
	5.50	6.30
$\bar{x}$	6.97	14.95
±	1.38	8.77

Table 2 contains change in lactate (La) concentration in the research test with and without visual information. In order to determine changes in lactate concentration between test tests A, B, C for two conditions, a difference test was performed. In the test with visual information lactate concentration between research test A and B was statistically significant (p = 0.019). Between the test A, and C also statistically significant (p = 0.014). There were no significant differences between research test B and C (p = 0.830). In the sample without visual information lactate concentration between research test A and B was statistically significant (p = 0.051). Between research test A and C (p = 0.069) and between research test B and C no significant differences were observed (p = 0.611). The results show that in exercise test with visual information, the changes in lactate concentration in blood were more significant compared to exercise test without information.

In contrast, no statistically significant differences (p = 0.710) were observed between exercise test with visual information and without information. Similarly, there was no difference in increase in lactate concentration ΔLa A-C (p = 0.947).

Table 2. Change in lactate (La) concentration in the test with and without visual information

	Visual speed control						No visual speed control					
	La before the test (mmol/l)	La in the middle of the test (mmol/l)	La after the test (mmol/l)	Δ La	Δ La	Δ La	La before the test (mmol/l)	La in the middle of the test (mmol/l)	La after the test (mmol/l)	Δ La	Δ La	Δ La
	A	B	C	A–B	A–C	B–C	A	B	C	A–B	A–C	B–C
	2.11	3.53	4.28	1.42	2.17	0.75	3.20	9.85	8.85	6.65	5.65	–1.00
	1.01	8.09	7.23	7.08	6.22	–0.86	5.78	6.74	14.57	0.96	7.79	7.83
	0.92	4.50	4.83	3.58	3.91	0.33	1.70	3.52	1.98	1.82	0.28	–1.54
	1.46	4.49	4.09	3.03	2.63	–0.40	1.51	2.81	2.35	1.30	0.84	–0.46
	1.64	4.60	5.85	2.96	4.21	1.25	1.59	5.70	5.55	4.11	3.96	–0.15
	1.95	2.55	1.94	0.60	–0.01	–0.61	2.14	2.36	2.33	0.22	0.19	–0.03
$\overline{x}$	1.52	4.63	4.70	3.11	3.19	0.08	2.65	5.16	5.94	2.51	3.28	0.78
±	0.48	1.87	1.78	2.24	2.11	0.83	1.65	2.86	4.99	2.42	3.49	3.50

Discussion

Swimming speed control is important aspect of training. First, in an effort to increase the chance of a more rapid adaptation to a performance during swimming training (Costill et al., 1991). Second, is to improve the economization of the movement as a result of stabilizing the swimming speed. The stabilization of swimming speed results in a reduction in the cost of physiological exercise (Barbosa et al., 2005). Third is to improve swimming technique during high-intensity exercise. Proper selection of training loads, in particular the intensity of the swimming exercise is an important factor enabling the mastery of a sport's technique used at a given speed of swimming. Fourth is to optimize the kinematic parameters of the cycle of swimming, for example; stroke length and stroke rate. The swimming stroke length is the distance of the horizontal displacement of the swimmer during one movement cycle (Hay, 2002). For these reasons, using control of speed of swimming is an important factor in the process of optimizing sports training (Chinnasamy, St Clair Gibson, Micklewright, 2013).

It is worth noting that there are numerous communication barriers in the aquatic environment. Communication barriers are created most often by the sound of water, head submerged in the water, swimming cap, and poor acoustics at the swimming pool. In these conditions, transfer of any information at all is difficult (Zatoń, Szczepan, 2014). Many authors have concluded that visual information is an important information medium, particularly in an environment where interference in communication occurs (Andrieux, Proteau, 2016). Visual information is beginning to be used in teaching swimming (Zaton, Kędrak, Rejman, 2016), improving technique (Zaton, Szczepan, 2014) and the swimming training process (Vezos et al., 2007). Additionally, it should be noted that in terms of time, as a criterion of information quality, immediate (in real time) transmission is considered the most effective form of information passed on to people performing motor activities by many authors (Lee, Swinnen, Serrien 1994; Schmidt, Lee, 2013).

The aim of this study was to determine the importance of visual control of swimming speed in threshold training for swimmers. The main findings of the work were to prove that visual information about flow rate control improves the accuracy of the training task. Test subjects floating with visual information obtained a smaller inaccuracy in time compared to the condition without information. The sum of differences in the time of overcoming ten repetitions with visual information was $\Sigma = 41.80$s, while without information $\Sigma = 89.70$s. Differences in inaccuracy in time of execution were statistically significant ($p = 0.057$). However, it was exhibited important parameters. Some participants maintained the designated speed without visual control. On the other hand, other people could not keep the indicated swimming without being in control, swimming or too fast. Therefore, one can conclude at the same time. More experienced swimmers are not bothered by speed control, while the less advanced swimmers are clearly helped by it. The obtained results correspond with the studies of Szczepan et al. (2016), in which also improved visual information accuracy during the flow.

Achieving the right time/speed for the respondents in the research test with visual information resulted in maintaining the intensity of the training threshold. Level of intensity for threshold training, measured by heart rate, and lactate concentration. Heart rate achieved after the threshold of training corresponded to $\bar{x}$162.7 ±15.9 beat/min. In contrast, lactate concentration was $\bar{x}$4.70 ±1.78 mmol/l, which was the purpose of the threshold training. This means that the subjects achieved the characteristic value of the anaerobic threshold of the lactate value of 4 to 5 mmol/l, which subject to the training objective. Without speed control participants after threshold training also achieved a similar level of appropriate intensity (Hr $\bar{x}$160 ±21.3, La $\bar{x}$5.94 ±4.99 mmol/l). When interpreting the results of increase in lactate concentration we may conclude that there was no significant difference between the increase in lactate concentration when visual control was used and when it was not ($p = 0.710$, $p = 0.947$). However, among 33.33% of the subjects, lactate concentration after training without visual information did not meet the standards (namely 4 to 5 mmol/l) of threshold training (8.85 mmol/l and 14.57 mmol/l). Even though the mean values of lactate concentration in the blood did not differ significantly in both conditions, it did not prove that the physiological costs for each swimmer were similar. The value of standard lactate concentration after the training in both cases was different. With visual information, the standard deviation of lactate concentration was ±1.78, which was 37.87% of the mean lactate concentration 4.70 mmol/l. On the other hand, in the condition without information, the standard deviation of lactate concentration was ±4.99, which was 84.00% of the mean lactate concentration 5.94 mmol/l. The lower variation of the standard deviation in the condition with visual information indicates the need to use visual control of the swimming speed.

In the present experiment, the Swimming Pace Control System (SPCS) device (Creosiv, PL) was used to provide visual information about the flow velocity in real-time (online) (Szczepan, Zatoń, 2017). In the past, devices such as Lap Track (Finis, USA) have been used for the same purpose and are displayed on the pool wall, or a hand chronometer (SportCount Chrono, USA). Also a visual means for the transmission of information via a timer submerged at the bottom of the pool has been used (Gonzalez et al., 2002; Perez et al., 2009). Other devices such as Lider (Kuca, PL) (Szczepan et al., 2016), GBK-Pacer (GBK-Electronics, PT), Pace2Swim (FADEUP Porto, PT), and SwimLead (Synerte, PL) report the speed of swimming in real time, using a beam of light moving along the swimming pool were used as well.

The presented research results should be interpreted carefully due to several limitations. It was not assessed whether the intervals between repetitions of pressures were sufficient to eliminate fatigue that could affect the results. The results could also have been influenced by experience, hence it is not known how visual control can affect children, and how on very advanced players. Similarly, the sex of respondents who can otherwise receive visual information. In addition, due to the pilot nature of the research, the number of respondents was small. In future studies, the emphasized restrictions should be taken into account.

To sum up, swimming with a given speed helps maintaining the desired intensity of physical exercise. This is important in such situations as when threshold training with multiple repetitions is performed. Real-time (online) swimming speed control using visual information emitted from the SPCS device facilitates achieving an appropriate level of intensity for threshold training, which was measured by swimming time, heart rate, and lactate concentration. Visual control is a method that can be used during various types of swimming training, and for many training groups, which constitutes the application value of the presented results.

Conclusions

Visual information used in controlling of swimming speed in real-time statistic significantly reduces the differences between the assumed and actual time needed to complete the test distance ($p = 0.057$). That means that the accuracy of threshold training performance increases, which allows for accomplishing training objectives in a more precise manner. Visual control of swimming speed resulted in achieving an appropriate level of intensity for threshold training, which was measured by swimming time (inaccuracy $\bar{x}$ 6.97 ±1.38 s), heart rate ($\bar{x}$ 162.7 ±15.9 beat/min), and lactate concentration ($\bar{x}$ 4.70±1.78 mmol/l). Comparing the increase in lactate concentration and exercise test with visual information, significantly statistical differences are not observed ($p = 0.710$, $p = 0.947$). However, among 33.33% of the subjects, lactate concentration after training without visual information did not meet the standards of threshold training. Additionally, value of standard deviations of lactate concentration after threshold training with visual information amounted to 37.87% mean of lactate concentration, and in the condition without information 84.00% mean of lactate concentration. The lower variation of the standard deviation in the condition with visual information and the indicated results indicate the need to use concurrent visual information transmitted in real-time enabling control of swimming speed in swimming training.

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ENERGY EXPENDITURE AND INTENSITY OF INTERACTIVE VIDEO DANCE GAMES ACCORDING TO HEALTH RECOMMENDATIONS

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Abstract Backround: The aim of this study was the assessment of energy expenditure (EE) and the intensity of physical activity (PA) of adult women during the interactive dance video game (IDVG) Dance Central on Xbox 360 Kinect in the context of health recommendations.
Methods*:* Twenty eight intentionally selected women (mean ± SD age: 21.8 ±1.1 years, body height: 167.3 ±6.1 cm, body mass: 59.3 ±5.9 kg, body mass index: 21.2 ±1.3) met the inclusion criteria and took part in to the experiment. Heart rate monitor, accelerometer, and pedometer were used as measurement tools. Participants performed the same easy dance routine three times (for a total of 10 min.). Trials consisted of imitating the motions presented by the virtual dancer.
Results: The data from accelerometer and heart rate monitor were similar, and indicated the moderate intensity of interactive dance video game (IDVG) Dance Central. However, energy expenditure assessed by pedometer was significantly lower.
Conclusion: IDVG Dance Central may be useful in increasing the daily dose of physical activity of adult women and meet the health-related recommendations provided its regular practice.

Key words interactive dance video games, active video games, energy expenditure

Introduction

In the past few years, in the video game market, more and more so-called active video games (AVGs) appear, in which the user controls the game by the movements of the whole body. This leads to a much larger motor activation of the players than during the typical video games controlled by typical pointing devices. Player movements are similar to the real movements, and the participants' involvement is increased by the forms of competition used in games.

Many authors see potential health and social benefits of participation in AVGs. It is confirmed by, among others, increasing number of research on effects of using this form of physical effort in physical education (Hayes, Silberman, 2007; Levac, Miller, 2013; Trout, Christie, 2007) treatment and physiotherapy (AlSaif, Alsenany, 2015; Howcroft et al., 2012; Kimhy et al., 2016; Miller, Hayes, Dye, Johnson, Meyers, 2012; Salonini et al., 2015) and promotion of health and physical activity (Biddiss, Irwin, 2010; Smallwood, Morris, Fallows, Buckley, 2012; Studenski et al., 2010; Taylor, Kerse, Frakking, Maddison, 2016).

In previous studies only one physical activity (PA) measuring tool was used. Meanwhile, the review indicates the legitimacy of the usage in the diagnosis of PA parameters several devices at the same time, which are recording both the physiological reactions of the organism to the physical effort (e.g. exercise heart rate, energy expenditure) and kinematic parameters of movements (e.g. the movement acceleration in the body axis, the number of steps) (Hills, Mokhtar, Byrne, 2014; Mynarski, Nawrocka, Rozpara, Cholewa, Tomik, 2013; Schutz, Weinsier, Hunter, 2001; Strath et al., 2013). Such a multifaceted PA diagnosis allows assessing the potential health benefits in reference to the different criteria of health-enhancing recommendations. Among these criteria, important are energy expenditure (EE), exercise heart rate (HR), number of steps (NS) and intensity effort (IE).

The cognitive aim of the study was evaluation (diagnosis and assessment) of EE, HR, NS and IE during the interactive dance video game (IDVG) “Dance Central” among 21-year-old women, who were measured by different measuring devices (heart rate monitor, accelerometer, pedometer) and the confrontation of the results with the criteria of health-enhancing PA. We assume that IDVGs can be useful in increasing daily dose of physical activity if practiced regularly.

The usage of three measurement tools during the research was supposed to allow an initial estimation of diagnostic accuracy in the evaluation of the above-mentioned PA parameters while practicing IDVG. Presumably, data obtained with HR monitor and accelerometer during IDVG will be similar and will differ from data obtained using pedometer, because during IDVG there are few locomotive movements.

Material and Methods

Participants

The study involved 28 intentionally selected female students of the Academy of Physical Education in Katowice (see Table 1 for subject characteristics). The participants had no history of seizures or epilepsy, and they were informed about the product safety information. Participants were familiarized with the aim of monitoring of physical activity, the process of measurement and forms of the usage of its results. They did not have any previous experience with the IDVG used in this study. All participants were instructed on use of the Xbox’s Kinect system and the Kinect dance game. Procedures were approved by the Research Ethics committee of the Jerzy Kukuczka Academy of Physical Education in Katowice.

Table 1. Participants characteristic

Variables	Mean	SD
Age (years)	21.8	1.1
Body height (cm)	167.3	6.1
Body mass (kg)	59.3	5.9
BMI (kg/m^2)	21.2	1.3

Procedures

To increase the reliability of the assessment of the results of physical activity monitoring during IDVG "Dance Central", measuring devices were used to record kinematic parameters of the movements (an accelerometer (Caltrac Monitor) and pedometer (Yamax SW-800)) and physiological parameters of the effort - pulsometer (Polar FT4). The first two devices were placed in a special belt worn on the hip of the participant. The receiver of the pulsometer was in the lower part of the forearm, above the wrist, and HR sensor was on the chest.

Before the research, participants' data were input into the memory of measurement tools; in the accelerometer: body weight and height, age, and gender; in pedometer: body weight and adopted by the manufacturer standard step length – 70 cm; The pattern was taken from other authors (Groffik, Frömel, Pelclová, 2008). Birth date, gender, weight and height parameters were insert into HR monitor.

Three measurement tools obtained information about:

- absolute EE of undertaken physical exercise in kilocalories (kcal), estimated in the tool's memory on the basis of the acceleration of movements (accelerometer), recorded steps (pedometer) and exercise HR (Heart Rate Monitor),
- relative EE designated by recalculating the absolute EE per kilogram of participants' body weight; this indicator was treated as a dimension of the intensity of undertaken physical effort in metabolic equivalent units (MET) (Ainsworth et al., 2011).

The study was conducted before noon, in the laboratory room, on a specially prepared stand equipped with a display of 32 inches diagonal set at the eye level of players, and Microsoft Xbox 360 Kinect gaming console. Participants, while playing, were moving at a distance of about 2–3 m away from the monitor calibrated by the Kinect sensor cooperating with the console. They had space that allowed them to move freely their body and limbs.

Before the game, the one-minute course of IDVG Dance Central (DC) was demonstrated to each participant, and they were allowed to perform the 30-second try (part of the game). During the measurement, participants performed three times in one day the same dance routine to the song by Lady Gaga "Just Dance" in the "Perform It!" mode, on the "Easy" level of difficulty, excluding periods of inactivity between game loading time. The easiest difficulty level was chosen because students did not have previous experience with IDVG DC. Described research procedures gave a total of ten-minute continuous physical effort. The essence of DC is the imitation of dance moves accurately and with the full amplitude, which are performed by a virtual dancer. The final result expressed in points depends on precise imitation of dance moves (similarity between player's moves and virtual pattern's moves).

Statistical analysis

For the statistical analysis, the Statistica v. 10 software (StatSoft Inc., USA) was used. Arithmetic Means (x), standard deviations (SD), and the differences between the mean values (d) were calculated. Oneway ANOVA with post-hoc t-tests was used to assess the statistical significance of differences between the results of participants' EE obtained with various measurement tools. The normality of data distribution was assessed with the Shapiro-Wilk test.

To compare EE during an interactive dance game to the selected criteria of health-enhancing PA according to the recommendations the World Health Organization (WHO) the following calculations were done:

- estimated for the measurement tools EE of 10-minute IDVG was converted into a one-hour effort in kcal,

– EE in kcal was converted into kilogram per body weight, obtaining information about the individual intensity of undertaken physical effort in metabolic equivalent units (METs).

As health-enhancing was the PA of at least moderate intensity, assessed according the following criteria:

– physical effort within the intensity of 3-6 METs (kcal / kg / h) (WHO 2010),
– physical effort in the range of 50-69% HR max (Strath et al. 2013),
– physical effort leading to do at least six thousand steps within one hour (steps/h) (Tudor- Locke et al., 2011).

Results

Studies indicated that the particular measurement tools identified the different value of absolute EE during the 10-minute DC game. It was demonstrated especially after the conversion of the results on the hour effort (Table 2). Similar results (within 90%) were obtained by heart rate monitor (249.9 kcal/h) and accelerometer (227.6 kcal/h). Energy expenditure, estimated from the number of steps, was significantly lower – 166.4 kcal/h. It was confirmed by the analysis of variance indicating the significant effect of the type of the measurement tool on the registered EE during IDVG ($p < 0.01$). Post-hoc tests indicate that EE estimated from the pedometer and heart rate monitor ($p < 0.01$) and the pedometer and accelerometer ($p < 0.01$) is significantly different (Table 2). Such difference does not occur between the results obtained by accelerometer and heart rate monitor.

Table 2. Absolute (kcal/h) and relative (METs) energy expenditure during interactive dance video game Dance Central on Xbox 360 Kinect

	Heart rate monitor	Accelerometer	Pedometer	d_1	d_2	d_3
EE (kcal/h)	249.9 ±115.0	227.6 ±70.0	166.4 ±54.2	22.3	83.5*	61.2*
EE (METs)	4.2 ±1.9	3.9 ±1.3	2.8±0.9	0.3	1.4*	1.1*

EE – energy expenditure, MET – metabolic equivalents, d1 – the difference between the results obtained by accelerometer and heart rate monitor, d2 – the difference between the results obtained by heart rate monitor and pedometer, d3 – the difference between the results obtained by accelerometer and pedometer * – the difference statistically significant at level $p < 0.01$.

The average intensity of physical effort during the DC game, estimated from the heart rate monitor (4.2 METs) and accelerometer (3.9 METs) do not differ significantly. Significantly lower intensity of physical effort (2.8 METs) was estimated on the basis of EE registered by the pedometer (Table 2).

The average intensity of physical effort estimated from the data obtained from the accelerometer and heart rate monitor was in the preferred (recommended) for health section of 3–6 METs, typical for the efforts of moderate intensity (WHO, 2010). Relative EE, estimated from the pedometer, identifies the intensity of IDVG physical effort on the low level (<3 METs), below the health benefits (Figure 1).

In subsequent analyses, results of physical effort heart rate (% HR_{max}), used calories (kcal/kg/h) and the number of steps (steps/h), obtained from the heart rate monitor, accelerometer and pedometer, during IDVG Dance Central on Xbox 360 Kinect, were referred to health standards recommended by other authors (Strath et al., 2013; Tudor-Locke et al., 2011). This approach to results shows that the accelerometer and heart rate monitor identify physical activity accompanying practicing IDVG DC as moderately intense, (Strath et al., 2013) and the pedometer – as low intense (Tudor-Locke et al., 2011) (Figure 2).

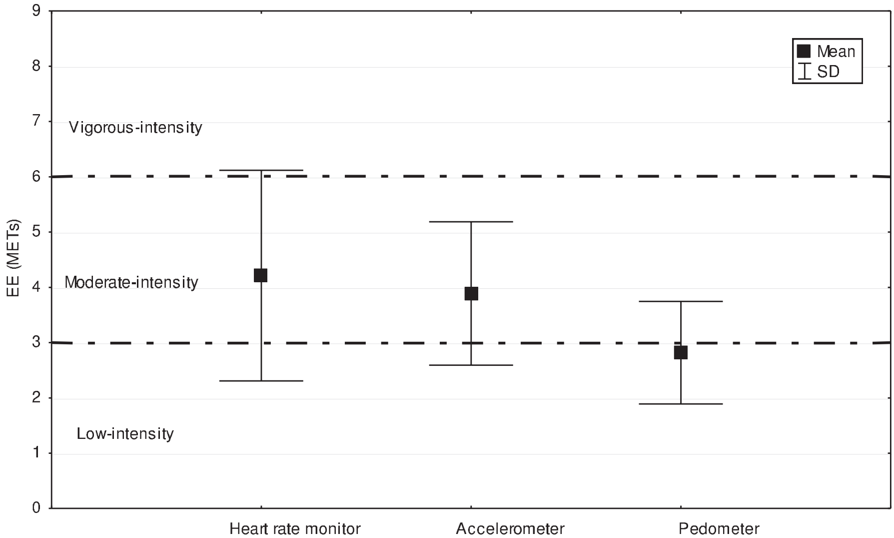

Figure 1. Relative (METs) energy expenditure of students during the interactive dance video game (IDVG) Dance Central (DC) on Xbox 360 Kinect, estimated with a heart rate monitor, accelerometer, and pedometer in the context to health recommendations

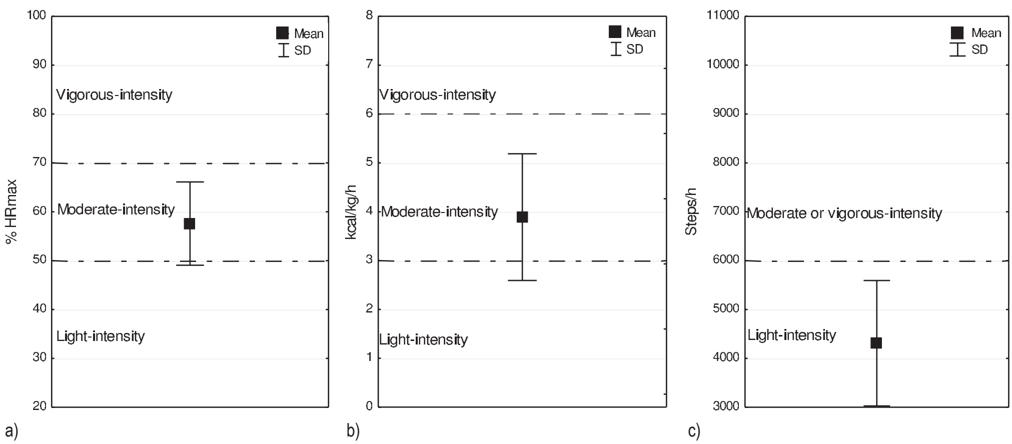

Figure 2. Kinematic and physiological parameters characterizing the physical activity during the interactive dance video game (IDVG) Dance Central on Xbox 360 Kinect, estimated with a heart rate monitor (a), accelerometer (b) and pedometer (c) in the context to health recommendations

Discussion

The aim of the research was to measure energy expenditure and intensity of physical effort during IDVGs DC practice by the students and preliminary assessment of the usefulness of measurement tools (accelerometer, strain gauge, and a pedometer) selected for this purpose.

The study showed the significant similarity between the results of the estimated EE of an hour practicing of IDVGs gained from the accelerometer (249 kcal/h) and heart rate monitor (227 kcal/h) and significantly lower from the pedometer (166 kcal/h).

The results recorded by the pedometer allow to accept the intensity of physical effort of IDVG players as low. The number of steps converted into an hour of the effort is clearly below the limit of moderate intensity, which is set on the level of 6,000 steps/h (Tudor-Locke et al., 2011). It allows to assume that the pedometer lowers energy expenditure during IDVG DC. It does not estimate EE because it records only the shocks caused by the steps, whereas while dancing there are movements around the torso and shoulder girdle with a particular EE. The research performed by Polechoński et al. (Polechoński, Mynarski, Nawrocka, 2015) suggests that a similar situation occurred in the case of Nordic Walking (NW). In some cases, the use of the pedometer to evaluate EE during the IDVGs may, however, be justified (Maloney, Threlkeld, Cook, 2012). It applies, for example, to an earlier version of IDVGs, such as Dance Dance Revolution (DDR), which involves putting feet (trampling) on special mats or platforms to the music and in accordance with the moving symbols (arrows) on the screen. In this case, the movement of the arms and torso does not matter. What counts are primarily movements of the lower limbs. Thus, according to Lin (2015) traditional dance games involve performing dance steps on the mat, modern IDVGs highlight the specific character of the dance moves.

The average intensity of physical effort during IDVG DC, assessed with the accelerometer and a heart rate monitor, ranged from 3 to 6 METs, typical for moderate intensive efforts (WHO, 2010). Similarly was in the case of the assessment of physical effort intensity on the basis of the % Hrmax (Strath et al., 2013). Furthermore, EE and the physical effort intensity estimated with a heart rate monitor and accelerometer did not differ statistically significantly. It can be assumed that both measurement tools have similar diagnostic value in the assessment of EE accompanying computer dance game practicing. This conclusion is eligible because the similarity between EE and physical effort intensity was presented, which were estimated on the basis of both physiological parameters of effort (heart rate monitor) and biomechanical characteristics (accelerometer). However, in study performed by Tripette et al. (2014) AVG intensities have been slightly but significantly underestimated by the accelerometer-based monitor compared to the indirect calorimetry.

Practicing IDVG DC is related to physical efforts. However, it should be remembered that such an effort will be beneficial for the health of people who practice it when it is properly distributed in time. According to WHO experts, adults (18–65 years) should, among others, perform physical exercises or other physical efforts of moderate intensity (3–6 METs) for a minimum of 150 minutes per week. Under this assumption, the efforts of the above-mentioned intensity should last at least 30 minutes (WHO, 2010). Therefore, the DC IDVG could be useful in increasing the daily dose of physical effort and have health benefits when it is undertaken several times a week for several dozens of minutes (e.g., 5 × 30 min.).

Although the physical activity during IDVG DC fulfills the health-enhancing recommendations regarding physical effort intensity, in comparison with classical forms of dance and movement ranks on a low level (Ainsworth et al., 2011). Regarding the intensity, it a heads only some of the Caribbean dances and slow ballroom dances such as the waltz, foxtrot, tango. It should be emphasized, however, that the intensity of physical effort during IDVG DC would be higher when playing at a higher level than „Easy". It is pointed in studies conducted by Noah et al. (Noah, Spierer, Tachibana, Bronner, 2011) during IDVG DDR in a group of adults (from 18 to 53 years), which show that during the game at the „Heavy" level, the average intensity of physical effort was 8 METs, and energy expenditure was 9 kcal • min^{-1}. Other studies show that higher motivation and physical effort can also be obtained by introducing the element of competition in AVGs in multiplayer mode (McGuire, Willems, 2015). Used in the present study, IDVG DC enables, among others, the usage of this mode.

According to Epstein et al. (Epstein, Beecher, Graf, Roemmich, 2007), IDVGs motivate children to physical effort, which seems to be the consequence of a natural fascination of the young generation with the „virtual world". Surprising is the fact that this also applies to adults. The study of 40 postmenopausal women (57 ±5 years) playing IDVGs shows that among the benefits of recreational practicing of such physical activity they see mostly entertainment values and the improvement of coordination. The participants also pointed to the body weight reduction, and to the fact that game is a challenge that encourages progress) (Inzitari, Greenlee, Hess, Perera, Studenski, 2009).

The positive influence of IDVGs on functional efficiency of middle-aged and older people speaks for the use of IDVGs as a beneficial form of physical activity. Mejia-Downs et al. (2011) during the six-week study with the usage of IDVGs, noticed the improvement of cardio-respiratory efficiency (cardiorespiratory status) measured with the ability to absorb oxygen and to reduce the BMI of adults. The participants stated that the IVDGs program was a good workout and motivated them to begin and continue the physical effort. As many as 40% of participants noticed better sleep and nearly half of the participants was considering the purchase of IVDGs. Pichierri, Murer, de Bruin (2012) observed the improvement of walk parameters among elderly people after a 12-week training program supplemented with IVDGs in comparison to a typical training program without such games. Chuang et al. (2015) argue that IDVGs DDR may improve cognitive functions in older women. Smith et al. (Smith, Sherrington, Studenski, Schoene, Lord, 2011) express the belief that IDVGs DDR can be a low budget home training method of older people and increase their involvement in the physical effort.

Our results and conducted discussion point the need of further, in-depth research on the caloric cost and intensity of physical activity associated with IDVGs practicing. In comparison to pedometers, more useful for this purpose are techniques of accelerometers and pulsometers. The value of these techniques in the assessment of varying IDVGs parameters may be clearly assessed only when confronted with the results of oxygen exchange during physical effort. The results of such research may also be useful for potential buyers of IDVG game console and enable them to choose the right interactive software for planning and undertaking the physical activity of a health-enhancing workout.

Conclusions

1. Playing IDVG Dance Central on the difficulty of „Easy" by women without experience in this area is characterized by a moderate intensity of physical effort.

2. IDVG Dance Central is a specific form of dance-movement and can be useful in increasing daily dose of physical activity and comply with the health recommendations if practiced regularly.

3. Data obtained with HR monitor and accelerometer during Dance Central IDVG are similar.

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PHYSICAL FITNESS OF PRISON OFFICERS

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Abstract The objective of the study was to investigate the career-choice motives for one's entering the prison service as an operational officer, and the level of physical fitness.
The study was conducted in April 2015 and included 100 officers employed in Biała Podlaska prison. The examined group consisted of 93 males, aged 23–52, mean age 37.2, and 7 females aged 3–43, mean age 37.7 (30–43). 61 (61%) of the males were employed as security guards, while 39 persons (39%), including 7 females, as clerks in the administration section. The study methods included a physical fitness test consisting of 5 physical performance tests, recommended by the regulation of the Minister of Justice, the International Physical Activity Questionnaire (IPAQ) – long-form, questions designed by the author of the paper.
Career-choice motives turned out to be conditioned purely be economic incentives and the professions' stability as opposed to other professional specialities. The respondents were fit and engaged in numerous physical activates. The factors which significantly determined the level of one's fitness depended on age, education, a high self-report on physical fitness, total physical activity and the number of done sports.
The originality of the study is based on investigating the condition of physical fitness of prison officers with the use of currently recommended assessment methods in Poland.

Key words Prison Service officers, physical activity, health

Introduction

Working in the uniformed services seems to require special motivation for choosing a job and, undoubtedly, high physical fitness in the employees of these occupational groups. Maintaining a high level of physical fitness requires a regular daily physical activity, which is especially vital in occupations in which physical fitness is an indispensable attribute. The recent studies concerning physical efficacy have been conducted among policemen (Bukowiecka, 2006; Bullock, 2007; Gajewski, Biernat, Jasionek, 2004; Rossomanno, Herrick, Kirk, Kirk, 2012), firemen (Moulson-Litchfield, Freedson, 1986), security forces officers (Ambroży, Stanek, Ciućmański, 2009; Hoffman, Collingwood, 2005; Klukowski, Raczyński, Mazurek, 1997; Tomczak, 2010), as well as prison service personnel (Bourbonnais, Malenfant, Vézina, Jauvin, Brisson 2005; Dixey, Woodall, 2011; Jamnik, Thomas, Burr, Gledhill 2010; Jaskowiak, Fontana, 2015; Jaworska, 2015; Łapiński, 2002; Wojciechowski, Bergier, 2016). Scientific reports concerning the physical activity of the uniform services draw attention to the work difficulty and specificity (Moulson-Litchfield, Freedson, 1986), indicating problems with coronary disease and the necessity of regular training programmes, as well as regular work assessment ability. The need for systematic physical fitness testing is also stressed.

In recent years, some work on physical fitness tests has been done for candidates and prison service officers (Łapiński, Głuch, Sołtys, Krotoszyńska, Kaczmarek, 2016), which resulted in the creation and publication of a new regulation by the Minister of Justice of 22 September 2015 on physical fitness assessment in the Prison Service (Regulation, 2015; Clause, 1580).

The objective of the study described in this article is to indicate the career-choice motives of those entering the service, the level of physical activity and the factors that condition fitness in Prison Services officers.

Material and methods

The study was conducted between 22nd and 23rd of April 2015 and included 100 out of 119 officers in Biała Podlaska prison. The absence of the remaining officers resulted from sick leaves, vacation leaves or business trips. The research tool which was used involved a test on physical fitness consisting of 5 performance elements that enabled measuring the officer's basic motor skills, i.e., speed, agility, strength, power (jumping), and suppleness (Regulation, 2011). The tests were conducted in the following order: standing long jump; 2 kg medicine ball forward throw; forward bend (from standing position); 3 × 5 rectangle zigzag run (metres); 10 × 10 (metres) shuttle run, or in the case of women and men from the security section who are above 50, a 6 × 10 (metres) shuttle run. The officers performed the first 3 tests 3 times, and only the best result was included in the final assessment. The last 2 tests were performed only once. The results obtained were used to determine the number of scores using a 7-degree scale, where the score 0 would indicate a negative evaluation, and 6 – a very high evaluation.

In addition, physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), long-form, supplemented with questions designed by the author concerning motives for choosing the occupation, a self-report on physical fitness, amount of leisure time, done sports, and those which the respondents would like to do, as well as the body weight and height, which enabled measuring the BMI. In addition, the metric survey included questions on gender, age, education and weight and height, which enabled calculating the BMI.

The statistical analysis was performed by the STATISTICA v. 10 software. Non-parametric U Mann-Whitney and Kruskal-Wallis tests were used to detect statistically significant differences for quantitative values. As for the qualitative analysis, a table was prepared and the Pearson Chi-square test was used. In all analyzed cases, the assumed significance level was $p = 0.05$.

Results

Characteristics of the prison officers examined

The study group consisted of 93 males aged 23–52, mean age 37.2, and 7 females aged 30–43, mean age 37.7. In the group of males, 61 were employed in the security service, including 32 persons (52%) with secondary school education and 29 (48%) with university education. As for the administrative staff (32 persons), 5 employees (16%) had secondary school education and 27 (84%) university education. While on duty, the security service officers perform tasks typical of the prison environment (Regulation, 2011) consisting of surveillance, delivery, escorting offenders, patrolling the area of the unit, checking the technical-security protection system, searching rooms and persons. The administrative group's duties involved considerably more varied service tasks, consisting of correction, education, socialization and welfare. Besides, they were responsible for typical office jobs relating to information technology, nursing, maintenance and repair, depository, driving motor vehicles, activities within the area of culture and sports, rearing and education, as well as those within the scope of management (management of the facility) (Pływaczewski, Pomiankiewicz, 2014).

All women involved in the study were employed in the administrative section and possessed university education. Considering the small number of women (N = 7), which is typical of this profession (Wojciechowski, Bergier, 2016), the authors could not demonstrate significant correlations between males and females in regard to physical fitness and factors that affected it. Thus, women have been characterized only in terms of their total physical fitness in regard to other assessment norms and physical activity, including sports disciplines.

Profession-choice motives

Considering the fact that the work of a prison officer in the administration and security service differ considerably, as the security group have direct contact with offenders, the analysis was performed to indicate the carrier-choice motives for each group separately. In both groups, similar motives were observed; however, with different ones being highlighted. In security guards, the motive of a stable job in a state institution prevailed, followed by earlier retirement rights − 64%, economic incentives (salary) − 49%, and work with people − 28%. What was surprising was that only 8% of the respondents pointed to the job being interesting and diversified.

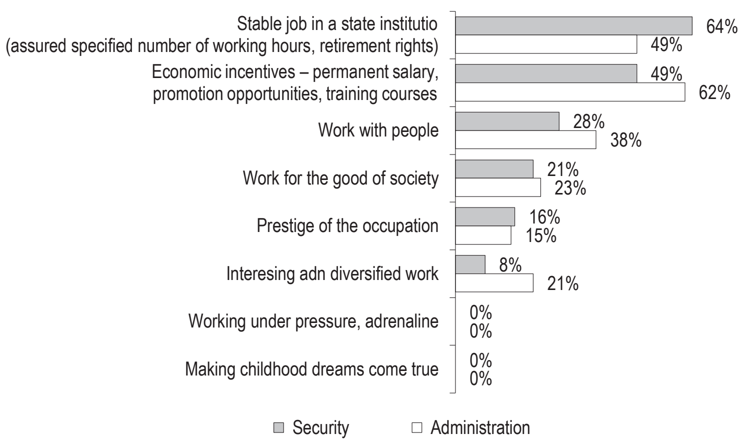


Figure 1. Profession-choice motives with regard to work environment (administration, security)

In the administrative group, the primary motive behind choosing the profession was the economic incentives − 62%, followed by a stable job in a state institution − 49%, and work with people − 38%. Work for the good of the society was also mentioned and obtained high indicators − 23%, which was followed by interesting and diversified work – 21.0% (Figure 1).

Level of physical activity

The mean fitness of prison officers (both males and females) calculated after 5 tests was 4.83, which, according to the present standards, allows for a good or very good evaluation of the workers' fitness. In females, the evaluation result was within the 4–6 range, mean value 5.14, while in males within the 2–7 range, mean value – 4.81. Because of the small number of females (N = 7), further research concerning age and specialisation was done only in males (N = 93). Males doing administrative work were characterized by higher physical fitness (mean evaluation 5.38) than those working in security service (mean evaluation 4.51), although in both cases the evaluation was good. As for the age factor, the younger personnel showed better results in both groups (Table 1).

Table 1. Evaluations of physical fitness test in prison service officers with regard to gender, specialty and age

Age	Females		Males – administration		Males – security service	
	range of evaluations	mean evaluation	range of evaluations	mean evaluation	range of evaluations	mean evaluation
Up to 29	–	–	6–6	6.00	3–6	4.58
From 30 to 39	5–6	5.33	4–7	5.56	2–6	4.63
From 40 to 49	4–6	5.00	4–6	5.00	3–6	4.33
Over 50	–	–		–	4–4	4.00
Total	4–6	5.14		5.38	2–6	4.51
Mean evaluation – males						4.81
Mean evaluation – males and females						4.83

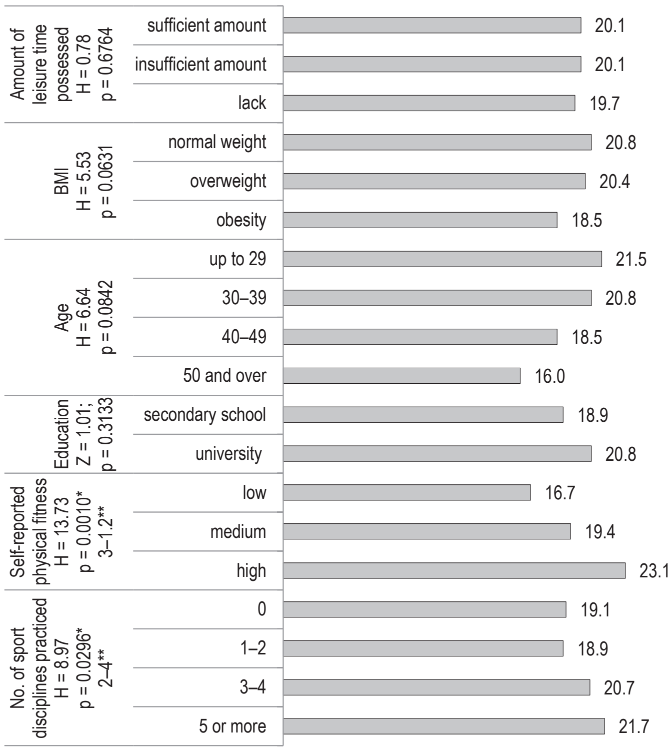
Further analysis of scaled test results (in scores), i.e. a) below 18 scores, b) 18–22 scores, c) more than 22 scores, did not show more significant differences within the occupational specialities (Tabela 2). It is noteworthy that in the security service specialty a higher number of officers showed lower fitness; that is, below 18 scores (29.5%), when compared to administration employees (12.5%). On the other hand, a high level of physical fitness (more than 22 scores) was observed in the security service specialty (27.9%), when compared to administration (18.8%).

Table 2. Number of scores obtained in physical fitness tests by prison service officers with regard to age and specialty (%)

Age	Males – administration			Males – security service		
	<18 scores	18–20 scores	>22 scores	<18 scores	18-20 scores	>22 scores
Up to 29	–	66.7	33.3	16.8	41.7	41.7
From 30 to 39	6.3	62.5	31.3	14.8	51.9	33.3
From 40 to 49	23.1	76.9	–	52.4	33.3	14.3
Over 50	–	–	–	100.0	–	–
Total	12.5	68.8	18.8	29.5	42.6	27.9

Factors conditioning physical fitness

It was found that the factors which are significantly related with a higher level of physical fitness included age, education, self-reported physical efficacy, and the number of practised sports disciplines. However, no significant relationship was found between the level of physical fitness and the amount of possessed leisure time, and the BMI index (Figure 2).



H – value of Kruskal-Wallis test; Z – value of Mann-Whitney U test.
* Significant difference at $p < 0.05$.
** Groups between which statistically significant differences were observed.

Figure 2. Factors conditioning physical fitness of Prison Service officers

Higher physical efficacy was found in the group of the youngest officers, i.e., those aged up to 29, and within the range 30–39, and was subsequently lower, with the worst result at the age of 50 and over.

Also, higher physical fitness was observed in the group with a university education, compared to those with the secondary one.

The highest results concerning physical fitness concerned those respondents who perceived their fitness as high, and decreased with the level of self-reported fitness, reaching the lowest level in those with low self-esteem. The respondents who practised the largest number of sports, i.e., 5 and more disciplines, and 3–4, were characterized by the highest physical fitness, compared to the less active ones. However, there was found no significant correlation between higher physical fitness and the amount of free time and BMI.

Physical activity and physical fitness

Considering the commonly emphasized role of the level of physical activity in one's lifestyle, its self-reported level was analyzed in males and females. To do the study, the International Physical Activity Questionnaire (IPAQ extended-form) was used.

The total level of physical activity in the examined males was 3.618,5 MET-min/week,[1] while in females – 2.335,6 MET. Thus, it was significantly higher among males.

In males, the highest percentage of physical activity concerned moderate efforts and intensive efforts – 1,620.3 MET and – 1,555.5 MET respectively, whereas walking accounted for 442.7 MET. In females, moderate efforts were clearly dominant – 1,410.9 MET, whereas intensive ones – 582.9 MET. The activities related to walking accounted for 341.8 MET (Figure 3).

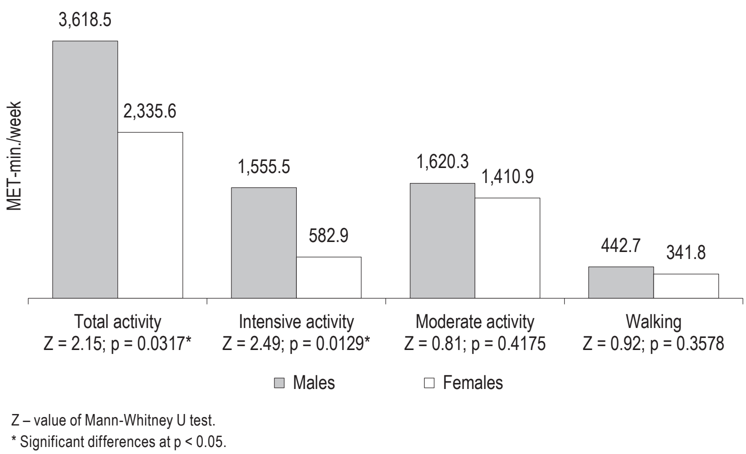
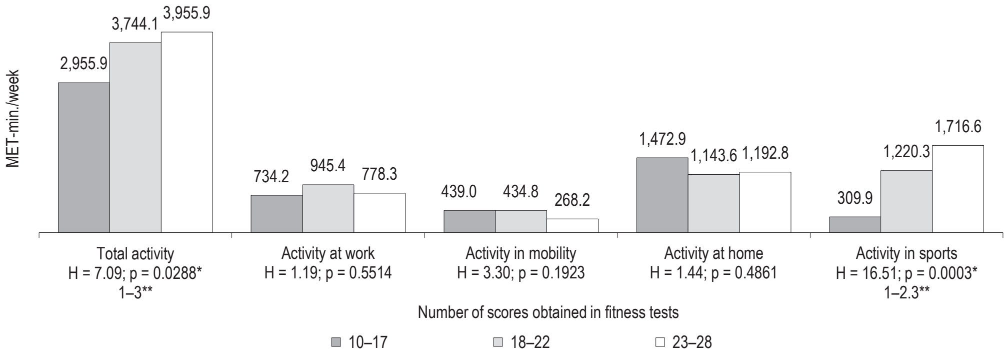


Figure 3. Level of physical activity and its domains in prison service officers broken down by gender

Significant relationships were observed between the level of physical activity and the level of physical fitness (Figure 4).

The respondents with the highest level of fitness (22–28 scores) showed the highest level of total physical activity – 3,955.9 MET, i.e., a significantly higher level when compared to the group with the lowest physical fitness (10–17 scores), in which the level of total physical activity was the lowest –2,955.9 MET.

[1] The abbreviation „MET" will be used further in the paper.



H – value of Kruskal-Wallis test.
* Significant differences at $p < 0.05$.
** Groups between which statistically significant differences were observed.

Figure 4. Level of physical activity and its domains, and the level of physical fitness of prison service officers

Significant relationships were also found between physical activity in the area of participation in sports and the level of physical fitness, where the respondents with the highest fitness (22–28 scores) achieved the level of 1,716.6 MET, i.e., significantly higher compared to the group with fitness assessed within 18–20 scores – 1,220.3 MET, and the group with the lowest fitness results (10–17 scores) – 309.9 MET (Figure 4).

Forms of physical activity

Physical activity was also assessed with respect to the forms of the activity (sports disciplines) practised by the respondents, and those which they would like to do. Males most often mentioned cycling – 60.2% and walks – 47.3%, which was followed by running − 34.4%, swimming – 33.3%, football – 26.9%, and fishing – 25.8% (only those forms are indicated which obtained a minimum of 20% of the choices) (Tab. 3).

Similarly to males, the majority of females preferred bicycle riding – 71.4%, and walks – 47.3%, which was followed by swimming, aerobic/fitness and dancing − each scoring 28.6% (Table 3).

Table 3. Forms of present physical activity undertaken by prison service officers broken down by gender

Forms of physical activity	Males		Females	
	%	ranking position	%	ranking position
Cycling	60.2	1	71.4	1
Walking	47.3	2	47.3	2
Running	34.4	3	14.3	6
Swimming	33.3	4	28.6	3
Football	26.9	5	–	–
Fishing	25.8	6	–	–

In the future, the respondents would like to practice slightly different sports disciplines, among which males mentioned mainly running – 19.4%, swimming – 17.2%, going to the gym – 17.2%, and cycling – 11.8% (only those activities were included that obtained a minimum of 10% of the choices) (Table 4). Women would like to do things related to running – 42.9%, as well as cycling, swimming, and horse riding − each scoring 28.6%. It should be noticed that the respondents had relatively modest requirements concerning new forms of physical activity.

Table 4. Forms of physical activity which the prison service officers would like to practice in the future broken down by gender

Forms of physical activity	Males		Females	
	%	ranking position	%	ranking position
Running	19.4	1	42.9	1
Swimming	17.2	2	28.6	2
Working out	17.2	2	14.3	5
Cycling	11.8	4	28.6	2
Horse riding	2.7	14	28.6	2

Discussion

Considering the career-choice motives involved in one's becoming the Prison Service officer, the phenomenon of occupational burn-out should also be remembered (Mickiewicz, Herkt, 2016; Piotrowski, Mazurkiewicz, 2012; Sęk, 2000;). The conducted studies showed that the officers who have direct contact with offenders are especially exposed to occupational burn-out; therefore, they should show appropriate personality traits (Mickiewicz, Herkt, 2016; Sęk, 2000;). Various reasons for choosing the job were observed in the examined prison officers. As for the employees of the security service specialty, the dominant motive was a secure job in a state institution, while in the administration specialty – the economic incentives; the ones that directly affect the benefits related to following this occupation. The motives which referred to work for the good of society, the prestige of the occupation, or interesting work (especially in the security service group) turned out to be much less motivating while choosing such a difficult job. Therefore, it may be assumed that the motives behind the choice of the carrier were, to a large extent, accidental. Other researchers also indicate that the decision concerning taking a job in the Prison Service is accidental (persuasion by a friend), or results from a very difficult situation on the labour market and lack of prospects in the learned profession (Urlińska, Urlińska, 2015).

Undoubtedly, the persons working in Prison Service, the formation responsible for public safety (Basińska, 2013), should be physically fit, which, according to the results of the presented study, is the case in the examined group as all officers as their level was assessed as a good or even very good. Younger officers achieved higher evaluations in the physical fitness test and these assessments gradually decreased with the age of the examined persons, with the exception of the security service specialty, in which the highest mean result was achieved by males aged 30–39. In Poland, doing physical fitness tests is obligatory for the officers of all uniform services, i.e., army, police, the prison system, border guards and fire department (Decision, 2005; Regulation, 2014; Regulation, 2015, Clause 1121; Regulation, 2005). Despite a number the tests performed, their scope and obtained scores, there is too much variation between the services, which makes it difficult to compare the results. Of all the above-mentioned uniform services, only in the Prison Service are there different evaluation categories in the physical fitness test for the security officers and administration personnel, with slightly lower requirements put on the latter.

The lower requirements, when compared to those demanded from for instance police officers, result from the workplace specificity of the prison guards, who need to focus mainly on penal and educational activities.

While looking at the factors conditioning the level of physical fitness, it was confirmed that the most significant ones include age, education, self-reported physical fitness and the number of practised sports disciplines. A considerable decrease in physical fitness with age is especially evident in the oldest age group, i.e., aged 50 and above, who probably require special programme activities. A higher level of physical fitness in the group of employees with university education may result from their greater knowledge of the role of physical efficacy in one's lifestyle, including such a specific occupation. The fact that the highest level of the results concerning physical fitness was observed in the group which expressed the highest self-evaluations of their own fitness proves that these persons know themselves well. The number of sports disciplines practised, much possibly resulting from what the persons did in the youth, presently conditions their level of physical fitness in a positive way.

The lack of a significant relationship between a more substantial amount of leisure time possessed and the level of fitness may indicate that it is not the amount of free time at one's disposal that counts, but the awareness of how significant one's fitness is. It is somewhat surprising that no relationship was found between physical fitness and the value of the BMI index, although it should be noted that the persons with a normal BMI value were characterized by slightly higher physical fitness.

It should also be stated that both males and females were mainly involved in doing traditional forms of physical activity, i.e. cycling and walking. As for the less popular pastimes, males pointed to fishing, whereas females – dancing. What was worrying was that the tested persons did not express any desire to get involved in other forms of activity. The number of positive indications was very low. Apart from the traditional forms, both males and females mentioned swimming and running, as well as working out – in case of men, and horse riding – in the case of women. Such a situation is possibly conditioned by too few opportunities of practising various other forms of physical activity available in the local environment. What is also noteworthy is that, apart from being evaluated well in the measured physical fitness tasks, Prison Service officers are also involved in a number of activities in various areas of daily life (work, mobility, duties at home and around the household, sports and forms of spending free time), which allows for a positive assessment of physical activity as an essential component of their lifestyle.

Accordingly, it may be said that the high evaluation of the total level of fitness is due to the relationship between higher physical fitness results obtained in the norms regarding the force requirements and the level of physical activity resulting from everyday life activities.

Conclusions

The results of the study concerning the career-choice motives, level of fitness and physical activity in the Prison Service officers, allow for formulating the following conclusions:

1. The decisions for choosing the occupation seem to be too random for such a specific job, and the distinction between those relating to the security officers and administration are insufficient.
2. The level of fitness and physical activity is high, irrespective of the work specialty.
3. The factors which significantly condition the state of physical fitness are age, education, self-reported physical fitness, number of disciplines practised, and the level of physical activity.
4. The domains of practised forms of physical activity as well as those desired are very traditional, both in males and females.

5. The survey results show that there is a large group of respondents who are overweight and obese, which creates the need for participation in fitness programmes.

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RELIABILITY OF FITNESS TRACKERS AT DIFFERENT PRICES FOR MEASURING STEPS AND HEART RATE: A PILOT STUDY

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Abstract The purpose of this pilot study was to assess the accuracy of steps and heart rate measurement of wrist fitness trackers at different prices. Four healthy college students voluntarily tested three wrist fitness bands and a sports watch (Xiaomi Mi Band, Fitbit Charge HRm, Fitbit Surge, and sports watch Polar M400). Subjects performed two sets of 10 series of 100 steps wearing the fitness trackers on an indoor track in two situations: walking and jogging. In the walking situation, the subjects wore a winter coat and gloves. The variables measured were the number of steps, the heart rate, and the level of error. The steps error percentage for all four devices was lower than 8%. The Fitbit Surge registered significantly more steps in the walking situation ($p < 0.001$). No significant differences were found in the steps measurements in the jogging situation ($p = 0.138$). In the jogging situation, significantly lower values in the heart rate measurements for the Xiaomi Mi Band, Fitbit Charger HR, and Fitbit Surge were found ($p < 0.001$). The results showed that the wearable fitness trackers were relatively accurate for tracking steps (on average, there was a level of error of 2–6%). The assessment of the steps was more accurate in the jogging situation (higher and faster arm swing) than in the walking situation, which involved wearing coats and gloves. The results showed that the wearable fitness trackers that were tested underestimate the heart rate with a level of error of approximately 6–11%. The step error was lower in the walking situation (less mobility of the devices). The price of the devices that were tested did not affect the accuracy of the steps and heart rate assessment. Further studies with a larger sample and more type of devices are needed to confirm these results.

Key words technology, assessment, physical activity, exercise

Introduction

Advances in technology have allowed the general population to easily utilize fitness trackers in their daily life. This type of instrument provides information about our physical activity and exercise. These data can help to establish a baseline of physical activity, monitor one's activities, and provide immediate feedback about it. In a review of the market options, it is possible to find a wide variety of fitness trackers with different characteristics and prices. Most of the fitness trackers allow for monitoring steps, displacement, and heart rate. Their prices range from less than $20 to more than $300. These differences lead to questions about the reliability of the fitness trackers at the different price ranges that are available in the market during the different situations of our daily life. Fitness trackers measure the steps taken and the physical activity carried out using a 3D accelerometer, and they measure the heart rate using LED lights. It is important to keep in mind that these are not research or medical devices (Kroll, Boyd, Maslove, 2016). They are instruments developed and orientated for the general population. These devices are used by the general population to obtain feedback about their physical activity and exercise. However, these devices need to be accurate to properly guide one's workout and lifestyles. It is not clear how changes in our movement patterns affect the accuracy of our devices. For example, wrist fitness trackers indirectly assess the steps from the arm swing of the subject, which changes according to different walking and jogging movements.

The 3D accelerometer of the fitness trackers measures the movement done by the person in the different planes of the space. A wrist fitness tracker measures the wrist movement when the subject moves. These data allow us to indirectly estimate the steps taken through the displacement of the wrist and the anthropometric characteristics of the person. Each company uses different algorithms to calculate the steps from the movement measured by the device. However, the calculation does not have the possibility to consider whether the movement is affected due to our clothing, because we are carrying something, etc. Previous studies have not shown differences in the accuracy of the step measurement regarding the prices of the fitness tracker (El-Amrawy, Nounou, 2015). These studies found an error of underestimation between 2% and 30% in the step measurement between different brands and models (El-Amrawy, Nounou, 2015; Montoye et al., 2016; Nelson et al., 2016). Using the indirect estimation of the steps, the time, the type of movement, and the information about the subject regarding weight and age, the devices estimate the caloric expenditure done by the subject. The current research available about this indirect estimation shows that fitness trackers are not reliable to estimate the energy expenditure at rest or in exercise situations (Brazeau et al., 2016; Evenson, Goto, Furberg, 2015; Montoye et al., 2016; Nelson et al., 2016; Sasaki et al., 2014).

To assess the heart rate, the fitness trackers measure the reflection of their LED lights on the wearer's skin to detect blood volume changes in the capillaries and, from that, estimate the heart rate. Not all LED lights' reflection has the same precision in the measurement. Green LED lights are less precise, are cheaper, and consume less battery than red LED lights (El-Amrawy, Nounou, 2015). Fitness trackers use heart rate, age, and gender to estimate the intensity of the activity the subject is doing. Several studies have shown that the estimation is not accurate for most of the devices and they have a 15–20% error (El-Amrawy, Nounou, 2015). The accuracy is greater when the fitness tracker combines the use of green and red LED lights and when a higher number of LED lights are used. The accuracy of the heart rate assessment improves when the measure is done in laboratory-based activities (Shcherbina et al, 2017). Fitness trackers are intended to provide information about physical activity and fitness to the general population. The users of these devices need to know how precise the information that fitness trackers provide is. This information, together with the price, is critical in deciding whether the different fitness trackers are worth buying (ratio of assessment accuracy to price). Previous research has shown that they are not accurate for monitoring patients in hospital settings as early warning systems (Kroll, Boyd, Maslove, 2016). The results of this study will provide information regarding the accuracy that devices at different price points provide and whether they can be used to guide exercise. The purpose of this pilot study was to assess how reliable the step and heart rate measurements of wrist fitness trackers at different price points are.

Material and methods

Four healthy and active college students voluntarily participated in this pilot study (mean age, 21.7 ±1.2 years old; height, 1.69 m ±0.06 m; weight, 70.5 ±6.3 kg). A snowball sampling technique was used to select the sample (Trochim, Donnelly, 2001). The participants completed a written informed consent, PARQ+ (Warburton, Jamnik, Bredin, Gledhill, 2011), and weekly levels of physical activity and exercise before beginning the study. No financial or academic incentive was given to the students for participating in the study. Three wrist fitness bands (Xiaomi Mi Band, Fitbit Charge HRm, Fitbit Surge) and one sports watch (Polar M400) were analyzed in this pilot study (Table 1). The criteria used to select the fitness trackers was the price. A device costing less than $25 (Xiaomi Mi Band), a device around $120–150 (Fitbit Charge HRm), and a device around $200–250 (Fitness Surge) were selected for this study. The Polar M400 with a pulse sensor H7 was selected because it was a sports watch with step count and a chest band to monitor the heart rate ($150–200). The four devices used a 3-axis accelerometer to assess the steps. The Xiaomi Mi Band, Fitbit Charge HRm, and Fitbit Surge used two LED green lights to assess the heart rate. The study was pre-approved by the Institutional Review Board of the principal researcher and followed ethical standards of the Helsinki Declaration.

Table 1. Type, price, and characteristics of the wrist fitness trackers and the sports watch tested (Xiaomi Mi Band, Fitbit Charge HR, Fitbit Surge, and Polar M400)

	Xiaomi Mi Band S1	Fitbit Charger HR	Fitbit Surge	Polar M400
Type	Wrist fitness tracker	Wrist fitness tracker	Wrist fitness tracker	Sports watch
Price	$15–20	$120–150	$200-250	$180–200
Battery life	20–30 days	3–5 days	3–5 days	20–30 days
Display	No	Yes	Yes	Yes
3-D accelerometer	Yes	Yes	Yes	Yes
LED Lights	2 LED green lights	2 LED green lights	2 LED green lights	No, chest band

Subjects performed two sets of 10 sets of 100 steps wearing the fitness trackers on an indoor track in two situations: walking and jogging. Participants walked and jogged at a normal self-selected pace. In the walking situation, the subjects wore winter coats and gloves. The Xiaomi Mi band and Fitbit Surge were worn on the dominant wrist and the Fitbit Charge HR and Polar M400 were worn on the non-dominant wrist. Additionally, the subjects wore a chest band to monitor the heart rate with the Polar M400. The variables measured were the total steps and the heart rate after every 100 steps. Before starting the data collection, the subjects' information related to gender, height, weight, age, and arm used to wear the devices were introduced in the app or in the device. A test lap on the indoor track was carried out before the data collection to ensure that step counting and heart rate measurements were working in the devices. Use recommendations, updated app and updated firmware (Spring, 2016) for each device were used. At every 10-step interval, two researchers counted aloud the number of steps. If the researchers' counts did not match, the trial was started again. After each set, one researcher recorded the steps and heart rate from each device. The reliability of this method was tested by comparing a video recording for two walking and running video sequences of one of the subjects. An intra-class correlation coefficient value of 0.99 was obtained through the analyses of the video sequences and the steps recorded by the researchers. For the Xioami Mi Band, the data was obtained for its app (Android Mi Fit, version 2.2.3). After the data collection, the data were transferred to a spreadsheet.

The error for the steps and for the heart rate for each device were calculated. For the steps, the researchers' counting was used as the reference to evaluate the step measurement by the devices. For the heart rate, the Polar M400 with the chest band was used to evaluate the heart rate measurement of the wrist fitness trackers (Nunan, et al. 2009; Terbizan, Dolezal, Albano, 2002). A descriptive analysis (mean, standard deviation, and percentages) and an inferential analysis were performed using SPSS statistical analysis software (SPSS version 23.0, Chicago, USA). The Kolmogorov-Smirnov test was used to analyse the normality of the sample. Since the sample was non-parametric, a Wilcoxon Test was used to compared the differences between the step and heart rate assessments of the different devices. The level of statistical significance was set at $p \leq 0.05$.

Results

Table 2 and Figure 1 show the results of the step count trials for the wrist fitness trackers and the sports watch. The Polar M400 sports watch counted significantly fewer steps in the walking situation ($p < 0.001$). The Fitbit Surge counted significantly more steps in the walking situation ($p < 0.001$). No significant differences were found in the steps measurements in the jogging situation ($p < 0.138$). The Xiaomi Mi Band and Fitbit Charge HR presented the smallest levels of error in the step count. Both counted more steps for the walking situation and fewer steps for the jogging situation. Therefore, the total step count error was compensated, and the total error was less than 2%. The error percentage for each of the devices studied was lower than 8%. The sports watch presented greater variability than the fitness trackers in all the situations (average of 28.6 steps).

Table 3 and Figure 2 show the degree of error in the heart rate measurements of the fitness trackers when compared to the Polar M400 sports watch, which was used as a reference. In the walking situation, significantly lower values in the heart rate measurements for the Fitbit Charge HR were found ($p < 0.001$). In the jogging situation, significantly lower values in the heart rate measurements for the Xiaomi Mi Band, Fitbit Charger HR, and Fitbit Surge were found ($p < 0.001$). All the wrist fitness trackers registered fewer beats per minute than the Polar M400. The percentage of error was between 5 and 11% for each of the devices studied.

Table 2. Errors in number of steps measured by the different devices tested (Xiaomi Mi Band, Fitbit Charge HR, Fitbit Surge, and Polar M400 sports watch) in the situations of walking and jogging (values expressed in steps)

Situation	Xiaomi Mi Band S1		Fitbit Charger HR		Fitbit Surge		Polar M400	
	average	SD	average	SD	average	SD	average	SD
Walking	4.8	4.5	7.7*	5.5	7.6*	6.3	–8.7*	27.9
Jogging	–3.9	4.0	5.3	5.9	3.3	6.2	–2.8	29.3
Total	0.9	4.2	1.7	4.2	5.4	6.2	–5.8	28.6

* Significantly different from steps reference assessment ($p < 0.05$).

Table 3. Average heart rate measurement error for the different wrist fitness trackers (Xiaomi Mi Band, Fitbit Charge HR, and Fitbit Surge) in the situations of walking and jogging (values expressed in heartbeats per minute)

Situation	Xiaomi Mi Band		Fitbit Charger HR		Fitbit Surge	
	error	SD	error	SD	error	SD
Walking	–2.7	13.5	–9.5*	10.7	–0.5	8.5
Jogging	–11.7*	12.3	–17.9*	13.43	–14.6*	8.2
Total	–7.2*	13.0	–13.7*	12.0	–7.6*	8.4

* Significant differences found with heart rate reference assessment ($p < 0.05$).

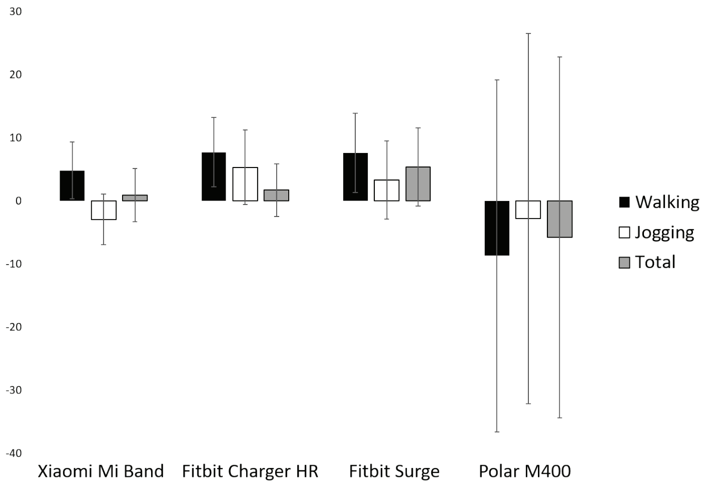

Figure 1. Average steps error for the different wrist fitness trackers and the sports watch (Xiaomi Mi Band, Fitbit Charge HR, Fitbit Surge, and Sports watch Polar M400) in the situations of walking and jogging (values expressed in steps)

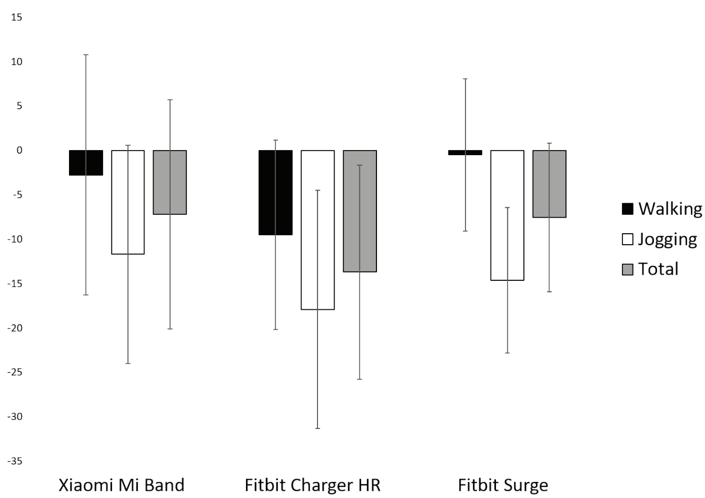

Figure 2. Average heart rate measurement error for the different wrist fitness trackers (Xiaomi Mi Band, Fitbit Charge HR, and Fitbit Surge) in the situations of walking and jogging (values expressed in heartbeats per minute)

Discussion

The purpose of this pilot study was to assess how accurate the steps and heart rate measurements of common wrist fitness trackers at different price ranges are. The results showed that the fitness trackers were relatively accurate for tracking steps with an average level of error of 2–6%. The sports watch studied presented high variability in step counting (almost ±30 of 100 steps). The devices tracked the steps in the jogging situation better than in the walking situation. These differences could be related to the shorter and slower arms swing when the subjects walked with winter coats and gloves. Fitness trackers indirectly measure the steps through the interpretation of the data collected by a 3-axis accelerometer of the movement done by the subjects' wrist. Each company has an algorithm that takes into consideration the wrist acceleration to establish whether a step was taken or not. The type of arm swing could affect the wrist acceleration generated and whether the threshold of the fitness tracker is reached. Regarding the prices, no significant differences were found between devices of different price ranges . The cheaper devices presented similar or lower levels of error than the more expensive devices studied. Fewer errors were found when compared to previous studies about the accuracy of the assessment of the fitness tracker (El-Amrawy, Nounou, 2015; Evenson, Goto, Furberg, 2015; Kooiman et al., 2015; Montoye et al., 2016). From a practical perspective, these results show the use of inexpensive devices is adequate for the general population to monitor physical activity due to their acceptable level of assessment and affordable price.

Regarding the heart rate assessment, the results showed that the wrist fitness trackers underestimate the heart rate when compared to the sports watch with a chest band. The level of error of the wrist fitness trackers was around 6–11% on average. The chest band was used as a reference since it provides valid measurements to monitor heart rate variability for walking and jogging (Nunan et al., 2009; Terbizan, Dolezal, Albano, 2002). The fitness trackers analyzed used two LED green lights and analyzed the reflection of the skin to detect changes in expansion and contraction of the capillaries when the heart beats. Algorithms interpret the data from the LED green lights' reflection in order to calculate the heart rate. Previous studies have found similar levels of error when LED green lights are used (El-Amrawy, Nounou, 2015). Another possible problem of the assessment was that the device moved along the wrist during the assessment, although criteria proposed by each company were followed. Most of the devices presented better values in the walking situation, in which the subjects used a winter coat and gloves. This type of clothing could help to maintain the same position of the fitness tracker during the assessment. In the jogging situation, when the arm swing is higher and faster, the devices had a higher amount of error in the assessment. The results from previous studies have found a similar problem with the chest band. At high speeds, the devices move, and they do not properly assess the heart rate (Terbizan, Dolezal, Albano, 2002). The same problem was found with fitness trackers, but it occurs also at lower speeds, because the device sits more loosely on the body. Regarding the prices, no differences were found in the accuracy of the assessment. The cheaper and the more expensive devices presented similar levels of error. From a practical perspective, these results showed how the use of the fitness tracker should not be used as a guide for an aerobic workout. The level of error does not allow one to accurately use it as a method to establish the intensity of the exercise.

In summary, the fitness trackers analyzed better assessed the step count than the heart rate. The devices studied underestimate the heart rate of the subject by approximately 10–15 beats per minute. It must be considered that this paper is an exploratory study and it has some limitations. Possible limitations of this study are: small number of participants, sample characteristics (young active adults), small number of devices, and wearing multiple fitness bands at the same time, which might affect the assessment. These limitations do not allow us to generalize the results. However, the paper presents some insights related to the accuracy of steps and heart rate, specifically related to the price of these fitness trackers. The findings of the study show how the different activities, clothing, etc. can influence their assessment. The current rapid evolution of our technology makes it necessary to constantly evaluate the accuracy of the available fitness trackers. Future studies need to evaluate the accuracy of the new models of the fitness trackers (hardware and software) and the criteria general population use to select them.

Conclusions

The results show that the price is not a factor to consider in the selection of the fitness trackers related to counting the steps. All wrist fitness trackers studied provided acceptable measurements of the steps. The devices studied did not provide reliable information related to heart rate. These devices can provide complementary information about the physical activity done (steps), but they should not be used as a way to establish the aerobic workout intensity alone (heart rate). The results of this study cannot be generalized due to the small sample used (subjects and devices). However, the present pilot study shows differences in the assessment of the devices studied in two common situations of life: walking while wearing a coat and gloves and jogging. The current advances in technology and fitness trackers require the constant evaluation of the accuracy of the new devices that provide us feedback regarding our physical activity and exercise.

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EVALUATION OF THE IMPACT OF PHYSIOTHERAPY ON PHYSICAL FITNESS AND RANGES OF MOTION OF SELECTED JOINTS OF ELDERLY WOMEN FROM THE KARKONOSZE UNIVERSITY OF THE THIRD AGE IN JELENIA GÓRA – PRELIMINARY RESULTS

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Abstract An important aspect of a senior's life is to be able to function independently in his or her own and family surroundings as long as possible, actively participate in social life without economic barriers. Numerous studies show that the quality of life and the biological condition of the elderly alongside nutrition are clearly dominant and have a positive effect on their functional physical fitness. In order to promote physical activity and physiological prevention among the elderly, a physiotherapeutic program was organized under the "Summer Sanatorium of Prevention of the spine pain syndrome", which was attended regularly by a group of senior citizens from the Karkonosze University of the Third Age in Jelenia Góra. The aim of the study was to compare the level of functional physical activity before and after treatment among the participants.

The study was conducted among 20 women aged 60–75 years, before and after 6 weeks of treatment, which included: gymnastics for prevention of back pain syndromes, relaxation training, full spine massage, TENS electrotherapy and ultrasound in the lumbar and cervical spine. Research included; assessment of functional physical fitness by the Functional Senior Fitness Tests: „stretching behind" and "slope forward", ranges of motion within the selected joints of the spine, upper and lower limbs.

The selected form of physiotherapeutic treatment improves the results obtained after test with the Functional Senior Fitness Test and influences the range of motion in the selected joints, which demonstrates that physical fitness is improved.

Physical activity in the form of general-purpose gymnastics favors higher levels of functional fitness of elderly women, physical therapy and massage improves mood and makes older people more willing to participate in physio preventing programs. The conducted research proves that the developed program was optimal and showed a positive effect on the daily functional fitness of the examined persons.

Key words seniors, functional physical fitness, physiotherapy treatments, range of joint mobility

Introduction

Among the increasing number of elderly people in society, the key task is to take care of the seniors' quality of life. An increasing number of people over 65, not only in Europe, will be associated with the health, economic and social consequences for the entire population (Mossakowska, Więcek, Błędowski, 2012). Due to the increasing progress of medicine in the field of diagnostics and treatment, a significant extension of human life is observed, which has a significant impact on increasing the elderly population not only among Polish society but also in Europe and in the entire world. The greater number of seniors and the decreasing number of children and young people caused that European societies exceeded the threshold of demographic aging (Wieczorkowska-Tobis, Kostka, Borowicz, 2011). Demographic forecasts for the next 35 years indicate a steady increase in the number of people aged 65 and over, both women and men, and this process will be much more intensive than before (Błędowski, 2012; Giannakouris, 2008; Kozdroń, 2014). Undoubtedly, an important aspect determining the older people quality of life is their biological condition, which is influenced by economic, social and health factors. The consequences will be associated with the functional efficiency of seniors, translating into health and physical fitness conditioning independence in their own and social environment.

Aging is a natural physiological process that is the last stage of ontogenesis. Late adulthood starts already in middle age and grows over time, and involutional changes taking place in particular organs and systems are irreversible and naturally affect the limitation of people's fitness, even in a situation of independence (Park, 2017; Skalska, 2012; Sygit, 2015).

As a result of the civilization progress, the incidence of morbidity and mortality is still increasing on so-called civilization diseases related to metabolic disorders such as diabetes, obesity, diseases related to cardio-respiratory disorders and deepening deficits in the movement system caused by involutional changes and degenerative processes in the skeletal system and neuromuscular conduction (Mossakowska et al., 2012; Roberts, Philips, Cooper, Gray, Allan, 2017; Skrzek et al., 2015; Sygit, Sygit, Pietrzak, 2016). All these changes are the cause of dysfunction of the musculoskeletal system, reduce the functional efficiency and independence of the elderly person.

The involutional changes affecting the functional efficiency of an elderly person comes first in the muscular system, where the decrease in muscle mass after the age of 35 increases and in people aged 50 and over, the decrease in muscle mass can reach up to 30% compared to people aged 25 years (Skrzek et al., 2015). With the decline in muscle mass as a result of involutional processes, there is a reduction in muscle strength and disturbances in neuromuscular excitability. The myelin sheaths of the nerves are degenerating, the number of motoneurons in the anterior corneas of the gray matter of the spinal cord is reduced, which significantly limits the neuromuscular transmission. Progressive degenerative and atrophic changes in the nervous system and a decrease in muscle tone and weakness of reflexes are the cause of balance and body postural instability disorders (Ignasiak et al., 2017; Kubica, 2015; Park, 2017).

One of the key elements of dignified aging is the ability to function independently and secure one's own needs enabling self-service in the basic activities of everyday life and self-fulfillment in the family and society. These activities are significantly influenced by the range of suppleness, mobility of the joints, muscular strength and sense of balance, which are limited as time passes.

There is still no consensus what treatments are the most beneficial in the slowdown of involution processes that occur as a result of the aging of the human body and at the same time affect the functional efficiency of older people. There are various forms of movement available for seniors, to which each of them reacts individually.

Numerous studies clearly prove that various forms of physical activity, appropriately selected, have a positive effect on the functional status of elderly people. For this reason, it is important to convince seniors to use certain forms of physical activity, by carrying out preventive activities in gerontology. An example of such activities may be disseminated general improvement programs among older people (Adamo, Susan, Goldberg, 2015; Kostka, Kostka, 2011; Kozdroń, 2014; Ossowski, Wawryniku, Česnaitiene, 2015; Wesołowska 2016).

Changing environmental conditions, dynamic urbanization require optimal programs and therapies that will be available and encouraging for older people. It will allow to achieve the goal of maintaining physical fitness for as long as possible, giving them the opportunity to perform everyday tasks on their own and optimally functioning in present-day reality (Ignasiak, Nowak, Domaradzki, Falkengerg, 2013; Osiński 2013; Wizner, Skalska, Klich-Rączka, Piotrowicz, Grodzki, 2012). For seniors, undoubtedly the most important factor is good health, which translates into quality of life and functional independence. Therefore, general improvement programs containing elements of physioprophylaxis can be, along with other forms of adaptive physical activity, more motivating for these people (Nowocień, 2012; Roberts et al., 2017).

The aim of the study was to evaluate the effectiveness of 6 weeks therapy to improve flexibility and increasing functional physical fitness in older women, students of the Karkonoski University of the Third Age in Jelenia Góra.

Material and methods

The research was carried out in the second half of 2015. Participants were the students of the Karkonoski University of the Third Age at the Karkonosze State College in Jelenia Góra. The research was carried out twice by the same team of employees of the Karkonosze State College and the author of the work.

The first tests took place in mid-August 2015 before the start of therapy, the second study was repeated in the first week of October 2015 after completing the planned treatments. The research material were the results of measurements obtained before and after the therapy among the same group of women of 20 people in the 60–75 age group. The average age of the surveyed women was 67 years.

Conditions for inclusion in tests:

- sex and age – women between 60 and 75 years of age,
- subjectively feel of good health,
- written consent of the primary care physician for the patient's participation in the project and no contraindications to perform certain physiotherapy treatments and the planned scope of research,
- signing a voluntary consent to participate in research. Each participant was informed about the purpose of the research, the type and method of conducting them and the possibility of giving up treatments and examinations without giving reasons.

Physiotherapy lasted 6 weeks, treatments were performed three times a week with an even distribution on Mondays, Wednesdays and Fridays, each time included the following program, the same for each participant:

- general group gymnastics aimed at the prevention of spinal pain syndrome, which lasted 45 minutes,
- relaxation break lasting 10–15 minutes,
- classical massage of the back muscles – 25 minutes,

– L-TENS electrotherapy treatment lasting 20 minutes, for the first three weeks applied to the lumbosacral region of the spine, for the next three weeks, applied to the cervical-thoracic segment of the spine,
– treatment in the field of sonotherapy – ultrasound (about 6 minutes), for the first three weeks applied to the region of the lumbar-sacral spine, for the next three weeks applied to the region of the cervical-thoracic segment of the spine.

The treatments were carried out under the supervision of a physiotherapist, author of work in kinesiotherapy, physiotherapy and massage clinics at the Karkonosze State College, equipped with appropriate specialist equipment.

The applied research methods included:

1. Evaluation of flexibility within the upper and lower body made using the selected set of functional tests from the Functional Senior Fitness Test battery (Rikli, Jones, 2001): "stretching behind" and "slope forward".
2. Measurements of motion ranges within selected upper limb and lower limb joints: brachial, ulnar, iliac, were made using a goniometer in accordance with the accepted test methods (Skolimowski, 2009). For the purposes of the research, the ranges of active movements in the joints performed by the strength of the examined muscles were measured. All measurements were started from the zero position. The examined woman after take the starting position for the measurement in a given joint do the maximum movement. The result was given in degrees and recorded in accordance with the SFTR method.
3. Assessment of mobility in the lumbar spine. Meausermentswere made using a centimeter tape with an accuracy of 0.5 cm according to the Schober test (Skolimowski, 2009).

The project was positively evaluated by the Senate Committee for Ethics of Scientific Research at the University of Physical Education in Wrocław (resolution number on the opinion on the project of the cognitive experiment 12/2016).

Methods of statistical elaboration

In the elaboration of the collected material, the following were used:

1. Descriptive statistics methods: arithmetic mean (x) and standard aberration (s) before and after therapy.
2. The significance of the mean differences between the pre- and post-therapy tests was assessed by the test t-Student for dependent groups.

The material distribution was normal. In all tests, $p < 0.05$ was considered statistically significant.

Results

The result of the "stretching behind" test evaluating the flexibility of the upper body turned out more advantageous by almost 3 cm after treatment. The difference between the pre-and post-therapy tests was statistically significant. After analyzing the test – a "slippery slope" assessing the flexibility and range of mobility in the joints of the lower limbs and the spine, an average increase in the mobility of 5.5 cm was noted. The difference between the pre- and post-therapy tests was statistically significant (Table 1, Figure 1). Positive changes were observed after the therapy ended and the analysis of the tests evaluating the flexibility of the upper and lower body was carried out.

Table 1. Statistical characteristics and assessment of the differences between the means of functional physical fitness in terms of elasticity of upper and lower body before and after 6-week therapy (Student's t-test for dependent tests)

Variable	Before	s	After	s	Before/after d	Student's test	p < 0.05
"Stretching behind"	–6.40	7.47	–3.53	6.53	–2.88	2.6800	0.0074
"Slope forward"	1.35	5.95	6.43	6.51	5.53	4.4095	0.0002

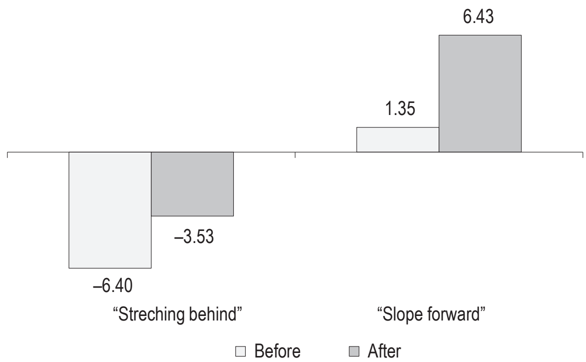

Figure 1. The average values of flexibility within the upper and lower body before and after therapy among the surveyed women (cm)

As a result of involutional changes occurring in various systems and organs in the aging process of the organism there is a limitation of the mobility within the joints of the upper limbs, lower limbs and torso, which affects the functional efficiency and the biological condition of an elderly person. In order to check the effectiveness of the treatment effect, we examined the ranges of mobility in the joints: shoulder, ulnar and hip joints as well as the extent of the forward flexion movement in the lumbar spine (Table 2, Figures 2–6).

In the shoulder joint and the shoulder girdle, the ranges of motion in the sagittal plane were measured: the movement of the back and the forebending in the right and left shoulder joint. In the study prior to the program, the mean extent of the retraction movement in the right shoulder was 54°, after therapy it was 60°, in the left shoulder joint – it was 57° before therapy, after therapy 62°. The analysis of the data shows that the extent of the torsional movement increased by 6° in the right shoulder and by 5° in the left shoulder, and the difference was statistically significant (Table 2, Figure 2). The average range of the anterior movement in the right shoulder increased statistically significantly after the therapy by almost 3°, in the left shoulder – about 4° (Table 2, Figure 3). It can be concluded that the total range of motion in the sagittal plane, adding up the positive effects of the movement of the back and the forebrain, increased on average by 9° in the right and left shoulder after 6 weeks of therapy.

Table 2. Statistical characteristics and evaluation of differences between the average of motion ranges in selected joints before and after 6 weeks of therapy in the studied women

Variable	Before	s	After	s	Before/after d	Student's test	p < 0.05
Shoulder joint P backbone (°)	53.75	10.99	59.75	8.66	–6.00	4.5418	0.0001
Shoulder joint P pre-bending (°)	167.25	8.65	170.00	6.69	–2.75	2.9039	0.0045
Shoulder joint L back (°)	57.00	9.92	61.50	9.05	–4.50	3.2432	0.0021
Shoulder joint L anterior thrust (°)	167.50	7.34	170.25	6.17	–3.75	3.2065	0.0011
Elbow joint P bend (°)	142.00	6.57	145.00	5.38	–3.00	3.1864	0.0024
Elbow joint L bend (°)	140.25	8.18	144.75	7.16	–4.50	4.9780	0.0000
Hip joint P bend (°)	110.00	11.81	119.50	10.87	–9.50	5.1453	0.0000
Hip joint L bend (°)	108.00	10.93	119.00	10.07	–11.00	5.9593	0.0000
Lumbar spine joints (cm)	5.55	1.16	6.15	0.84	–0.60	3.2505	0.0021

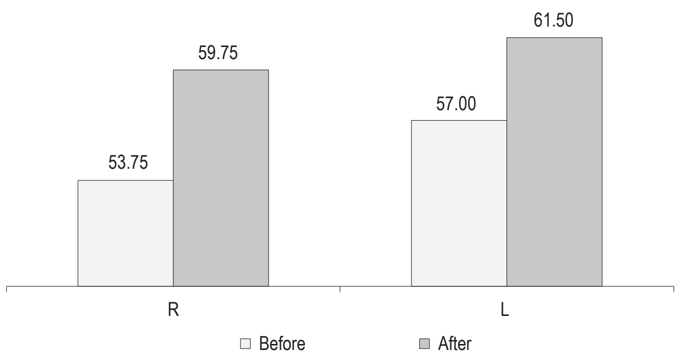

Figure 2. The mean values of the range of movement in the right (R) and left (L) shoulder joint before and after the therapy among the examined women (°)

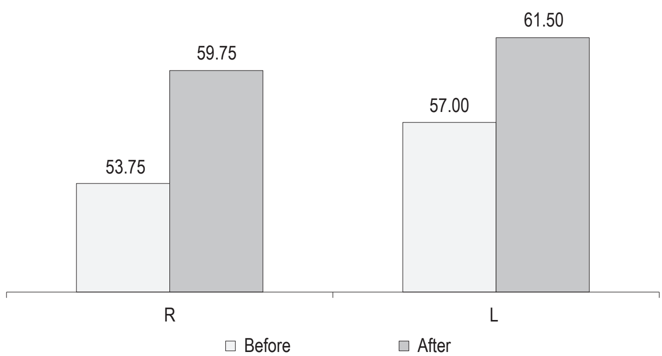

Figure 3. The mean values of the anterior deflection range in the right (R) and left (L) shoulder joint before and after therapy among the studied women (°)

An important factor that is important for self-service and functional ability in everyday life for an older person is mobility in the elbow joint.

In the research, the extent of flexion movement in the right and left ulnar joints was measured, which before the therapy was on average 142° – in the right elbow joint, 140° – in the left elbow joint. After therapy, it increased by 3° in the right elbow joint and by 4.5° in the left elbow (Table 2, Figure 4).

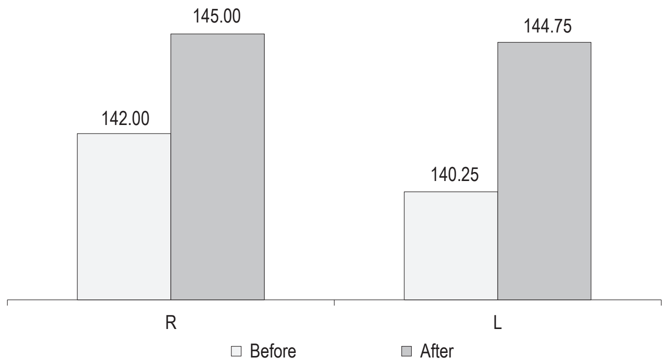

Figure 4. The average values of the movement range of flexion in the right (R) and left (L) elbow joint before and after therapy among the examined women (°)

Obtained results of measurements within the upper limb are statistically significant and testify to the positive effects of the appropriate treatments.

Retaining mobility in the joints of the lower limbs is necessary to locomotion and determine its quality and functionality. An important aspect in the possibility of walking and sitting are the sagittal movements of the hip and knee joints. In the lower limb, the movements of the left and right hip flexion were examined. The range of flexion movement in the right hip joint was improved by an average of 9.5° and by 11° in the left hip joint (Table 2, Figure 5).

All measured movements within the upper limb and lower limb, both before and after the therapy, are within the range of standards for a given age group (Skolimowski, 2009).

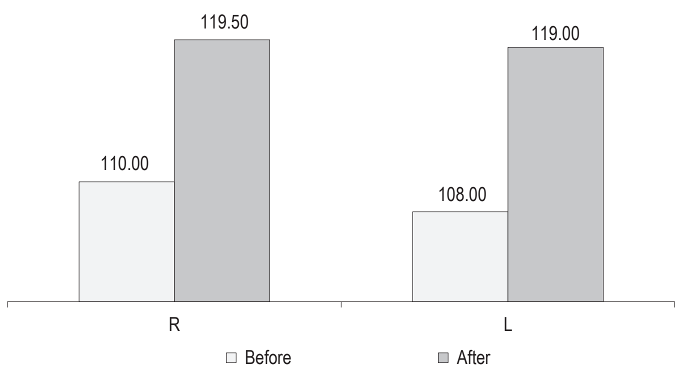

Figure 5. The average values of the movement range of flexion in the right (R) and left (L) hip joint before and after therapy among the examined women (°)

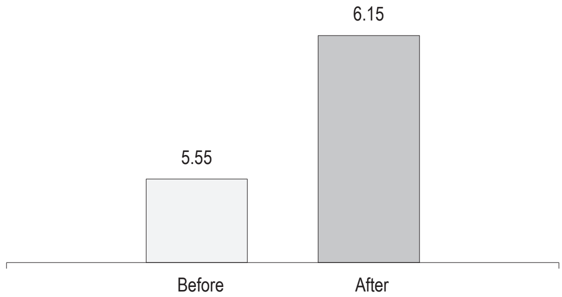

Figure 6. The average values of the extent of flexion movement of the front lumbar spine before and after therapy among the examined women (cm)

One of the most important problems affecting the functional efficiency of the elderly are the deepening deficits in the movement system associated with the restriction of mobility within the spinal joints (Szewczyk, 2016). The mean values of the difference of results obtained between the extension and then the bending of the spine examined before and after the 6-week treatment were taken for analysis. Before therapy, the difference between extension and flexion in the sagittal plane of the lumbar spine was 5.6 cm, after therapy – over 6 cm. After therapy, it was noticed that flexibility improved within the lumbar spine, increasing its elasticity by 0.6 cm. The difference between measurements shows statistical significance (Table 2, Figure 6).

Discussion

With age, all functions of the human body gradually deteriorate. Changes occurring in particular systems and organs affect the way of moving and performing everyday activities. Adamo et al. (2015), Sygit (2015) draw attention to the fact that, to a large extent, the dynamics of involutional processes in an adult person is affected by physical activity carried out by him both in everyday life and at work. Systematically practiced physical activity by older people determines efficiency, independence and resourcefulness in everyday life, significantly affects the slowing down of degenerative processes in particular systems, and especially in the musculoskeletal system, determines well-being and quality of life. In order for physical activity to slow down the regression phenomena of seniors' motor skills, it should be properly planned and dispensed taking into account the physical condition, subjective health and functional state of the elderly (Roberts et al., 2017; Skrzek et al., 2015).

Duda (2008) and Kozdroń (2014) draw attention to the low interest in recreation among older people, which results mainly from ignorance or insufficient information on the preventive role of physical activity. According to Kozdroń (2014) in Poland 50-70% of the population admit to a passive lifestyle, depending on age, and only 12% of people aged 60+ take up physical activity at least once a week. The necessity of practicing systematic and regular physical activity among seniors in order to preserve the biological condition was also noticed by Duda (2008). The author presents the results of research on the activity and physical fitness of people aged 60-69. Subjective assessment of own activity and physical fitness by participants in the studies was placed at the medium level. The obtained results indicated a greater activity of women than men towards the regular practice of sports and recreation (39%). In most women, the author noted the average level of endurance. The most often mentioned form of physical activity among the subjects was walking. In addition, women preferred gymnastics (49%). According to the author, physical activity should be used systematically, even permanently applied in the lifestyle of older people in particular. Also, the offer addressed to seniors should include a wide range of opportunities for active and healthy spending of free time.

An important issue is the promotion of a healthy lifestyle among older people, in other words, actions towards healthy aging. At the same time, many authors indicate beneficial results in the field of improving functional fitness and biological condition. through the application of a comprehensive physiotherapy (Hawrylak et al., 2010; Ignasiak, Ziółkowska-Łajp, 2012; Szewczyk, 2016).

Ignasiak, Ziółkowska-Łajp (2012) draw attention to the beneficial effect of sanatorium comprehensive physiotherapeutic treatment on functional fitness, health and better well-being among from rural areas. The author's 6-week comprehensive therapy carried out as part of the physiotherapeutic program "Summer Sanatorium of Spinal Pain Relief Therapy", in which a group of seniors from the Karkonoski University of the Third Age in Jelenia Góra systematically participated, positively influenced the improvement of physical fitness. Authors Ignasiak, Ziółkowska--Łajp (2012), however, suggest that in order to maintain the positive effects of the functional state, obtained during the rehabilitation period, it would be necessary to multiply the frequency of sanatorium stays for women from rural areas. Residents of cities are definitely more likely to use spa treatment.

The conducted 6 weeks author's therapy program improve the ranges of mobility in the examined joints of the upper limbs and lower limbs. The extent of the spinal flexion in the lumbar region has improved. The flexibility in the upper and lower body after the treatments has increased. A similar assessment of therapeutic effects was made by Szewczyk (2016) in his work proving that comprehensive therapy used in sanatorium and outpatient treatment brought benefits in the area of increasing physical activity, improving mobility and reducing pain in the lower section spine. The author, however, convinces that spa treatment has more beneficial effect on the progress of rehabilitation than outpatient treatment thanks to the support of traditional physiotherapeutic treatment by natural methods used in spa sanatoriums, such as mud treatments, salt baths and the advantages of the spa environment.

Similar conclusions regarding the continuation of functional improvement after the stay on the rehabilitation in the sanatorium and carrying out tests controlling the effects of therapy presented by Hawrylak et al. (2010). The authors point out that the three-week period of rehabilitation has positively influenced the improvement of all assessed functional parameters in patients with degenerative changes of the lower spine (in the 53–71 age group). However, therapy should be continued to preserve its effects.

Positive results obtained after the 6-week therapeutic program point the authors of the project that the program will be extended to a larger group of seniors, both women and men, which will enable further research.

The authors confirm that all kinds of therapies affecting the functional efficiency of older people will not bring long-lasting results if they are not continued and repeated.

Conclusions

The therapy improve flexibility in the upper and lower body of older women by increasing the ranges of mobility within selected joints of the upper and lower limbs and joints of the lumbar spine. This is important in many self-service and daily activities, allowing to maintain functional independence not only in everyday life.

Older people willingly participate in the form of related physical activity with elements of physioprophylaxis, for them health and functional efficiency become the most important value in their lives.

It should be assumed that properly selected forms of physical activity and physiotherapeutic programs for the elderly will allow them to maintain a good biological condition and function independently in the social and family environment.

Optimal biological condition of seniors and prolonged independence will have beneficial economic effects significantly reducing the state's financial resources directed to the medical care of seniors. Therefore, programs of systematic classes in physical activity combined with physioprophylaxis should be developed and implemented. They will help maintain optimal fitness of the body and a higher quality of life for older people.

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PHYSIQUE AND FITNESS OF SWIMMERS FROM WEST BENGAL

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Abstract The purpose of the present study is to assess the physique and fitness status of young school and college age swimmers from West Bengal. This cross sectional study was carried out on 46 male and 9 female swimmers of 9–20 years of age. The study parameters include body height, body weight, BMI, different anthropometric parameters, skinfold thickness and aerobic power, strength, flexibility, blood pressure and pulmonary function. Besides, history of training was taken by questionnaire. In the present study male and female adolescent swimmers have significantly higher body fat than non-swimmer ones. Besides, respiratory capacity, max. oxygen consumption and flexibility parameters are significantly higher in male and female swimmers than those in the control group. Besides, highly significant correlation has been found between sitting height, arm span and hand span of swimmer with swimming speed, years of training(swimming) and percentage of body fat. Again, pulmonary function, strength and max. oxygen consumption parameters are significantly correlated with years of training and speed of swimming (swimming efficiency). Therefore, simple regression equations are constructed to predict strength, respiratory and cardio-vascular parameters of adolescent swimmers on the basis of years of swimming and speed of swimming. When different style of swimming is considered it has been observed that highest VO_{2max} value has been found in free style and butterfly swimmers followed by breast stroke and then back stroke swimmers. Swimmers of the present study when compared to international standard, they are shorter and lower in body fat content values and some physiological parameters like Vo_2 max, flexibility and hand grip strength than international standard values. From this study it can be concluded that as there is no available information regarding strength, cardiovascular and respiratory status of adolescent girls and boys swimmers of West Bengal, this study can be said to be a pilot study on the basis of which further elaborate investigation requires to be initiated. Thus these baseline information of physique and physiological parameters of adolescent swimmers will provide local database for coaches and sports physiologists to develop proper training schedule and for identification of talent in the early ages.

Key words body composition, motor fitness, pulmonary function, max. oxygen consumption, swimmers

Introduction

Swimming is not only an athletic endeavor but also a lifesaving necessity. Everyone is able to learn to swim and most suitable years for learning to swim are ages between 10 and 12 (Statkeviciene, Venckunas, 2008) for boys and girls. Those have features determined by heredity factors as well as inborn abilities, a suitable training programme can enhance their performance as well as anthropometric parameters suitable for making them good swimmers.

Performance in athletes is influenced by many factors such as aerobic and anaerobic capacity, muscle power, neuromuscular coordination technique, motivation etc. The aerobic capacity is the dominant factor in endurance events like long distance running, walking and games. Muscular strength can be increased by regular exercise and total body muscular activity. Swimming produces maximum effect associated with lung capacities compared to other sports (Kate et al., 2012). Regular swimming practice should produce a positive effect on the lungs by increasing pulmonary capacity and thereby improving the lung functioning.

Certain anthropometric characteristics must be taken into consideration in analyzing sprint swimming performance including body height, arm span and lean body mass (Jurimae et al., 2007; Strzala, Tyka, 2009). These somatic attributes are largely inherited and determine swimming technique to a high degree.

Physical characteristics and body composition have been known to be fundamental to excellence in athletic performance (Mathur, Salokun, 1985). Specific athletic events require different body types and weights for maximum performance (American Dietetics Association, 1987). In swimmers, fat mass (Tuuri et al., 2002), upper extremity length (Geladas et al., 2005) and body height (Geladas, Nassis, Pavlicevic, 2005, Jagomagi, Jurimae, 2005) seem to have an influence on performance over short distances of 100 m, but there seem to be differences in gender. In female swimmers body height, body weight, percentage of body fat, fat free weight have an effect on swim performance, these effects have not been shown in male swimmers (Siders, Lukasaki, Bolonchuk, 1993).

In fact, Geladas et al. (2005) found that total upper extremity length, leg power and handgrip strength could be used as predictors of 100 meter front crawl performance in 12–14 years old boys. A multivariate analysis of swimming performance of male swimmers (11–12 years) of high national level revealed that predictive variables pertaining to the anthropometric (sitting height), physiological (aerobic capacity, speed and endurance) and technical (swimming index) domains explained 82.4% of competitive performance (Saavedra, Escalante, Rodriguez, 2010).

If athletic potentiality can be explored in the young age, proper training will produce a beneficial effect in making a successful swimming future. Keeping this view in mind we planned to:

1. Evaluate the anthropometric, body composition and physiological profile of young school and college age (9–20) swimmers from West Bengal.
2. Compare the anthropometric, body composition and physical ability parameters of swimmer boys and girls with their control group as also to compare with other present standards.

Methods

Subjects – This cross sectional study was carried out on 46 male and 9 female swimmers who were aged between 9–20 years of different swimming clubs of Hooghly district of West Bengal. A age matched control group (10 female and 12 male), non-swimmer subjects of equivalent age were chosen from different schools of West Bengal.

The test items, questionnaire administered and the methods used are given below:

Study design – This cross sectional comparative study includes the use of questionnaire, history of athletic activities, strength and speed. It was done among male and female swimmers of age range (9–20 years from different swimming clubs of Hooghly district of West Bengal. A control group was taken from school and college students of the same area.

Study area – There are many swimming clubs and training institutes in Hooghly district of West Bengal surrounding Uttarpara, Rishra, Chandannagar where from the subjects were selected at random. The research study was conducted qualitatively and quantitatively. Collection of data was done through questionnaire, interviews and experimental work by post graduate students, research scholars and teachers of Serampore college and Raja Peary Mohan college.

Study questionnaire

- Year of swimming.
- Average practice hours per day.
- Level of play (state/national/international).
- Style of swimming.
- Family income.
- No. of Family members.
- Respiratory Diseases (Asthma) and other diseases.

Ethical consideration – The ethical approval was obtained from Human Ethical Committee of Serampore College, 2014–2015. Besides, written consent was taken from club authority and parents of swimmers before the beginning of the study.

Parameters studied

Age (years): Age of subject was determined from their date of birth recorded in the club register and it was rounded off to the nearest whole number.

Anthropometric measurements and somatotyping

3. ***Body weight*** (kg) (Damon, Standt, McFarland, 1996): It was measured by standard weighing machine with lightly clothed and barefooted.
4. ***Body height*** (cm): It was taken by anthropometric rod barefooted.
5. ***BMI:*** It was calculated from height and weight by using the equation of Meltzer, Mueller, Annegers, Grines, Albright (1988).
   BMI (kg/m^2) = (Body weight in kg)/(Body height in meters)^2.
6. ***Sitting height*** (cm): Vertical distance from the sitting surface to the top of the head (vertex). Sitting height is measured with an anthropometer.
7. ***Arm span*** (cm): With back against the wall, arms were extended horizontally. Distance taken from out stretched finger tips of one hand to the other.
8. ***Hand span*** (cm): It was the maximum distance between the tip of the thumb and the tip of the little finger in expanded position of the hand.
9. ***Waist circumference*** (cm): Horizontal circumference at the level of the greater lateral indentation of trunk.
10. ***Hip circumference*** (cm): Horizontal circumference at the level almost near protrusion of the buttocks.
11. ***Waist/hip ratio***: It was calculated from waist circumference divided by hip circumference.
12. ***Skin fold measurement*** (mm): Skin fold thickness was measured by Haltain Skinfold Caliper (Haltain Ltd, UK) with constant tension by following guidelines of Johnson, Nelson (1982). Biceps, triceps, sub scapular,

supraspinale and medial calf skinfolds were measured on the right side of the body (Chatterjee, Mandal, 1993).

13. ***Percentage of body fat***: It was calculated by using the formula of Parizkova (1961).
The following formula was utilized for calculation of percentage of body fat of boys at the ages of 9–18 years.
Percentage of body fat = **[(4.95/D) – 4.50] × 100**
Where D is the body density
Now, in case of 9–12 years old boys, the body density (D) is,
$D = 1.108 – (0.027 × logx_4) – (0.0388 × logx_5)$
For, 13–16 years old boys, the body density (D) is,
$D = 1.130 – (0.055 × logx_4) – (0.026 × logx_5)$
Where x_4 = Triceps skinfold in cm.
And x_5 = Subscapular skinfold in cm.
The formula was also utilized to calculate the percentage of body fat of the girls of 9–17 years,
Percentage of body fat = **[(4.95/D) – 4.50] × 100**
Where D is the body density
For 9–12 years old girls, the body density (D) is,
$D = 1.088 – (0.014 × logx_4) – (0.036 × logx_5)$
For 13–17 years old girls, the body density (D) is,
$D = 1.114 – (0.031 × logx_4) – (0.041 × logx_5)$
Where x_4 = Triceps skinfold in cm.
And x_5 = Subscapular skinfold in cm.
The following formula was also utilized to calculate the percentage of body fat of young boys and girls, age ranging from 18 to21 years
Percentage of body fat = **[(4.95/D) – 4.50] × 100**
Where D is the body density
For, 19–21 years old boys, the body density (D) is,
D = 1.1043 – 0.00132 (Thigh skinfold) – 0.00131 (Subscapular skinfold)
For, 18–21 years old girls, the body density (D) is,
D = 1.0852 – 0.00076 (Suprailliac skinfold) – 0.00107 (Thigh skinfold)

Motor fitness and strength parameters

1. Resting heart rate (bpm) and blood pressure (mmHg) by Auscultatory method (Guyton, 1991).
2. ***Measurement of maximum oxygen consumption by Queen's college step test*** (L/min) (MacArdl, Katch, Katch, 2001): This test was used for assessing cardiorespiratory fitness by using the following equations:

$$\text{Men} – VO_{2max} = 111.33 – [0.42 × \text{step test pulse rate (b/min)}]$$

$$\text{Women} – VO_{2max} = 65.81 – [0.1847 × \text{step test pulse rate (b/min)}]$$

3. Sargent vertical jump test (Sargent, 1924) (cm).

4. ***Measurement of hand strength by hand grip dynamometer*** (kGs) (Philips, Hornark, 1979): The measurement was taken with the best of two trials with 30 seconds rest between trials. The dynamometer scale was read in kGs.
5. ***Flexibility by sit and reach test*** (cm) (Ostyn, Simons, Bunen, Renson, Gerven, 1980): The best three trails measure to the nearest half cm (0.5) were the test score.

Lung function parameters

1. ***Peak expiratory flow rate*** **(*PEFR*)** (lit/min): It is the maximum flow which can be sustained for a period of 10 seconds during a forced expiration starting from a total lung capacity.
   It was measured by Weight's peak flow meter.
2. ***Pulmonary function test by spirometer***: Pulmonary function test (PFT) were performed in their work place by using automatic spirometer (Spirovit SP 1 model) according to the guidelines recommended by American Thoracic Society. The relevant data- age, sex, body weight were recorded. The tests were repeated three times and best result was considered for analysis. Following tests were measured:
   - Forced vital capacity (FVC) (lit).
   - Forced expiratory volume in 1 second (FEV_1) (lit).
   - FEV_1/SVC.
   - $FEF_{0.2-1.2\%}$ (lit/min).
   - $FEF_{25-75\%}$ (lit/min).
   - $FEF_{75-85\%}$ (lit/min).
   - Maximum voluntary ventilation (MVV) (lit/min).
   - Minute ventilation (MV) (lit/min).

Athletic ability

Speed of swimming: Swimming speed of 50 meters was measured in a 25 meters swimming pool by stopwatch.

Statistical analysis: Mean, standard deviation, correlation between parameters were analyzed. Student's t-test was performed to compare the mean between two groups after performing the normality test by histogram, b_1, b_2 method and Q-Q Plot method.

Results

Table1 represents the mean ± SD values of some physical, physiological, anthropometric and different pulmonary function parameters of male and female swimmers and a control group of West Bengal. All the physical parameters of male and female swimmers are significantly different from the control group except greater skinfold thickness of both male and female swimmers and thigh skinfold of female swimmers are significantly ($P < 0.01$) higher in comparison to control group. Anthropometric parameters of swimmers are not significantly different from control group. All the pulmonary function parameters are significantly higher in swimmer boys and girls than the control group indicating greater respiratory capacities and respiratory muscle strength of swimmers. Maximum O_2 consumption values are significantly ($P < 0.01$ for female and $P < 0.001$ for male) higher in swimmers than the control group. Handgrip strength is significantly higher in male swimmers than control group. Leg strength although insignificant is lower in swimmers than control group. Flexibility of both male and female swimmers is significantly

($P < 0.001$ and $P < 0.01$) higher in comparison to control group. Heart rate values are significantly lower in swimmers than control group indicating greater efficiency of swimmers. SBP values are greater in swimmers insignificantly but DBP values are slightly lower in swimmers, of which DBP value of female swimmers is significantly lower than control group.

Table 1A. Mean ±SD and 't'-test of physical, physiological, body composition, respiratory and athletic ability parameters of male and female swimmers and control group

Parameters	Swimmers		Control		't'-Test	
	mean ± SD					
	male (n = 46)	female (n = 9)	male (n = 12)	female (n = 10)	male	female
Age (years)	13.53 ±3.87	12 ±4.06	15.25 ±3.02	14 ±3.27	0.110	0.260
Height (cm)	153.02 ±14.92	149.02 ±8.91	152.85 ±11.14	142.77 ±11.82	0.960	0.210
Weight (kg)	48.35 ±16.06	44.78 ±9.99	42 ±12.88	35.4 ±12.31	0.160	0.080
BMI (kg/m^2)	20.06 ±3.72	19.99 ±3.08	17.74 ±3.95	16.93 ±3.83	0.080	0.070
W/H ratio	0.93 ±0.15	0.92 ±0.04	0.90 ±0.05	0.93 ±0.05	0.070	0.960
Triceps skinfold (mm)	12.09 ±10.51	13.47 ±2.91	6.94 ±2.69	9.94 ±3.85	0.004^{***}	0.030^{*}
Subscapular skinfold (mm)	9.17 ±3.03	11.56 ±4.68	8.41 ±4.06	8.24 ±5.61	0.550	0.170
Suprailleac skinfold (mm)	9.91 ±4.17	13.1 ±2.95	10.12 ±5.73	11.6 ±5.81	0.910	0.480
Thigh skinfold (mm)	13.09 ±5.08	17.67 ±5.18	13.03 ±4.10	11.1 ±3.79	0.970	0.007^{***}
% of body fat	18.36 ±8.85	20.69 ±2.06	16.20 ±6.08	20.44 ±6.69	0.330	0.910
Sitting height (cm)	80.61 ±7.43	78.33 ±4.85	81.89 ±5.60	75.16 ±6.08	0.520	0.220
Arm span (cm)	158.48 ±19.44	152.04 ±12.01	155.89 ±13.21	143.47 ±12.55	0.590	0.140
Hand span (cm)	18.16 ±2.84	17.28 ±1.46	18.89 ±1.91	17.81 ±1.80	0.310	0.480
Speed of swimming (50m) (sec)	40.52 ±16.21	43.68 ±16.89	_	_	_	_
Year of swimming	4.72 ±2.74	6 ±4.47	_	_	_	_
Average practice hour per week	11.79 ±6.07	9.4 ±2.63	_	_	_	_

Table 1B. Mean ± SD and 't'-test of physical, physiological, body composition, respiratory and athletic ability parameters of male and female swimmers and control group

Parameters	Swimmers		Control		't'-Test	
	Mean ± SD					
	male (n = 46)	female (n = 9)	male (n = 12)	female (n = 10)	male	female
1	2	3	4	5	6	7
FVC (lit)	2.51 ±0.87	2.19 ±0.44	2.25 ±1.09	1.54 ±0.36	0.010^{***}	0.010^{***}
FEV_1 (sec)	2.27 ±0.83	2.04 ±0.46	1.98 ±0.93	1,37 ±0.41	0.020^{**}	0.010^{***}
FEV_1/SVC%	87.77 ±18.92	96.62 ±13.85	87.07 ±19.31	84.11 ±11.58	0.030^{*}	0.050*
$FEF_{0.2–1.2\%}$ (lit/min)	4.35 ±1.85	4.12 ±1.59	3.24 ±1.78	1.99 ±0.65	0.010^{***}	0.003^{***}
$FEF_{25–75\%}$ (lit/min)	3.44 ±1.36	3.29 ±0.99	2.94 ±1.42	2.07 ±0.68	0.003^{***}	0.010^{***}
$FEF_{75–85\%}$ (lit/min)	2.11 ±0.94	1.81 ±0.98	1.73 ±0.99	1.43 ±0.27	0.010^{***}	0.240
MVV (lit/min)	89.20 ±30.74	77.57 ±17.84	86.81 ±36.26	59.53 ±16.05	0.040^{*}	0.030^{*}
MV (lit/min)	22.07 ±9.57	19.67 ±7.85	21.92 ±18.80	13.81 ±7.28	0.060	0.050^{*}
PEFR (lit/min)	312.61 ±101.42	283.33 ±56.57	325 ±101.76	233 ±49.90	0.010^{***}	0.020^{**}
SBP (mmHg)	123.33 ±17.76	119.11 ±13.06	118.83 ±12.60	115.8 ±13.18	0.320	0.580
DBP (mmHg)	65.43 ±8.75	67.44 ±7.30	66.42 ±5.76	77.2 ±8.02	0.640	0.010^{***}
Heart rate (beats/min)	80.20 ±12.90	91.78 ±14.14	95.75 ±19.69	110.9 ±8.52	0.020^{**}	0.003^{***}

1	2	3	4	5	6	7
Flexibility (cm)	25.02 ±6.43	26 ±6.70	17 ±3.04	16.55 ±3.61	0.00000026****	0.002***
Leg strength (cm)	28.67 ±11.87	21.68 ±6.42	33.66 ±6.71	23.37 ±5.53	0.060	0.550
Handgrip strength (R) (kg)	31.15 ±14.72	22.78 ±14.71	22.92 ±6.72	14.8 ±7.64	0.007***	0.170
Handgrip strength (L) (kg)	26.5 ±15.43	17.11 ±9.52	20.33 ±12.50	12.5 ±6	0.050*	0.230
VO_{2max} (ml/kg/min)	44.26 ±7.40	35.85 ±3.51	28.17 ±8.43	30.64 ±4.53	0.000018****	0.010***
VO_{2max} (lit/min)	2.19 ±0.93	1.60 ±0.38	1.17 ±0.44	1.06 ±0.34	0.0000030****	0.004***

Table 2 represents correlation between physical, some motor fitness parameters and pulmonary functions of swimmer. It has been observed that significant positive correlation exists between age, body height, body weight, BMI and pulmonary function parameters except FEV_1%, $FEF_{75-85\%}$ and MV. PEFR has strong correlation with age, body height, body weight and BMI in male swimmers. No significant correlation has been found between physical parameters and pulmonary function parameters except FVC & FEV_1 in female swimmers probably due to small number of female swimmers in our study. Blood pressure and heart rate values are significantly correlated with age, body height, body weight and BMI for male swimmers. No significant association has been found between flexibility and physical parameters except forage in male swimmers ($P < 0.001$). Again, handgrip strength and maximum O_2 consumption (lit/min) are significantly associated with age, body height, body weight and BMI. VO_{2max} when expressed in ml/kg/min(per kg of body mass), no significant association has been found in the above mentioned parameters in male swimmers.

Table 2. Correlation between different body parameters, respiratory parameters and motor ability parameters of male and female swimmers

Parameters	Age		Height		Weight		BMI	
	male	female	male	female	male	female	male	female
FVC	0.33*	0.65*	0.52****	0.67*	0.410***	0.78**	0.220	0.64
FEV_1	0.37**	0.54	0.57****	0.57	0.460***	0.72*	0.250	0.52
FEV_1/SVC%	–0.30*	–0.39	–0.21	–0.21	–0.230	–0.21	–0.180	–0.28
$FEF_{0.2-1.2\%}$	0.45***	0.23	0.53****	0.53	0.470	0.33	0.290	0.26
$FEF_{25-75\%}$	0.46***	0.08	0.55****	0.54	0.490****	0.15	0.310*	–0.05
$FEF_{75-85\%}$	0.30*	0.12	0.23	0.42	0.250	0.25	0.220	–0.02
MVV	0.60****	0.47	0.64****	0.63	0.500****	0.58	0.260	0.45
MV	0.05	0.41	0.08	–0.31	–0.005	0.18	–0.004	0.47
PEFR	0.78****	0.42	0.84****	0.51	0.750****	0.53	0.470****	0.39
SBP	0.56****	0.32	0.59****	0.12	0.560****	0.40	0.460***	0.47
DBP	0.42***	0.51	0.38***	0.17	0.340*	0.40	0.250	0.47
Heart rate	–0.52****	–0.49	–0.51****	–0.64	0.520****	–0.71*	0.380***	–0.54
Flexibility	0.59****	0.64	0.28	0.32	0.240	0.64	0.110	0.62
Leg strength	0.79****	0.24	0.76****	0.44	0.680****	0.43	0.420***	0.31
Handgrip strength (R)	0.84****	0.91****	0.80****	0.55	0.670****	0.94****	0.410***	0.93****
Handgrip strength (L)	0.91****	0.91****	0.83****	0.39	0.750****	0.85***	0.510****	0.93****
VO_{2max}	0.54****	0.04	0.48****	–0.57	0.460***	–0.20	0.330*	0.09
VO_{2max} in lit/min	0.83****	0.91****	0.85****	0.53	0.940****	0.92****	0.780****	0.91****

Table 3 represents correlation between speed of swimming, years of swimming and percentage of body fat with body weight, BMI, sitting height, arm span, hand span and physiological parameters of swimmers. Highly significant correlation has been found between sitting height, arm span and hand span with swimming speed, years of swimming and percentage of body fat. No significant correlation has been found between speed of swimming, year of swimming and percentage of body fat with physiological parameters but the relation between speed of swimming and physiological parameters are negative although insignificant.

Table 3. Correlation between different body parameters, athletic ability parameters and motor ability parameters of male and female swimmers

Parameters	Speed of swimming		Years of swimming		Percentage of body fat	
	male	female	male	female	male	female
Weight	–0.42***	–0.47	0.44***	0.88***	–0.46***	0.31
BMI	–0.25	–0.41	0.39***	0.89***	–0.25	0.12
Sitting height	–0.39***	–0.79***	0.47****	0.81***	–0.59****	0.58
Arm span	–0.53****	–0.78**	0.40***	0.63	–0.65****	0.50
Hand span	–0.48****	–0.34	0.39***	0.59	–0.61***	0.46
Average practice hour per week	–0.25	0.01	0.08	0.18	–0.60***	0.07
Flexibility	–0.22	–0.20	0.22	0.73	–0.53	0.27
Leg strength	–0.45	–0.81	0.39	0.48	–0.61	0.22
Handgrip strength (R)	–0.50	–0.31	0.42	0.82	–0.64	0.15
Handgrip strength (L)	–0.49	–0.41	0.40	0.88	–0.73	–0.17
VO_{2max}	–0.35	–0.11	0.29	0.002	–0.45	0.31
VO_{2max} in lit per min	–0.45	–0.42	0.48	0.81	–0.55	0.43

Table 4 represents correlation between physical, physiological and pulmonary function parameters with years of swimming and speed of swimming. Pulmonary function parameters and other physiological parameters and physical parameters have significant ($P < 0.05–0.001$) correlation with years of swimming and speed of swimming.

Table 4. Correlation between different body parameters, athletic ability parameters, respiratory parameters and motor ability parameters of male and female swimmers

Parameters	Years of swimming	Speed of swimming (50 m)
1	2	3
Age	0.53****	–0.43***
Height	0.32**	–0.49****
Weight	0.45****	–0.42***
BMI	0.46****	–0.27*
% of body fat	–0.13	0.23
Flexibility	0.37***	–0.21
Vertical jump	0.34**	–0.48****
Handgrip strength (L)	0.42***	0.48****
Handgrip strength (R)	0.43***	–0.47****
VO_{2max}	0.12	–0.30*
VO_{2max} in lit/min	0.40***	–0.44****

1	2	3
Heart rate	–0.33**	0.29*
FVC	0.25	–0.41***
FEV_1	0.22	–0.38***
PEFR	0.42***	–0.52****

Table 5 and 6 represent simple regression equations of strength, respiratory and cardiovascular parameters and BMI on the basis of years of swimming and speed of swimming respectively.

Table 5. Simple regression equation of BMI and some physiological parameters on the basis of years of swimming

Parameters	Coefficient	Constant	R value	Standard error estimation (SEE)
BMI (kg/m2)	0.5278x	17.474	0.43****	0.49
PEFR (lit/min)	13.251x	243.13	0.41****	12.94
Heart rate (beats/min)	–0.609x	85.179	0.13	1.85
Flexibility (cm)	0.7102x	21.5	0.34***	0.87
Leg strength (cm)	0.4924x	25.254	0.13	1.52
Hand grip strength (l)(kg)	2.0751x	15.397	0.42****	1.98
Hand grip strength (r)(kg)	2.1093x	20.03	0.43****	1.96
VO_{2max} (lit/min)	0.1171x	1.5182	0.39***	0.12

x = Year of swimming, * P < 0.05; ** P < 0.02; *** P <0.01; **** P < 0.001.

Table 6. Simple regression equation of BMI and some physiological parameters on the basis of speed of swimming

Parameters	Coefficient	Constant	R value	Standard error estimation (SEE)
BMI (kg/m^2)	0.0882x	17.582	0.39***	0.49
FVC (lit)	–0.0014x	2.4961	0.03	0.11
FEV_1 (lit)	0.0036x	2.0982	0.08	0.10
PEFR (lit/min)	1.9646x	252.81	0.33***	12.94
VO_{2max} (ml/kg/min)	0.135x	39.1	0.29*	1.02
VO_{2max} (lit/min)	0.0228	1.4528	0.41****	1.12
heart rate (beats/min)	–0.1304x	85.743	0.15	1.85
leg strength(cm)	0.2668	20.06	0.37***	1.54
handgrip strength (l) (kg)	0.4468x	12.455	0.48****	2.02
handgrip strength (r) (kg)	0.5357x	14.782	0.58****	2.01

x = Speed of swimming; * P < 0.05; ** P < 0.02; *** P < 0.01; **** P < 0.001.

Figure 1 shows VO_{2max} values according to different style of swimming. Highest VO_{2max} values have been observed in free style and butterfly swimmers, then breast stroke swimmers and finally back and free style swimmers.

Figure 2 represents comparison of aerobic power of male and female swimmers of present study with international standard value of swimmers, basketball players, gymnasts, track and field players.

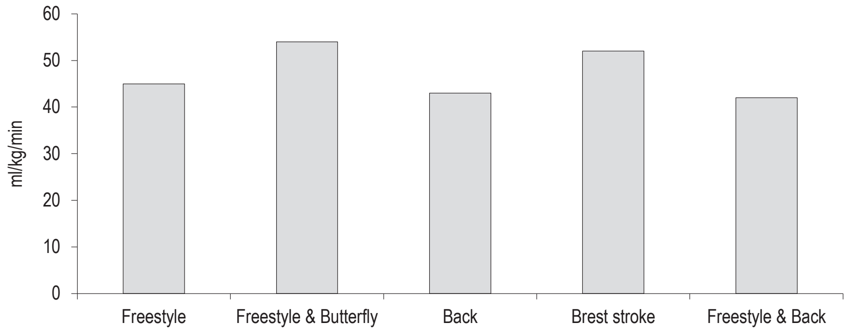

Figure 1. Comparison of aerobic power values of swimmers depending on different style of swimming

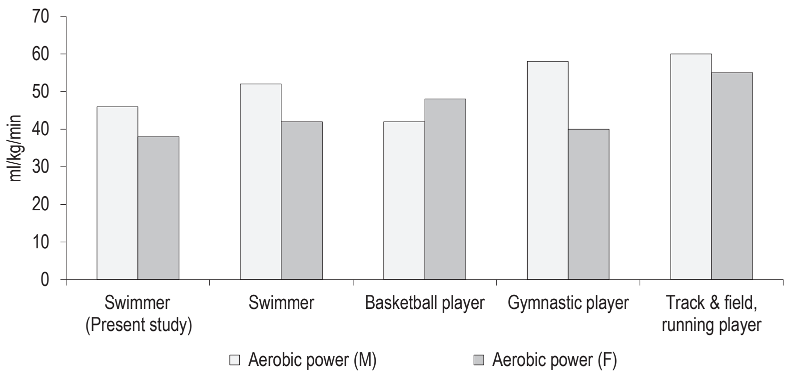

Figure 2. Comparison of aerobic power of male & female among swimmers (Present study) with International standard value of swimmers, basketball players , gymnasts & track & field athletes, runners

Discussion

A young body is flexible and susceptible to various stimuli, which exceed the limit of biological tolerance of the body and are inadequate for the level of development of somatic and motor capacities of a child and may affect the processes of body growth and maturation. Somatic features are an important factor conditioning an achievement in sports (Siders et al., 1993) and are one of the elements taken into consideration during the selection process in specific sports events.

Adolescent male and female swimmers when compared with adult athletes of South Australia (Withers et al., 1987), China (Chen et al., 1989), Israel (Hanne, Dli, Rotstein, 1986) and Nigeria (Mathur, Sulokun, 1985), it was found that in each case swimmers of our study have greater body fat than athletes of other countries probably due to difference in age group, level of training, genetic and environmental factors.

Mathur, Salokun (1985) found that athletes with lower percentage of body fat had higher maximum O_2 uptake. Athletes with lower percentage of body fat seem to utilize O_2 more efficiently (Heek, 1980) while excess body fat reported to be deterrent to physical performance (Leelarthaepin, Chesworth, Boleyn, 1983). Again, Smith (1984) observed that a minimum level of fat mass are advantageous for gymnasts, wrestlers, distance runners etc. Adolescent male and female swimmers also have greater body fat when compared with non-athletes (Chatterjee, Mandal, 1993; Mandal, 2005). This difference might be due to level of training, lower number of swimmers in comparison to non-athlete boys and girls and nutritional factors.

Similarly, body height and body weight of boys and girls of present study are shorter and lighter (for girls)/ heavier (for boys) in comparison to young boys and girls of Poland (Ostrowska, Domaradzki, Ignasiak, 2006) at the age of 12. These differences in body dimension in these two groups of boys and girls might be due to difference in age group (mean age for boys of our study is 13.53 and for girls is 12 years) and the ethnic variation between these groups. Again Statkeviciene, Venckunas (2008) pointed out that taller people have the ability to swim better and more correctly. Skinfold fat makes the body more buoyant in the water, if fat distribution over the body is uniform, and that is typical for male. Besides, the ability to maintain body on the surface of water depends not only on body composition but also on the body shape. They concluded that tall people having relatively small body mass and relatively small extremity dimensions but larger skinfold content will learn to swim faster and with higher grades than people with different body dimensions.

Colantonio, Barros, Kiss (2003) reported the aerobic capacity of swimmers as well as other athletic activities on treadmill exercise and on swimming flume. The VO_{2max} value (ml/kg/min) was significantly higher than in male and female swimmers of our study. These differences might be due to differences in method used for measurement of VO_{2max}, difference in age group, body mass and stature which have direct influence on VO_{2max}. Besides, genetic factor and the level of training might be the reason for higher VO_{2max} of swimmers of our study.

Again anthropometric parameters body height, body weight, BMI, sitting height, triceps and subscapular skin fold thickness values of adolescent male and female swimmers show significantly higher values than sedentary boys and girls of West Bengal (Chatterjee, Mandal, 1991, 1993; Mandal, 2006). However, the percentage of body fat value is higher in male swimmers but significantly lower in female swimmers in comparison to their non-swimmer females (Chatterjee, Mandal, 1993). These differences indicated differences in dietary pattern and training regimen of swimmers in comparison to non-swimmers (Nudri, Ismail, Zawiak, 1996)

The consistent relationship between height and swimming performance could be explained by the fat than taller swimmers seem to glide better through water (Geladas et al., 2005; Toussaint, Hallander, 1994) and taller swimmers usually show a longer arm span which benefits swimming efficiency (i.e., larger stroke length) (Saavedra et al., 2010). They also suggested that the length of the upper extremities and shoulder width combined may be related with biomechanical factors relevant to propulsion. Leone, Lariviere, Comtois (2002) suggested that certain physical characteristics such as height and limb length are associated with higher level of performance in a particular population of athletes. Siders et al. (1993) reported that anthropometry and other physical characteristics were related to swimming performance.

Statkeviciene, Venekunas (2008) stated that height, body part's dimensions and the skin fold content were important parameters of swimming performance. The tall person with relatively small body mass and relatively small extremity dimensions but larger skinfold content will learn to swim faster and with higher grade than persons with different body dimensions.

VO_{2max} (ml/kg/min) values of male and female swimmers of present study are significantly lower than standards value of international standard of swimmers, gymnastics and runners but they have significantly higher VO_2 max value than sedentary girls of West Bengal (Mandal, 2006). These differences might be due to genetic, socioeconomic factors, environmental factors and level of training among the groups (Figure 2).

Besides FVC and FEV_1 values are much higher in swimmers than non-swimmers. This might be due to physical activity having positive influence on the cardiovascular and respiratory system (Dziedziczak, Witkowski, 1988; Ostrowska, Demczuk-Wlodarczyk, Rozek-Mroz, 2001). Ostrowaska et al. (2006) reported that cubic content (body weight, muscles, chest circumferences) indirectly inform about vertical capacity and circular respiratory system efficiency. The diaphragm and accessory muscles reported to physical training in the same way as other muscles and it has been suggested that hypertrophy of the respiratory musculature may account for the higher values of FVC and FEV_1 (Maksud, Hamilton, Couths, Wiley, 1971). Vaccaro, Clarke, Morris (1980) found that the FVC and FEV_1 values of young male swimmers (13–16 years) were 10–16% above normal.

From this study it can be concluded that aerobic capacity of young boys and girls swimmers is much lower than distance runners, rowers, road cyclists, cross country skiers and swimmers of international class.

As there is no available information regarding strength, cardiovascular and respiratory status of adolescent female and male swimmers of West Bengal, this study can be considered to be a pilot study on the basis of which further elaborate investigation requires to be initiated.

Besides, potentiality of swimming performance can be assessed in the adolescent stage (11 and 15 years) and evaluation of their swimming technique is impacted by their anthropometric indices- height, body mass, body part's dimensions and the skinfold fat content. Thus, this baseline data may be helpful for the indication of talent and application of proper training schedule and improvised technique of swimming for adolescent swimmers of this area of West Bengal.

Practical application

This is the first and most comprehensive physique and physiological profile study of Indian (Bengali) swimmers and this test data will provide good baseline reference data for coaches, sports physiologists, physiotherapists and future investigators of this area.

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