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A HALF CENTURY OF SCIENTIFIC RESEARCH IN FIELD HOCKEY

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ABSTRACT
Purpose. Using databases available on the Internet, the number of scientific papers on the subject of field hockey were examined. **Basic procedures.** As a result, 208 scientific studies covering the fields of biochemistry, physiology, sport injuries, psychology and tactics were found, which were published within the last 50 years (from 1960 to 2010). Despite the popularity of field hockey and its status as an Olympic sport, the number of scientific studies which focused on field hockey was much smaller when compared to the amount of publications on other team sports, such as soccer, basketball, or baseball. **Main findings.** It was found that the greatest number of publications (61.06%) originated from five English-speaking countries (UK, USA, Canada, Australia, and New Zealand), with the majority focusing on sport psychology, injuries and biochemistry. What was discovered was that the vast majority of scientific studies used field hockey merely as a reference point in comparison to other team sports. **Conclusions.** The varying topic diversity of the scientific studies found among the databases significantly hinders an effective comparison of findings, especially considering that most of the studies focused on only a few selected aspects of the problem matter and were chiefly small sample studies, nor were they repeated.

Key words: biochemistry, physiology, tactics, nutrition, injuries, psychology

Introduction

Thanks in part to the Internet, searching for scientific information can begin from entering a few key words into a specialist database search engine, which hosts original research papers published in specialist community-wide journals, guaranteeing that the found texts are both accurate and of high quality. Such databases also feature a number of review works, which give critical analyses of research undertaken in various scientific fields.

Nearly every sport can be characterized by, among other things, what terms are applicable towards to what research findings in the biological sciences. In particular, the literature available on sports that have a long tradition, such as field hockey, could be expected to provide a comprehensive description of players' physical reactions to a specific physical exercise, as determined by the rules of the game. Having examined the available specialist literature, however, one needs to verify that assumption. The findings which have been published to date on the biological aspects of field hockey are rather random, incomplete, and usually do not allow for comparisons with the findings of our current research. Similar conclusions are drawn with respect to other scientific areas, which also include field hockey from a biological point of view. These include psychology, nutrition (especially the problems associated with supplementation), as well as tactics.

Thus, the aim of this paper is to examine and describe the current state of scientific research concerning the biological aspects of field hockey, including, but not limited to, questions regarding physical fitness, physiological and psychological comfort, as well as the techniques used to monitor these features in players.

Material and methods

The research materials consisted of scientific studies on field hockey hosted on a number of available databases. They were obtained by browsing for publications on a variety of topics in the PubMed and EBSCOhost databases, which include Academic Search Premier, SPORTDiscus, Hospitality & Tourism Complete, Health Source: Consumer Edition, Health Source: Nursing/Academic Edition, MEDLINE, Business Source Complete, Library, Information Science & Technology Abstracts, MasterFILE Premier, Newspaper Source, Regional Business News, Agricola, and Academic Search Complete. Moreover, in order not to omit other valuable studies relevant to this paper which have not been included in the above mentioned databases but are available on the Internet, www.scholar.google.pl was also used.

The search covered those publications entered into the databases between 1960 and 31 December 2010, which were accessed after entering the term "FIELD HOCKEY".

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This paper also takes into account studies published in Polish ($n = 6$) and Russian ($n = 1$) which had not been registered in the analyzed databases by the specified end date.

Thus, the spectrum of the obtained publications covered all areas of science which determine the biological profile of field hockey players. It consists not only of a description of physiological and biochemical indices, but also points to direct and indirect factors which may affect the value of such indices. They include, but are not limited to, improving various elements of the game which can affect a team's ability to succeed in matches and tournaments, the methods of preparing players for the competition season and maintaining players' fitness levels during that period, as well as numerous psychological and social aspects. The field hockey studies found in the databases have been divided into the following seven thematic groups:

– Biochemistry. Mostly studies describing research in which biochemical indices in the blood of field hockey players were determined, or describing changes in the concentration of selected biochemical parameters influenced by a given training load or physical performance tests.
– Physiology. Studies aimed at determining players' physical fitness and their predisposition to handle aerobic and anaerobic exercise.
– Tactics. Studies describing methods of improving players' training and effectiveness in matches. Works in this field also examined the objectivity of, or compared various endurance performance tests on, the basis of physical performance results obtained by field hockey players.
– Nutrition. Primarily studies characterizing the dietary habits of players or describing the influence of selected dietary supplements on their fitness.
– Anthropometrics. Studies discussing the structure and composition of the body and the differences between players of national or/and international clubs, or in presenting the found relationships within a single team.
– Injuries. Studies concerning the occurrence of trauma in field hockey players, discussing prevention methods, and presenting selected cases of injury.
– Psychology. Studies focusing on the psychological profile of players, interactions between them, and reactions to fear or aggression.

Results

EBSCOhost's browser showed 7459 results for "FIELD HOCKEY," a small number compared to other

Table 1. Number of citations found in EBSCOhost base after selecting a team sport

Search day – 31.12.2010

Team sport	No. of citations
Hockey	229133
Field Hockey	**7459**
Ice Hockey	12428
Lacrosse	22700
Basketball	570309
Volleyball	58495
Handball	13575
Baseball	570722
Softball	51755
Water Polo	7898
Cricket	182759
Soccer	258943
Football	1025038

team sports (Tab. 1). A search in the same database for lacrosse ("LACROSSE"), a less popular sport in many countries, is referred to over three times more frequently (22,700 times). Moreover, a detailed analysis of the articles concerning field hockey revealed that only 200 related directly to that sport. In other publications, field hockey was used as a comparative sport to those results obtained or observations made. 208 studies published in the last 50 years, from 1960 until 2010, were chosen for the purposes of this analysis.

It was found that over two-thirds of all analyzed studies concerning field hockey (142 out of 208, i.e. 68.27%) were published in the last ten years, from 2000 to 2010, which could indicate an increased interest in the sport (Tab. 2). The increase in the number of published papers was gradual and took place during years in which the Summer Olympics were held, in particular during those organized in Sydney (2000, 7 publications), Athens (2004, 24 publications), and Beijing (2008, 19 publications). However, such a dynamic rise in scientific studies concerning field hockey was still inferior to that of other team sports (Fig. 1).

An analysis of the 208 studies showed that a significant portion of them (68.60%) focused on research carried out exclusively on field hockey players. The remaining papers took into account other sports, usually soccer, basketball, cycling, rugby, or lacrosse, where field hockey players were a control group. Table 3 contains a division of the analyzed studies (n = 208) by thematic group as specified in the methodology section.

Out of the 208 studies on field hockey found in the databases, the most numerous were articles published

Table 2. Number of papers published in the last 50 years, from 1960 to 2010, on football, soccer, hockey and field hockey

Search day – 31.01.2011

Years	Summer Olympic Games (year)	Football	Soccer	Hockey	Field hockey
2008–2010	Beijing (2008)	296319	82327	62610	2172
2004–2007	Athens (2004)	362256	90719	60957	1757
2000–2003	Sydney (2000)	177251	45310	37713	732
1996–1999	Atlanta (1996)	78062	16275	24034	485
1992–1995	Barcelona (1992)	47978	9379	20317	332
1988–1991	Seoul (1988)	25675	4346	9322	360
1984–1987	Los Angeles (1984)	18960	3109	5581	300
1980–1983	Moscow (1980)	3591	1847	1655	300
1976–1979	Montreal (1976)	3099	1717	1975	196
1972–1975	Munich (1972)	1470	456	767	48
1968–1971	Mexico City (1968)	603	152	286	25
1964–1967	Tokyo (1964)	335	76	132	13
1960–1963	Rome (1960)	270	46	74	10

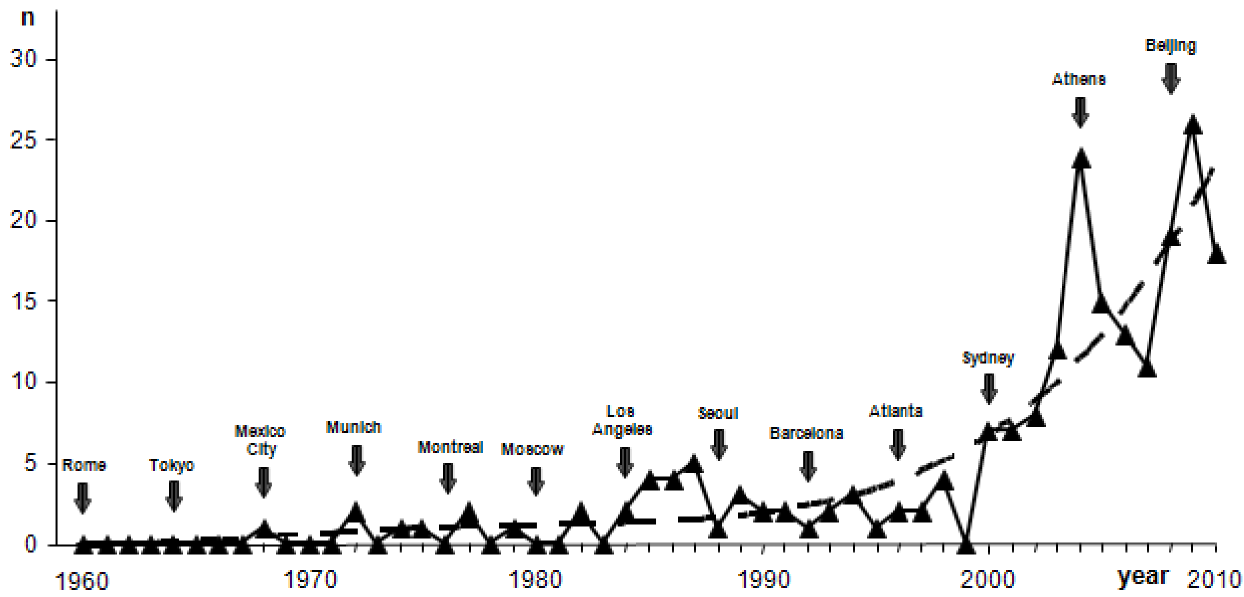

Figure 1. Number of papers published in the last 50 years, from 1960 to 2010. Arrows show the number of papers published in the year of the Summer Olympic Games. The discontinuous line shows an increasing trend in the number of publications

by authors from the United States (n = 44), the United Kingdom (n = 43), Australia (n = 29), Poland (n = 25), and the Netherlands (n = 12). A relevant comparison is presented in Table 4. Teams from two of those five countries, Australia (4 gold, 3 silver, and 4 bronze medals) and the Netherlands (4 gold, 2 silver, and 6 bronze medals), belong to the three most successful teams of the Olympic Games in the last 50 years. The third best team with the most medals (4 gold, 4 silver, and 1 bronze) is Germany (in both male and female categories). This fact, however, is not reflected by the number (n = 9) of scientific studies from that country found in the databases (Tab. 4).

In the analyzed studies on field hockey found within the databases, the largest research group composed of women (33.17%), followed by men (36.06%) and then with samples from both genders (30.77%). Some research, 6.25%, was carried out with respect to groups of school-age children and youths between the ages of 8 and 16. Eight studies (3.85%) described individual cases of injury, focusing on their causes, symptoms, and the most suitable methods of treatment.

Table 3. Percentage share of publication's theme groups (Number of publications = 208)

Theme group	No. of publications	Percent (%)
Anthropometrics	14	6.73
Biochemistry	32	15.38
Injuries	36	17.31
Nutrition	7	3.37
Physiology	43	20.67
Psychology	40	19.23
Tactics	36	17.31
Total	208	100.00

Table 4. Number of papers published in the last 50 years, from 1960 to 2010 on field hockey in several countries (Number of publications = 208)

Country	No. of publications	Percent (%)
Australia	29	13.94
Canada	7	3.37
Germany	9	4.33
India	7	3.37
Netherlands	12	5.77
New Zealand	4	1.92
Poland	25	12.02
South Africa	8	3.85
Spain	7	3.37
UK	43	20.67
USA	44	21.15
Others	13	6.25
Total	208	100.00

Discussion

Those studies on field hockey, as found in the databases, describe all aspects of the sport. They are presented according to the structure depicted in the "Material and methods" list of thematic groups:

Biochemistry

Studies in biochemistry (n = 32; 15.38%) are primarily concerned with issues related to the body's reactions to physical exercise and the characteristics of both aerobic and anaerobic metabolism in field hockey players as a response to physical activity. Compared with other team sports, such as soccer, there were a lack of articles offering a wider cross-section of research problems in the case of field hockey.

Typically, in order to monitor the level of fitness in sportsmen, biochemical indices were determined by using body fluid counts [1]. Blood tests were the most frequently performed on field hockey players (featured in 21 studies), used to measure the concentration of lactic acid. An evaluation of the changes found throughout a yearlong training cycle allows, according to Strzelczyk et al. [2], one to determine the level of a players' preparation for competition in terms of their fitness level. An increase in lactate concentration after a routine warm-up may also help assess the body's adaptation to anaerobic metabolism, and changes in the concentration of that factor allow one to determine a field hockey player's commitment to a match, according to Ghosh et al. [3]. It can be pointed out, however, that the high rate of lactate synthesis in working muscles significantly increases the concentration of hydrogen ions circulating in the blood, which leads to metabolic acidosis. That, in turn, led to a decrease in the ability to perform short-term physical exercises by female field hockey players [4]. According to Spencer et al. [5], such an adverse tendency may be, to a large extent, prevented in part by following a 7-week strength-training plan, which resulted in a significant reduction of hydrogen ion production in the body. At the same time, Bishop & Spencer [6] observed a decrease in the concentration of hypoxanthine, which is formed in the body as a byproduct of damage to purine nucleotides. It was observed that the quantity of this compound increases in the field hockey players' blood in proportion to their lactate content. Moreover, both decreased pH levels and the buffer capacity of blood was found in players after performing a single high-intensity physical exercise [6].

Research conducted by Kryściak et al. [7] in a different sample of field hockey players has also indicated an obvious post-exercise increase in the concentration of hypoxanthine and uric acid [8]. The above-mentioned authors discovered a highly negative correlation between VO_2max and the concentration of uric acid and the threshold for anaerobic metabolism, as well as negative correlation between the exercise-related concentration of xanthine and hypoxanthine ($p < 0.001$). Their data explicitly indicates that high-intensity exercise is associated with energetic stress, which in turn may lead to the damage of purines. The primary cause is usually associated to free radicals, themselves very reactive endogenic compounds produced during both aerobic and anaerobic metabolism. They stimulate the production of compounds which are adopted as determinants of oxidative stress. They include conjugated dienes and thiobarbituric acid-reactive substances (TBARS) [9], which are created as a result of fatty acids damage, and allantoin [10], which is a product of oxypurine and uric acid damage.

Iron is an integral component in both oxygen transport and storage as well as in the catalysis of several biochemical reactions. Concerns on the supply and circulation of iron in the body, which can permit the possibility of an athlete enduring a full exercise load, was discussed in 6 studies on field hockey. The relative lack of interest in iron stands in contrast to the extensive literature available on other team sports, particularly soccer [11]. Hinrichs et al. [12] showed that the total mass of hemoglobin correlated to VO_2max, but its level did not influence the actual iron status in field hockey players.

Athletes engaged in highly active sports are often diagnosed with so-called sports anemia, which manifests itself with, among other things, a reduction in the body's performance. This syndrome is usually caused by disturbances in iron balance resulting from insufficient iron intake from food, magnified by the fact that the body has an increased demand for that element. Douglas [13] found that the concentration of hemoglobin, the value of hematocrit, and the number of red blood cells in female field hockey and soccer players at the beginning, middle, and end of the season did not exceed any norms adopted for women of that age, and that the employed training cycle did not cause the occurrence of sports anemia symptoms. Different results were obtained in research carried out on a group of female field hockey players, where the level of ferritin concentration was measured during three consecutive seasons. The concentration of iron in their blood decreased with each competition season [14]. Thus, we can assume that playing field hockey may lead, in some athletes, to a decrease in the level of iron, especially as the deficiency of that element grew gradually in female field hockey players in proportion to the number of years of active team participation.

Such trends were not supported, at least in the precompetition period, by recent research concerning the concentration of iron and the total iron-binding capacity (TIBC) in field hockey players at rest and after exercising with increasing intensity on a treadmill until they reached maximum individual load [15, 16].

Physical exercise leads to a disturbance of homeostasis, which manifests from a change in the concentration of certain hormones. A higher activity of gastrointestinal hormones, including glucagon, gastrin, and pancreatic polypeptide, was found in the blood of field hockey players who were subjected to submaximal exercise at different stages of their sporting career [17]. However, no differences were found in the concentration of insulin. A minor upward trend was seen in better-trained field hockey players with respect to post-exercise increases in gastrin, while a major upward trend was shown with respect to pancreatic polypeptide [17]. Exercise on a cycle ergometer, which field hockey players and cyclists were subjected to, affected the activity of lysosomal enzymes in both the blood and urine [18]. The level of alkaline phosphatase, arylsulfatase and β-glucuronidase increased in both groups after exercise, however, a higher increase was observed in cyclists. According to the cited authors, the increased activity of lysosomal enzymes in urine may also be caused by a higher glomerular albumin filtration rate, and their secondary resorption in the proximal urethra.

The body's main defense mechanism against infections is immunoglobulin A (IgA), which occurs naturally in respiratory, gastrointestinal and genitourinary secretions. According to Mackinnon et al. [19], both high-intensity physical exercise and interval exercise, to which players were subjected to in training, significantly decreased the concentration of IgA in their saliva. Their research showed that field hockey players and squash players were more susceptible to upper airway infections. At the same time, it was demonstrated that the content of IgA in the saliva of infected field hockey players was lower by 20–25 percent in comparison to healthy athletes.

The level of biochemical and morphological indices is also affected by physical factors, such as heat and cold [20]. It was demonstrated that there was a temporary increase in the number of red blood cells, the value of hematocrit, and the concentration of hemoglobin in the blood of field hockey players after eighteen sessions held in a cryogenic chamber, lasting a maximum of three and taken twice a day. All values, apart from hemoglobin concentration, returned to their initial levels one week after the cycle of sessions in the cryogenic chamber were finished. Other parameters that measure immune response, i.e. the number of white blood cells and their fractions, and the level of interleukin 1 beta (IL-1β) did not change significantly as a result of such treatments, though the concentration of IL-1β increased in some field hockey players [21]. Research on the effect of cold temperature on athletes has been carried out to a much larger extent in other sports.

The results of biochemical tests may be also affected by injuries sustained during tournaments and matches. In such cases, one can expect a change in the level of interleukins and other inflammatory factors. Research carried out on the influence of increased physical exercise on the secretion of these substances has not been conducted on field hockey players. However, tests carried out on other athletes have shown, among other things, an increase in the concentration of pro-inflammatory interleukin 6 (IL-6) in a group of triathletes after competition [22], or the tumor necrosis factor alpha (TNF-α) in athletes after finishing a marathon [23].

These aspects remain largely absent in studies on field hockey as was found in the analyzed databases.

Physiology

The analyzed databases contained 43 studies on physiology which were conducted on field hockey players. These focused primarily on an athletes' endurance capacity, the characterization of their muscle fibers, and the effects of exercise tests on selected blood parameters.

Some authors conducted electrophysiological studies to establish specific reference values, which can be helpful in the training process and later in diagnosing sports injuries. Electromyography studies of elite field hockey players indicate different values of ulnar and tibial motor nerve conduction velocity compared to the values obtained by soccer and tennis players [24]. On the other hand, comparative electromyographic measurements of bicep femoris and semitendinosus muscle activity in field hockey players have shown that they have a much larger tolerance in maintaining an extended knee position without feeling any pain, when compared with those who do not practice any sport. According to Jaeger et al. [25], such an ability (or lack of it) is determined by the composition of muscle fibers. Research carried out on a group of female hockey players and on a control group revealed that the sportswomen had a higher percentage of oxidative-glycolytic muscle fibers (FTa), and their share and histochemical features were similar to those typically found in males. In the case of fast-twitch fibers (FTa), it has also been demonstrated that there is a direct relationship between the transverse section area of muscle fibers and their oxidative activity [26]. Moreover, Cochrane & Stannard [27] noted that high-intensity vibration training helps develop muscle mass and increases flexibility in female hockey players.

Muscle strength and body flexibility also depend on the quality of the connective tissue present, which forms, among other things, tendons and muscle attachments. The principal amino acid building connective tissue is hydroxyproline. According to Krawczyński et al. [28], the metabolism intensity of that amino acid correlates with the amount of training undergone. It has been demonstrated that hydroxyproline excretion in urine in cyclists with a few years of training (1–3 years) was higher than in field hockey players who underwent a longer period of training (over 6 years), both at rest and after exercise. The results of this research also suggest that the domination of certain endurance elements in the training process influences the metabolism of connective tissue.

An increased level of excreted creatine was found in the urine of well-trained athletes who were subjected to a medium-intensity exercise test. However, the physical fitness of field hockey players had a lesser effect on the level of creatinuria [29]. Therefore, one may assume that adapting more efficiently to long-term training coincides with the faster utilization of creatine that is generated in working muscles.

The mechanism of maintaining the correct acid-base homeostasis by the kidneys was investigated by Bittner et al. [30]. They demonstrated that a field hockey player's fitness level was not characterized by variations of renal balance during submaximal exercise, and that being more efficient in such regulatory activity, which was itself determined on the basis of blood pH, pCO_2, and pO_2 levels as well as on the concentration of hydrogen carbonate and ammonium ions, depended on the length of their sports career. Moreover, it was explained, with reference to the case of female field hockey players, that physical exercise, which does not cause metabolic acidosis, is able to induce regulatory processes in the kidneys [31].

A number of studies concerning the physiology of field hockey players mentioned that regular training and high physical activity cause changes to body composition, including bone mass. Bone metabolism may be subjected to sudden changes, especially in women, as it is connected with hormonal balance, particularly that of estrogens [32]. A comparison of bone composition in women practicing contact (basketball, netball), limited-contact (running, field hockey), and non-contact sports (swimming), and of a control group, revealed that there is a positive correlation between the degree of contact experienced in sport and the average bone density and higher mineralization of leg and arm bones. The results suggest that women who regularly participate in contact sports during the pre-menopause period have higher bone mineral density in comparison to women who do not practice any sport [33]. A team of researchers led by Sparling [34] compared three different methods of determining total bone mineral density and body composition of the 1996 United States Olympic Team for Women's Field Hockey: they were: dual energy X-ray absorptiometry (DXA), hydrostatic weighing, and the sum of seven skinfolds. The obtained results were very convergent. What was also demonstrated [35] was that forearm bone mineral density in female field hockey players increased during their training season. At the same time, the total amount of body fat decreased while the lean body mass increased. It was also determined that muscle strength and maximal oxygen uptake (VO_2max) increased during the training season [36], although this correlation could differ considering the position played by an athlete on the field. The highest value of VO_2max (59.9 ml · kg^{-1} · min^{-1}) was found in centre midfield players. It was 11.4 ml · kg^{-1} · min^{-1} higher than the value found in right back position players [37].

Horváth et al. [38] pointed out the beneficial effects of playing recreational field hockey as well as other forms of regular physical exercise. They carried out an electrocardiographic examination of 215 men and women, which demonstrated a significant reduction in the risk of hypertension in persons whose parents had high blood pressure.

Tactics

According to one definition, game tactics is the purposeful, effective and planned way of competing, which pits one's own and their rivals' skills during a match. It also defines the playing field and conditions of the competition, as well as the rules and regulations applicable to a given game [39–41]. Thus, with an idea of what tactics are, can allow several indices to be included, including those that are biochemical in regards to tests which measure a players' endurance capacity. It also touches upon several other physiological and biochemical issues, which frequently are only indirectly alluded to in regards to a players' fitness, such as their body position their ability to be in peak physical shape.

Even a rough analysis of the available studies reveals a lack of data resulting from a more in-depth motor analysis of field hockey players during matches and practices with respect to different age groups as well as regarding the gender or the length of one's sporting career. As in the case of the other thematic groups, field hockey is usually found in the background in other conducted research or plays only a minor role in the topic discussion.

Research carried out by Reilly & Seaton [42] showed that the typical body positions adopted when playing a field hockey match have an influence on overall posture shaping, e.g. such as having the spine shortening while running as well as on physiological test results. Field hockey players, depending on the position they play, cover a distance ranging from 9300 to 10870 meters [43, 44]. That distance may be divided into segments which vary in terms of motion intensity, i.e. the walking, jogging, standing, striding, and sprinting, and which have a share of 46.5 ± 8.1, 40.5 ± 7.0, 7.4 ± 0.9, 4.1 ± 1.1 and 1.5 ± 0.6 percent respectively in respect to the duration of a match [45]. Those time relationships are not fixed and are subject to significant alterations with each played game. For example, the stopover duration of three consecutive matches was, respectively, 7.4, 11.2 and 15.6 percent of game duration [46].

A similar time-motion analysis was also carried out during matches featuring female field hockey players [47]. The distances covered during three consecutive matches were significantly shorter than those covered by males, and amounted, on average, ranges between 3850 and 4250 meters [48]. Similar results were obtained from research carried out on a group of amateur field hockey players [49].

The art of keeping a field hockey player in peak condition involves using selected physiological parameters such as heart rate (HR), maximal oxygen uptake (VO_2max) or time to exhaustion. During competition, well-trained players subjected to high-intensity physical exercise demonstrate the highest values of VO_2max [50], furthermore, their exhaustion time is longer [51].

Analyzing the progress of a player's physical health, or obtaining information on their fitness levels during a competition season, is performed using a set of tests. It was statistically demonstrated that there are significant variations in the results of tests which a assess player's physical condition, dependant on the time when they are carried out, especially if conducted during the preseason and de-conditioning periods. It was also established that the extent of those differences depended on the sport played and athlete's gender. In the case of men, a lower variability was observed in Australian football, soccer, and rugby players, and a higher variability among softball players. For women playing soccer however, the seasonal variations of fitness levels, as found by a number of physical performance tests, was lower when compared to female field hockey players [52].

The wide range of physical performance tests allows for a greater degree of comparison and selection which is particularly helpful in determining a players' motor abilities. Sometimes, the aim of research in such a field as tactics is to compare the physical performance tests in order to define the optimal motor abilities of players. Lemmink et al. [53] evaluated the usefulness of a shuttle run test and a slalom run test in establishing the parameters of sprinting and dribbling in young field hockey players. Moreover, by using two varieties of the shuttle run test, the authors evaluated their influence on the aerobic and anaerobic metabolism of athletes [54]. It was shown that goalkeepers had the highest lower body strength and the lowest anaerobic capacity, while midfielders had the highest anaerobic capacity [55].

Bishop et al. [56] pointed out the importance of selecting the right test for evaluating a player's endurance capacity. On the basis of using a repetitive test (with a rep of 5 × 6-second maximal exercise) carried out on a cycle ergometer in order to determine an athlete's endurance capacity, they demonstrated that such a test needs to be modified and adapted to the specific characteristics of a given sport. Currently, new techniques based on global positioning satellite (GPS) systems can be used in analyzing the motion of all field hockey players during a single match. This method may be useful in the training process, especially in regards to maintaining correct load optimization as well as to an athlete's physiological welfare during competition [57]. Similar results can also be attained by analyzing selected camera recordings, including important parts of game play, such as penalty corners [58].

In determining the actual endurance capacity of field hockey players, a 5-meter multiple shuttle run test turned out to be the most useful [59, 60]. The advantage of this test was not only the ease with which it could be organized and the minimal equipment requirements, but also the short period of time during which an entire group of field hockey players can be assessed. A good measurement of training progress is also a multiple shuttle run test when measuring the total distance covered together with the heart rate. Another helpful device in determining the progress of team players is measuring the speed, time and, kinetic energy of a player during a 60-yard shuttle run test, using laser timing systems [61]. According to Boddington et al. [62], the evaluation of the average heart rate together with fragments of the 5-meter shuttle test are reliable measurements in assessing the endurance capacity of female field hockey players. However, they demonstrated that an evaluation of the degree of tiredness using the Borg scale and the difference between the longest and shortest distances of a shuttle run are not a reliable measurement of fitness of female field hockey players. Therefore, the authors suggested that the aforementioned parameters should be interpreted with caution, especially when players are taking the test for the first time. In addition, using a 40-meter shuttle test and running on a treadmill did not make it possible to find a correlation between the total running time and maximal oxygen uptake (VO_2max) in soccer and field hockey players [63]. Thus, the authors suggested modifying such tests in order to obtain results that are more satisfying. Lakomy & Haydon [64] postulated that the introduction of a delay into the 40-meter shuttle run test, which consisted of an enforced, rapid deceleration after crossing the finish line. They noticed that the group of athletes who participated in the test with enforced, rapid deceleration displayed a higher degree of fatigue. This may prove the validity of using such a method in a general training schedule, particularly in the case of team sports.

In order to choose the right exercise load for players in a training cycle, which is a key factor in preparing them for long-term high-intensity exercise, a method known as training impulse (TRIMP) is used, among other available techniques. A modification of this method, which consists by taking into consideration the weighting factor into account (TRIMPMOD), quantifies the training load of team sport athletes and may be useful in maintaining or increasing aerobic capacity during the season [65]. An one-week training impulse correlated ($p < 0.05$) with changes in VO_2max and a growth of the concentration of lactates, reaching 4 mmol/L while running on a treadmill.

The training methods used by athletes of a given sport were reflected by the results they achieved. Stagno et al. [66] examined two methods of training field hockey players, each with 11 persons who were subjected to extensive or intensive interval training for 12 weeks. An assessment of VO_2max, the speed required to reach the threshold of anaerobic metabolism (V_{OBLA}), and the time to exhaustion explicitly indicated that in the case of field hockey players, an intense interval training method proved more advantageous [66]. Registering the heart rate (HR) during training makes it possible to select the appropriate physical exercise needed to develop the desired motor features, endurance or strength of a player. Heart rate is an efficient and proven parameter which is helpful in designing training exercise loads [67]. Moreover, Lothian & Farrally [68] established that heart rate is a good intermediary parameter determining maximal oxygen uptake (VO_2max). However, the authors did not show a correlation between VO_2max and the activity of female field hockey players during a match. Other research [69] indicates a gradual increase in VO_2max during a training cycle. However, these changes were not statistically significant. Moreover, these changes did not translate into significant differences in heart rate.

Physical performance tests taken by field hockey players under conditions specified by the above methodology have recently been compared to energy expenditure measurements taken during a match by means of the so-called Sport Testers, which measure cardiac action. Boyle et al. [70] determined that the average energy expenditure of field hockey players during an entire match was 5.19 MJ. Moreover, they established that those values were significantly higher in midfielders (83 KJ/min) when compared to right- and left-wing players (61.1 KJ/min). The authors confirmed that a field hockey player primarily utilizes aerobic energy sources, and that their energy expenditure is at a relatively high level.

Attempts to improve the condition of field hockey players require a proper selection of new and innovative training methods and techniques. One of them is the use of training equipment, e.g. sled towing (a device which resists the motion of an athlete). When used in preparing field hockey, rugby and Australian football players; this increases an athlete's coordination and fitness. The resistance the sled gives must be carefully chosen to match the mass and height of the athlete [71]. What was also established was that the tactical skills of a field hockey player may also be improved by examining the power used when hitting a ball during a block [72] which can improve ball push, [73] or an analysis of the ball's direction during a shot [74]. One of the more recent methods of training field hockey players involves the audiovisual recording of matches and practices, and by analyzing this footage in order to determine a players' skill level [75] or a goalkeepers' abilities and potential [76]. Player progress may also be assessed on the basis of a testing battery, which is particularly useful in evaluating the skills of long- and short-training players [77, 78].

Nutrition

Seven out of the 208 analyzed studies on field hockey concerned themselves with nutrition. They focused on assessing the calorific value of meals eaten by athletes and on optimum hydration. Authors additionally raised the issue of using supplements and additives in nutrition and the physical performance enhancements they had on field hockey players.

The need to analyze the nutrient supply in players, which plays a fundamental role towards maintaining good physical fitness, has been documented. Such nutritional analysis, performed on the Canadian Olympic Women's Field Hockey team, revealed that the average 24-hour energy value of their meals was 1966.6 kcal, out of which 42.0% were carbohydrates, 38.7% fats, and 15.3% proteins. Such a diet, when combined with an average maximal oxygen uptake (VO_2max) of 51.0 mL/kg/min. and the associated energy expenditure, did not guarantee meeting the minimum energy requirements in a number of athletes. The nutritional deficiencies found among those players were, among other things, the lack of certain vitamins and iron [79]. Furthermore, Lee et al. [80] demonstrated that apart from iron deficiencies, inappropriate nutrition might also be the cause of calcium deficiencies. Successful attempts at preventing deficiencies by using specifically prepared iron supplements in sportswomen who were already lacking iron yet did not show any symptoms of anemia, explicitly indicated that iron injections were more effective than taking iron tablets. The concentration of ferritin (an iron storage protein) in the blood increased from 20 ± 2 to 63 ± 7 μg/L after a series of injections, while only from 27 ± 3 to 41 ± 5 μg/L in female athletes who took iron supplements orally [81].

The dietary supplement most frequently used by athletes is creatine, which usually increases the concentration of phosphocreatine in the muscles, a compound responsible for anaerobic metabolism. Research that was carried out among field hockey players provided ambiguous results in the usage of creatine supplementation [82]. In the search of supplements which could improve an athlete's fitness, some authors made reference to players using unusual diets or substances. An attempt to use an extract from lingzhi (Ganoderma lucidum), a fungus used for hundreds of years in traditional Chinese medicine for improving body strength and reducing body mass, was found to insignificantly improve a well-trained field hockey player's aerobic and anaerobic parameters [83]. In addition, the taking of a bovine colostrum preparation for eight weeks did not change the endurance performance results and body composition of the Dutch National Men's and Women's Field Hockey Teams [84]. The authors hypothesized that those substances, rich in proteins and antibodies, may stimulate a greater storage of phosphocreatine in the muscles as well as accelerate the dephosphorylation of ATP.

One of the essential elements of maintaining a high fitness level of field hockey players is ensuring appropriate hydration [85]. Dabinett et al. [86] pointed to certain methods which facilitate the monitoring of the proper hydration of athletes, such as evaluating average body mass fluctuations, heart rate measurements, and in taking a player's temperature from his eardrum during training. They also pointed out that the preferred liquids for athletes are specialized isotonic drinks and still water. Matches played during very hot and humid conditions should also encourage the match organizers to call for more time outs, and for athletes to take in more liquids and to cover their bodies with cold clothing [87]. By observing these recommendations a player can offset hyperthermia, which itself causes the reduction of stamina.

There were no differences between the average core, skin and ear canal temperatures between professional male and female field hockey players when exercising with an intensity of 50% VO_2max for 60 minutes. However, the dynamics of sweating, determined by body mass loss, was significantly higher in men than in women after the exercise period was concluded [88]. Goalkeepers, who wear special clothing, are especially at risk to their core temperature increasing [89]. Sunderland & Nevill [90] established that exercising in elevated ambient temperatures causes a rise in rectal temperature and increases the feelings of thirst and tiredness. The authors also noticed that an increase in temperature caused a reduction in the concentration of glucose and aldosterone in the blood, but did not affect the concentrations of cortisol, ammonia, lactates, and plasma volumes.

Anthropometrics

It cannot be ruled out that establishing a somatic and psychological profile for those wishing to practice a given sport may enable team managers to make the right choices when selecting future players [91]. Keogh et al. [92] pointed out that body physique and composition may affect tactical features, i.e. agility, running speed, and aerobic power, all of which factor in marking the difference between a well-trained and poorly prepared field hockey player. There is a large diversity in the physique of athletes who play field hockey. Most commonly, the players are slim (ectomorphic) with differing muscular builds (mesomorphic) [93, 94], with the different builds usually related to the position in which they play. Female goalkeepers are characterized by the highest body mass and the highest percentage of fat, while in players who play other positions the diversity of body build and composition was lower [95]. It was found that field hockey players have different physiques depending on their country of origin. A comparison of Asian and European field hockey players revealed that the former have not only a body type with stronger muscular features, but also a more massive skeleton [96].

Injuries

Injuries are discussed by authors (n = 36, 17.31%) in a variety of aspects, such as those resulting from the rules of field hockey, technical equipment (sticks, shin guards), and also local infrastructure (field surface). The occurrence of injuries also correlates with the intensity of physical effort during training, the number of matches played, the position a player plays, and what adopted tactics were used. Out of 36 studies, a small number (n = 8) describe individual cases of injuries in male and female field hockey players.

One aspect that played a significant role in injuries that field hockey players sustain is the field surface on which matches are played. The mechanics of players' motion and the pace of the game are different depending on what surface is used [97]. An analysis of field hockey players' subjective opinions during an intensive match on both an indoor surface and on artificial turf indicates that the latter is characterized by higher degree of hardness, which in turn led to an overall faster game play caused by higher ball rebounds [98–100]. It was also established that synthetic turf led to a higher frequency of acute injuries, which primarily resulted from the increased pace of the game [101], modified equipment, e.g. hockey sticks [102], or through an improvement of tactics used by means of training on smaller-scale fields. Coaches introduce such practices in order to improve the endurance capacity and effectiveness of players when playing in competitions [103]. Game dynamics may also be improved by introducing new elements to general field hockey rules. In particular, the risk of facial injuries caused by tossing the ball explains why an amendment to the rules on taking short corners, introduced by the International Hockey Federation on January 1, 2003, was quickly annulled after a few matches [104].

According to research carried out on a large group of school-aged children (n = 7468) who took part in team sports, injuries occur more frequently when playing field hockey and basketball. The injuries were mostly minor (concussions and slight joint sprains) and in three out of four cases normally occurred in the lower extremities [105]. At the same time, it should be pointed out that the risk of spraining an ankle was almost 1.5 times higher among female hockey players [106]. Yet field hockey was found to have the lowest injury rate when compared to ice hockey and lacrosse [107], as well as to Gaelic football, rugby, soccer, hurling and basketball [108].

An analysis of sustained injuries carried out during a period of 15 years among 5385 female field hockey players showed that the most frequent injuries included ankle sprains, knee disorders, and finger fractures. The likelihood of a concussion or head injury was 6 times higher during a match than during training [109]. What was also discovered was that the risk of injury was significantly reduced when female hockey players were appropriately prepared such as by taking part in neuromuscular balance programs or using ankle-stabilizing bands, or by using helmets and padded gloves. Moreover, dedicated educational programs on injury conducted from the very beginning of seasonal training significantly reduced the number of injuries as well as treatment costs [110].

Studies published to date indicate that of the level of contact field hockey players experience with the ball, a stick or another player may be the reason for injury, particularly to the upper body, the neck and the head. Authors noticed that goalkeepers and midfielders are the most susceptible to injuries [111]. It was estimated that only 20 percent of international field hockey players use intra-oral mouth guards on a regular basis. Consequently, there are frequent facial injuries which require a physician's and/or dentist's attention [112, 113] in addition to ocular injuries [114]. The cause of such injuries is the reluctant use of face shields by players, which they justify by the breathing difficulties experienced [115]. Players in the English Hockey League do use mouth guards during matches, but less frequently in training [116].

During the 2004 Summer Olympic Games in Athens, there were relatively few injuries among both genders in team sport disciplines (soccer, volleyball, basketball, handball, water polo, baseball, softball, and field hockey). 377 injuries were recorded in 456 matches, which was [117] calculated to average out to 0.8 injury per match or 54 injuries per 1000 players. The most frequent type of injury involved damage to a player's lower extremities which resulted from the direct contact with another player. It should be pointed out, however, that the degree of injury did not necessarily prevent players from training or participating in the next match. One issue, which remains unresolved, is the assessment, classification and standardization of bodily injuries sustained by players [118].

Problems connected with injuries triggered by overloading are described explicitly in a specific case study. A case of posttraumatic sacral spine fracture in a female field hockey player was presented in a study by Slipman et al. [119]. Wood-LaForte & McLeod [120] described the intense pain felt by a female field hockey player due to a bilateral femur fracture or another player who was diagnosed with a fracture of the superomedial surface of the acetabulum [121]. Radiating pain in the foot of a German National Team field hockey player during training and matches resulted in an arthroscopy procedure during which a torn ligament and the presence of scar tissue were revealed [122]. Overloading was also the cause of tendinitis and a posterior talus fracture of a female field hockey player [123]. An analysis of two further cases of female field hockey players did not explicitly demonstrate that increased exercise or viral meningitis [124] was the cause of an aneurysmal bone cyst of the femur [125].

In order to prevent injuries caused by overloading, authors of these various scientific studies recommended plyometric training, which increases leg muscle activity during a training cycle [126], and regular hamstring stretching [127], which effectively reduces the risk of tendon strain and knee and ankle joint injuries.

Research carried out by Mark F. Reinking [128] showed that leg pain found among players of numerous sports is closely related to physical exercise. The pain usually escalates during the competition period. The authors state that field hockey players and cross-country skiers are those who complain the most frequently of lower extremity pain, while soccer players complain the least. At the same time, it was not demonstrated that age, muscle length, dietary habits, BMI, menstrual cycle or bone mineral composition had an effect on athletes' differing experiences with pain reception.

Psychology

Studies concerned with psychology ($n = 40$, 19.23%) focus on the changes in the behavior and perception of athletes when faced with an important and at a given venue. They also discuss aspects on players' feelings and interpersonal relations when they win or lose. In the available literature, problems connected with the experiences and age of players, their origin and social status, religious faith, and sexual identity are raised quite frequently.

Psychological factors, apart from having an effect on physical activity, manifest themselves as changes in the biochemical parameters in an athlete's blood, usually n the form of hormones. It has been demonstrated that participation in sports tournaments unbalances the secretion of sex hormones in female field hockey players. The level of the luteinizing hormone (LH) increased across the period of time from pre-training to competition, the level of progesterone increased only during the training period, while the concentration of estradiol decreased during competitions. Only the concentration of the follicle-stimulating hormone (FSH) showed a high stability throughout the entire research period [129]. The results also demonstrated that female field hockey players experienced stronger reactions toward an approaching competition period, which manifested itself with an increase in the concentration of adrenaline and noradrenaline, but not cortisol, as was determined in saliva samples taken twenty-four, two and one hours before a tournament [130].

Measurements of anxiety experienced by the Japanese Women's National Field Hockey Team, which was carried out by means of questionnaires, showed that psychological stress during a World Cup qualifying tournament gradually decreased with each match [131]. It was also observed that there was no direct correlation between the body's emotional response and the final match score. Players with a strong belief in their abilities experienced significantly lesser physical and psychological stress than athletes who doubted their skills [132]. An analysis of data from soccer and field hockey players, presented by Sewell & Edmondson [133], revealed that goalkeepers displayed, statistically, a higher level of recognizable tension in comparison to players in other positions, and were more somatically anxious and less confident than defenders. Non-midfielders and forwards were more nervous than defenders and midfielders. The latter, in turn, were less confident than defenders [134].

What psychological stress a player experiences also depends on the venue. Female field hockey players were much more confident playing at home than away [135]. Arathoon & Malouff [136] recommend that after a lost match, field hockey players should not even try to recall the more positive moments during game play as this leads to a worsening of their state of mind and towards worrying even more about a defeat. Lamb [137] demonstrated that female field hockey players with low self-esteem are much more susceptible to injury. The author stated that the potential for injuries depends partly on the aggression displayed by the athletes.

An examination of Canadian female athletes found that women selected for the field hockey team were significantly more aggressive, had higher leadership ambitions and were psychologically stronger than team members in other sports. Moreover, female players in offensive positions accepted a coach's advice far more easily than those in defensive positions. In most cases, players selected for the team came from middle-class families that had both parents present, and were frequently the oldest child [138]. According to research done by Zamboanga et al. [139], one of the ways of maintaining unity in sports groups, e.g. female college field hockey teams, were get-togethers where alcohol was consumed. The authors pointed out that, depending on the sport, there were differences in the amount of alcohol consumed, yet the authors did not reveal which discipline had the highest amount of alcohol consumption.

Hockey players can acquire new abilities through physical and theoretical training. Doody et al. [140] demonstrated that experienced athletes are significantly better than inexperienced ones at perceiving and applying the instructions given by coaches and during visual presentations. It was also observed that field hockey and soccer players are much better at transferring information and strategies from other disciplines when compared to volleyball players [141]. Video analyses also reveal that the behavior of an experienced field hockey coach may change within as short of a period of time as one year. With time, his/her acceptance and willingness to give praise grows as the tendency to give orders and criticize decreases [142].

The improvement of fixed game play in field hockey can be improved the simple repetition of an exercise on a regular basis. Research has shown that even mentally projecting penalty shots by players, who underwent a period of seven weeks of research, was found to significantly improve the effectiveness of those game elements when compared to a control group [143]. Nieuwenhuis et al. [144] demonstrated that through using 16 kinanthropometric measurements, 6 motor skill assessments, and 2 psychological tests, one may effectively distinguish the difference between more or less talented female field hockey players. They stated that better hockey players had significantly better results in eight of these tests. At the same time, they indicated that such a method allows for the quicker identification of more talented players, which in turn shortens the length of time required for professional training [144]. Multiple task tests make it possible to obtain important information on the cognitive abilities and skills among field hockey players [145].

Two of the articles on field hockey available in the databases raised the topic of sexual identity and the tolerance of homosexual behavior. Roper & Halloran [146] did not observe any significant differences in athletes' attitudes towards gays and lesbians across a wide range of sports. The acceptance of homosexual athletes among female field hockey players was said to have been the cause of hem having contact with a homosexual female coach. Research by Shire et al. [147] showed that a small group of homosexuals was fully accepted by a team of female field hockey players. However, in the case where a majority of team, almost 84%, was homosexual or exhibited homosexual preferences, the heterosexual minority felt rejected and not accepted, which in turn had an adverse effect on relationship between individual female players.

Conclusions

1. An analysis of the scientific studies that focused on field hockey, as found in the analyzed databases, indicates that researchers have a wide scope of interests when it came to analyzing the sport of field hockey. However, due to the relatively small number of publications when compared to other team sports, the scientific information provided by them rarely allow for a comprehensive assessment of a given issue. Moreover, as found in numerous studies field hockey was only a reference point in research with regards to other team sports.

2. The consequence of their being such a small number of studies on field hockey is the difficulty in providing a comprehensive assessment of several issues, particularly when applying additional criteria such as gender, age, or the length of sample studies. This situation exacerbated by the lack of comparative research, especially in terms of the methodology and background information in which experiments were carried out, and/or the lack of research carried out on the same player population throughout a longer period of time.

3. The authors did not perceive any objective reasons why a sport as popular as field hockey has been so rarely subjected to more investigative research, especially in biological terms, particularly those in biochemistry, physiology, psychology, and nutrition.

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NORDIC WALKING – A NEW FORM OF ADAPTED PHYSICAL ACTIVITY (A LITERATURE REVIEW)

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ABSTRACT
Purpose. The purpose of this study was to analyze scientific evidence on the effects that Nordic Walking (NW) has on the human body. **Basic procedures.** A comprehensive search of computer databases (MEDLINE/PubMed, CINAHL, and SPORTDiscus) was conducted to identify relevant English and Polish studies on NW that were published from 1995 to 2009 and based on scientific research. **Main findings.** A total of 26 studies met the inclusion criteria. The majority of studies (12) discussed physiological issues, eleven studies were dedicated to NW as a form of rehabilitation (including one case study), and three studies focused on biomechanical issues present in NW. **Conclusions.** Not all of the widely promoted benefits of NW were confirmed in the results of the found scientific studies. Often analyzed issues did not provide sufficient explanation. There is a large discrepancy in the results of physiological responses during NW in a variety of conditions (on a treadmill with/without grade; field – uphill/downhill/horizontal level terrain). The results of studies analyzing the effects of NW training as a form of rehabilitation particularly in the areas of cardiology confirmed the positive aspects of including NW towards a patient's rehabilitation after acute coronary syndrome, with intermittent claudication, and after coronary artery disease, or after myocardial infarction. Contrary to popular belief and previously done studies, recent research has shown that NW does not reduce the loading of the knee joint.

Key words: review, Nordic Walking, adapted physical activity, physical activity

Introduction

Recently there has been a growing interest in Nordic Walking (NW), i.e. walking with poles similar to those used in cross-country skiing [1–3]. The popularity of NW should not be surprising as it is typical way of human locomotion and one of the most common forms of everyday physical activity [4, 5]. The undoubted advantage of NW is its natural and simple movement. In addition, it is an automated activity, which under normal conditions does not require a lot of concentration during its execution. Due to the popularity and attractiveness of NW, the possibility of using it as a form of exercise in various areas of sport, recreation, tourism and rehabilitation is increasingly becoming more popular. NW can be divided into three basic categories: *Health*, *Fitness* and *Sport*, which itself has numerous variants, e.g. an introduction to jogging or/and running (*Nordic Walking Running*), its application to rollerblading (*Nordic Walking Blading*), or on snowshoes (*Nordic Snowshoeing*) [1]. In popular literature such as health magazines, handbooks and web sites, NW is recommended for everybody – children, adolescents, adults, seniors, pregnant women and those after childbirth, as well as for people with different health problems (hypertension, atherosclerosis, arthritis, back pain, sciatica, osteoporosis, obesity, underweight, depression) [6–8]. Therefore, NW can be considered as a form of adapted physical activity recommended for different groups of people with special needs. The authors of such popular literature state, that among others, the NW can provide the following benefits: reinforcing of the immunological system, a reduction in cholesterol levels [6], an improvement in the blood supply, an increase in red blood cell count, a 30% reduction of joint stress, better mood [6, 7], the engagement of 70–90% of the body's muscles, a reduction in pulse rate while at rest, and a reduction of the load on knee joints [8]. It raises the question whether the beneficial effects of practicing NW, so widely touted, are in fact confirmed by scientific evidence?

Thus, the objective of this study was to analyze the available scientific literature on the effects of Nordic Walking on human body.

Material and method

The available Polish and foreign literature (only scientific journals) on NW published between 1995–2009 was analyzed. In searching for the available foreign lit-

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erature the following databases were used: the bibliographic database of the US National Library of Medicine (NLM) and National Institute of the Health (NIH) – MEDLINE/PubMed, SPORTDiscus and CINAHL databases. "Nordic Walking" and "walking poles" were the key terms used to find the articles. Only English language research papers were taken into consideration. This criteria were met by 23 items out of 122 found in the three databases: SPORTDiscus – 73, MEDLINE/PUBMed – 43 and CINAHL – 6 (after excluding those entries that appeared more than once in the databases). Polish literature was screened analyzing the content of the Central Library (BIBLO) database which includes Polish scientific literature in the field of sport, medicine, health and other related sciences. While searching BIBLO, the key term "Nordic Walking" was used. Only research papers were included in the analysis. There were three papers that met the inclusion criteria.

Results

A review of the literature indicates an increase in researchers' interest in Nordic Walking (3 manuscripts published in 1995–2000, 4 manuscripts in 2001–2005, 19 manuscripts in 2006–2009), however, in the available Polish literature only 3 manuscripts were found (tab. 1–3). Most of the studies (12) examined physiological issues in Nordic Walking [3, 9–19], ten papers were on the use of NW in rehabilitation [20–29] and three items concerned biomechanical aspects of NW [2, 30, 31]. One publication was a case study of NW used for treating of a sacral stress fracture that resulted from training overload [32].

Physiological changes during NW

In those studies which focused on physiological issues (Tab. 1), the authors analyze physiological indices in NW and those when walking without poles, or jogging executed on different conditions – in the field, or on a treadmill with different surfaces and inclinations. Church et al. [9] investigated walking with and without poles under field conditions. They noticed a significantly ($p < 0.001$) higher caloric expenditure when walking with poles (6.2 ± 1.7 kcal $\cdot$ min^{-1}) compared to walking without poles (5.2 ± 1.4 kcal $\cdot$ min^{-1}). Also the values of maximal oxygen uptake and heart rate were significantly higher ($p < 0.001$) when walking with poles (16.7 ± 3.6 ml $\cdot$ min$^{-1} \cdot$ kg^{-1}, 114 ± 15 beat min^{-1}, respectively) than when walking without poles (13.9 ± 2.7 ml $\cdot$ min$^{-1} \cdot$ kg^{-1}, 107 ± 13 beat min^{-1}, respectively). The authors showed there were higher energy cost (19%), maximal oxygen uptake (20%) and heart rate (6%) in NW than when walking under the field-testing conditions [9]. On the other hand, Knobloch [14] did not observe any differences in the hemodynamic parameters (heart rate, cardiac output, stroke volume) between NW and conventional brisk walking, without poles, in the field.

Some studies, which compared NW and walking without poles on a treadmill, reported no clear findings [17–19]. Porcari et al. [17] recorded an increase in oxygen cost even by 23% at a belt speed of 1.7 m $\cdot$ s^{-1} when comparing NW to walking without poles (24 ± 3.23 and 19.6 ± 3.08 ml $\cdot$ min$^{-1} \cdot$ kg^{-1}, $p < 0.05$, respectively). The values of energy expenditure and heart rate were also significantly higher ($p < 0.05$) during NW (8.4 ± 1.97 kcal $\cdot$ min^{-1}, 132 ± 16 beat min^{-1}, respectively) than when walking without poles (6.9 ± 1.78 kcal $\cdot$ min^{-1}, 114 ± 13 beat min^{-1}, respectively) [17]. Rodgers et al. [18] presented a higher oxygen consumption, by 12%, when NW ($20.5 \pm 1{,}2$ ml $\cdot$ min$^{-1} \cdot$ kg^{-1}) was compared to walking without poles (18.3 ± 2.5 ml $\cdot$ min$^{-1} \cdot$ kg^{-1}) on a treadmill moving at a speed of 1.8 m $\cdot$ s^{-1}. Similarly, the results of research found by Porcari et al. [17] indicated significantly higher ($p < 0.05$) values of energy cost and heart rate in NW (173.7 ± 20.9 kcal, 132 ± 19 beat min^{-1}, respectively) than when walking without poles (140.7 ± 27.2 kcal, 121 ± 21 beat min^{-1}, respectively) [18]. Schiffer et al. [19] identified an 8% increase in maximal oxygen uptake at a treadmill speed of 1.8 m $\cdot$ s^{-1} when NW was compared to walking without poles ($p < 0.05$). These findings are in accordance with Rodgers' et al. [18] results, however, they are different from those reported by Porcari et al. [17].

In research performed on the impact of terrain inclination on maximal oxygen uptake in NW, Perrey et al. [16] showed a significant ($p < 0.05$) increase in maximal oxygen uptake (19%) when walking downhill (an inclination angle of 15%, i.e. about 8.5°) with poles compared to walking downhill without poles. Hansen and Smith [11] analyzed energy expenditure when walking without poles, both with standard poles and with poles 7.5 cm shorter, during uphill, downhill (an inclination angle of 12°) and horizontal level walking. The authors noted significantly higher energy expenditure during uphill, downhill and horizontal level walking with standard poles (10.9 ± 0.5, 5.3 ± 0.4, 8 ± 0.7 MET, respectively) when compared to walking without poles (10 ± 0.4, 3.5 ± 0.1, 4.8 ± 0.3 MET, respectively) [11]. Schiffer et al. [3] investigated the effects of three different surface conditions on energy cost during NW and reported significantly ($p < 0.05$) higher maximal oxygen uptake and energy cost (MET) in NW executed at a speed of 2.2 m $\cdot$ s^{-1} on the grass (36.1 ± 4.2 ml $\cdot$ min$^{-1} \cdot$ kg^{-1},

Table 1. Physiological changes in NW – a literature review compilation

Author	Year	*n*	Gender (F/M)	Age (years)	Aim of research	Measurements
Church et al. [9]	2002	22	11F/11M	27 ± 6(F), 34 ± 9(M)	A comparison of energy expenditures when walking under the field conditions with and without poles.	▪ HR ▪ indirect calorimetery
Hagner et al. [10]	2009	168	F	30–73	The effects of a 12-week NW program on basic indices characterizing premenopausal, perimenopausal, and postmenopausal women.	▪ HR ▪ indirect assessment of VO_2max ▪ lipid profile ▪ total fat mass ▪ waist circumference ▪ body mass index
Hansen et al. [11]	2009	12	11F/1M	50 ± 2	The effects of poles' length on energy cost during uphill, downhill and horizontal NW.	▪ HR ▪ indirect calorimetery ▪ self assessment of comfort
Jürimäe et al. [12]	2009	28	F	21 ± 2	The effects of NW intensity on physiological responses of young women of different aerobic capacity levels.	▪ HR ▪ direct assessment of VO_2max ▪ ratings of perceived exertion
Kamień [13]	2008	72	64F/8M	19–73	An assessment of endurance levels in people participating in a 8-week NW training program.	▪ 2 km walk test ▪ Physical Fitness Index
Knobloch [14]	2009	48	*	51 ± 11	The effects of NW and walking in the field on hemodynamic parameters.	▪ HR ▪ hemodynamic parameters ▪ perceived level of exertion
Kukkonen-Harjula et al. [15]	2007	106	F	54 ± 3	The effects of a 3-month NW program (with poles) and walking without poles on women's cardiorespiratory and neuromuscular fitness.	▪ HR ▪ LA_{max} ▪ direct assessment of VO_2max ▪ health related fitness tests (HRF)
Perrey et al. [16]	2008	12	7F/5M	28 ± 9	The effects of NW and walking on physiological and kinematic indices with respect to different terrain inclinations.	▪ HR ▪ direct assessment of VO_2max ▪ indirect calorimetery ▪ ratings of perceived exertion
Porcari et al. [17]	1997	32	16F/16M	24 ± 3(F), 23 ± 3(M)	The effects of using poles when walking on women's and men' physiological responses during a maximal treadmill test.	▪ HR ▪ direct assessment of VO_2max ▪ ratings of perceived exertion
Rodgers et al. [18]	1995	10	F	24 ± 4	A comparison of energy expenditures and physiological responses when walking with and without poles.	▪ HR ▪ direct assessment of VO_2max ▪ indirect calorimetery ▪ ratings of perceived exertion
Schiffer et al. [19]	2006	15	F	44 ± 6	A comparison of physiological responses during a gradually increasing intensity of NW, walking and jogging.	▪ HR ▪ direct assessment of VO_2max ▪ LA_{max}
Schiffer et al. [3]	2009	13	F	26 ± 4	The effects of different surfaces on energy expenditure during NW.	▪ HR ▪ direct assessment of VO_2max ▪ LA_{max} ▪ forces acting on the poles during ground contact

F – female, M – male, NW – Nordic Walking, HR – heart rate,
VO_2max – maximal oxygen uptake, LA_{max} – maximal lactate concentration in the blood

* no data

10.2 ± 1.2 MET, respectively) than on concrete surface (32.1 ± 2.5 ml · min^{-1} · kg^{-1}, 9.1 ± 0.7 MET, respectively). Jürimäe et al. [12] have tried to determine the influence of NW intensity (slow walking, usual walking speed, faster walking speed, maximal walking speed) on the physiological reactions of women having different aerobic capacity – group 1 (maximal oxygen uptake > 46 ml · min^{-1} · kg^{-1}, $n = 8$), group 2 (maximal oxygen uptake 41–46 ml · min^{-1} · kg^{-1}, $n = 12$), and group 3 (maximal oxygen uptake < 41 ml · min^{-1} · kg^{-1}, $n = 8$). No significant differences emerged between the three groups in their physiological responses during NW of various intensity [12].

Recently, some studies [10, 13, 15] have examined the effects of a NW training. Hagner et al. [10] assessed the effects of a 12-week NW programme on the basic indices characterizing female health in premenopause, perimenopause and postmenopause. The results revealed a significant ($p \leq 0.05$) increase in maximal oxygen uptake and high density lipoprotein (HDL), as well as a significant ($p \leq 0.05$) reduction in: total cholesterol level, low density lipoprotein (LDL), triglycerides, body mass index (BMI) and waist circumference in the three groups [10]. Kamień [13] presented the influence of a 8-week NW training programme on the performance of a 2 km walk test executed with poles and without poles in three groups – group 1: women who practice NW, aged 50 ± 12 years ($n = 32$) and 21 ± 1 ($n = 17$); group 2: women who walk without poles, aged 20 ± 1 ($n = 15$), group 3: men who practice NW, aged 52 ± 12 years ($n = 8$). The author suggests that the acquisition of a good NW technique may cause an improvement in the results obtained on a given distance without any visible increase on the physiological cost [13]. Kukkonen-Harjula et al. [15] did not notice any significant differences in maximal oxygen uptake between women who walked for 13 weeks with and without poles. Both training programmes similarly improved maximal oxygen uptake [15].

NW in the rehabilitation process

Due to attractiveness and popularity of NW, its application towards rehabilitation are increasingly considered [1]. Previous studies (Tab. 2) have mostly explored the effectiveness of NW in cardiac rehabilitation programmes for individuals after an acute coronary syndrome [21, 22], with intermittent claudication [23], with coronary artery disease [28] and after myocardial infraction [29]. Kocur et al. [21] analyzed the exercise capacity and physical fitness between three groups of patients who had just begun their rehabilitation after an acute coronary syndrome, i.e. a 3-week inpatient cardiac rehabilitation programme. A control group ($n = 20$, average age 54.5 ± 9.4 years) took part in a standard rehabilitation programme based on endurance training on a cycle ergometer and by doing calisthenics; the NW group ($n = 40$, average age 51.4 ± 6.3 years) participated in a standard rehabilitation programme and in NW training, whereas a walking group ($n = 20$, average age 51.3 ± 7.1 years), apart from doing the standard rehabilitation programme, participated in supervised traditional walking training. After the 3-week rehabilitation programme the NW group had a higher exercise capacity measured by a symptom-limited treadmill exercise test following the modified Bruce protocol (expressed in metabolic equivalents, METs) compared to the control group (10.8 ± 1.8 and 9.2 ± 2.2 MET, respectively; $p = 0.025$). Also, physical fitness, assessed by a Fullerton Functional Fitness Test, improved in the NW group and walking group, in contrast to the control group (except the 6-minute walk test). The authors concluded that NW can be used as a supplement to standard short-term rehabilitation in men after acute coronary syndrome, because it may enhance their coordination and exercise capacity [21].

In another study the same authors [22] compared the estimation methods of energy expenditure in patients after an acute coronary syndrome during NW, general fitness exercises and cycle ergometer training. Three estimation methods of energy expenditure (with the use of a heart rate monitor, an accelerometer and on the basis of heart rate calculated from mean exercise heart rate value based on the data from the treadmill exercise test) were examined during three forms of training used in cardiac rehabilitation – 20-minute cycle ergometer training, 30-minutes of NW and a 30-minute general fitness exercises. During NW, in patients after an acute coronary syndrome, no significant differences were observed between the energy expenditure indicated by a heart rate monitor (255.48 ± 103.5 kcal) and the energy expenditure calculated in relation to the exercise test results (262.10 ± 78.9 kcal), while the energy expenditure calculated in relation to the exercise test significantly ($p = 0.001$) differed from the energy expenditure assessed by accelerometer (227.78 ± 48.6 kcal). NW was characterized by the highest total energy expenditure (5–6 MET) of all the forms of training used in cardiac rehabilitation and examined in the study. The authors underline that applying NW (a 2.5 km walk with poles interrupted by a 5-minute active rest halfway through) as a supplementary activity to the standard rehabilitation programme (general fitness exercises and cycle ergometer training) may help to meet the minimal caloric load requirement of training (350–600 kcal for a daily train-

Table 2. NW in the rehabilitation process – a literature review compilation

Author	Year	*n*	Gender (F/M)	Age (years)	Aim of research	Measurements
Allet et al. [20]	2009	25	*	68 ± 9	The effects of various walking aids on walking capacity, gait parameters and satisfaction in patients with poststroke hemiparesis.	▪ temporo-spatial gait parameters ▪ 6-minute walk test ▪ perceived satisfaction
Kocur et al. [21]	2009	80	M		The effects of a 3-week NW training in the early rehabilitation stage of exercise capacities and physical fitness of patients after an acute coronary syndrome.	▪ HR ▪ exercise trial ▪ indirect calorimetery ▪ Fullerton Functional Fitness Test ▪ ratings of perceived exertion
Kocur et al. [22]	2009	40	M	51 ± 6	The comparison of the estimation methods of energy expenditure during NW, general fitness exercises and cycle ergometer training in patients after an acute coronary syndrome.	▪ HR ▪ indirect calorimetery
Oakley et al. [23]	2008	21	M	57–79	The effects of NW on walking distance and cardiopulmonary workload in patients with intermittent claudication.	▪ HR ▪ walking distance ▪ direct assessment of VO_2max ▪ ratings of perceived exertion and pain
Sprod et al. [24]	2005	12	F	*	The effects of a 8-week program of walking with poles on female after breast cancer.	▪ range of motion in the shoulder joint ▪ endurance tests of upper-body strength
Strömbeck et al. [25]	2007	21	F	41–65	The effects of a 12-week NW program on aerobic capacity, perceived fatigue, mood and quality of life in patients with primary Sjögren's syndrome.	▪ indirect assessment of VO_2max ▪ ratings of perceived exertion ▪ health related quality of life ▪ perceived fatigue ▪ depression and anxiety
Suija et al. [26]	2009	21	19F/2M	26–78	The effects of regular NW training on physical fitness and mood of patients with depression.	▪ HR ▪ 2 km walk test ▪ quality of life ▪ perceived mood
van Eijkeren et al. [27]	2008	19	M	58–76	An assessment of short-term and long-term effects of a 6-week NW program on fitness and quality of life of patients with Parkinson's disease.	▪ 10-meter walking speed test ▪ 6-minute walking test ▪ get-up-and-go-test ▪ quality of life
Walter et al. [28]	1996	14	M	62 ± 2	A comparison of the safety and effectiveness of walking with and without poles in cardiac patients with coronary artery disease in phase III/IV of cardiac rehabilitation.	▪ HR ▪ direct assessment of VO_2max ▪ ratings of perceived exertion ▪ electrocardiogram
Wilk et al. [29]	2005	30	*	40–66	The effects of NW on the improvement of exercise tolerance and physical performance in patients rehabilitated after a myocardial infarction	▪ HR ▪ exercise trial ▪ Fullerton Functional Fitness Test ▪ 6-minute walking test

F – female, M – male, NW – Nordic Walking, HR – heart rate, VO_2max – maximal oxygen uptake * no data

ing session) established for the prevention of secondary cardiovascular disease [22].

Oakley et al. [23] proved that men aged 57–79 with intermittent claudication can cover a significantly ($p \leq 0.001$) longer distance both without pain (130 m) and with pain (285 m) while walking with poles compared to walking without poles (77 m, 206 m, respectively). Moreover, at the maximal walking distance, patients experienced significantly (p = 0.002) less pain when using poles, assessed subjectively on a 10 point Borg scale (Borg CR-10), than when walking without poles (4.3 ± 0.5; 5.6 ± 0.5, respectively). Significantly higher maximal oxygen uptake when walking with poles was observed both without feeling pain ($1.12 \pm 0.08\ l \cdot min^{-1}$) and with pain ($1.20 \pm 0.05\ l \cdot min^{-1}$) compared to walking without poles ($0.95 \pm 0.06\ l \cdot min^{-1}$, $1.03 \pm 0.06\ l \cdot min^{-1}$, respectively). While walking those patients feeling pain evaluated their perceived exertion similarly on a Borg 20-point scale. The research findings imply that NW allows patients with intermittent claudication to increase the distance they can walk due to pain relief in their legs, despite higher cardiopulmonary work at maximal walking distance. It means that NW could become a useful exercise for improving cardiopulmonary fitness in this group of patients [23].

Similar results were obtained by Walter et al. [28] in men with coronary disease aged 48–71 years. Maximal oxygen uptake was significantly ($p \leq 0.05$) higher when walking with poles (1.60 ± 0.18 l · min^{-1}) than when walking without poles (1.30 ± 0.18 l · min^{-1}). Another important aspect of this study was a lack of disturbances in patients' ECG during the two walking variants which may indicate that NW can be a safe and effective method at increasing the walking intensity in the selected III/IV phase of cardiac rehabilitation in patients with coronary disease [28].

NW's influence on exercise tolerance and physical performance in patients after a myocardial infarction was examined by Wilk et al. [29]. The authors found significant ($p \leq 0.05$) effects of NW training on exercise tolerance, which was 7.9 ± 1.8 MET before the training sessions started and reached 10.3 ± 2.3 MET after 15 sessions of NW. Although a significant improvement was observed in the group without poles (14%), the percentage in the NW group was higher – 30%. In the Fullerton Functional Fitness Test both groups showed significant ($p \leq 0.05$) improvements in all variables except in tests measuring upper-body strength and coordination [29]. Similar effects of NW and walking without poles on the physical fitness of patients after an acute coronary syndrome was presented by Kocur et al. [21].

Two studies have investigated the application of NW as a form of neurological rehabilitation in patients after a cerebral stroke [20] and Parkinson's disease [27]. Allet et al. [20] analyzed the effects of three different walking aids (a simple cane with an ergonomic handgrip, a 4-point cane and a NW pole) on walking capacity and patient satisfaction with poststroke hemiparesis. Research indicated that the distance covered in a 6-minute walk test was significantly longer with the help of a simple cane with an ergonomic handgrip ($p = 0.008$) compared to a NW pole. No significant differences were observed among the three walking aids in the following temporo-spatial gait parameters: velocity, cadence, step time difference and step length difference. Patients with poststroke hemiparesis found the walking with a NW pole significantly less beneficial (in terms of subjective satisfaction) than when walking with a 4-point cane ($p = 0.002$) and a simple cane with an ergonomic handgrip ($p = 0.001$). In addition, it is not recommend to use NW poles in the rehabilitation of patients after a stroke [20]. Van Eijkeren et al. [27] demonstrated that after a 6-week NW training programme men with Parkinson's disease (Hoehn and Yahr scale stage range 1–3) may enhance both their physical fitness and quality of life. Significant ($p \leq 0.01$) improvements were noted: in the time length during a get-up-and-go-test and a 10-meter walking speed test, in the distance covered during a 6-minute walking test, and in the subjective evaluation of quality of life measured by a PDQ-39[1] questionnaire. What is very important, the benefits of training continued on after 5 months [27].

Sprod et al. [24] assessed the effects of an 8-week NW training programme on the shoulder function in female breast cancer survivors. An experimental group which used walking poles during aerobic training achieved significantly higher results in muscular endurance as measured by the bench press ($p = 0.046$) and latissimus dorsi pull down ($p = 0.013$) when compared to the control group. The authors suggest that NW can be a valid and attractive form of physical activity in this group of female patients, where the conditioning of the upper-body seems apparent [24].

The influence of a 12-week NW training programme on aerobic capacity, the perceived feeling of fatigue, mood and quality of life in patients with primary Sjögren's syndrome, aged 41–65 years was studied by Strömbeck et al. [25]. The authors presented significantly better results of the experimental group than the control one in: aerobic capacity measured by the Astrand test ($p = 0.03$), perceived feeling of fatigue rated on a VAS[2] scale ($p = 0.03$), the perceived exertion evaluated by the Borg Scale[3] ($p = 0.03$) and depression assessed by the Hospital Anxiety and Depression Scale (HADS) ($p = 0.02$). No differences were observed in the health related quality of life (HRQoL) and anxiety (HADS) of the two groups. However, a significant improvement in the quality of life related to the patient's health status, evaluated by the SF-36[4] in the categories of physical fitness ($p = 0.01$) and mental health ($p = 0.03$), was noticed in participants from the training group. The authors suggest that NW should be a part of the rehabilitation process for patients with primary Sjögren's syndrome [25].

Suija et al. [26] investigated the effects of regular NW training on physical fitness, the quality of life and

[1] Parkinson's Disease Questionnaire-39.
[2] Visual Analogue Scale.
[3] Ratings of Perceived Exertion (RPE).
[4] Short Form Health Survey 36.

mood in patients suffering from depression. Physical fitness was calculated by taking into account the time needed to walk a distance of 2 km (in minutes and seconds), the heart rate at the end of the walk, age (in years) and body mass index. Although an improvement in physical fitness was observed – it increased from 21.99 ± 20.38 to 37.80 ± 12.05 – due to the large variability of the results (high standard deviations) the difference was not significant. Initially, as based on the Composite International Diagnostic Interview (CIDI), depression symptoms were diagnosed in 16 persons (7 – mild, 5 – moderate, 4 – severe), whereas after the 24-week NW training programme depression symptoms were noticed in only 7 persons (5 – mild, 2 – severe). The findings of this study showed that regular NW could be used as a form of rehabilitation for depressed patients [26].

Knobloch et al. [32] presented an example of applying NW in the treatment of a sacral stress fracture caused by training overload in a 22-year-old female long-distance runner. After 2 weeks of complete physical inactivity the subject underwent moderate physical activity (stationary bicycle) for 60–90 minutes per day. After another 2 weeks, a 60–90 minute session of NW was included per day. Seven weeks after the sacral stress fracture was diagnosed the subject was able to run about 90 km per week without feeling pain. Based on the results, the authors recommend including NW in the treatment programme of sacral stress fractures caused by training overload as a physical activity of low intensity suitable for athletes.

The biomechanical aspects of NW

In studies which focused on biomechanical issues, [2, 30, 31] the authors analyzed the loadings of joints during NW (Tab. 3). Hansen et al. [2] made a three-dimensional gait analysis with and without poles. The authors calculated internal flexor and extensor joint moments around the ankle, knee and hip and measured both the internal compression and shear forces for the joints as well as the external ground reaction forces during NW and when walking without poles. No significant differences were observed in the compression or shear force acting on the knee joint during NW when compared to walking without poles. The peak knee flexion in the first half of the stance phase was significantly ($p = 0.02$) larger during NW (–32.5 ± 6.0°) than when walking without poles (–28.2 ± 4.2°), which may suggest a more "bouncy" walk in NW when compared to normal walking. The hip's range of motion was significantly ($p = 0.01$) increased during NW (64.4 ± 10.2°) when compared with walking without poles (57.8 ± 9.7°). Changes in the knee and hip joint angles were not followed by changes in joint dynamics [2]. Stief et al. [30] have tried to quantify any differences in joint loadings of the lower extremities among walking, NW and running using a three-dimensional kinematic analysis and force platform. The authors demonstrated that the higher knee extension moment in NW when compared with walking can be explained by the longer steps and the higher sole angle during the first part of the stance phase. In the transverse plane the ankle moments were significantly greater in NW (–16.49 ± 6.21 Nm) than in walking (–15.37 ± 5.84 Nm, $p = 0.03$) and running (–7.94 ± 3.9 Nm, $p = 0.001$) [30]. Another group of investigators [31] analyzed the kinetic variables when walking with and without poles. Willson et al. [31] showed that during NW such indices as walking speed (1.59 ± 0.20 $m \cdot s^{-1}$), stride length (1.77 ± 0.2 m) and stance (0.66 ± 0.02 s) were significantly higher ($p < 0.008$) than in walking without poles (1.48 ± 0.18 $m \cdot s^{-1}$, 1.57 ± 0.12 m, 0.65 ± 0.02 s, respectively). Another significant difference ($p < 0.008$) was a decrease in the vertical ground reaction force (Fz) during NW (372.39 ± 62.47 N) when compared to walking without poles (388.32 ± 81.97 N). Also, the vertical (compressive) knee joint reaction force when walking with poles was significantly ($p < 0.01$) lower, by 4.1% in the poles back condition and by 4.4% in the poles front condition, than when walking without poles, what causes a reduction in the loading of the knee joints when walking with poles when compared to walking without poles [31].

Discussion

It is worth noting that not all beneficial effects of NW, so widely promoted, have been confirmed by the research findings and the issues that undrewent scientific analysis have not always found clear explanations. There is a large discrepancy among the comparative results of maximal oxygen uptake during NW and when walking without poles on a treadmill [17–19]. Rodgers et al. [18] noticed that during NW, maximal oxygen uptake increased by 12% at a belt speed of 1.8 $m \cdot s^{-1}$, with Porcari et al. [17] – the increase amounted to 23% at a belt speed of 1.7 $m \cdot s^{-1}$, while Schiffer et al. [19] recorded an increase by only 8% at a belt speed of 1.8 $m \cdot s^{-1}$. A similar discrepancy can be observed between the results of heart rate measurements during NW and when walking without poles on a treadmill [17, 18], where the values are higher by 9–16%, whereas in the field [9] the heart rate is higher during NW by 6% when compared to walking without poles. However, it is important to underline that all the authors showed an

Table 3. Biomechanical aspects of NW – a literature review compilation

Author	Year	*n*	Gender (F/M)	Age (years)	Aim of research	Measurements
Hansen et al. [2]	2008	7	F	42–58	A comparison of the load on the knee, hip and ankle joints during NW and walking without poles.	▪ three-dimensional kinematic gait analysis
Stief et al. [30]	2008	15	M	31 ± 5	A comparison of the loadings of lower extremities joints during NW, walking and running.	▪ three-dimensional kinematic gait analysis
Willson et al. [31]	2001	13	5F/8M	30 ± 5	The efects of walking poles on lower extremity gait mechanics in healthy people	▪ three-dimensional kinematic gait analysis

F – female, M – male, NW – Nordic Walking

increase in maximal oxygen uptake and heart rate during NW both on the treadmill [17–19] and in the field [9], which may indicate that more intense work is performed during this form of physical activity when compared to walking without poles.

Research on the effects of terrain inclination on energy cost and maximal oxygen uptake during NW demonstrate an increase in oxygen uptake by 19% when walking downhill [16] and a higher energy expenditure when walking uphill (by 9%) and downhill (by 51%) [11] compared to walking downhill and uphill without poles. It was observed that the type of surface had influence on examined physiological indices during NW – on grass the energy cost was higher by 12%, and maximal oxygen uptake by 12.5% when compared to a concrete surface [3].

In two studies it was shown that regular NW training (8–13 weeks) in women leads to an increase in high density lipoprotein, a reduction in total cholesterol, low density lipoprotein, triacylglycerols and BMI [10], as well as an increase in maximal oxygen uptake [15], although no significant differences were noticed in the analyzed biomechanical and physiological indices between NW and walking without poles. It may prove that both NW and walking without poles have similar long term effects on the female body.

All of authors dealing with rehabilitation issues [20–29] underline the necessity of doing additional research. However, it seems that current scientific evidence, especially in the areas of cardiology [21–23, 28, 29], confirm the usefulness of NW in the rehabilitation programmes of patients after acute coronary syndrome, with intermittent claudication, with coronary artery disease, and after myocardial infarction. What seems particularly valuable is the possibility of continuing NW by cardiac patients on their own in the prevention of secondary cardiovascular disease.

Contrary to popular belief and the study by Willson et al. [31], recent research has indicated [2, 30] that NW does not reduce the load on the knee joint more than walking without poles. Moreover, Stief et al. [30] demonstrated an increase of the load on the ankle joints during NW when compared to walking without poles or running. Taking into consideration the discrepancies in the research findings, further studies are neccesary in trying to answer if NW reduces the loading of lower extremities joints.

Conclusions

The recent promotion of NW resulted in an increase in researchers' interest in this form of physical activity in different groups of people with special needs. However, the research results have so far not explained unequivocally the beneficial effects, so widely promoted, of NW. Thus, further investigation is needed to explain if NW does in fact reinforce the immunological system, increases the number of red blood cells, reduce joint stress by 30%, raises well-being, provides 70–90% of body muscle movement or reduces load on knee joints.

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BACK CARE PROGRAMMES: THE LOW PARTICIPATION OF TARGET GROUPS AND UNCLEAR EFFECTIVENESS AS PRIMARY PREVENTION

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ABSTRACT
Purpose. Back care programmes (BCPs) for the prevention of back pain are widespread in Germany. They are intensively promoted and financed by health insurance organizations. The goal of the conducted research was to investigate whether BCPs adequately reach the targeted risk groups for primary and secondary prevention and whether the interventions employed are effective in reducing work disability and absenteeism due to back pain. **Basic procedures.** Absenteeism associated with back pain (ICD-10 codes M40-M54) and with participation in a BCP were evaluated based on data from 2004 through 2006 for a random sample of 9,781 persons insured with an mandatory health insurance organization. **Main findings.** 97% of all BCP participants in 2005 had not received a sick leave certificate due to back pain in the previous year. Furthermore, neither bivariate, nor risk-adjusted logistic regression models demonstrated a significant relationship with BCP participation and the subsequent risk of back pain. **Conclusions.** Current BCPs show low participation of target groups. The effectiveness in primary prevention of new cases is unclear.

Key words: low back pain, patient compliance, health promotion, programme effectiveness, back school, back care programmes

Introduction

There is little doubt that low back pain (LBP) is the most serious form of pain experienced in Western industrialized nations [1–4]. In the U.S., LBP results in an estimated 149 million lost work days annually and chronic LBP is associated with productivity losses of approximately $28 billion each year [5]. Furthermore, depending on the health system, the indirect costs associated with LBP can be four to ten times higher than direct costs [5, 6]. In Germany, LBP is responsible for direct and indirect annual costs estimated at 54 billion euros, or 2.5% of Germany's GNP [7].

LBP is not a clinical diagnosis, but rather a symptom, with different stages of impairment, disability and chronicity [8, 9]. Furthermore, there are a variety of causes of LBP, with varying therapeutic options. For example, the recommended primary prevention measures differ from those used as secondary prevention measures in connection with specific causes (e.g. vertebral fractures, infections, tumours, inflammatory diseases, disc herniations, or spinal stenosis) or arising from non-specific causes. It should be noted that LBP caused by non-specific causes constitutes 85% of all cases [6, 8, 10].

As a result of the diversity in LBP symptomology and causality, an often confusing spectrum of LBP primary and secondary prevention options has evolved in many countries. The variation in LBP prevention approaches is also reflected in the number of back care programmes (BCPs) available. BCPs are common in Europe, USA, Canada and Australia, and typically involve seminars where factors such as posture, lifting techniques, exercises and back care during leisure and work activities are addressed. In general, however, BCPs offer prevention advice that is not backed by a uniform curriculum, standard evidence-based elements or professional supervision. In addition to these problems, participants usually choose their own BCP without professional medical advice. In Germany, mandatory statuary health insurance organizations are responsible for a large majority of both the direct and indirect costs associated with LBP, including disability payments. Currently, BCPs are a common form of primary and secondary prevention taken to minimise the incidence and prevalence of LBP among enrollees.

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Previous studies have found limited effectiveness associated with BCP participation [6, 10, 11]. Nevertheless, BCPs continue to proliferate. Given the costs associated with BCPs and their questionable effectiveness in reducing the risk of LBP, greater knowledge linking participation patterns and their outcomes is needed. Such an analysis would be helpful to potentially better align current BCPs, as well as for those in the field of LBP prevention in nations where BCPs are not currently put into practice, but where future implementation is considered.

In our study, three areas related to the participation and the outcomes associated with BCPs were investigated: (a) the incidence and prevalence of back pain among German employees from the service sector and the length of time, on average, that employees were unable to work because of problems with their spine or back; (b) the participation rate in BCPs, specifically among those at highest risk for recurrent back pain; and (c) the effectiveness of BCPs in preventing future periods of absence from work due to back pain. In general, German health insurance organizations have not released any statistics of BCP participation rates and outcomes. Our study, therefore, provides a unique insight into these BCPs and their current role in back pain prevention in Germany.

Material and methods

In Germany, nine out of ten employees are insured through mandatory health insurance organizations [12]. This study is based on data obtained from one of these organizations, insuring approximately 200,000 people at the time of this data assessment. Enrolment is open to all employees within Germany, but consists mainly of employees from the service sector.

Data, aggregated by year, was obtained from January 2004 to December 2006. A longitudinal study design was used to investigate the relationship between prior work disability due to back pain in 2004 and participation in a BCP in 2005 and the association of participation in a BCP in 2005 with recurrent and new episodes of back pain in 2006. To be included in the study, subjects had to (a) be continuously employed, either part-time or full-time, from 2002 to 2006; (b) be between the ages of 18 and 59 years old, as of January 1st, 2005; and (c) have complete data on work disability claims for the years 2004 and 2006. Individuals who participated in a BCP during the period from January 2002 to December 2004 were excluded from the study to eliminate any confusion in case of any previous participation in a BCP. A random sample of 9,781 persons meeting these criteria was selected from the total insured population. Within the sample, 51.1% of the subjects were male, 48.9% were female and the mean age was 39.64 years (± 10.11).

The main dependent variable was absence from work due to disability claims in 2006 attributed to problems with the spine or back under ICD-10 codes M40-M54. In Germany, employees must obtain a sick leave certificate and doctors must report to the health insurance organizations the certificates they have given, categorized according to ICD-10 codes. For each subject included in the study, the number of sick leave certificates received, and the total number of days absent from work due to back pain-related disability, were assessed for the year 2006.

The number of sick leave certificates received and the total number of days absent from work due to back pain claims under ICD-10 M40-M54 for each subject was investigated for 2004. The participation of subjects in BCPs held in 2005 was also assessed. The BCPs in which the subjects participated included a range of courses, with titles such as "Spine Gymnastics", "Back School", "Back Training" and "Back Fitness". Participation in these programmes was reimbursed by the health insurance organization which provided the data for this analysis. The programmes were typically offered through sports/health clubs, night schools, local health departments, self-help groups, private institutions or other health insurance organizations. The participation in stress prevention and stress reduction courses (e.g. "Relaxation Techniques", "Progressive Muscle Relaxation" and "Autogenic Training") was also measured to investigate their relationship with subsequent work disability claims due to back pain separately.

Descriptive statistics were first calculated on the 2006 data, including calculation of the prevalence, frequency and duration of work absences due to back pain-related disability. Next, two cohorts were created according to the methods of Beaglehole et al. [13]. Cohort 1 consisted of subjects who had not missed work in 2004 due to a back pain disability claim (n = 9,493). Cohort 2 included those subjects who had submitted at least one back pain-related work absence certificate from their doctor in 2004 (n = 288). For both cohorts, participation in a BCP in 2005 and work absences in 2006 due to back pain-related disability were assessed. Finally, bivariate and multivariate logistic regression analysis was carried out. In the multivariate models, the receipt of a back pain-related work absence certificate in 2006 was the dependent variable and participation in a BCP in 2005 was the independent variable, adjusted for age and gender. The study complies with the principles of the Declaration of Helsinki. As we used anonymised secondary data no ethical approval was required. All statistical tests were performed with the SPSS for Windows 18.0 package, with a significance level set at $p < 0.05$.

Results

In 2006, 3.2% ($n = 310$) of all subjects included in the study had submitted at least one certificate for work absence due to a disorder of their back or spine. In the large majority of cases (87%), only one back pain-related disability claim was made. Thirty-one subjects (10%) submitted two certificates and ten (3%) submitted three or more. Among subjects with a work absence due to back pain, 36.1% were unable to work for a period of one to five days. The median annual number of days absent was 14 days for subjects with a back pain-related disability claim in 2006, ranging from one to 365 days. As observed in previous studies [14, 15], women within the study, as well as older workers, were at greater risk of being absent from work due to back pain (Tab. 1).

Absence from work was asymmetrically distributed (Fig. 1). Three quarters of those who submitted back pain certificates in 2006 were responsible for only 2,732 days of absence (1st to 3rd quartile; Fig. 1). The remaining 25% of those with back pain claims had a total of 10,816 days of absence from work, or 80% of all days of absence from work were attributable to back pain claims.

Of the subjects who did not have a back pain-related claim in 2004 (Cohort 1), 1.7 % (159 out of 9,493) participated in a BCP in 2005 (Fig. 2). Participation in BCPs in 2005, among subjects with a back pain-related claim in 2004 (Cohort 2), was even lower (4 out of 288, or 1.4%). Only 1% of subjects in Cohort 1, and 2% of subjects in Cohort 2, participated in stress reduction programmes in 2005 (results not shown).

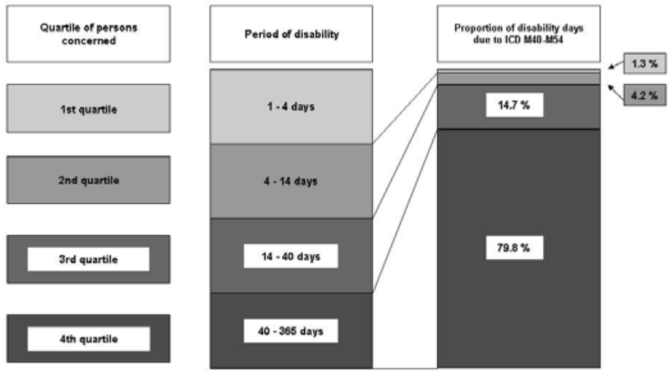

Figure 1. Distribution of approved absences from work of all individuals with sick leave certificates under ICD-10 M40-M54

For subjects in Cohort 1, there was no bivariate association, nor a significant relationship within the risk-adjusted regression models, found between participation in a BCP in 2005 and the subsequent risk for back pain in 2006 (Tab. 1). The same result was also observed for participation in stress reduction programmes. Due to the small number of BCP participants in Cohort 2, an analogous analysis of the effect of participation in a BCP on secondary prevention of back pain was not performed.

Table 1. Association of participation in a BCP in 2005 with recurrent and new episodes of back pain in 2006 for individuals without an approved absence from work due to back pain in 2004 (t_0) (crude and adjusted for gender and age)

	Model 1 Crude		Model 2 Adjusted for Gender and Age	
	Relative Risk RR	Odds Ratio OR [CI]	Relative Risk RR	Odds Ratio OR [CI]
First Participation in a Back Care Program in 2005	1,81	1,856 [0,902 – 3,820]	1,81	1,688 [0,818 – 3,485]
Gender: female[a]	–	–	1,22	1,431** [1,115 – 1,838]
Age in years	–	–	–	1,039*** [1,025 – 1,052]
Intercept[b]		–3.556		–3.543
r^2 adjusted[c]		0.001		0.019
n		9493		9493

Dependent variable: Disability days in 2006 due to ICD M40-M54 = 1; *** $p < 0.001$, ** $p < 0.01$
[a] Reference category: male
[b] Regression coefficient b
[c] According to Nagelkerke

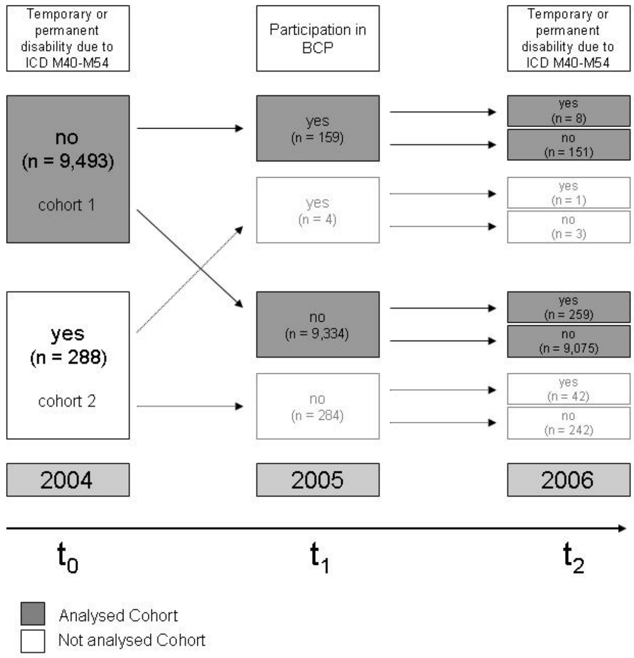

Figure 2. Flow-chart of study design to investigate rates of participation in BCPs and effectiveness of BCP for individuals with and without prior back pain-related work absence

Discussion

In Germany, a variety of BCPs are offered by the mandatory health insurance organisations, but the programmes are not standardised, nor evaluated or validated. Participation in such courses generally occurs without any professional medical advice and without recommendation for specific target groups. Based on the data provided by one such organization, our study found that the majority of BCP participants (97%) enrol as a primary prevention strategy, with no prior back pain claim. However, no significant association was found between participation in a BCP and the subsequent risk of back pain.

The strength of our study lies in its unique insight into insurance data, its longitudinal design and its sample size. To date, participation in BCPs in Germany has only been investigated within cross-sectional studies. As with our study, women and older workers were found to be at greatest risk of back pain, but prevention programmes were found to be more often utilized by persons with the lowest risk of pain [14, 16, 17]. Our longitudinal study design further permitted the investigation of the outcomes associated with BCP participation separately among persons with and without prior episodes of back pain. In addition, unlike many previous studies of the effectiveness of BCPs [18], we employed a standardized assessment of back pain based on doctor-approved certificates for work absence due to a back pain disability according to ICD-10 codes. Typical sources of bias (e.g. social desirability bias, memory and interview bias; [19]) associated with self-reported assessment of back pain disability were thereby minimized.

However, the sample investigated consisted exclusively of insured persons working within Germany's service sector. This is a result of the specific client structure with the health insurance organization providing the data for analysis. On one hand, this limits the external validity of our results and our ability to generalize the study findings to other employee groups, such as blue-collar workers. On the other hand, internal validity is enhanced because of the homogeneity of our sample.

Furthermore, due to restrictions in accessing data, we did not have information on BCP course participation in 2004 and 2006, nor data of the approved absences from work in 2005. Therefore, it might be possible that persons without back pain in 2004 were absent because of back pain at the beginning of 2005 and subsequently participated in a BCP in midyear of 2005. However, based on our data, among those identified as free of back pain in 2004, less than 290 people should have been absent in the following year due to back pain, and less than 5 subjects from this subgroup would have participated in a BCP. Therefore, the impact of subjects without back pain in 2004, absent due to back pain at the beginning of 2005, participating in BCPs in 2005, should be limited. Nevertheless, we cannot explicitly measure the occurrence of this, or similar, scenarios within our dataset. These methodological limitations must be considered in the interpretation of our results.

Another limitation arises from possible bias from the under-reporting of subjects' participation in BCPs. The health insurance organization that provided the data for analysis reimburses BCP fees up to 500 euros per year. Although insured persons are broadly informed about BCP coverage through various sources (e.g. brochures, hotlines, the Internet), it should be assumed that not every covered BCP participant requested reimbursement. This reporting bias, however, should have equally affected both cohorts (i.e. those with no prior back pain claims and those with prior back pain claims).

Relation to other studies and explanations

The low participation of target groups: Our results on BCP participation are in line with studies on participation in other health promotion programmes [20–25]. For example, participation in health-related awareness campaigns (e.g. smoking prevention and weight reduction) often show a phenomenon that is termed "preaching to the converted" [22, 26]. Awareness campaigns and health promotion programmes are mainly attended by individuals who already demonstrate a healthy and risk free lifestyle. Marstedt et al. [27] describe the typical participant at training and health programmes as sports-loving, more attractive than average, and youth-oriented. This dominant subgroup of individuals may create a competitive atmosphere and barrier to participation for persons at higher risk. Fear of increased pain or shying away from social contacts or competitive situations might also be expected of individuals suffering from chronic pain and could serve as a further explanation for the observed, low participation rates of target groups. Clearly, participation in LBP prevention programmes is not driven only by an individual's objective evaluation of their burden of disease or risk assessment. The decision to participate is also influenced by numerous other factors that are not related to LBP's current or future symptoms [28]. Therefore, the widespread BCP mottos in Germany to "train one's back" are also more likely to attract those with the lowest risk of future back pain [24].

Furthermore, those who would profit most from participation in BCPs are unfortunately the ones more likely not to attend: individuals of lower social status, manual labourers, shift workers and those with irregular working hours [25]. People in these subgroups may face additional, information and health education-related barriers to participation. Specifically, to be able to seek out BCPs through one's own initiative requires sufficient background information. Individuals at higher risk of suffering from back pain often do not have regular access to the Internet or print media, where information about BCPs is most readily available. Additionally, an intellectual understanding of and confidence in the effectiveness of such programmes is a prerequisite for voluntary participation in such courses.

Finally, structural barriers may, in part, explain the observed low participation rates of target groups. This is especially true in rural areas, where adequate financial means to pay for a car or public transport often determines whether sufferers can reach seminar venues. To compound these access issues, BCPs are often held during the day, usually during the morning or early afternoon. As a result, the participation of individuals at risk who must work during these hours is further limited.

Unclear Effectiveness: The non significant effect of BCPs (Tab. 1) could be attributed, in part, to the low participation of at-risk target groups. Only weak evidence has been found to support the effectiveness of BCPs for random participants. In addition, sufficient evidence of the long-term effects is clearly lacking [3, 10, 29].

Furthermore, mandatory health insurance organisations finance a conglomeration of courses under the name "BCP". These courses consist of a wide variety of activities and exercises, most of which are neither standardised nor evaluated. It is well known that numerous, highly complex bio-psycho-social aspects must be taking into consideration when dealing with the aetiology of LBP [15, 30]. This demonstrates, that with a clear definition of target groups, that specialised BCP selection and participation thanks to individualized medical advice can be as strongly recommended on our part as the implementation of standardised elements and course curriculums.

Conclusions

Those involved in LBP prevention program planning and health care politics, both in Germany and in other nations, can learn from the results presented here. One of the most important lessons to be learnt is that the current approach to BCPs result in low participation in secondary prevention and have unclear effects for primary prevention. More importantly, our findings support Meschnig's thesis [31] that health promotion activities in their current form add to social injustice and fail to meet the central aim of prevention politics in "reducing existing inequalities in exposure to risks" [15, 32, 33].

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AN ASSESSMENT ON THE AEROBIC AND ANAEROBIC CAPACITIES OF A TENNIS PLAYER

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ABSTRACT
Purpose. The purpose of this research was to determine the relationship between a tennis players' technical abilities and their capacity evaluated in both a laboratory and on the tennis court. **Basic procedures.** Twelve tennis players participated in the study. The anaerobic capacity test (Wingate) and the progressive test were performed on a Monark E 895 cycloergometer. The aerobic and anaerobic capacities were evaluated in the laboratory. The Weber capacity test was performed on a tennis court. **Main findings.** The research did not reveal any significant correlation between the Wingate's mechanical parameters and the physiological parameters of the Weber test. A correlation of the maximal oxygen uptake with stroke precision on a tennis court can be observed. The research found that the maximal power output (P_{max}) and total work (W_{tot}) found in the laboratory is related to the stroke precision on a tennis court. **Conclusions.** The results may suggest that both tests can be applied in the assessment of capacity and the effects of training. From the results of the laboratory and on-court tests, it is possible to specify a player's semi-specific endurance.

Key words: laboratory and on-court tests, tennis, anaerobic capacity, aerobic capacity

Introduction

In literature the characteristics of tennis as a sport have already been described in detail. It includes a precise match analysis on tactics, biomechanics (technique) as well as the behaviour of top level players' organisms and their physiological reaction they have during a match.

According to Groppel and Roeter [1], from a physiological point of view, a player should be characterised by high aerobic and anaerobic capacity, as well as having a suitable level of motor skills and high mental resistance. Other authors share this opinion. Kovacs [2] reports that an elite tennis player should be trained in four important facets: the technical, tactical, physical and mental. Ziemann [3] writes that tennis belongs as an acyclic and open sport which is characterised by changeable intensity and a variable match duration. The factors which determine the achievement of top performance, according to the author, are as follows: motor preparation as well as technical, tactical and mental ones. Ładyga [4] claims that such qualities as mental resistance, speed, strength, power and nerve-and-muscle coordination are particularly desirable in tennis players.

Kovacs [2] believes tennis has a few exceptional aspects which do not occur in other sports. They include primarily the kind of movement on a tennis court, the duration of stroke exchanges and the duration of intervals. Another aspect, as Ziemann underlines [3], is the difficulty in foreseeing how many matches the athlete will play in a given tournament, how long each match will last, and how heavy the loads (the cost of physiological effort) will be. Kovacs [5] implies that the duration of a tennis match also depends on such factors as: court surface, playing style adopted by the athlete, environment, skill level, stroke speed and motivation. Laurentowska et al. [6] claim that the factor which determines a player's movement on a court is the length of stretches they cover. Ferrauti [7] reports that 80% of all strokes are executed at a distance of 2.5 m from the player, 10% at a distance that ranges from 2.5 to 4.5 m from the player. The remaining strokes are executed at a distance longer than 4.5 m. A player hits the ball 2.5–3 times during a stroke exchange, which depends on the style, kind of stroke, court surface and strategy; in addition, one changes the direction of movement on the court on average four times [5, 8]. Numerous studies have also analysed the time of stroke exchanges and time of rest during matches in elite tennis players. In the analysed matches, the ratio between work and rest oscillated from 1:2 to 1:5, where the mean time of stroke exchange between players ranged from 3 s (on fast courts – grass, carpet, and hard surfaces as defined in the International Tennis Federation ITF regulations as courts of categories 2 and 3) to 15 s on a slow surface, i.e. clay courts (category 1 according to the ITF regulations from 2006) [5]. Research done by Ferrauti et al. [9] indicate that the

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effective length of playing time expressed as a percentage share of the entire match amounts to 20% – 30% for clay courts and 10% – 15% for fast surfaces. An explanation to these findings is provided by Parson and Jones' research [10]. They sustain that each court surface requires a different game strategy. It is related to the speed of a stroke and its rotation, which, in consequence, determine the duration of matches.

The above data which characterises tennis points to the importance of various physiological parameters, such as heart rate (HR), maximal oxygen uptake ($\dot{V}O_{2max}$) and lactate concentration in the blood (LA), which can have a significant influence on an athlete's succes. In the available literature, heart rate (HR) is usually given in mean values [5, 8, 11], however some authors [2–4] say that such values do not reflect the interruptive character of the game. Novas et al. [12] proved that oxygen uptake ($\dot{V}O_2$) regenerates faster than HR. Bergeron et al. [13] report that measuring HR during a game can be imprecise due to dehydration, thermal stress or climatic conditions. The data obtained by various researchers [9, 14–16] indicate the importance of high $\dot{V}O_2$ in this sport. Kovacs [2], after Bernardi, recognised that athletes whose playing style is aggressive have a lower current HR and $\dot{V}O_{2max}$ than those playing defensively behind the baseline. The same author states that the mean values of maximal oxygen uptake $\dot{V}O_{2max}$ obtained from tennis players oscillate between 50–55 ml · min^{-1} · kg^{-1}.

The energy during a stroke exchange in a match is generated mainly through a consumption of adenosine triphosphate stored in muscles and its resynthesis by means of creatine phosphate (CP) [9, 17]. The time needed to regenerate CP is about 15 s in resynthesising 50% of its capacity, whereas in the case of full resynthesis, the time needed amounts to 1–5 min [18]. All the regenerating intervals during a match are fixed by ITF regulations which exactly define their maximum length. Currently, these times are: 20 s between scoring points in a game, 90 s between games and 120 s between sets [8]. In this process, the role of oxygen metabolism plays an important role as it helps resynthesise adenosine triphosphate during intervals [18–20]. It can be one of the causes of a high maximal oxygen uptake ($\dot{V}O_{2max}$) in athletes at the highest performance levels [17, 21, 22].

Kovacs [2] claims that having a very high $\dot{V}O_{2max}$ (above 65 ml · min^{-1} · kg^{-1}) does not necessarily improve one's game more than an oxygen uptake around 55 ml · min^{-1} · kg^{-1}. Therefore, he suggests devoting more time in tennis players' training to perfect other elements: the physiological, technical, tactical and mental. In some researchers' studies [1, 5, 9, 23] no difference has been found among professional tennis players. The studies indicate lower values of $\dot{V}O_2$ (in comparison to $\dot{V}O_{2max}$) registered on a court in men than in women. This could have been caused by the duration of stroke exchange, which is statistically shorter in the case of men than women.

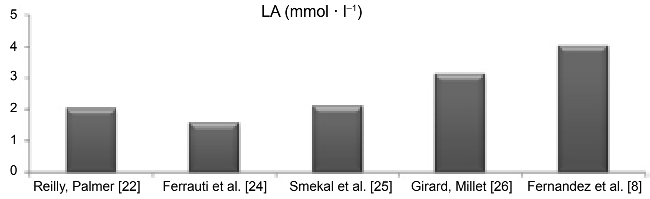

Figure 1. LA concentrations registered during playing in the studies done by the above mentioned authors

In the available literature, the results in lactate concentration (LA) (2–4,5 mmol · l^{-1}) registered during playing indicate that an overwhelming amount of energy comes from anaerobic, non lactic acid energy sources (Fig. 1).

However, one should not forget that during long and intensive tennis duels, LA can increase even to 8 mmol · l^{-1} which can imply that simultaneously other glycolytic sources of energy are engaged. McCarthy-Davery [27] reports that on LA concentration amounting to 7–8 mmol · l^{-1} of plasma disturbs the technical and tactical skills of the player. According to Christmass et al. [21] fatigue worsens a player's technical skills, movement coordination and concentration by over 80%.

The above data indicate that aerobic and anaerobic non lactic acid sources of energy play a fundamental role when playing tennis. However, during long and closely fought matches, LA concentration considerably increases and the concentration intensity can influence the result of the match.

The aim of this study was to determine the relationships between an athlete's technical playing skills and their capacity assessed in the laboratory and on the court during the Weber test. An analysis of the changes in the physiological parameters was to show which of the parameters examined can have a significant influence on the results obtained. Another aim of the study was to select the most effective assessment method of a tennis player's aerobic and anaerobic capacity.

Material and methods

Subjects

The study comprised of 12 professional tennis players. Their selected anthropometric and morphological data

Table 1. Anthropometric and morphological characteristics of the examined group

Anthropometric characteristics	Mean value $\bar{x}$	SD
Age (years)	21.83	3.88
Height (cm)	183.75	3.41
Weight (kg)	77.60	6.74
BMI (kg/m^2)	23.04	1.80
Body fat (%)	11.98	3.35
Water (%)	63.68	4.25
Water (l)	49.98	3.54

Table 2. Position in the PZT ranking

Tennis player	Position in ranking	Years of training
1.	537**	14
2.	157** (doules ranking)	16
3.	6	6
4.	45	7
5.	53	7
6.	6*	6
7.	8*	6
8.	97*	7
9.	1DV	12
10.	1DV	12
11.	NC	9
12.	NC	7

* Position in the PZT ranking – Juniors
** ATP – world ranking
1DV – first division (USA)
NC – non-classified

are shown in Table 1. Their ranking in the PZT (Polish Tennis Association) are shown in Table 2 [28].

The study was carried out in two stages. The first stage included an examination in the Sport Endurance Testing laboratory (which presently has a PN-EN ISO 9001-2001 quality certificate). A week later, the second stage was held, i.e. an examination on indoor tennis courts with the use of a breath analyser and a ball throwing machine.

The subjects had on average 9-years experience in playing tennis, which ranged from 6 to 16 years. One of the subjects was the Polish Indoor Champion in the senior category (Tab. 2).

Methods

Endurance test of anaerobic capacity (*Wingate test*)

In the laboratory test, athletes exercised for 30-seconds on a cycloergometer (Wingate test). The aim of the test was to determine their anaerobic capacity. It was conducted according to the methods proposed by Bar-Or [29]. The subjects underwent a 30-second Wingate test on a cycloergometer Monark E 895, with an individually selected load following the principle of 75 g on 1 kg of body mass. During the trial, the following parameters were measured by means of the computer program MCE v. 2.3:

– maximal power output (P_{max}) achieved at the moment of the highest pedalling rate,
– total work done during the 30-second effort (W_{tot}),
– time needed to reach (t_{rmp}) maximal power and its duration (t_{dur}),
– drop in power output (DP).

While undergoing the Wingate test, athletes were connected to a K4b^2 analyser by Cosmed (Italy), which measured cardio-respiratory parameters during the effort and restitution. The measured parameters were: oxygen uptake ($\dot{V}O_2$ ml · min^{-1} · kg^{-1}) and heart rate (HR) per minute.

Before the exercise and three minutes into the exercise a blood sample was taken from the finger tip in order to determine the lactate concentration (LA). The LA was measured by Dr. Lange's enzymatic method, the LKM 140 test.

Progressive test on the cycloergometer

In the second stage of the study, athletes underwent a progressive test on a Monark E 895 cycloergometer whose aim was to measure their aerobic capacity. The test started with a load of 50 W and was increased every 3 minutes by an additional 50 W. It continued until the maximal heart rate was reached. The cycloergometer was controlled by a computer which registered moment power, work time, and rotation; on these results the program calculated the total work done during the test. Maximal oxygen uptake ($\dot{V}O_{2max}$) as well as other cardio-respiratory parameters were measured by the Quark analyser (Cosmed).

Before the exercise and three minutes into the exercise blood was taken from the finger tip in order to determine the lactate concentration (LA). The LA was measured in the same way as above.

Weber method

The test performed on the tennis court based on Weber's method [30], was to assess an individual's endurance by simulating playing tennis.

According to Weber [30], an exact reconstruction of a tennis player's playing effort is possible only with the use of a ball throwing machine. In the test described here, a Miha 2002 training machine was used. It threw balls at a constant speed and frequency as well as at constant angles of delivery and bounce, alternatively for a forehand and backhand swing. The balls used were new Penny Championship, which provided equal ball compression and bounce.

In the trial, athletes had to perform four successive strokes (Fig. 2):

- forehand – cross, i.e. directing the ball from the right side diagonally to the opposite side of the court onto the marked zone (in the figure – zone B),
- backhand – cross, i.e. directing the ball from the left side diagonally to the opposite side of the court onto the marked zone (in the figure – zone B),
- forehand – down the line, i.e. directing the ball from the right side along the line to the opposite side of the court onto the marked zone (zone B),
- backhand – down the line, i.e. directing the ball from the left side along the line to the opposite side of the court onto the marked zone (zone B).

The subjects were asked to hit both forehand and backhand strokes from the "forehand corner" and "backhand corner" for the ball to hit the marked zone. During the test, oxygen uptake ($\dot{V}O_2$) expressed in ml · min^{-1} · kg, heart rate (telemetria – K4b^2 by Cosmed) and lactate concentration (LA) in the blood were measured by the way as described above.

In addition, the number of balls which hit the marked zone on the opposite side of the court were counted, i.e.

The succession of strokes onto the marked out zone (B) in the test:
1. Forehand cross (grey colour)
2. Backhand cross (grey colour)
3. Forehand down the line (white colour)
4. Backhand down the line (white colour)

Figure 2. Tennis endurance test – the Weber test

both zones for the forehand and backhand swings were marked 1.7 m from the singles lateral line by special markers so that the athletes could see the destination zone (zone B) better. Anaerobic capacity was measured by the Weber test [30]. The test was proceeded by a 5-minute warm-up on the machine delivering balls at a constant speed (15–16 balls per minute). A relatively low starting load appears to be indispensible as a continuation of the "warm-up phase", which is especially useful for getting used to load conditions unusual for the subjects (running in different directions, shot combinations, blood sample taking) [30]. As a rule, the loads were gradually increased. An increase in loading was obtained by changing the lob rate. The initial load was 15 balls · min^{-1} (trial A), then 18 balls · min^{-1} (trial B), in each successive trial the number of balls were increased by 3 per minute in comparison to the preceding one. The test finished when the subject was not able to hit the balls in time or when the rate reached 30 balls · min^{-1} (maximal trial – E).

At the beginning of the third minute interval a blood sample was taken from a finger tip. A telemetric gas analyzer K4b^2, worn by athletes during the trial (effort and interval), made it possible to conduct tests with laboratory precision, yet in a natural environment, i.e. on the court. The device was attached by special straps worn by the player; its weight was 600 g and it did not disturb the athlete in playing tennis. The data obtained were transmitted by radio to a computer, which allows real time observation of the subject's reaction to their physical effort (the rate of the balls hit in the marked zone).

The results from both the laboratory and tennis court were worked out and presented in tables and figures. The arithmetic mean ($\bar{x}$) and standard deviation (SD) of selected mechanical parameters for the whole group were calculated. A comparative correlation between the mechanical parameters from the Wingate test and the physiological parameters from the Weber test, as well as a correlation between the physiological parameters and accuracy, were calculated by means of Spearman's rank-order in Statistica 8.0. The statistically significant level was set at $p < 0.05$.

Results

Table 3 shows the values of the mechanical parameters measured during the 30-minute Wingate test.

Athletes needed from 4.61s to 8.42 s to reach maximal power at the level $\bar{x} = 10.29 \pm 0.84$ [W · kg^{-1}] and they maintained it from 2.39 s to 5.80 s. Mean value of total work was $\bar{x} = 19.65 \pm 2.35$ [kJ]. While comparing

Table 3. Mechanical parameters obtained in the Wingate test of anaerobic capacity

Tennis players	Maximal power (P_{max}) ($W \cdot kg^{-1}$)	Time to reach max power T_{rmp} (s)	Time of duration T_{dur} (s)	Work done (W_{tot}) (kJ)	Drop in power Index (DP) (%)
$\bar{x}$	**10.29**	**5.57**	**4.38**	**19.65**	**19.25**
SD	**0.84**	**1.06**	**1.01**	**2.35**	**3.86**

Table 4. Correlation of mechanical parameters in the Wingate test and physiological parameters in the Weber test with the accuracy in each trial of the Weber test

Correlation	Accuracy (%)				
	P_{max}	W_{tot}	HR	LA	$\dot{V}O_2$
Weber test	Spearman's *r*				
A	**0.69**	**0.73**	**–0.78**	–0.13	–0.40
B	**0.61**	**0.79**	–0.49	–0.12	–0.19
C	0.46	0.41	–0.40	0.01	0.01
D	**0.70**	**0.64**	–0.14	**0.63**	–0.08
E	0.11	–0.19	**–0.87**	–0.32	0.26

Statistically significant correlations are in bold type.
P_{max} – maximal power output W_{tot} – total work
T_{rmp} – time to reach maximal power T_{dur} – time of its duration
LA – lactate concentration
$\dot{V}O_2$ – oxygen uptake

Table 5. Correlation between $\dot{V}O_{2max}$ and the accuracy achieved in the Weber test

	Accuracy (%)				
	Trial A	Trial B	Trial C	Trial D	Trial E
$\dot{V}O_{2max}$	**0.93**	0.26	**0.71**	**0.58**	**0.87**

Statistically significant correlations are in bold type.

the results of the mechanical parameters in the Wingate test with the physiological parameters in the Weber test, some significant single correlations were identified which prevented the calculation of the direction of adaptation (Tab. 4). Results obtained by comparing maximal power (P_{max}) expressed in Watt and the work done on the cycloergometer (W_{tot}) with the accuracy in the Weber test indicated that these factors significantly correlate with each other in trials A, B and D. No significant correlation was observed in trial C (21 balls thrown per minute). In the maximal trial (E) most athletes started losing their game rhythm half way through the exercise. Therefore, the trial was often suspended, which probably influenced the results. Correlation between lactate concentration (LA) in plasma and the accuracy (%) in the Weber test was observed only in trial D (Tab. 4). The results of $\dot{V}O_2$, compared to the accuracy obtained in the Weber test, did not show significant correlations (Tab. 4).

Maximal oxygen uptake ($\dot{V}O_{2max}$) measured during the progressive test on the cycloergometer and in four trials correlate significantly with the accuracy (Tab. 5).

Table 6 shows the accuracy achieved by athletes in each trial of the test of playing on a court. In this study, the percentage of accuracy was assumed as a measure of technical skills. In order to show the differences, a graphic comparison between the athlete with the highest score of accuracy (74.29%), ranked as the 537th in the world (ATP – Association of Tennis Professionals), and the athlete with the poorest accuracy (35.51%), 97th in the Polish junior ranking (PZT – Polish Tennis Association).

A comparison of selected mechanical and physiological parameters of the athlete with the best accuracy and the one with the worst is shown in Figure 3.

Table 6. Accuracy of tennis players in each trial of the Weber test as a percentage (%)

Trial – accuracy (%)	Tennis players											
	1	2	3	4	5	6	7	8	9	10	11	12
Trial A	46.67	46.67	53.33	73.33	80	60	33.33	33.33	80	80	60	73.34
Trial B	33.33	27.78	61.11	66.67	61.11	61.11	58.89	50	61.11	88	66.67	77.28
Trial C	66.67	28.57	47.62	52.38	76.20	52.38	42.86	33.33	71.34	66.67	47.61	80.95
Trial D	37.50	37.50	37.50	62.50	62.50	62.50	41.67	37.50	62.5	62.5	29.17	66.67
Trial E	60	37.03	51.85	60	33.33	40.74	18.52	37.03	59.26	–	–	59.26
$\bar{x}$	49.38	35.51	50.28	62.98	62.63	55.35	39.05	38.24	66.84	74.29	50.86	71.50
SD	**16.44**	**7.73**	**8.65**	**7.78**	**18.35**	**9.06**	**14.74**	**6.87**	**8.70**	**11.80**	**16.48**	**8.65**
PZT Ranking [28]	6*	97*	53	8*	1DV	1DV	NC	NC	6	537**	45	157***

* Position on PZT ranking – Juniors, ** ATP – world ranking, *** ATP – world doubles ranking
1DV – first division (USA), NC – non-classified players

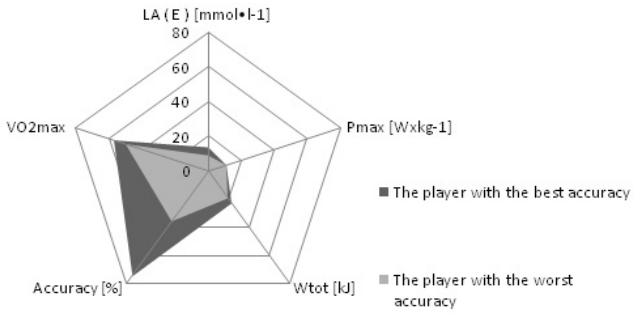

Figure 3. Comparison of the parameters achieved by two selected tennis players

Discussion

Kovacs [2] claims that the aim of basic anthropological and physiological measurements is to help coaches, athletes, researchers indentify talented athletes, monitor their progress as well as motivate them to hard work, i.e. training.

Ziemann [3] reports that the Wingate test is useful for assessing a tennis players' anaerobic capacity. It provides information on the efficiency of the phosphagen and glycolytic systems which provide the muscle with energy when playing, which according to literature amounts to 80% of the energy demand in tennis players during a match [31]. The results obtained in the Wingate test showed that maximal power reached, at $\bar{x} = 10.29 \pm 0.84$ [W · kg^{-1}] was close to the maximal power obtained by Laurentowska et al. [6] in their research conducted on nine Polish tennis players (P_{max} $\bar{x} = 10.31$ [W · kg^{-1}]).

Comparison of P_{max} and total work (W_{tot}) with the accuracy as performed in the Weber test showed correlation in 3 trials (A, B, D). Trial E (maximal) was not always completed by the tennis players. Hence, the lack of correlation and negative values are justified. This correlation indicates that level P_{max} and W_{tot} obtained in the Wingate test does have association with the accuracy in the test performed on the court. Maximal power indicates phosphagen capacities which can provide 70% of the energy demands in tennis players according to the ITF sources [31]. Total work in the test indicates glycolytic capacities of athletes which amount, according to ITF sources, 10% of the energy demands [31]. However, it is good to keep in mind that the usage of energy sources depends on the duration of stroke exchanges, the intervals between them which, in consequence, contribute to the duration of the whole match. Comparison between the mechanical parameters obtained in the Wingate test and the physiological parameters of the Weber test showed significant single correlations which did not allow for the calculation of the direction of adaptation.

The physical effort performed by professional tennis players has increased in the last several years [19]. In reference to the results obtained in the Weber test, one can notice that the heart contraction rate did not correlate with the accuracy in the test. The lack of such correlations of HR measurements during tennis play can be caused by the interruptive character of the game [2–4]. Other authors [9, 14–16] point to the considerable significance of high $\dot{V}O_2$ in this sport. With the use of modern equipment measuring the composition of exhaled gas, it is possible to control the player's oxygen uptake during a match. In studies carried out by Fernandez et al. [8], oxygen uptake ranged from 23 to 29 ml · min^{-1} · kg^{-1}. It amounted to 46% – 56% of athletes' $\dot{V}O_{2max}$ and differ from the values reported by König et al. (60–70% $\dot{V}O_{2max}$) [32]. Although tennis can be classified mainly as an anaerobic activity, a high efficiency of cardio-respiratory reaction can prevent fatigue and help regenerate the organism between game intervals, matches and tournaments, which in turn favour good performances [33] (Fig. 4).

Having a high aerobic capacity is important when playing and in-between-tournaments periods [2, 5, 33, 34]. A tennis player is recommended to try to reach a value of maximal oxygen uptake which exceeds 50 ml · min^{-1} · kg^{-1} [2, 8]. The results of maximal oxygen uptake in the subjects obtained in the laboratory ranged from 42 to 59 ml · min^{-1} · kg^{-1}. Oxygen uptake during the Wingate and Weber tests did not show any significant correlations with the on-court accuracy. Maximal oxygen uptake ($\dot{V}O_{2max}$) measured in the lab in the progressive test correlated with the accuracy achieved in the Weber test. As it was highlighted before, $\dot{V}O_{2max}$ can play an important role during a tennis competition, but

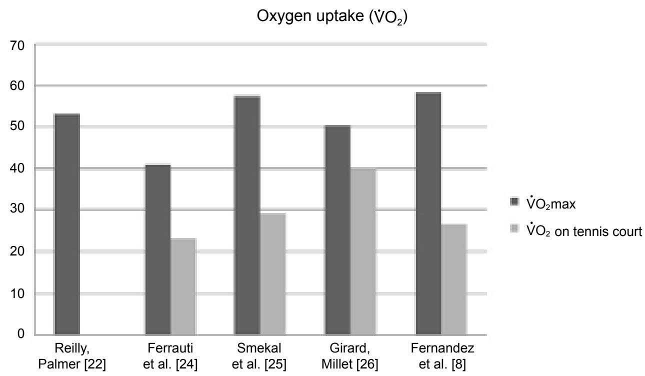

Figure 4. Mean values of $\dot{V}O_{2max}$ obtained in the studies done by the above mentioned authors and oxygen uptake ($\dot{V}O_2$) during a match (light grey)

(particularly) during training. The aerobic system helps resynthesize adenosine triphosphate during intervals [18–20]. The correlation obtained confirms the implications as described in the literature.

According to Banzer et al. [19], one's ATP tennis ranking correlates with maximal oxygen uptake ($\dot{V}O_{2max}$). These authors mention in their study that such correlations also occur in other sports (cycling, skiing, soccer). Since the subjects were classified in different rankings, it was impossible to verify this assumption. However, it must be taken into consideration that tennis player's training is extremely demanding and comprehensive. In order to sustain it, to exercise more and with more intensity, one needs high $\dot{V}O_{2max}$ which determines the effectiveness of capacity adaptation they develop when training.

Based on the implications mentioned in literature and concerned with the significance of lactate concentration (LA), a correlation between LA and accuracy obtained in the Weber test was calculated. The correlation, however, did not find any relationship. Fernandez et al. [8] noted that maximal values of LA during a tournament in professional players amount to circa 8,6 mmol · l^{-1}. At the same time, the authors claim that LA analysis during a tennis match should be interpreted with considerable caution, because the value of LA concentration is affected by physical preparation, stress, time of measurement, environmental conditions, etc. Besides, due to the natural intervals in game play, the LA level measures an activity level that the player had reached a few minutes before the blood sample was taken (in the case examined here – a minute of effort).

Periods when the player is walking on the court or resting probably enable a reduction in LA in the blood and muscles, which can have an influence on the results obtained in the test. It is possible to say that the higher intensity of effort, the higher LA concentration will be in the blood. An increase in LA concentration in the Weber test is not correlated significantly with accuracy.

Comparative characteristics of the player with the best accuracy to the player with the worst accuracy showed that physiological parameters (LA, $\dot{V}O_{2max}$) and total work (W_{tot}) were at a higher level in the player whose stroke accuracy was the best. The player was 47.88% more accurate than the worst one (Fig. 3). The results indicate that technical skills (with high endurance as well) were decisive, in this case, in the accuracy measured in the trials.

Parameters such as $\dot{V}O_{2max}$, $\dot{V}O_2$, HR, and LA are found in the available literature to be also important in assessing the training effects in tennis. Ferrauti [7] claims that anaerobic and aerobic capacities are among the most important factors influencing a tennis players' ability, second only to agility and speed. Smekal et al. [35] maintain – that after having compared one test in the lab to one on a tennis court – that higher values are achieved by a player in the trials performed in a laboratory, which can be taken into consideration when assessing a tennis players' general endurance. The same authors believe that more information on the "specific" preparation of a player can be deduced from tests performed on the court. Ferrauti et al. [9] claim that a tennis player's endurance training should be focused on shaping all-round endurance, semi-specific and tennis-specific in appropriate training periods.

That is why conducting tests in the laboratory and on the court can help coaches evaluate the true state of fitness in a given player. The Weber test, as applied in this study, can be an example of a "semi-specific" endurance assessment. Exercises that shape tennis-specific endurance should be executed under conditions of a real match. To this purpose various exercises which simulate game play (by using fragments of game play) are employed in maintaining restitution as close as possible to a match. In the literature, no test imitating mutch condition, has been found. The latest test used to assess endurance on the tennis court is "The Hit & Turn Tennis Test", elaborated by Alessandro Ferrauti in 2008 [36], which reflects only " tennis semi-specific" endurance. The best assessment of specific endurance (an athlete's level of fitness) is the performance achieved in tournaments.

Conclusions

1. A significant correlation was observed between the anaerobic capacity characteristics and accuracy achieved in the Weber test, which can suggest the validity of both tests in assessing endurance and the effects of training.

2. Maximal oxygen uptake ($\dot{V}O_{2max}$), measured in the progressive test, correlates with accuracy, which indicates an important role of the parameter in tennis.

3. LA concentration does not correlate with accuracy (in the Weber test).

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THE RELATIONSHIP BETWEEN 500 M AND 2000 M SIMULATED ROWING TIMES FOR SCHOOLBOY ROWERS OVER A TRAINING PERIOD OF THREE YEARS

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ABSTRACT

Purpose. Available data finds that for schoolboy rowers the 2000 m on-water or laboratory rowing distance causes fatigue and depresses their ability to train during the following days. Thus, looking for a less demanding test we evaluated the relationships between 500 m and 2000 m laboratory performance in schoolboy rowers. **Basic procedures.** A total of 10 boys participated in the study. All of the subjects simulated rowing "all-out" in either the 500 m or 2000 m rowing distance using a Concept II ergometer (Morsville, VT, USA). The tests were performed in November (transition phase), in January (general preparation phase), in March (specific preparation phase) and in June (competitive phase) throughout three successive years of training. **Main findings.** The mean power output during the 2000 m row gradually increased in the second year of training vs. the first one, and in the third year of training vs. the second one ($p < 0.001$). The times markedly improved in each year of training ($p < 0.001$). The mean power output and the time of the 500 m distance improved significantly in each year of training. In each training phase during the three years of training there were significant correlations between the rowing times in the 500 m and 2000 m distances. The coefficients of determination ($r^2 \times 100$) in the first year varied from 66.9 to 85.6%, in the second year – from 62.0% to 92.3%, and in the third year – from 76.4 to 89.5%. **Conclusions.** The relationship between the times measured in the of the 500 m and that of 2000 m one is affected by both the annual training phase and training experience. Thus, the 500 m laboratory rowing test may be useful in assessing the ability of schoolboy rowers to perform a competitive distance, but the results require careful interpretation.

Key words: adolescent athletes, laboratory rowing, training

Introduction

It is well documented that rowing is primarily a strength-endurance sport which in order to succesfully perform requires a high level of both aerobic and anaerobic capacities [1]. In elite rowers the physiological determinants of aerobic performance such as maximal oxygen uptake (VO_2 max), lactate and ventilatory thresholds reach high values during exertion [2–4]. Recent data have indicated that during a competitive 2-km distance aerobic energy is responsible for about 87% of total energy demands [5]. In addition, a close correlation has been found between rowing performance and VO_2 max [6].

On the other hand, the importance of an athlete's anaerobic capacity to perform successfully should not be neglected. It has been found that time of a simulated 2000 m rowing is in 75.7% related to the peak power output during 30 s of all out exercise [7]. In addition, a significant and positive correlation between the time of a simulated 2000 m rowing and maximal power output during 5 s all out exercise has also been noted [8]. Furthermore, isokinetic and isometric knee extension strength and power during simulated rowing exercises are also correlated with ergometric rowing performance [9, 10]. Recently anaerobic energy sources were found to provide 13% of total energy demands during on-water 2000 m rowing with similar contribution to the lactic and alactic pathways (6 % and 7%, respectively) [5].

The data cited above concern themselves with elite national and international junior or senior rowers. However, rowing training starts at the age of 12–14 years, during a period of intensive growth and development [11, 12].

It is clearly recognized that the early participation of children and adolescents in elite sports through intensive training programs led to an increase in the risk of thermal strain, cardiac disorders, injuries and overexertion [13]. Raglin et al. [14] have found that 35% of young athletes had been overtrained at least once. In addition, Kenttä et al. [15] have noted that incidence rates of overtraining in individual sports are higher than in team sports. Thus, the training of youths has to be carefully monitored to prevent any adverse effects [16].

However, to the best our knowledge, data on the training of adolescent rowers are scarce and fragmen-

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tary. The training of adolescent rowers was found to be stressful for muscle cells inducing a significant elevation in plasma creatine kinase (CK) activity and in the fatty acid binding protein level [17]. In addition, in rowers aged 12–13 years, their 1000 m ergometer rowing performance was found to be significantly and positively correlated with the maximal oxygen uptake and body size to those athletes with longer training experience [18, 19]. Recent data have demonstrated that in rowers aged 12–14 years, sport-specific training stimulates significant improvement in anaerobic performance during 30 s all-out exercise even after an athlele's body size is taken into consideration [20].

It should be pointed out that the Olympic rowing distance of 2000 m, lasting 6–7 min, is extremely exhausting especially for adolescent rowers. Thus, it is why rowers aged 12–13 years compete and undergo laboratory testing in the 1000 m distance [12]. Our observations indicate that even for schoolboy rowers aged 14–15 years the 2000 m on-water or laboratory rowing causes fatigue and depresses their ability and motivation for training during the following days.

Similarly, an analysis of rowing speed strategy in elite rowers has indicated that the performance of the first and last 500 m of the Olympic rowing distance are characterized by the highest speed and may be critical for achieving the best performance [21].

Thus, looking for a reliable, but less exhausting test, we undertook this study which evaluated the relationships between the 500 m and 2000 m performance of schoolboy rowers in laboratory trials during different annual training sessions over three years of training.

Material and methods

The prospective subjects were recruited among male students aged about 15 years. Because of their age, of each subject's parents (or legal guardians) were asked to give their consent prior to any tests. All the participants underwent medical examination including rest and post-exercise (30 sit downs done at maximal speed) electrocardiography, and anthropometric measurements. The preliminary procedures took place in March, in August the accepted subjects participated in a training camp where they took part in different types of physical activity such as sports, running, gymnastics, as well as ergometer and on-water rowing. A total of 10 boys were accepted by their coach for further participation in rowing training. All experimental procedures were in compliance with internationally accepted policy statements regarding the use of human subjects.

The subjects were asked not to participate in any physical activity in the 24 h before testing and to abstain from eating for 2 h before testing. All the participants were familiarized with the laboratory procedures to be carried out during a training camp in September of their first year of training. In each of the 3 years of training that was monitored, simulated rowing was undergone four times – in November (transition phase), in January (general preparation phase), in March (specific preparation phase) and in June (competitive phase). The tests were performed on two separate days of the same week and began at 9:00 a.m. Before testing, the subjects' weight and height were measured using medical scales. The warm-up consisted of using a Concept II ergometer (Morsville, VT, USA) on a damper setting of 4–5 lasted 14 min, thereafter all the participants simulated "all-out" rowing in either the 500 m or 2000 m distance with verbal encouragement to provide maximal effort. The readings of mean power and time of the distance were taken from the ergomete's registration system. Intra- and inter-coefficients of variation in 500 m trials did not exceed 5%.

Throughout the trials, the training loads expressed as hours of training were precisely registered by the coach and expressed as the percentage of total training volume in the respective years of training an athlete had.

The Shapiro-Wilk test was used for data distribution evaluation. The one-way ANOVA for repeated measures and the post-hoc Tukey test were used for data comparison. Correlations between the time performance for in the 500 m and 2000 m distances were calculated as according to Pearson. Data are presented as means and standard deviations, with the statistical significance set at $p < 0.05$. All calculations were performed using Statistica v. 7.1 software (StatSoft, USA).

Results

The training volume increased gradually in each year of training. In the second year of training total volume was greater by 7% vs. the first year (Tab. 1). In the third year of training the total volume was greater by 11.4% and 4.3% in comparison with the first and second year. The third year constituted the most of total training volume and training. In the first year, training was rather non-specific, consisting of gymnastics, running, games and swimming, however, in the subsequent years of training there was a gradual increase in rowing-specific training.

The subjects' anthropometric data are shown in Table 2. Their weight and height significantly increased in the successive years of training being greater in the second year vs. first ($p < 0.001$) and in the third vs. first ($p < 0.001$) and second ($p < 0.02$) year of training. Similarly,

Table 1. Total training volume and the contribution of different training modalities to overall training in schoolboy rowers

	I*	II*	III*
Total training volume (h)	454	485	506
Training modality		% ^	
On-water rowing	27	38	35
Ergometer rowing	4	14	17
Pool rowing	15	4	4
Strength training	11	17	18
Alternative training[a]	43	27	26

* denotes year of training; ^ percent of total volume in each year of training; [a] including games, gymnastics, running, and swimming

the subjects' BMI increased in the successive years of training. However, only minor changes in subjects' weight, height and BMI were noted in different training sessions during the same year of training.

Mean power output during the simulated 2000 m distance gradually increased in the second vs. first year of training and in the third vs. second year of training ($p < 0.001$) (Tab. 3). In consequence, the times markedly improved in each year of training ($p < 0.001$). Similarly, the mean power output and times during the simulated 500 m distance significantly improved in each year of training (Tab. 4).

In each training phase during the three years of training there were significant correlations between the times measured in the 500 m and 2000 m distances, and correlation coefficients did not significantly differ with respect to the training phase. (Tab. 5). However, coefficients of determination ($r^2 \times 100$) in the first year of training varied from 66.9 to 85.6 %, in the second year – from 62.0% to 92.3%, and in the third year – from 76.4 to 89.5%.

Discussion

The physical characteristics of our subjects at the beginning of the study were similar to those reported by Huang et al. [22] in club rowers with the mean age of 17.4 years. At the beginning of the study the mean power output during the 2000 m ergometer rowing in our subjects was lower, but in the third year of training it was higher, than in experienced rowers aged 18.1 years [23]. The time of the 2000 m distance in the first year of training was longer, that in schoolboy rowers aged 16.9 years [24], but in the competitive phase of the second year of training it was shorter.

Table 2. Anthropometric characteristics of the subjects (means ± SD)

	November	January	March	June
I*				
Age (years)	15.4 ± 0.3	15.6 ± 0.3	15.8 ± 0.3	15.9 ± 0.3
Weight (kg)	67.2 ± 9.6	72.0 ± 7.6[a]	70.4 ± 8.3	71.0 ± 6.5
Height (cm)	181.9 ± 0.5	181.9 ± 0.5	182.6 ± 0.4[b]	182.6 ± 0.4[b]
BMI	20.3 ± 2.3	21.8 ± 1.8[c]	21.1 ± 2.0	21.3 ± 1.5
II*				
Age (years)	16.4 ± 0.3	16.5 ± 0.3	16.7 ± 0.3	16.9 ± 0.3
Weight (kg)	72.6 ± 6.7[d]	74.0 ± 6.9[e]	74.6 ± 6.5	74 0 ± 6.5
Height (cm)	186.7 ± 0.5[k]	186.7 ± 0.5[k]	187.3 ± 0.5[k]	187.3 ± 0.5[k]
BMI	20.8 ± 1.2	21.2 ± 1.4[h]	21.3 ± 1.5	21.0 ± 1.1
III*				
Age (years)	17.4 ± 0.3	17.5 ± 0.3	17.7 ± 0.3	17.9 ± 0.3
Weight (kg)	75.6 ± 6.6	76.6 ± 7.8[f]	76.8 ± 8.2[g]	76.8 ± 8.1[i, j]
Height (cm)	187.6 ± 0.5[k]	187.6 ± 0.5[k]	187.6 ± 0.5[k]	187.6 ± 0.5[k]
BMI	21.4 ± 1.1[l]	21.8 ± 1.4	21.8 ± 1.5	21.8 ± 1.5

* denotes year of training

[a] $p < 0.007$ – significantly higher vs. November of the same year; [b] $p < 0.05$ – significantly higher vs. January of the same year; [c] $p < 0.007$ – significantly higher vs. November of the same year; [d] $p < 0.03$ – significantly higher vs. November of the first year of training; [e] $p < 0.007$ – significantly higher vs. November of the first and second year of training; [e] $p < 0.05$ – significantly higher vs. January of the first year of training; [f] $p < 0.006$ – significantly different vs. January of the first and second year of training; [g] $p < 0.006$ – significantly different vs. March of the first year of training; [h] $p < 0.007$ – significantly different vs. June of the first year of training; [i] $p < 0.02$ – significantly higher vs. June of the second year of training; [j] $p < 0.007$ – significantly higher vs. June of the first year of training; [k] $p < 0.006$ – significantly higher vs. respective months of the first year of training; [l] $p < 0.005$ – significantly higher vs. November of the second year of training

Table 3. Mean power output and 2000 m times of distance in schoolboy rowers during a laboratory Concept II trial, performed during different periods over three years of training (means ± SD)

	November	January	March	June
		I*		
Mean power (W)	288.9 ± 24.4	299.6 ± 29.9[a]	306.3 ± 21.7[a]	311.7 ± 22.6[a]
Time (s)	429.9 ± 11.9	422.1 ± 14.5	418.8 ± 10.1[e]	416.2 ± 10.3[e]
		II*		
Mean power (W)	329.1 ± 21.7[d]	327.5 ± 22.7[d]	328.3 ± 25.1[d]	337.8 ± 27.9[b, d]
Time (s)	412.49 ± 9.6[g]	409.4 ± 9.7[g]	409.2 ± 10.2[g]	405.0 ± 9.7[f, g]
		III*		
Mean power (W)	343.2 ± 24.9[d]	337.6 ± 24.3[d]	352.7 ± 32.0[d]	360.1 ± 26.7[c, d]
Time (s)	403.1 ± 9.9[g, h]	405.1 ± 9.7[g]	399.1 ± 12.3[g, h]	396.9 ± 9.8[g, h]

* denotes year of training

[a] $p < 0.001$ – significantly higher vs. November of the same year of training; [b] $p < 0.04$ – significantly higher vs. November of the second year of training; [c] $p < 0.004$ – significantly higher vs. March of the same year of training; [d] $p < 0.001$ – significantly higher vs. respective month of the previous year of training; [e] $p < 0.03$ – significantly different vs. November and January of the same year of training; [f] $p < 0.02$ – significantly different vs. November of the same year; first year of training; [g] $p < 0.001$ – significantly different vs. respective months of the first year of training; [h] $p < 0.04$ – significantly different vs. respective months of the second year of training

Table 4. Mean power output and 500 m times of schoolboy rowers during a laboratory Concept II trial, performed during different periods over three years of training (means ± SD)

	November	January	March	June
		I*		
Mean power (W)	405.2 ± 41.5	425.6 ± 43.6	432.9 ± 34.7	447.7 ± 46.3[a]
Time (s)	95.4 ± 3.2	93.9 ± 3.3	93.3 ± 2.5[d]	92.3 ± 3.2[d]
		II*		
Mean power (W)	463.7 ± 42.9[c]	479.5 ± 41.0[c]	494.6 ± 52.7[c]	495.9 ± 53.0[c]
Time (s)	91.4 ± 2.9[f]	90.2 ± 2.7[f]	89.3 ± 3.2[e, f]	89.3 ± 3.[e,f]
		III*		
Mean power (W)	506.9 ± 44.7[c]	520.9 ± 53.4[c]	536..5 ± 51.3[c]	559.0 ± 54.2[b, c]
Time (s)	88.5 ± 2.8[f, g]	87.9 ± 3.2[f, g]	86.9 ± 2.8[f, g]	85.6 ± 2.9[f, g]

* denotes year of training

[a] $p < 0.003$ – significantly higher vs. November of the same year of training; [b] $p < 0.001$ – significantly higher vs. November and January of the same year of training; [c] $p < 0.004$ – significantly higher vs. respective months of the previous year of training; [d] $p < 0.001$ – significantly different vs. November and January of the same year of training; [e] $p < 0.05$ – significantly different vs. November of the same year of training; [f] $p < 0.001$ – significantly different vs. respective months of the first year of training; [g] $p < 0.02$ – significantly different vs. respective months

Table 5. Pearson correlation coefficients between 500 m and 2000 m laboratory times of schoolboy rowers

	November	January	March	June
		I*		
r	0.899[a]	0.879[a]	0.818[b]	0.925[a]
$r^2 \times 100$	80.8	77.3	66.9	85.6
		II*		
r	0.868[c]	0.961[a]	0.788[d]	0.883[a]
$r^2 \times 100$	75.3	92.3	62.0	77.9
		III*		
r	0.874[a]	0.901[a]	0.946[a]	0.886[a]
$r^2 \times 100$	76.4	81.1	89.5	78.5

* denotes year of training
[a] $p < 0.001$; [b] $p < 0.004$
[c] $p < 0.002$; [d] $p < 0.007$

The mean power output during the 500 m rowing distance throughout our study was markedly lower and the times significantly longer than in elite senior rowers aged about 24 years [25, 26]. These differences were due to the subjects' shorter training experience, but also to their markedly smaller body size (both in mass and height) of our participants vs. elite senior rowers. However, the 500 m time performance of our subjects was significantly better than those reported in untrained university students who participated in 500 m indoor rowing championships [27].

The significant relationships between the mean power and times for both the 500 m and 2000 m simulated rowing distances are in accordance with other studies. According to Smith [25], elite rowers' best times for the 500 m distance strongly correlated with their 2000 m test performance (r = 0.960). Thus, the study found the 500 m time performance could account for 92.2% of the time variable of the 2000 m distance.

Our study confirmed that significant correlations existed between the time performance in the 500 m and 2000 m distances in schoolboy rowers and this relationship was affected neither by their training period nor training experience. On the other hand, the coefficients of determination ($r^2 \times 100$) differ with respect to the annual training period and years of training. Thus, the 500 m rowing time may be useful in predicting the performance of adolescent rowers in the 2000 m distance, however, if any doubts exist on the effectiveness of any training, the 2000 m test has to be recommended. Additionally, it should be pointed out that the results of any laboratory rowing cannot predict the outcome in on-water competition [28, 29].

Conclusion

Our study revealed that the performance of schoolboy rowers in both the 500 m and 2000 m distances markedly improved throughout their three years of training. In addition, the times of both distances significantly correlated with each other, but the coefficients of determination differ in each annual training period and the year of training. Thus, the 500 m laboratory rowing test may be useful in a brief assessment of schoolboy rowers ability to perform the 2000 m distance, however, its results require careful interpretation.

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INVOLUTION OF SIMPLE AND COMPLEX REACTION TIMES AMONG PEOPLE AGED BETWEEN 21 AND 80 – THE RESULTS OF COMPUTER TESTS

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ABSTRACT
Purpose. The aim of this case study is to define the involution of simple and complex reaction times in groups of adult men and women. **Basic procedure.** The tests were carried out during the years 2007–2008 among 128 men and 136 women aged between 21 and 80. Those examined were divided into three groups according to their calendar age. In order to define the meaning of differences of the analyzed reaction time between the results of the three age groups, the analysis of variance (ANOVA) method for independent attempts was used. Additionally, normalized differences between the groups as well as indices of sexual dimorphism were defined. **Main findings.** Among both men and women, gradual deterioration of reaction time performance with age can be observed. The scale of normalized differences shows that the most distinct differences are noticed between the first and the third group. They amount up to 1.3 of the standard deviation in men and up to 1.7 in women. **Conclusions.** The results derived from the following study confirm a long period of relative stabilization for all simple and complex reaction times among both genders. Significant involution of reaction times can be observed for all analyzed features only after the age of 55. Indices of sexual dimorphism indicate that men gain better results in all age groups. Indices of sexual dimorphism diminish with age.

Key words: coordination motor abilities, reaction time, involution, sexual dimorphism

Introduction

Nowadays, there are over 650 million people at the age of 60 or older around the world. According to a demographic forecast made by WHO [1], this number will increase to about 1.2 billion in the year 2025 and about 2 billion in 2050. The forecast made by the Central Statistical Office also indicates that Polish society is ageing. It is estimated that in 2030–2035 every fourth Pole will be an old-age-pensioner. The extension of average life expectancy causes new challenges for social, health and preventive politics. It is necessary to emphasise that only systematic physical exercise will allow a person to be healthy, keep fit and enjoy oneself until the end of their life. Readers can make themselves acquainted with an extensive overview of literature on the influence and importance of physical exercise among elderly people in survey works by Osiński [2] and Drabik [3]. Many authors [4–8] stress that the ‘style of life’ in earlier periods of ontogenesis undoubtedly influences the level of motor abilities. It is vital to promote adequate programmes in order to raise the quality of one’s lifestyle [9, 10].

It appears from the overview of literature that there are a lot of studies on the course of progressive development. Issues related to physical as well as functional development seem to be discussed very deeply. However, there are decidedly fewer research papers on involuntary changes in mature years and in the period of ageing. Most research works on the subject are mainly concerned with changes of basic somatic parameters (height, body mass and its components). There are definitely considerably fewer reliable research works based on a vast number of people that evaluate changes comprehensively, both on the level of functional and somatic parameters [11–15].

Conditions of human existence in the contemporary world cause higher and higher requirements for a person. With the progress of civilization, preferences in motor abilities are changing. Nowadays, in times of common automation and computerization, most authors emphasize the importance and meaning of coordination motor abilities. The level of their development, involution with age, determinants, dimorphic diversity, as well as fitness training among elderly people are extensively described in a survey work by Lyakh [16]. This author intensively analyses about 100 titles from Polish and foreign literature on the subject of coordination among elderly people. Similar issues are also dis-

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cussed by Starosta in his work [17]. As far as elderly people and children are concerned, most studies on coordination abilities are connected with reaction times (overview of research papers [13, 18]). However, the analysis of literature shows that due to the specified period of research, equipment and the amount of material, the results were sometimes divergent. In this situation a new approach to the subject seems to be justified.

The aim of the following case study is to define the regress of simple and complex reaction times in a group of adult men and women aged between 21 and 80. The research and its results will provide answers to the following questions:

1. What are the size, range and direction of diversity among the examined factions determined on the basis of normalized differences between the groups?
2. Which abilities show the largest sexual diversity?
3. How do indices of sexual dimorphism shape the chosen calendar age groups?

Material and methods

The material of the case study comprises the results of simple and complex reaction times to visual and acoustic stimuli. The tests were carried out during the years 2007–2008 among 264 men and women aged between 21 and 80. The examined individuals people were divided into three groups according to their age (up to 35; between 36 and 55; and above the age of 56).

The number of characters in three separate age factions is presented in Table 1.

Table 1. Number of tested people in three calendar age group

Group	Male		Female	
	N	$\bar{x}$ age	N	$\bar{x}$ age
Group I (21–35 calendar age)	29	32.00	63	31.53
Group II (36–55 calendar age)	51	42.80	33	43.42
Group III (56–80 calendar age)	48	67.75	40	68.30
TOTAL	128		136	

Some selected types of reaction time were considered: reaction time to the visual stimulus (minimal, average, maximal), reaction time to the acoustic stimulus (minimal, average, maximal) and complex reaction time (minimal, average, maximal). The tests were positively verified as far as reliability and accuracy are concerned [19, 20]. The precise description of each test together with the measurement units is included in the aforementioned work. The tests (performed in a quiet and calm room) were made with the use of a mobile computer "tablet" with touch screen (Toshiba Satellite R15).

Statistical methods for handling the material:

1. Basic statistical characteristics of the examined coordination motor abilities were calculated in three factions divided according to age and gender. Normality of arrangements was verified by means of the Shapiro-Wilk W test. Homogeneity of variance was evaluated by means of the Levene's test [21].
2. In order to define the meaning of differences of the analyzed reaction time between the results of the 3 age groups, the analysis of variance (ANOVA) method for independent attempts was used. The Tukey's Post Hoc Test for various N was used.
3. The size, range and direction of diversity of tested reaction times between the 3 age groups were determined on the basis of normalized intergroup differences. The normalization was used for the oldest group mean and standard deviation.
4. In order to examine the range of diversification between male and female subjects, standardized indices of sexual dimorphism were calculated (ISD), according to the equation developed by Szopa et al. [22]:

$$ISD = \frac{2(\bar{x}_m - \bar{x}_w)}{SD_m + SD_w},$$

where:

$\bar{x}_m$ – arithmetic mean of the men in their calendar age group

$\bar{x}_w$ – arithmetic mean of the women in their calendar age group

SD_m – standard deviation of the men in their calendar age group

SD_w – standard deviation of the women in their calendar age group.

The research results were analyzed with the use of STATISTICA PL v. 6.0 software.

Results

Basic statistical characteristics of the analyzed reaction times among men in the three chosen calendar age groups are presented in Table 2. The analysis of arithmetic averages shows gradual deterioration of performance with age. This regularity concerns all analyzed features. Table 2 also includes the evaluation of statistical significance of arithmetic average differences concerning the examined reaction times between the per-

Table 2. Basic statistical parameters of the analysed men's features in calendar age classes as well as statistical significance of differences between groups (in milliseconds)

Variable	Group I 21–35 calendar age		Group II 36–55 calendar age		Group III 56–80 calendar age	
	$\bar{x}$ ± SD	p I–II	$\bar{x}$ ± SD	p II–III	$\bar{x}$ ± SD	p I–III
Reaction time to the visual stimulus – minimal	235.51 ± 19.00	0.836	249.80 ± 34.78	**0.000**	396.72 ± 150.82	**0.000**
Reaction time to the visual stimulus – average	259.62 ± 27.87	0.693	283.80 ± 46.00	**0.000**	477.06 ± 177.76	**0.000**
Reaction time to the visual stimulus – maximal	298.27 ± 54.12	0.543	339.21 ± 82.17	**0.000**	583.12 ± 220.07	**0.000**
Reaction time to the acoustic stimulus – minimal	197.93 ± 22.57	0.568	230.98 ± 74.41	**0.000**	408.12 ± 186.54	**0.000**
Reaction time to the acoustic stimulus – average	216.13 ± 22.15	0.433	262.02 ± 87.99	**0.000**	485.75 ± 211.46	**0.000**
Reaction time to the acoustic stimulus – maximal	244.82 ± 27.85	0.328	310.58 ± 131.58	**0.000**	581.62 ± 251.68	**0.000**
Complex reaction time – minimal	283.44 ± 43.93	0.644	312.74 ± 79.22	**0.000**	509.85 ± 183.51	**0.000**
Complex reaction time – average	420.00 ± 69.07	0.497	466.84 ± 100.56	**0.000**	732.83 ± 230.18	**0.000**
Complex reaction time – maximal	612.07 ± 142.18	0.630	668.43 ± 142.56	**0.000**	1045.31 ± 339.30	**0.000**

Quantities in bold mean significant differences between averages at least on the level of $p \leq 0.05$

Table 3. Basic statistical parameters of the analysed women's features in calendar age classes as well as statistical significance of differences between groups (in milliseconds)

Variable	Group I 21–35 calendar age		Group II 36–55 calendar age		Group III 56–80 calendar age	
	$\bar{x}$ ± SD	p I–II	$\bar{x}$ ± SD	p II–III	$\bar{x}$ ± SD	p I–III
Reaction time to the visual stimulus – minimal	255.35 ± 34.05	0.321	281.00 ± 68.64	**0.000**	431.36 ± 122.83	**0.000**
Reaction time to the visual stimulus – average	282.17 ± 40.44	0.113	322.50 ± 80.18	**0.000**	520.75 ± 136.64	**0.000**
Reaction time to the visual stimulus – maximal	317.14 ± 53.28	0.161	365.37 ± 101.48	**0.000**	605.48 ± 189.74	**0.000**
Reaction time to the acoustic stimulus – minimal	210.35 ± 27.56	0.388	235.15 ± 46.17	**0.000**	409.51 ± 145.10	**0.000**
Reaction time to the acoustic stimulus – average	231.60 ± 30.05	0.231	270.62 ± 60.47	**0.000**	515.51 ± 183.29	**0.000**
Reaction time to the acoustic stimulus – maximal	260.35 ± 43.77	0.075	376.25 ± 97.52	**0.000**	689.12 ± 245.30	**0.000**
Complex reaction time – minimal	300.17 ± 60.88	0.228	337.12 ± 81.01	**0.000**	486.58 ± 149.24	**0.000**
Complex reaction time – average	451.91 ± 77.28	0.345	481.32 ± 78.98	**0.000**	723.07 ± 166.11	**0.000**
Complex reaction time – maximal	662.68 ± 184.92	0.155	743.25 ± 177.60	**0.000**	1046.60 ± 274.44	**0.000**

Quantities in bold mean significant differences between averages at least on the level of $p \leq 0.05$

Table 4. The sizes of normalized intergroup differences of the tested reaction times between chosen calendar age groups

Variable	Male				Female			
	d_1	z_1	d_2	z_2	d_1	z_1	d_2	z_2
Reaction time to the visual stimulus – minimal	–161.21	–1.07	–146.92	–0.97	–176.01	–1.43	–150.36	–1,22
Reaction time to the visual stimulus – average	–217.44	–1.22	–196.26	–1.08	–238.58	–1.75	–198.25	–1.45
Reaction time to the visual stimulus – maximal	–284.85	–1.29	–243.91	–1.10	–288.34	–1.52	–240.11	–1.26
Reaction time to the acoustic stimulus – minimal	–210.19	–1.13	–177.14	–0.95	–199.16	–1.37	–174.36	–1.20
Reaction time to the acoustic stimulus – average	–269.62	–1.27	–223.73	–1.06	–283.91	–1.55	–244.89	–1.34
Reaction time to the acoustic stimulus – maximal	–336.80	–1.33	–271.04	–1.07	–428.77	–1.75	–312.87	–1.27
Complex reaction time – minimal	–226.41	–1.23	–197.11	–1.07	–186.41	–1.25	–149.46	–1.00
Complex reaction time – average	–303.83	–1.32	–265.99	–1.15	–271.16	–1.63	–241.75	–1.45
Complex reaction time – maximal	–433.24	–1.27	–376.88	–1.11	–383.92	–1.40	–303.35	–1.11

$d_1 = \bar{x}_{GrI} - \bar{x}_{GRIII}$; $z_1 = d_1/SD_{GRIII}$; $d_2 = \bar{x}_{GRII} - \bar{x}_{GRIII}$; $z_2 = d_2/SD_{GRIII}$

Table 5. Variation with age indices of sexual dimorphism (ISD) of individual reaction times in chosen age groups

Variable	ISD values		
	Group I 21–35 calendar age	Group II 36–55 calendar age	Group III 56–80 calendar age
Reaction time to the visual stimulus – minimal	–0.75	–0.60	–0.25
Reaction time to the visual stimulus – average	–0.66	–0.61	–0.27
Reaction time to the visual stimulus – maximal	–0.35	–0.28	–0.11
Reaction time to the acoustic stimulus – minimal	–0.49	–0.07	–0.01
Reaction time to the acoustic stimulus – average	–0.59	–0.12	–0.14
Reaction time to the acoustic stimulus – maximal	–0.41	–0.57	–0.43
Complex reaction time – minimal	–0.32	–0.30	–0.14
Complex reaction time – average	–0.44	–0.16	0.05
Complex reaction time – maximal	–0.50	–0.46	–0.01

formances of men from three calendar age groups. The conducted analysis presents unequivocally that no significant deterioration of the results concerning all features between groups I and II can be noticed. By contrast, in all cases the results of variance analysis show significant statistical differences in average reaction times among groups II and III as well as between the outermost groups.

In turn, Table 3 presents basic statistical characteristics as well as the results of variance analysis ANOVA for the analyzed features among women. The obtained results reveal similar regularities to those obtained by men. Again gradual deterioration of arithmetic averages with age as well as statistically significant differences between groups II and III, and between groups I and III (in all cases), are observed.

Regardless of the significance of differences evaluation, it is worth observing how their direction and size shape. To do that the results of all analyzed features were normalized in order to obtain the average as well as the standard deviation for the oldest group. The results for men are presented in Table 4. Our analysis will start with the size of normalized differences between the outermost groups (z_1). On the whole, it can be stated that the direction of diversity for all features is in accordance with the assumed age gradient ('minus' illustrates worse results in the older group). The scale of diversity is quite significant because it amounts to about 1.3 of standard deviation for almost all features. Then, analysing normalized differences of the results between groups II and III again, better results are noticed among men from the younger group. However, the scale of diversity is slightly smaller and it fluctuates within 1 of standard deviation.

Normalized differences obtained by women are also presented in Table 4. Similarly to men, the most significant normalized differences are observed between the outermost groups (I–III). The sizes of z_1 show definitely better results for all examined features among the youngest women. The scale of diversity is slightly bigger than the one observed among men. The sizes of z_1 are contained within –1.25 to –1.75 of standard deviation. In turn, normalized differences z_2 are slightly smaller but still show definitely better reaction times in the group of younger women. The sizes of z_2 fluctuate within 1.3 of standard deviation.

Additionally, the subject of the analysis was variability with age of normalized indices of sexual dimorphism (ISD) of the examined reaction times. The results presented in Table 5 indicate unequivocally that in the discussed period and for all the test differences between genders shape in favour of men. Among all analyzed features, the highest indices of sexual dimorphism were observed for velocity of reaction to visual stimulus – minimal (I group, ISD = –0.75). However, analysing variability ISD values in age groups, it can be stated that the scale of differences between genders diminishes with age of the individuals examined. Thus, indices of ISD in the first age group are comprised within –0.75 and –0.32, in the second group within –0.61 and –0.12, and in the third group within 0.43 and 0.05.

Discussion

It has already been mentioned in the introduction that comparing the obtained results with the data included in literature is considerably limited. Different types of test equipment with various strength of stimuli emission (usually not given), computer tests (computers with different parameters and programs) as well as population tests ('grab at Ditrich stick', stopping a falling target, etc.) have been applied while examining reaction times. These limits lead to various research results, which can therefore be treated only approximately.

It can be stated from the overview of literature [13, 18, 23–25] that the progressive period of developing velocity of reaction lasts up to the age of 16–17 among women and up to the age of 19 among men. By contrast, Mleczko [26, 27] as well as Raczek and Mynarski [28] found that this period ends at about the age of 11–13 among girls and about 13–14 among boys. However, the velocity of complex reaction times reaches its highest level much later that is at about the age of 17–20. After the period of developing, long stabilization starts that is relatively moderate involution. On the basis of Szopa's research [13], it can be deduced that among men between the age of 17–19 and 55 reaction time to visual stimulus deteriorates only by 8.3% while among women by 18.9%. Reaction time to acoustic stimulus seems to have bigger dynamics of involution (11.3% among men, 24.5% among women). Moreover, a very long period of stabilization for reaction times to visual stimulus was obtained among a rural population settled around Żywiec [29]. German research findings show slow involution of most coordination abilities from the age of 30–35 to the age of 45–50 [30, 31]. Only after the age of 65 was a significant tendency of reduction in the level of coordination abilities observed in these studies. Slightly different results in a group aged 7 to 70 were obtained by Hirtz [32]. The level of compound reaction time among participants aged 55 was slightly higher than in the group of participants aged 20. However, such findings are very rare.

By contrast, the analysis of arithmetic averages of reaction times in the whole period of ontogenesis shows definitely better results (among both sexes) in the velocity of visual rather than acoustic reaction. The only exception is the data obtained by Mleczko [18] and Szopa [13]. The authors explain such an arrangement of arithmetic averages as a result of applying relatively weak stimulus in measuring the velocity of acoustic reaction.

The results derived from this study confirm a long period of relative stabilization for all compound and complex reaction times among both sexes. By the age of about 55, the results of variance analysis show that differences of arithmetic averages (between Groups I and II) are statistically insignificant. Involution that can be observed becomes more intensive only after the age of 56–65, which is proved by data concerning normalized results between outermost calendar age groups. All studies quoted above were only connected with average reaction times, as there are no findings on the subject of involution of maximum and minimal times in literature. The results of the present research confirm regularities observed for average reaction times. In this research, a higher level of arithmetic averages of acoustic rather than visual reaction is recognised in all age groups and among both sexes. It is in accordance with the data found in almost every comparative material.

Additionally, the objective of the study was to evaluate dimorphic differentiation of analyzed features in chosen calendar age groups. From the overview of literature quoted above, it was determined that men achieve better results than women during nearly the entire whole period of ontogenesis. The analysis of the obtained results makes it possible to formulate similar conclusions. Moreover, the regularity observed in studies by Szopa et al. [22] concerning a smaller scale of dimorphic diversity of acoustic rather than visual reaction times was confirmed as well. However, the results of the study show unambiguously that indices of sexual dimorphism diminish with the age of the participants. These results cannot be proved by the data on Cracow's population [13]. However, they are in accordance with common observations concerning ontogenesis variability of coordination abilities [33].

On the whole, it can be stated that in most cases boys and men get better results as far as psychomotor abilities are concerned with an occasional advantage in favour of pubescent age women [11]. Such an effect is likely generated by characteristics of male and female nervous systems, strength of genetic and environmental conditions of functional features, as well as the psychoneurological sphere.

Conclusions

As far as the examined population is concerned, influence of calendar age on the reaction times among both sexes is noticed. It means a gradual deterioration of performances with the age of the examined individuals. This phenomenon is especially distinct after the age of about 55.

Sexual dimorphism indices prove that men present a higher level of the analyzed reaction times. Among all analyzed features the highest sexual dimorphism indices were observed for visual minimal reaction time.

Sexual dimorphism indices diminish with the age of those examined.

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A CONFIRMATORY FACTOR ANALYSIS OF THE OTTAWA MENTAL SKILL ASSESSMENT TOOL (OMSAT-3*) – ROMANIAN VERSION[1]

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ABSTRACT
Purpose. The goal of this study was to assess the factorial validity of the Romanian version of the Ottawa Mental Skills Assessment Tool – 3* – OMSAT-3*. **Basic procedures.** Cross-sectional with self-reported questionnaire. The sample included 212 athletes (98 women, 114 men; age = 24.3) competing at international and national levels in different sports. **Main findings.** Confirmatory factor analysis of the Romanian version of the OMSAT-3* replicated the factor structure of the original instrument displaying an adequate level of goodness-of-fit. **Conclusions.** This study provided support for the factor structure of the Romanian version of the OMSAT-3*. This version expands the possibility of assessing the psychological resources of athletes in order to increase their performance and awareness of towards mental skills.

Key words: confirmatory factor analysis, mental skills, goodness-of-fit indices, factorial validity, performance

Introduction

The high level of modern sport performance increasingly takes on a psychological dimension. Often athletes attributed their failures or their successes to various psychological aspects of performance. Applied sport psychology consultants are interested in developing the psychological resources of athletes via mental skills training interventions. Educational interventions via psychological skills training (PST) are offered more and more often in modern sport preparation. These PST programs are generally aimed at helping athletes acquire and strengthen their psychological skills in order to improve their sport performance and generate a positive approach to competition [1]. Numerous studies have reported favorable effects of mental training programs on competitive performance and for specific psychological/mental skills, such as states of somatic and cognitive anxiety, self-confidence, imagery ability or team cohesion.

Many inventories have been developed to evaluate a single psychological skill, for example, attention, imagery and leadership. In terms of attention, the Test of Attentional and Interpersonal Style – TAIS [2] is the most utilized and cited in literature. For the evaluation of imagery, there is The Imagery Use Questionnaire [3], while leadership could be assessed with the Leadership Scale for Sport [4].

To monitor the effects of educational intervention, experience gained from psychological skill development has created a need for broad-based tools that measure a range of mental skills and to conduct research on athletes and coaches. Usually, researchers utilized a couple of inventories that assess mental skills in sport. Two of these are: the Test of Performance Strategies – TOPS, [5] and Athletic Coping Skills Inventory – ACSI-28 presented by Smith et al. [6]. The Athletic Coping Skills Inventory (ACSI-28) was adapted to Romanian norms [7]. The authors of these instruments have stated that they have sound psychometric properties, but certain aspects remain questionable and unclear. Some items appear vague and there are conceptual problems with the whole inventories [8]. Researchers have also mentioned problems with reliability and, therefore, some aspects which require further discussion and refinement. The purpose of our study was to assess the factorial validity of the Romanian version of the Ottawa Mental Skills Assessment Tool – 3* – OMSAT-3* [9].

The OMSAT

In order to correct the lack of validity and reliability of the majority of multidimensional psychological tests, researchers have tried to create more advanced instruments. The first step was to determine which mental

[1] A confirmatory factor analysis of the Romanian version of OMSAT-3* was made in order to replicate the factor structure of the original instrument.
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skills were important to perform well in sport at a high level. For example, in comparison to athletes competing at a lower level, top competitors were more confident, better focused before and during competition, less anxious, they had better imagery abilities and were more committed to excel in sport [10]. The OMSAT was originally developed by Salmela [11] after an extensive literature review. Bota [12], after conducting analysis with the first and second versions of OMSAT suggested that the instrument must be revised and tested. The initial version of the OMSAT consisted of 14 mental scales and 114 items. The imperfections of this first attempt led Bota [12] to construct a new version of OMSAT (OMSAT-2) with 12 mental skill scales and 71 items. Durand-Bush et al. [9] developed a new inventory assessing a range of mental skills that are used in the sport realm. The Ottawa Mental Skills Assessment Tool (OMSAT-3*) measures three conceptual components; each encompassing several mental skills. The Romanian version was produced through a translation-retroversion methodology that led to sound exploratory analysis results [13].

Material and methods

Participants

The surveys were collected from 212 athletes (99 elite athletes competing in Division I of the Romanian championship and 113 athletes were juniors competing in youth Division) in different sports: soccer, judo, water polo, basketball, handball, rugby, volleyball, track and fields. The majority of participants were selected from the Cluj sport club "Universitatea". The first author of this paper is a sport psychology consultant at this sport club. To be considered elite athletes, participants must compete for at least three years in international or national championships. The elite group included 99 athletes, 45 women and 54 men, aged between 20 and 37 years, with a mean age of 24.6 years. The junior group included 113 athletes, aged between 14 and 19 years (50 women and 63 men), with a mean age of 16.8 years.

Measures

The present version of the inventory – *the Ottawa Mental Skills Assessment Tool -3* (*OMSAT-3**) – includes 48 items and 12 mental skills groups (4 items per group), under three main conceptual components. The authors obtained permission to adapt this inventory from the Mindeval company who hold the rights for this instrument. Foundation skills represent an athlete's fundamental mental skills. These skills are fundamental and essential for consistent high levels of performance in sport and they are the building blocks for other mental skills [14]. Goal Setting is the process of establishing objectives or goals which provide a sense of direction and motivation. A sample item for goal setting is: "I set daily goals." Self-Confidence is the feeling or belief in one's abilities and goals. An example: "I act confidently even in difficult sport situations. I believe." Commitment displays an individual's intensity and dedication to goals. An example item for commitment is: "I am determined to never give up in my sport." Psychosomatic skills involve mental skills that include control of variations in physiological arousal. Stress reactions are bodily responses to the demands that are placed upon it. A sample item for stress reactions is: "My body tightens unnecessarily in competition." Fear control is the individual's capacity to cope with situations that induce fear or apprehension. An example item for fear control is: "There are a number of things in my sport that are potentially dangerous and make me afraid." Activation is the process where physiological and mental states are increased in situations that require heightened senses. A sample item for activation is: "I can increase my energy level when I am tired in training." Relaxation is the process where physiological arousal, muscle tension, heart rate, and anxiety are decreased, helping to control attention. A sample item for relaxation is: "I can relax effectively during critical moments in a competition." Cognitive skills are dependent on cognitive processes and activities. Imagery is the process where images and sensations are used to experience different situations. An example item of imagery is: "I have clear mental images." Mental practice is a process where physical skills, plays, or parts of a performance are mentally rehearsed without physical movement. A sample item of mental practice is: "I mentally practice my sport on a daily basis." Focusing is the ability of an individual to direct and maintain attention on certain cues. A sample item of focusing is: "I lose my focus during important competitions." Refocusing is the ability to recover concentration on task when distractions suddenly appear. An example of refocusing is: "Mistakes often lead to other mistakes when I compete." Competition planning is the reflection and development of plans that will guide thoughts, emotions, and actions before, during, and after competition. A sample item of competition planning is: "I plan a regular set of things to do before a competition."

A 7-point Likert scale is used, where options range from *strongly agree* to *strongly disagree* with an available neutral choice.

Procedures

Athletes were recruited by coaches and through other informal contacts from several sport clubs from the city of Cluj-Napoca. The participants were informed of their participant rights during the study and explained that all answers and information were anonymous. The modified OMSAT-3* was administered in a classroom type environment. Researchers gained approval of the study from their club managers.

Results

Confirmatory Factor Analyses of Scales

Confirmatory factor analysis (CFA) of the proposed 12 dimensional factor structure of the original scale was conducted using the Robust Maximum Likelihood method. The software used was the LISREL 8.8. All goodness-of-fit indices reached acceptable values (see Tab. 1). Due to the controversy regarding the evaluation of model fit, we decided to report multiple indices. Data on criteria to determine the adequacy of model fit are shown in Table 1.

Table 1. Confirmatory factor analysis (CFA) of the OMSAT-3* Romanian Version

Fit index	First order CFA	Second order CFA	Criterion for good fit
χ^2	1823,45	1856,23	
df	1046	1042	
CFI (The Comparative Fit Index; [15])	.94	.96	Above .90
TLI (The Tucker-Lewis Index; [16])	.87	.88	Above .90
GFI (The Goodness of Fit Index; [17])	.81	.82	Above .90
PCFI (The Parsimony Comparative Fit Index)	.78	.76	Above .50
RMSEA (the Root Mean Square Error of Approximation; [18])	.05	.05	Below .05

All χ^2 values are significant at $p < .01$.

The factorial structure of the Romanian version of OMSAT-3* is satisfactory. From these fit index, only the Tucker-Lewis Index (TLI) is below the conventional .90 criterion. This attenuation of model fit results from the significant multivariate kurtosis generated when we have a large number of items. All parameters were statistically significant and within an acceptable range.

Standardized factor loadings and error variances for OMSAT-3* scores supported for the notion that items load onto their hypothesized subscale (Fig. 1). The strength of an item is indicated by high factor loadings and low standard errors. Comrey and Lee [19] suggested that factor loadings higher than .71 (50% overlapping variance) are excellent, .63 (40% overlapping variance) very good, .55 (30% overlapping variance) good and .45 (20% overlapping variance) fair. In the present analysis, 16 of the 48 items could be considered excellent, and 14 could be considered very good.

As psychometric data have a tendency to not be normally distributed, attention was given to the Mardia coefficient. In the current study, Mardia values showed significant deviation from normality in both samples, which suggests that the data were not multivariate normal (multivariate kurtosis = 612.21; $Z = 21.65$, $p < .001$).

In Figure 1 we have factor loadings and error uniqueness and the correlations between the latent factors are shown in Table 2. The magnitude of these correlations was small.

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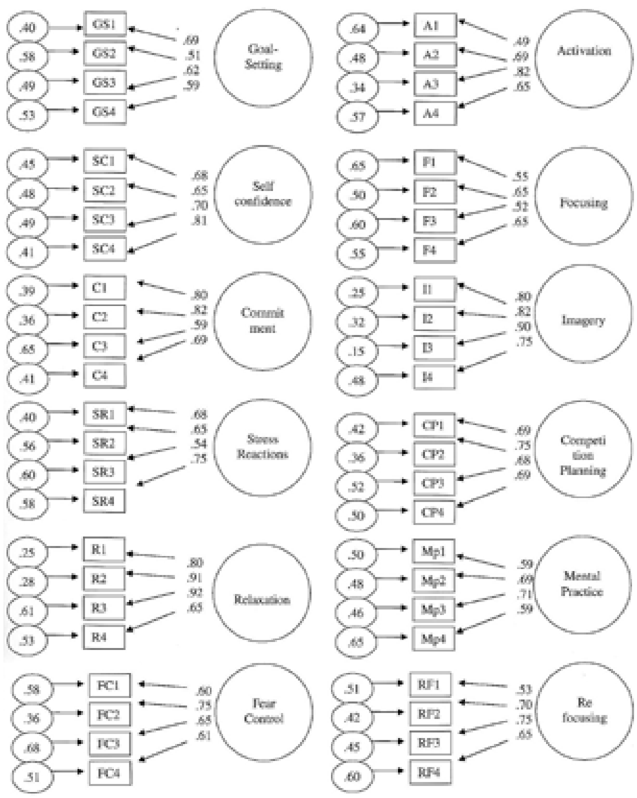

Figure 1. Confirmatory factor analysis of the OMSAT-3 Romanian Version. All parameters are standarized and significant at the .01 level

Table 2. Correlation coefficients between OMSAT-3 subscales

	GS	SC	CO	SR	RX	FC	AV	FO	IM	CP	MP	RF
GS	1.0	.49*	.52*	.10	.20*	.07	.40*	.28*	.25*	.45*	.47*	.09
SC	.40*	1.0	.39*	.30*	.35*	.38*	.13	.40*	.45*	.20*	.40*	.30*
CO	.42*	.39*	1.0	.05	.25*	–.20	.23*	.19*	.13	.21*	.35*	.10
SR	.09	.27*	.09	1.0	.39*	.50*	.23*	.52*	.20*	.11	.12	.50*
RX	.21*	.34*	.30*	.25*	1.0	.14	.32*	.24*	.40*	.19	.30	.32
FC	.02	.04	–.10	.30	.10	1.0	.12	.41	.15	.03	.05	.37
AV	.32*	.39*	.20*	.20*	.34*	.10	1.0	.39*	.29*	.37*	.29*	.13
FO	.23*	.38*	.19*	.39*	.25*	.31*	.27*	1.0	.39*	.09	.35*	.47*
IM	.24*	.19*	.18*	.21*	.47*	.10	.29*	.25*	1.0	.24*	.51*	.23*
CP	.28*	.23*	.20*	.12	.19*	.04	.31*	.05	.20*	1.0	.38*	.02
MP	.30*	.29*	.33*	.10	.25*	.03	.30*	.21*	.34*	.10	1.0	.12
RF	.08	.20*	.09	.38*	.29*	.39*	.10	.29*	.21*	.02	.10	1.0

GS – Goal-setting, SC – Self-confidence, CO – Commitment, SR – Stress reactions, RX – Relaxation, FC – Fear Control, AV – Activation, FO – Focusing, IM – Imagery, CP – Competition Planning, MP – Mental Practice, RF – Refocusing. * $p < .01$

Second-order CFA for Broader Conceptual Components

As we see in Table 1, the low value of TLI represents an underestimation of model fit because of the presence of significant multivariate kurtosis. All hypothesized relationships were significant with acceptable magnitude, except from the path between the cognitive skills factor, the Imagery subscale and Competition planning, and the path between the psychosomatic skills factor and the fear control subscale (Fig. 2).

Inter-correlations between OMSAT subscales were examined to ascertain if excessive multicollinearity ($r > .80$) existed between subscales (Tab. 2). All correlations were below .80 and were in the predicted conceptual direction.

Multivariate analysis of variance

We conducted MANOVA to establish if OMSAT-3* could differentiate between the scores of elite and junior athletes. Descriptive statistics are presented in Table 3. There is a significant difference between the elite and junior groups regarding dependent variables – F (12,211) = 4.43. $p < .001$. Univariate F – tests revealed that 7 from 12 scales significantly discriminated between the two groups of athletes (commitment, focusing, refocusing, self – confidence, stress reactions, goal – setting, activation have p values below .01).

Reliability

Means, standard deviations, and alpha reliability coefficients for all variables in the study are presented in Table 3. For the OMSAT-3 subscales, all subscales met the .70 criterion advocated by Nunnally [20], so we have no lack of reliability.

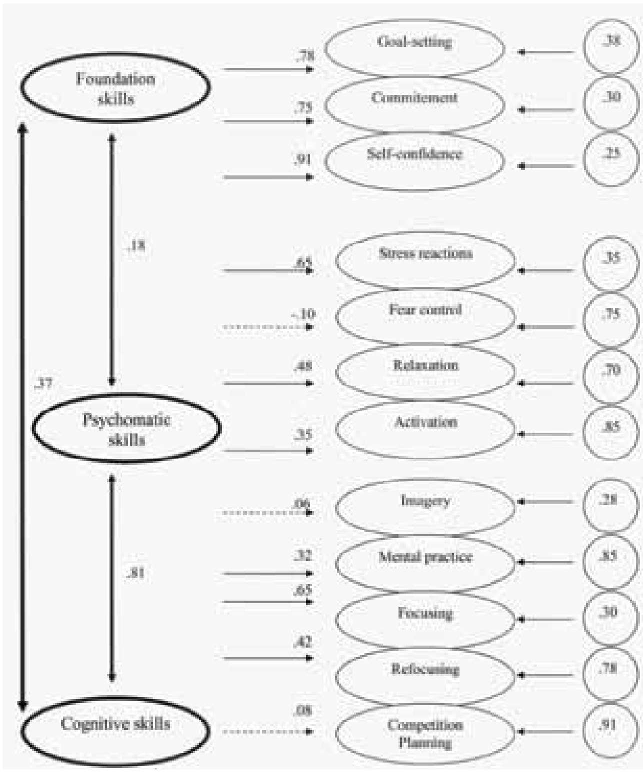

Figure 2. Second-order confirmatory analysis OMSAT-3. With exception of three paths represented by a dashed arrow, all parameters are standarized and significant

In Table 3, we have summarized the estimated values of internal consistency and interclass reliability of the OMSAT-3*. Internal consistency estimates varied from .71 to .83, with a mean value of .78. Interclass reliability scores ranged from .78 to .93 and yielded a mean temporal stability score of .82.

Table 3. Descriptive statistics of the OMSAT-3* scales for two groups (elite and junior)

Scale	Elite M (SD)	Junior M (SD)	Internal con-sistency	Inter-class reliability
Goal setting	5.28 (.67)	5.07 (.89)	.81	.86
Self-confidence	5.21 (.79)	4.88 (.91)	.80	.82
Commitment	5.71 (.80)	5.09 (.81)	.81	.90
Stress reactions	4.89 (1.45)	4,22 (1.21)	.78	.82
Relaxation	4.26 (1.31)	3.67 (1.32)	.83	.85
Fear control	5.12 (1.04)	4.98 (1.11)	.72	.80
Activation	5.20 (1.21)	4.75 (1.03)	.78	.82
Focusing	5.02 (1.11)	4.67 (1.20)	.73	.80
Imagery	5.12 (1.42)	4.83 (1.32)	.78	.89
Competition planning	5.03 (1.23)	4.67 (1.31)	.83	.78
Mental practice	4.02 (1.03)	3.96 (1.23)	.71	.78
Refocusing	4.78 (1.12)	4.24 (1.31)	.80	.82

Discussion

The results indicate that the factorial validity and reliability of the Romanian version of the OMSAT-3* are acceptable. This version extends the possibility to assess psychological resources of elite athletes in order to increase their performance. OMSAT is a valid inventory intended to evaluate mental resources after mental skills training interventions.

The results of the first-order CFA revealed that OMSAT-3* scales had a sound factorial structure. The model, composed of 12 mental skill scales, adequately represented the covariance within the study sample. The results of the second-order CFA revealed that the proposed higher-order factors displayed a sound structure, the magnitude of the second order factor loadings was quite similar. There are non-significant loadings between the cognitive skills component and the mental practice scale and between the psychosomatic skills component and the activation scale. All other relationships between first-order factors and second-order ones supported our hypotheses. The second-order model represented the covariance within the sample in a satisfactory manner.

In terms of the known group analysis, the OMSAT-3* significantly differentiated between elite and junior athletes. This fact suggests that athletes competing at a high level possess more refined mental skills than less skilled athletes do. The studies carried out by Orlick and Partington [8] and Gould et al. [21] showed that the best athletes have better mental abilities than less skilled athletes do.

The commitment scale showed a significant difference. Indeed, elite athletes are extremely dedicated individuals who will do anything to become the best, even sacrifice other important activities. The self-confidence scale also significantly differentiated between the two groups of athletes, suggesting that elite athletes believe more in themselves and their abilities to achieve their goals than their less skilled colleagues do.

Negative reactions to stress can be detrimental to performance, while positive reactions can lead to enhanced performance [22]. In this view, the significant difference between the elite and junior athletes on stress reaction scale suggests that experienced athletes most likely react to stress in more positive ways.

Another significant difference between the two groups regards their focusing and refocusing scales, indicating that elite athletes in this study were probably able to better focus their attention and regain their focus when faced with distractions than their less skilled counterparts were.

The two groups differ significantly in the activation scale. Indeed, a proper activation leads the athletes to optimum performance and an experienced athlete is more aware of it.

The alpha coefficients indicated that the reliability of each of the 12 subscales was adequate, with internal consistency ranging from 0.71 to 0.83 (Tab. 2). These results, which were consistent with the validation study of Durand-Bush at al. [9], provided evidence for the adequate internal consistency of the 12 subscales of the Romanian OMSAT-3*.

Conclusions

The results of our study support the validity and reliability of the OMSAT-3*, Romanian version. From a practical perspective OMSAT-3* could be useful for coaches and consultants helping them to assess the mental skills of athletes competing in different sports and their levels of competence. More specifically, filling out the questionnaire takes approximately 15 minutes and consultants gain a better understanding of strengths and weaknesses of athletes. The items are clear and the scores are easily calculated and graphed to provide a summary profile an athlete's mental skills. OMSAT-3* is appropriate for working with a large group of athletes when it is difficult to meet with all of them individually. However, our findings are affected by some limitations. In spite of our care to recruit participants from a wide variety of sports, the present data are not guaranteed to replicate in other sport disciplines. New studies must be done to determine the usefulness of this instrument in other sport activities.

Moreover, our study had a correlational design. We could expand our information on the psychometric properties of the OMSAT-3* by studying its predictive validity using a longitudinal design. The inventory could be administered at the beginning and the end of a mental skill training program to investigate empirically its effects regarding some mental skills development. Also, a line for research could be applied to determine the effects of variables such as age, gender, type of sport, etc.

The Romanian version of the OMSAT-3* offers the possibility of assessing the psychological resources of athletes in order to increase the performance and awareness of mental skills. Our hope is that OMSAT-3* will help athletes to develop the performance by using their psychological resources more efficiently.

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THE DIFFERENCES BETWEEN MEDALISTS AND NON-MEDALISTS AT THE 2008 OLYMPIC GAMES TAEKWONDO TOURNAMENT

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ABSTRACT

Purpose. To establish the differences in some morphological characteristics and competitive efficacy parameters between the medal winners and other competitors in male and female competitions at the Olympic taekwondo tournament in China 2008. **Basic procedures.** Athlete profiles were obtained from the "Official Olympic site" which included weight category, weight, height, age, given points, received points, warnings, deduction points, defensive/offensive kicks, and punches. A total of 128 athletes competed (64 males and 64 females) in the Games. **Main findings.** In males ANOVA found significant differences in both the sub patterns between the medal winners and other competitors in: the average number of given points per fight, average number of points received per fight, and average number of given defensive kicks to the trunk. Among females, significant differences were found in all the previously specified variables together with the average number of given offensive points to the trunk, average number of given offensive points to the head, and average number of warnings per fight. **Conclusions.** The differences between male medalists and non-medalists were observed in the DK1P (average number of defensive kicks to the trunk) variable, whereas in the female competitors the largest differences were in the average number of offensive points to the trunk and head (OK1P and OK2P). The medal winners achieved better results in those variables when compared with non-winners in both male and female categories. In comparison to the last two Olympic games, certain changes in the trend in how points are given among the male and female competitors are evidenced. When compared with the 2000 and 2004 Olympic games, the Beijing games were dominated by defensive kicks among the male competitors, whereas in female athletes, greater homogeneity and changes in the style of fighting were observed.

Key words: competitive efficacy, combat sport, weight categories

Introduction

Taekwondo (TKD) can be described as a high-intensity martial art and modern Olympic sport, in which the aim is to defeat the opponent using quick and precise kicks. TKD competitions are held based on three traditional disciplines: sparring, patterns, and breaking (a power test). Currently, sparring is the only Olympic category among them. Sparring consists of three 2-minute rounds, with a 30-second interval between each of them. The fight duration and intensity primarily demand the use of anaerobic as well as aerobic capacity [1–3]. In particular, speed, agility, and muscular endurance are important during sparring [4], so that the fighters, whose above-mentioned motor abilities are more pronounced, have an advantage over their opponents with comparable technical skills. An excess of subcutaneous adipose tissue implies greater total trunk mass, leading towards being placed in a higher category, which generally diminishes the chances for success at a competition [5, 6]. Hence, it can be concluded that TKD is a complex sport, where a considerable number of different anthropological dimensions play an important role in the final winning result.

Two major taekwondo competition systems are recognized (the WTF and ITF) and can be differentiated by the competition rules, techniques and equipment used. The WTF competition system [7] regulates full contact and kicks and strikes to the body and head as assented techniques. The following protection equipment is prescribed: trunk protector, dobok (white trousers and jacket), forearm and shin guards, head protector, groin guard and belt. ITF competitors [8], contrary to WTF, do not wear trunk protectors but have hand and feet safety equipment, while strikes are performed through light contact. The same techniques are allowed as in the WTF with the addition of the head punch. Currently, the WTF sparring discipline is the only Olympic category among them.

TKD has significantly evolved since it became an Olympic sport (in 2000). During this period, the rules have often been changed to make the competitions more

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dynamic. For example, the round duration was reduced from 3 to 2 minutes and a kick to the head now gives 2 points. In case of a tied result an extra round is provided. The fighting area is reduced to 10 × 10 meters and competitors are obliged to wear TKD gloves. In addition, "Win by superiority" (when a competitor scores a maximum of 12 points the match is stopped and winner declared) and "Win by point ceiling" (when a seven-point gap is reached) have been established [7].

However, every change in the rules has resulted in changes in the order and significance of the competitive efficacy parameters. This necessitates important modifications in the technical-tactical performance of the competitors. Hence, it is extremely important for the competitors to constantly follow the trends of the competitive efficacy parameter changes, which are decisive in the creation of training plans and programs. Studies concerning competitive efficacy parameters in sports generally as well as in TKD are very rare [9–12]. Previous investigators [9] concluded that training should be focused on offensive technique and tactics. On the other hand, Kazemi et al. [10] analyzed the data from the Sydney 2000 games, and did not obtain any statistically significant differences in any of the analyzed competitive efficacy variables between the winners and the other competitors. Furthermore, by analyzing the results from the Athens 2004 Olympic Games (OG), Kazemi et al. [11] concluded that both males and females used more frequently one-point offensive kicks to score the maximum number of points, followed by defensive kicks and offensive two-point kicks. They also concluded that the fighting style in the 2004 OG was more dynamic when compared with the 2000 OG that took place in Sydney. Therefore, it would be interesting to compare similar parameters from the data of the past 4 or 8 years, a period when TKD as a sport underwent significant changes.

The basic aim of this study is to establish the differences in a variety of morphological characteristics and competitive efficacy parameters between the medal winners and other competitors in both male and female competitions at the Olympic taekwondo tournament in China 2008.

Material and methods

The sample for this study comprised of all participants in the Olympic taekwondo tournament in Beijing 2008 (128 athletes; 64 males and 64 females) from 22 countries, who passed the demanding qualifying tests to participate in the OG, and competed in 4 male and 4 female weight categories. Taekwondo competition at the OG is carried out as a single elimination tournament system with double repechage (among all the losers of the contestants after the final match) for 3rd place [13]. For the purpose of this research study, all the participants who participated in the Olympic taekwondo tournament (128) and all their fights (152 fights) were analyzed, and the following variables were chosen: age (AGE), body weight (WEIGHT), body height (HEIGHT), and Body mass index (BMI). The competitive efficacy variables of the participants were warnings (KJP), penalty points (GJP), offensive kicks to the trunk (OK1P), offensive kicks to the head (OK2P), defensive kicks to the trunk (DK1P), defensive kicks to the head (DK2P), given points (POPP), and received points (PRIP). According to the WTF TKD rules [7] competitors score points when contact is made to the torso (by punches and kicks) or the head (only by kicks). Penalties are divided into "Kyong-go (warning)" and "Gam-jeom (penalty point). The specified variables were obtained from the "Official Olympic site" in accordance with article 9, paragraph 2 of the IOC – Archives access rules [14].

Due to the competition system, the participants took part in different number of fights at the tournament. Hence, the competitive efficacy variables of the participants were transformed into average values per fight, that is, the relative values of the above-mentioned variables for each participant were calculated.

Based on the obtained rankings, the criterion variable of success was established. Dependant on that variable, the participants were divided into two groups: a) medal winners and b) the others.

Statistica v.7 software and ANOVA were used to determine the significant differences between the groups of winners and the others. All the results were expressed as mean (± SD). In all the analyses, the 5% critical level ($p < 0.05$) was considered to indicate statistical significance.

Results

From Table 1, we can conclude that male medal winners are slightly older (0.25 years), taller (almost 3 cm), and have slightly lower BMI (21.99 vs. 22.39), when compared with the non-medalists. However, differing results were obtained with female athletes (0.19 years, 2.32 cm, and 0.40 BMI). Both male and female medal winners achieved better results in all the competitive efficacy variables and the number of given and received points when compared with the non-winners, which is both logical and predictable. However, medalists had significantly different results in comparison to the others, among the variables DK1P (medalists 1.76 ± 0.82 vs. others 0.90 ± 1.06), POPP (medalists 3.07 ±

Table 1. Descriptive statistics (Means and Standard Deviations – SD); ANOVA statistic significance with demographic, anthropometric and competitive efficacy variables between medalists and non-medalists in male and female competitors

Variables	Medalists (males) mean ± SD	Others (males) AS ± SD	*F*-test	Medalists (females) AS ± SD	Others (females) AS ± SD	*F*-test
AGE	25.44 ± 3.67	25.19 ± 4.29	0.04	23.00 ± 2.63	23.19 ± 4.62	0.02
HEIGHT	182.73 ± 8.99	179.74 ± 8.50	1.44	169.41 ± 7.86	171.72 ± 6.18	1.45
WEIGHT	73.99 ± 13.88	72.78 ± 12.10	0.11	60.81 ± 9.17	62.13 ± 8.16	0.30
BMI	21.99 ± 2.47	22.39 ± 2.25	0.36	21.10 ± 2.22	21.00 ± 1.93	0.03
KJP	1.09 ± 0.48	1.02 ± 0.81	0.11	1.24 ± 0.61	0.80 ± 1.02	2.68
GJP	0.23 ± 0.23	0.29 ± 0.36	0.37	0.36 ± 0.29	0.13 ± 0.30	**7.13** [b]
OK1P	1.16 ± 0.92	0.83 ± 1.10	1.16	1.17 ± 0.51	0.55 ± 0.58	**1.79** [b]
OK2P	0.19 ± 0.25	0.10 ± 0.34	0.89	0.14 ± 0.27	0.03 ± 0.11	**4.95** [a]
DK1P	1.76 ± 0.82	0.90 ± 1.06	**8.56** [b]	1.54 ± 0.84	0.77 ± 0.78	**11.32** [b]
DK2P	0.05 ± 0.10	0.01 ± 0.07	2.49	0.08 ± 0.15	0.03 ± 0.12	1.67
POPP	3.07 ± 1.01	1.71 ± 1.80	**8.13** [b]	2.90 ± 0.91	1.38 ± 1.01	**20.95** [b]
PRIPP	1.78 ± 0.91	3.00 ± 2.09	**5.09** [a]	1.41 ± 0.73	2.66 ± 1.21	**9.61** [b]

* *F*-test – univariate test results; [a] $p < 0.05$; [b] $p < 0.01$

Abbreviations used: (AGE) age, (HEIGHT) body height, (WEIGHT) body weight, (BMI) Body mass index, (KJP) warnings, (GJP) penalty points, (OK1P) offensive kicks to the trunk, (OK2P) offensive kicks to the head, (DK1P) defensive kicks to the trunk, (DK2P) defensive kicks to the head, (POPP) given points, (PRIP) points received

1.01, vs. others 1.71 ± 1.80) and PRIPP (medalists 1.78 ± 0.91 vs. others 3.00 ± 2.09) in the male competitors, whereas in the female competitors, the variables GJP (medalists 0.36 ± 0.29, vs. others 0.13 ± 0.30), OK1P (medalists 1.17 ± 0.51, vs. others 0.55 ± 0.58), OK2P (medalists 0.14 ± 0.27, vs. others 0.03 ± 0.11), DK1P (medalists 1.54 ± 0.84, vs. others 0.77 ± 0.78), POPP (medalists 2.90 ± 0.91, vs. others 1.38 ± 1.01), and PRIPP (medalists 1.41 ± 0.73, vs. others 2.66 ± 1.21) showed statistically significant differences. Furthermore and what was quite interesting, the female medal winners, on average, had more warnings (KJP). They also had significantly more penalty points (GJP) when compared with the non-medalists. Among the male medal winners, we noticed a slightly higher number of warnings, which, however, were not statistically significant (0.23 vs. 0.29). Nevertheless, both the male and female medalists scored most of their points by giving defensive kicks to the trunk (DK1P).

Discussion

The results from Table 1 show that the BMI values of top male and female TKD athletes were in the normal range (18.5–24.9) and probably in the lower part of the normal range, because this sample population comprised of the elite athletes who have higher muscle mass when compared with the general population [15]. In general, the average BMI of male medalists was lower than that of male non-medalists, but did not show any statistical significance. This may suggest that the medalists had a leaner body than the non-medalists, and lower body fat content, as observed by Chan et al. [16], who showed that the dominant somatotype (endo-meso-ecto) for males (4.2 – 4.7 – 2.9) and females (6.3 – 4.2 – 2.0) was a well-proportioned stature, well-developed muscles and skeletons, and low subcutaneous fat. The BMI values in female athletes were almost identical among both the medalist and non-medalist groups, and the values in the non-medalists were even slightly lower.

Furthermore, the results given in Table 1 show a contradictory fact, according to which, female non-medalists are, on average, taller than female medalists, although no statistical significance could be observed. Earlier research has shown that taller athletes have a significant biomechanical advantage over their shorter competitors. Taller athletes have longer upper and lower limbs, which translates into longer levers, providing them with greater ability to cover a larger area with less energy [10]. Nevertheless, it is presumed that female medalists compensated this "handicap" with greater dynamics, speed, agility, and better attack timing, which, according to certain authors, is considered to be the most important factor for success in TKD [10]. However, these assumptions should be proven in future studies.

The finding that there were no significant differences in the weight between medalists and non-medalists among both male and female athletes is completely logical, as all the fighters are categorized on their weights, and the competitors are generally recommended to maintain the upper limit weight of their weight category [5, 6].

Interestingly, no major differences in the BMI, AGE

Table 2. Comparison of the results from the last three Olympic Games with anthropometric and demographic variables

Variables	Sydney 2000	Athens 2004	Beijing 2008
BMI (M) medals	21.9 ± 2.4	22.4 ± 2.3	22.0 ± 2.5
BMI (M) no medal	22.8 ± 3.3	22.5 ± 2.5	22.4 ± 2.3
BMI (F) medals	20.8 ± 2.3	20.4 ± 2.5	21.1 ± 2.2
BMI (F) no medal	21.3 ± 2.7	21.1 ± 2.2	21.0 ± 1.9
HEIGHT (M) medals	183 ± 0.1	183 ± 0.1	183 ± 9.0
HEIGHT (M) no medal	179 ± 0.1	181 ± 0.1	180 ± 8.5
HEIGHT (F) medals	170 ± 0.1	173 ± 0.1	169 ± 8.0
HEIGHT (F) no medal	169 ± 0.1	169 ± 0.1	172 ± 6.2
WEIGHT (M) medals	73.4 ± 12.1	75.8 ± 16.1	74.0 ± 13.9
WEIGHT (M) no medal	73.7 ± 14.3	74.1 ± 13.0	72.8 ± 12.1
WEIGHT (F) medals	60.3 ± 9.1	61.3 ± 10.5	60.8 ± 9.2
WEIGHT (F) no medal	61.3 ± 10.9	60.9 ± 9.4	62.1 ± 8.2
AGE (M) medals	24.4 ± 3.3	26.1 ± 4.6	25.4 ± 3.7
AGE (M) no medal	25.2 ± 4.3	26.0 ± 4.3	25.2 ± 4.3
AGE (F) medals	23.1 ± 3.9	24.3 ± 4.9	23.0 ± 2.6
AGE (F) no medal	24.9 ± 4.7	24.5 ± 4.7	23.2 ± 4.6

Abbreviations used: (AGE) age, (HEIGHT) body height, (WEIGHT) body weight, (BMI) Body mass index, (M) males, (F) females

and HEIGHT variables could be observed between the medalists and non-medalists among both male and female competitors when the results from the last three OG were compared (Tab. 2). The competitors who took part in the Athens Olympics were slightly older than those competing in the Beijing and Sydney Olympics.

Unfortunately, we were unable to compare the completely competitive efficacy variables from the last three OG for the following reasons:

a) Although the analyzed variables from the Sydney 2000 OG [10] and the Athens 2004 OG [11] gave useful data, they presented absolute values, which, according to their authors, may result in a doubtful interpretation of the results because participants took part in a different number of fights. In other words, taking into consideration the specific type of competition, in which all the participants do not take part in the same number of fights, it is necessary to consider the total number of fights in relation to the observed parameters, which allow for the calculation of the relative values for each fighter, as was done in this study.

b) When compared with the research carried out by Kazemi et al. [10] using data obtained from the Sydney OG or that carried out by Kazemi et al. [11] using data from the Athens OG, a greater number of fights were analyzed.

c) Numerous changes in the competition rules have occurred in the meantime, in addition to other changes (in training technology, the character of the game, etc.). Thus, it is interesting to observe the way the above-mentioned changes influenced the characteristics of TKD sparring. For example, on analyzing the data from the OG held in Sydney in 2000, Kazemi et al. [10] found no statistically significant differences in any of the analyzed variables between the winners and the other competitors. It is obvious that a period of 8 years (two Olympic cycles) brought considerable differences in the way point are awarded among the world's top TKD athletes. This probably might have been caused by certain changes in the rules during that period (as mentioned, the round duration was reduced from 3 to 2 minutes and the kick to the head gives 2 points). In addition, the results obtained from the Athens 2004 OG [11] were also significantly different from those presented here. In other words, offensive kicks in both male and female competitors were still dominant at those games, which was not observed in the Beijing 2008 OG (especially among male competitors) (Tab. 1). Interestingly, this was already remarked by the Koreans in the Sydney 2000 OG [10], where they had considerably more points than their opponents. A comparison of the results of male and female competitors (Tab. 1) revealed that the differences in the analyzed competitive efficacy variables between the medalists and non-medalists were considerably more pronounced in female athletes. Thus, only the variable defensive kicks to the trunk (DK1P) distinguished successful competitors from the less successful ones, while in female athletes, the medal winners, on average, used considerably more offensive kicks (OK1P and OK2P) and even had more penalty points (GJP) when compared with the non-medalists. According to the authors, such results were primarily conditioned by a great homogeneity of male athletes in all weight categories, when compared with the female competitors. Kazemi et al. [10] confirmed this notion by concluding that female Taekwondo athletes participating in competitions and generally in the sport started much later than male athletes. In addition, the number of female Taekwondo athletes in the world is lower than that of male athletes. In some countries, such as Iran, the participation of female Taekwondo athletes in international competitions is banned owing to religious beliefs. This may affect the amount of emphasis put on developing elite international female Taekwondo athletes in different countries, thus explaining the large difference in scoring between female winners and non-winners. However, it seems that gender differences in that segment are not as pronounced today. In particular, in the Sydney 2000 and Athens 2004 OG, there was a considerably greater number of fights won by superiority among female competitors when compared with males (even up to 8 times), which points to considerable differences in quality of fighting between the winners and the other female athletes. For example, in the Beijing 2008 OG, there were practically no differences between males and females in that parameter, and only 5 fights in the female category and 3 fights in the male category ended that way.

It is also evident that in the last OG, the fighting style of female athletes changed when compared with male athletes, which is indicated by two facts:

a) Female medalists had, on average, more warnings and penalty points when compared with male medalists (1.24 and 0.36 when compared with 1.09 and 0.23).
b) Female medalists obtained a higher number of warnings and a considerably greater number of penalty points when compared with the non-medalists.

Such results significantly differ from those obtained from the Athens 2004 OG [11], and based on the way the competitors used to win (a greater number of offensive kicks and knock downs), it was concluded that male athletes had a more dynamic fighting style than female athletes. The importance of the fighting dynamics is observed in other combat sports such as judo [17]. It is obvious that in Beijing, the successful female competitors often attacked and took more risks, but also made more mistakes in their fights. For more accurate conclusions, future research should include round analysis between the medalists and non-winners.

Male medalists achieved higher results than male non-medalists only in the number of defensive kicks to the trunk. Thus, it can be concluded that male athletes were very uniform, and, according to their technical and tactical characteristics, more homogeneous than female athletes. Thus, male athletes "maneuvered" more and waited for a wrong move by their opponent, without taking too many risks, and to launch a counter-attack at the right moment in order to gain the advantage. It is known that defensive techniques result in "cleaner and more impressive" points [18], and hence, it is not surprising that those techniques clearly distinguished medalists from non-medalists. However, the obtained results are partially contradictory to the conclusions of Yujin and Zeng [9] who suggested that TKD training should be based on offensive techniques. Nevertheless, according to the presented results, this statement is not valid any more, especially with regard to male competitors. It is interesting to note that during the analyzed TKD tournament, the competitors did not obtain any points through punches to the trunk (hence, that variable was not used in the research). As no effective punches were recorded at the Athens OG as well, we can conclude that it is a trend in modern TKD. Thus, it can be stated that these techniques should be practiced only in trainings with the purpose of improving conditioning and tactics, and certainly not as a direct technique instrumental in being awarded points.

Conclusions

According to the results presented and discussed herein, the following conclusions can be drawn:

– Diverse results were found in the male and female population: male medalists and non-medalists differ in defensive scoring (medalists having higher values) and female in offensive scoring (medalists having higher values).
– Remarkable changes were found in the trends in obtaining points with regard to the last two OG (defensive kicks were dominant among male athletes, while there was a noticeable homogeneity and change in the style of fighting among the female athletes).
– Future studies should analyze the relationships between the variables of competitive efficacy and other anthropological characteristics variables and also a round analysis between medalists and non-medalists.

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A PARADIGM FOR IDENTIFYING ABILITY IN COMPETITION: THE ASSOCIATION BETWEEN ANTHROPOMETRY, TRAINING AND EQUIPMENT WITH RACE TIMES IN MALE LONG-DISTANCE INLINE SKATERS – THE 'INLINE ONE ELEVEN'

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ABSTRACT
Purpose. The association between anthropometric and training characteristics on an athlete's performance has been investigated in swimmers, cyclists and runners, but not in inline skaters. The aim of this study was to investigate the relationship between anthropometry, pre race preparation and equipment in the finishers of the longest inline race in Europe, the 'Inline One eleven' over 111 km in Switzerland. **Basic procedures.** We investigated the association of anthropometry, training, and equipment variables with race times in 84 male ultra-endurance inline skaters using bi- and multivariate analysis. **Main findings.** In the multivariate analysis, percent body fat, duration per training unit, and personal best time in the 'Inline One eleven' was related to the race time for all finishers. Out of the 84 finishers, 58 had already finished an 'Inline One eleven' while 26 participated for the first time. Speed in training and the kind of skates worn were related to race times of the 26 inexperienced finishers. The inexperienced finishers skating with custom made skates were significantly faster with 229.1 (12.7) min compared to inexperienced finishers using ordinary skates finishing within 290.8 (35.4) min ($p < 0.001$). For experienced inliners, body mass, the sum of skin-folds and percent body fat correlated to race time. **Conclusions.** We assume that inexperienced athletes in ultra-endurance skating need time to gain the experience necessary in choosing the correct equipment and doing the training in order to successfully finish a long-distance inline race. Experienced inliners can only improve race performance in an ultra-endurance inline race such as the 'Inline One eleven' through a reduction of their body fat.

Key words: skin-fold thickness, body fat, skate shoe, ultra-endurance

Introduction

In endurance athletes, the association between anthropometric variables such as body mass, body height, body mass index, the length and girth of extremities, body fat and skin-fold thicknesses have been investigated mainly in the disciplines of swimming, cycling, running and the triathlon. Body mass was related to the performance of athletes in a 3,000 m steeplechase [1], marathon [2] and ultra-marathon [3]. Apart from runners, body mass also showed a relationship with performance in cyclists, where road cyclists [4] and off-road cyclists [5, 6] with a lower body mass had an advantage in endurance cycling during climbs. Body height seems to be associated with swimming performance, especially in female swimmers, where body height was significantly related to the 100 m freestyle time in girls [7]. In another study, of a 100 yard swim, body height was significantly related to each female swimmer's major competitive stroke [8]. Regarding the length of the swimming distance, body height was related to both short and long-distances in pool swimmers from 50 m to 800 m [9]. Body mass index and endurance performance were negatively correlated to running speed in a 161-km trail run [10]. The relationship of the circumference of limbs with performance has mainly been investigated in runners. The circumference of the upper arms seemed to be related to performance in ultra-endurance runners [3, 11]. In swimmers, the upper extremity length was a predictor variable of 100 m freestyle performances in both boys and girls [7]. Body fat was related to performance in female marathon runners [12], in male ultra-marathoners [13], in female swimmers [8, 14], and in male Ironman triathletes [15, 16]. The association between skin-fold thicknesses and endurance performance was mainly investigated in runners. The total sum of five skin-fold thicknesses was related to performance in male 10 km runners [17] and the sum of seven skin-folds was correlated to marathon performance times [2].

Apart from anthropometry, the volume and intensity in training seem to influence performance in runners. In marathoners, the longest mileage covered per training session was the best predictor for the successful completion of a marathon [18]. Scrimgeour et al. described that runners training more than 100 km per week had sig-

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nificantly faster race times over 10 km to 90 km than athletes covering less than 100 km [19]. Bale et al. demonstrated, in 60 male runners, that elite runners with a higher training frequency, higher weekly training volume and longer running experience had better 10 km performance [17]. Hewson and Hopkins showed a correlation between seasonal weekly duration of moderate continuous running for runners specialising in longer distances [20]. Apart from volume, the running intensity in running was also of some importance. According to Billat et al., top class marathon runners trained for more total kilometres per week, and at a higher velocity, than runners at a lower level [21]. Peak running velocity in training was highly related to 5 km run times for both male and female athletes [22]. In ultra-endurance swimmers, speed in training was related to race performance in a 26.4 km open-water ultra-swim [23]. In addition to training, pre race experience was also associated with endurance performance, as described for Ironman triathletes. Gulbin and Gaffney described that the previous best performances in an Olympic distance triathlon, coupled with weekly cycling distances and longer training rides, could partially predict overall Ironman race performances [24]. Also, in recent studies investigating ultra-runners, a personal best marathon time was related to performance in a 24 hour run [25] and with race times in both a 100 km ultra-marathon [26] and multi-stage mountain ultra-marathon [27].

The sports discipline of inline speed skating is a special endurance discipline with a technical aspect. Inline skaters use special skates where the number, size and hardness of the wheels can be changed and may affect performance. Before each race the athletes assemble their skates as dictated by the race course. Also, these athletes can use ordinary skates or custom made skates, and these skates can be differentiated by the wheel bearing used. Apart from anthropometry, training and pre race experience, the kind of skates might be differently related to performance in long-distance inline skaters.

The aim of this study was to investigate the association of anthropometry, training, and equipment variables with race times in the longest inline marathon in Europe, the ‘Inline One eleven’ in Switzerland. Since inline skaters use skates that can be adjusted by the kind of skates (ordinary skates or custom made skates), the kind of wheel bearing (small or large) and the size, number and hardness of wheels, we also took these variables as well as the anthropometry and training variables into consideration. We hypothesized also that in long-distance inliners like in other endurance disciplines, both of anthropometry and training variables would be related to performance.

Material and methods

The organiser of the ‘Inline One eleven’ in St. Gallen, Switzerland contacted all the participants of the race via a separate newsletter upon joining the 2009 race, the 12th year of this event. The ‘Inline One eleven’ was the longest inline skating race in Europe, covering a total distance of 111 km with a total altitude of 1,400 m to climb. The start of the race was in the heart of the City of St. Gallen, and then went on a large loop of 111 km in the East of Switzerland returning to St. Gallen. Inliners from all over Europe came to St. Gallen for the longest inline race in Europe, held on completely closed routes.

Subjects

A total of 92 male athletes volunteered for this study. They all gave their written informed consent. The study was approved by the local Institutional Ethics Committee of the Canton St. Gallen, Switzerland. The athletes came on Saturday 15th August 2009 to get their race numbers and instructions for the race. On 16th August 2009 at 07:00 a.m., the race started. During the 111 km, the organizer offered 11 refreshment points including an opportunity to repair their skates in case of a malfunction. Split times and total race time were measured using an electronic chip system.

Procedures

The day before the start of the race the subjects’ body mass, body height and thickness of skin-folds (pectoralis, axillar, triceps, subscapular, abdomen, suprailiac, thigh and calf) were measured. With this data, body mass index, the sum of eight skin-folds and percent body fat were calculated. Body mass was measured using a commercial scale (Beurer BF 15, Beurer, Ulm Germany) to the nearest 0.1 kg. Body height was measured using a stadiometer to the nearest 0.5 cm. Skin-fold data was obtained using a skin-fold caliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) and recorded to the nearest 0.2 mm. One trained investigator took all the measurements as intertester variability is a major source of error in skin-fold measurements. All skin-fold thicknesses were determined on the right side of the body in all the athletes. The skin-fold measurements were taken three times and the mean was then used for the analyses. The skin-fold measurements were standardized to ensure reliability and readings were performed 4 s after applying the caliper, according to Becque et al. [28]. An intra-tester reliability check was conducted on 27 male runners prior to testing. No significant differences between the two trials for the sum of skin-folds were observed ($p > 0.05$). The intra-class correlation (ICC) was high at $r = 0.95$. The same investigator was also compared to another trained investigator to determine objectivity. No significant differences were found between the testers [29]. Percent body fat was calculated using the following anthropometric formula according to Ball et al. [30]: Percent body fat = $0.465 + 0.180(\Sigma7SF) - 0.0002406(\Sigma7SF)^2 + .0661(\text{age})$, where Σ7SF = sum of skin-fold thickness of pectoralis, axillar, triceps, subscapular, abdomen, suprailiac and thigh. This formula was evaluated using 160 men aged 18 to 62 years old and cross-validated with DXA (dual energy X-ray absorptiometry). The mean differences between DXA percent body fat and calculated percent body fat ranged from 3.0% to 3.2%. Significant ($p < 0.01$) and high ($r > 0.90$) correlations existed between the anthropometric prediction equations and DXA.

Upon their inclusion in the study, and until the start of the race, the athletes were asked to maintain a comprehensive training diary recording training sessions showing the distance and duration in preparing for the race. The training record consisted of the number of weekly training units in inline skating, showing duration, kilometres and pace. Furthermore, they reported on the number of years they had been active inliners, including participation in inline races, as well as the number of completed 'Inline 111' races, including their personal best time for that course.

Statistical analysis

The Shapiro-Wilk test was used to check for normality distribution. Data is presented as mean and standard deviation (SD). The athletes were categorized into groups such as finishers and non-finishers, and finishers who had completed an 'Inline One eleven' race (experienced) and finishers who had not completed one (inexperienced). Parameters of age, anthropometry, pre race experience, training and skates were compared between these groups using the Kruskal-Wallis equality-of-populations rank test. The coefficient of variation of performance (CV % = 100 × SD/mean) for total race time was calculated. Race time was also expressed as a percentage of the course record. In order to reduce the variables for the multiple linear regression analysis, bivariate correlation analysis between the mentioned variables body mass, body height, body mass index, circumference and length of limbs, body fat, sum of skin-folds, skin-fold thickness at thigh and calf, volume and intensity in training, personal best time and race time were performed using the Pearson correlation analysis. Multiple regression analysis was then used to investigate predictor variables for race time including significant variables after the bivariate analysis. A power calculation was performed according to Gatsonis and Sampson [31]. To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal correlation between race time and anthropometric variables of 20% (i.e. coefficient of determination $R^2 = 0.2$) a sample of 40 participants was required. An alpha level of 0.05 was used to indicate significance.

Results

A total of 651 male inliners started in the 'Inline One eleven' in 2009, and 611 male athletes (94%) arrived at the finish within the time limit of 10 hours. A total of 92 male study participants started in the race, 84 subjects (91%) finished. The finishers completed the 111 km within 264 (41) min (CV = 15.6%), equal to 4:15 (0:41) h:min. The athletes were skating at an average speed of 25.8 (4.0) km/h. Expressed as a percentage of the overall course record, of 3:07 h:min by Tristan Loy (F) in 2003, the subjects completed within 144 (22) %. Among the eight non-finishers, three skaters had to stop due to problems with their locomotor system; five gave up due to exhaustion. No athlete suffered an accident and no athlete complained about having a problem with his inline skates.

Table 1 represents the age and anthropometric variables of the eight non-finishers and the 84 finishers and the association between the variables with race time for successful finishers using bivariate analysis. The eight non-finishers were taller and had longer extremities than the 84 finishers. Age, body mass, body mass index, circumference of limbs, skin-fold thickness of the lower body, the sum of skin-folds and percent body fat were related to the race times of finishers. Regarding training and pre race experience, no differences were found between non-finishers and finishers (see Tab. 2). For finishers, both the duration and speed per training unit and the personal best time in an 'Inline One eleven' race were related to race time in the bivariate analysis. Non-finishers and finishers showed no differences regarding their skates and wheels (see Tab. 3). The kind of skates and the size of the wheels used were related to the race time for the finishers. When we inserted the significant variables after the bivariate analysis for all finishers in the multiple linear regression analysis, percent body fat, duration per training unit, and personal best time in an 'Inline One eleven' were related to race time (see Tab. 4).

Table 1. Comparison of age and anthropometry between finishers and non-finishers and the association between variables with race time for finishers. Values are given as mean (SD). * = $p < 0.05$, ** = $p < 0.01$. p-value is given in case of a significant correlation

Age and anthropometry	Non-Finisher (n = 8)	Finisher (n = 84)	r
Age (y)	41.3 (11.0)	40.7 (10.2)	0.30, p = 0.0056
Body height (m)	1.87 (0.09)	1.77 (0.06)*	0.17
Body mass (kg)	83.6 (12.0)	75.9 (9.6)	0.42, p < 0.0001
Body mass index (kg/m^2)	23.8 (2.3)	24.1 (2.7)	0.35, p = 0.0011
Length of leg (cm)	91.6 (5.5)	86.7 (4.5)*	0.04
Length of arm (cm)	85.9 (2.7)	81.3 (4.0)**	0.10
Circumference upper arm (cm)	29.4 (1.4)	30.1 (2.3)	0.32, p = 0.0026
Circumference thigh (cm)	56.7 (2.9)	56.2 (3.0)	0.29, p = 0.0067
Circumference calf (cm)	39.7 (2.6)	38.3 (2.3)	0.38, p = 0.0004
Skin-fold front thigh (mm)	15.1 (6.9)	13.3 (6.9)	0.22, p = 0.0484
Skin-fold medial calf (mm)	6.4 (3.0)	6.2 (2.8)	0.27, p = 0.0119
Sum of eight skin-folds (mm)	101.5 (47.8)	91.3 (36.3)	0.43, p < 0.0001
Percent body fat (%)	17.7 (5.2)	16.4 (4.8)	0.45, p < 0.0001

Table 2. Comparison of training parameters between finishers and non-finishers and the association between training variables with race time in finishers. p-value is given in case of a significant correlation

Experience and training	Non-Finisher (n = 8)	Finisher (n = 84)	r
Years as active inliner	6.1 (3.5) (n = 8)	7.6 (3.6) (n = 78)	0.07
Number of weekly training units in inline skating	1.8 (0.9) (n = 8)	2.6 (3.3) (n = 80)	–0.14
Distance per training unit in inline skating (km)	31.0 (11.6) (n = 8)	31.4 (9.0) (n = 80)	0.14
Duration per training unit in inline skating (min)	86.2 (34.5) (n = 8)	97.2 (28.0) (n = 80)	0.33 p = 0.0031
Speed in inline skating during training unit (km/h)	23.4 (4.1) (n = 8)	22.7 (4.8) (n = 80)	–0.46 p < 0.0001
Number of finished ‘Inline One eleven’	2.5 (1.7) (n = 4)	3.5 (2.7) (n = 58)	0.04
Personal best time at ‘Inline One eleven’ (min)	288 (49) (n = 4)	257 (36) (n = 58)	0.71 p < 0.0001

Table 3. Comparison of skates and wheels between finishers and non-finishers and the association between training variables with race time in finishers. p-value is given in case of a significant correlation

Skates and wheels	Non-Finisher (n = 8)	Finisher (n = 84)	r
Kind of skates			0.57, p < 0.0001
Ordinary skates	6	54	
Custom made skates	2	30	
Wheel bearing			–0.17
Small	3	15	
Large	5	69	
Size of wheels			–0.46, p < 0.0001
80 mm		3	
82 mm		1	
84 mm	2	3	
90 mm		1	
100 mm	4	53	
104 mm		1	
110 mm	2	22	

Skates and wheels	Non-Finisher (n = 8)	Finisher (n = 84)	r
Number of wheels per skate			0.10
4	7	79	
5	1	5	
Hardness of wheels			–0.10
82	1	6	
83	1	5	
84	1	12	
85	3	31	
86	1	25	
87		2	
88		1	
90	1	2	

Table 4. Multiple linear regression analysis with race time as the dependent variable for finishers (n = 84) using all significant variables after bivariate analysis. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 75%. Twenty-six finishers had not completed at least one 'Inline One eleven' before this race

	β	SE	p
Body mass	1.55	0.64	0.021
Body mass index	–4.29	2.80	0.13
Circumference of upper arm	2.39	3.0	0.43
Circumference of thigh	–0.23	2.01	0.90
Circumference of calf	–0.28	2.49	0.90
Skin-fold of front thigh	–1.16	0.81	0.16
Skin-fold of medial calf	1.46	2.01	0.46
Sum of eight skin-folds	–1.22	0.64	0.06
Percent body fat	11.34	4.64	0.019
Duration per training unit in inline skating	0.33	0.13	0.019
Speed in inline skating during training unit	0.47	0.80	0.56
Personal best time in an 'Inline One eleven'	0.47	0.12	0.0005
Kind of skates	14.51	8.31	0.08
Size of wheels	0.002	0.62	0.99

Table 5. Multiple linear regression analysis with personal best time as the dependent variable for finishers (n = 58) using all significant variables after bivariate analysis. Variables of skates and wheels were excluded since inline skaters assemble their shoes according to the race. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 45%

	β	SE	p
Body mass	1.05	0.81	0.19
Body mass index	–5.98	3.44	0.08
Circumference of upper arm	6.92	3.67	0.06
Circumference of thigh	–1.42	2.59	0.58
Circumference of calf	5.62	3.07	0.07
Skin-fold of front thigh	–0.24	1.03	0.81
Skin-fold of medial calf	3.43	2.52	0.18
Sum of eight skin-folds	–1.61	0.79	0.047
Percent body fat	12.59	5.59	0.029
Duration per training unit in inline skating	–0.01	0.15	0.91
Speed in inline skating during training unit	0.07	1.03	0.93

The personal best time in an 'Inline One eleven' showed the highest correlation, and we performed a separate regression analysis with personal best time in an 'Inline One eleven as a dependent variable for the 58 experienced athletes who had already completed at least one 'Inline One eleven' (see Tab. 5). Inexperienced and experienced finishers were compared in Table 6. The inexperienced finishers had longer arms, but showed no other differences regarding anthropometry, training or pre race experience compared to the experienced finishers. When we compared inexperienced finishers and experienced inliners regarding the association of variables with race time, the speed in training and the kind of skates worn were related to race time in inexperienced finishers (see Tab. 7). Inexperienced finishers with custom made skates were significantly faster, with 229.1 (12.7) min, compared to inexperienced inline skaters using ordinary skates and finishing within 290.8 (35.4) min ($p < 0.001$). For experienced inliners, body mass, the sum of skin-folds and percent body fat correlated to race time (see Tab. 8).

Discussion

The aim of this study was to investigate the association between the variables of anthropometry, training, and equipment with race times in the longest inline marathon in Europe, the 'Inline One eleven' in Switzerland. Regarding existing literature on other endurance disciplines, we hypothesized that for these long-distance inliners, as

Table 6. Comparison of age, anthropometry and training between inexperienced and experienced inliners who had already finished at least one 'Inline One eleven'. * = $p < 0.05$

Age and anthropometry	Inexperienced finishers (n = 26)	Experienced finishers (n = 58)
Age (y)	37.8 (8.8)	41.9 (10.6)
Body height (m)	1.79 (0.05)	1.77 (0.07)
Body mass (kg)	76.1 (8.4)	75.9 (10.2)
Body mass index (kg/m^2)	23.6 (2.3)	24.2 (2.9)
Length of leg (cm)	87.2 (3.4)	86.4 (4.9)
Length of arm (cm)	82.6 (3.8)*	80.6 (4.0)
Circumference upper arm (cm)	29.8 (2.3)	30.2 (2.3)
Circumference thigh (cm)	55.9 (2.8)	56.4 (3.0)
Circumference calf (cm)	38.3 (2.0)	38.3 (2.4)
Skin-fold front thigh (mm)	12.7 (7.6)	13.6 (6.7)
Skin-fold medial calf (mm)	6.3 (3.1)	6.2 (2.6)
Sum of eight skin-folds (mm)	85.2 (32.6)	94.0 (37.9)
Percent body fat (%)	15.5 (4.2)	16.9 (5.0)
Years as active inliner	6.7 (3.6)	8.0 (3.6)
Number of weekly training units in inline skating	2.2 (0.8)	2.8 (4.0)
Distance per training unit in inline skating (km)	31.8 (8.8)	31.2 (9.1)
Duration per training unit in inline skating (min)	102.5 (28.8)	95.0 (27.6)
Speed in inline skating during training unit (km/h)	21.4 (4.9)	23.3 (4.7)
Race time (min)	274.3 (41.5)	259.7 (40.7)
Ordinary skates	19	35
Custom made skates	7	23

Table 7. Multiple linear regression analysis with race time as the dependent variable for inexperienced finishers (n = 26) using all significant variables after bivariate analysis. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 90%

	β	SE	p
Body mass	–2.32	1.30	0.10
Body mass index	–7.41	7.65	0.35
Circumference of upper arm	3.99	4.12	0.35
Circumference of thigh	4.42	3.95	0.28
Circumference of calf	7.57	3.51	0.05
Skin-fold of front thigh	–0.95	1.44	0.52
Skin-fold of medial calf	–3.00	3.46	0.40
Sum of eight skin-folds	1.20	1.11	0.30
Percent body fat	–4.06	8.22	0.63
Duration per training unit in inline skating	–0.09	0.21	0.65
Speed in inline skating during training unit	–4.90	1.06	0.0010
Kind of skates	29.62	11.91	0.0322
Size of wheels	–1.24	0.64	0.08

Table 8. Multiple linear regression analysis with race time as the dependent variable for experienced inliners in 'Inline One eleven' (n = 58) using all significant variables after bivariate analysis. β = regression coefficient; SE = standard error of the regression coefficient; coefficient of determination (R^2) of the model was 66%

	β	SE	p
Body mass	1.92	0.73	0.0124
Body mass index	–6.11	3.17	0.06
Circumference of upper arm	4.76	3.38	0.16
Circumference of thigh	–0.76	2.30	0.74
Circumference of calf	2.03	2.77	0.46
Skin-fold of front thigh	–1.07	0.93	0.25
Skin-fold of medial calf	2.60	2.28	0.26
Sum of eight skin-folds	–1.78	0.72	0.0185
Percent body fat	15.73	5.16	0.0040
Duration per training unit in inline skating	0.24	0.15	0.11
Speed in inline skating during training unit	0.51	0.92	0.57
Kind of skates	16.3	9.5	0.09
Size of wheels	–0.70	0.68	0.31

in other endurance athletes, both anthropometry and training variables would be related to performance.

Considering the whole sample of 84 participants, the personal best time in the 'Inline One eleven' showed the highest association with race time, apart from body mass, percent body fat and duration per training unit in inline skating. When we investigated, separately, the 58 experienced inliners who had already performed at least one 'Inline One eleven', anthropometric variables such as the sum of skin-folds and percent body fat were related to race time. For the 26 inexperienced finishers, speed in training and the kind of skates worn were associated with race time. We must therefore assume that beginners in long-distance skating rely more upon technical equipment, whereas experienced long-distance skaters already know their equipment and their long-distance performance relies more upon body composition such as body mass, skin-fold thickness and body fat.

The relationship of the physical characteristics such as body mass [1–6, 26, 32], body fat [3, 13, 15, 16, 26] and skin-fold thicknesses [17, 32–36] with endurance performance has mainly been investigated in runners, cyclists and triathletes. The finding that body fat was related to ultra-endurance performance in these athletes confirms the recent findings of Hoffmann et al. [13]. They described a significant and positive correlation between percent body fat and finish time for male ultra-marathoners in a 161-km trail ultra-marathon. However, regarding ultra-marathoners during a 100 km run, percent body fat was not related to race time [26]. Also in a 24-hour run, body fat showed no association with performance [25]. The correlation between both the sum of skin-fold thicknesses and single skin-folds with endurance performance has mainly been investigated in runners where studies over distances from 100 m to ultra-endurance had been performed. In male 10 km runners, the total sum of five skin-fold thicknesses was related to performance [17]. In marathoners, the sum of seven skin-folds was correlated to marathon performance times [2]. The length of a running performance may determine whether skin-fold thicknesses are related to performance. In male ultra-endurance runners during a 24 hour run, skin-fold thicknesses showed no association with performance [25] and also during a 100 km run, the sum of skin-folds was not associated with race performance [26]. The kind of performance seems to also influence this correlation. In cyclists, no correlation between skin-fold thicknesses and race performance has been found; neither in ultra-endurance road cyclists [34], nor in ultra-endurance mountain-bikers [36]. However, in ultra-endurance triathletes competing in distances longer than the Ironman distance, the sum of eight skin-fold thicknesses was related to race performance [35].

In the bivariate analysis, the duration and speed in inline skating during training and the personal best time in an 'Inline One eleven' were related to race times for all finishers. In the multivariate analysis, duration in inline skating during training and personal best time in an 'Inline One eleven' remained significant. When we compared inexperienced and experienced inliners in the 'Inline One eleven' we found no differences regarding training. However, speed in inline skating during training was related to race time for inexperienced finishers in the multivariate analysis. We must assume that training especially in the case of inexperienced finishers is, apart from equipment, an important determinant for race success in long-distance inline skating. McKelvie et al. [37] described that training pace was important in runners where faster workouts were associated with faster marathon times. Also Billat et al. [21] concluded that top class marathon runners trained for more total kilometres and at a higher velocity when compared to high-level marathon runners.

In the bivariate analysis, the kind of skates and the size of wheels were related to race time for all finishers. In the multivariate analysis with all finishers, equipment was no longer associated with race time. When we separately analysed inexperienced and experienced inliners, the kind of skates worn was associated with race times for inexperienced finishers in the multivariate analysis. Obviously, the skates of the inexperienced finishers were responsible for the significant association found in the bivariate analysis. Inliners can buy ordinary skates in the shop or order custom made skates to exactly fit the athlete's feet. Twenty-seven percent of the rookies wore custom made skates, whereas 40% of the experienced inliners had custom made skates; those inexperienced finishers with custom made skates were significantly faster compared to the inexperienced finishers with ordinary skates. We can compare the correlation of footwear for these inliners with the results of studies done on runners. In runners, increasing the shoe suppleness increased sprint performance [38]. Furthermore, athletic footwear affects the balance in athletes [39]. Athletes with adequate shoes have better balance, which is important in inline skating. Furthermore, athletic footwear can have a much larger influence on performance by minimizing a loss of energy [40].

Conclusions

To summrise, we found that in these ultra-endurance inline skaters anthropometry, training and pre race experience such as the personal best time in the 'Inline One eleven' were associated with race times for all finishers, where the personal best time in the 'Inline One eleven' showed the highest correlation. When experienced athletes were compared to inexperienced finishers, the kind of skates worn and the speed in training was associated with the race time for inexperienced finishers, whereas the sum of skin-folds and percent body fat was related to race time in experienced finishers. We assume that inexperienced finishers need time to gain the appropriate amount of experience in using the correct equipment, and to complete the difficult training in order to successfully finish a long-distance inline race. Experienced inliners using the appropriate equipment can only improve their race performance with a decrease in body fat.

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GROWTH AND FUNCTIONAL CHARACTERISTICS OF MALE ATHLETES 11–15 YEARS OF AGE

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ABSTRACT
Purpose. To evaluate the growth and functional characteristics of male athletes 11–15 years of age. **Basic procedures.** The sample included 190 boys, 10.5–15.4 years, undergoing training of sport schools for track and field (136) and other sports (54). Height, weight, three skinfolds and % Fat (NIR) were measured. Grip strength, standing long jump, 2 kg medicine ball throw and 20 m sprint were tested. Track and field athletes were compared by discipline and to athletes in other sports using MANCOVA (multivariate analysis of covariance). Multiple linear regression analysis was used to estimate the relative contributions of age, body size and adiposity to the four functional indicators in two age groups, those 11–13 years and 14–15 years. **Main findings.** All variables except the standing long jump and 20 m sprint differed significantly by track and field discipline. Only height and ball throw differed among athletes in other sports. Track and field athletes had a significantly lower BMI and % Fat and performed better in the jump and sprint than athletes in other sports. Variance explained in each of the functional indicators was greater in younger than in older athletes. The sum of skinfolds and % Fat exerted a negative influence on all functional indicators. **Conclusions.** Trends in body size of male athletes attending sport schools were consistent with observations for youth male athletes in several sports. Height, weight and adiposity accounted for significant portions of variation in the four functional indicators in each age group, but the explained variance was higher in younger athletes.

Key words: body size, adiposity, power, strength, speed, youth sports

Introduction

Young male athletes in a variety of sports have mean heights and weights that equal or exceed reference medians. Though less extensive, data for male gymnasts and figure skaters, on the other hand, present a profile of short statures and lower weights. The heights and weights of youth athletes in weight category sports such as wrestling and weight lifting are affected by competitive weight categories which obviously influence weight and also height [1–5]. Although mean weights tend to equal or exceed reference medians, the percentage body fat (% Fat) is lower than average in young male athletes with the exception of athletes specializing in track and field throwing events and the heavier weight categories in wrestling [6, 7]. In contrast to body size and body composition, the available data for maturity status in male adolescent athletes indicate a trend towards average and advanced status relative to the chronological age in most sports; an exception is gymnastics [1–3].

This paper is a sequel to a corresponding paper dealing with the growth, maturity and functional characteristics of female sport school participants [8]. It considers the growth and functional characteristics of male sport school participants 11–15 years of age for three purposes: (1) to evaluate the growth and functional status of sport school participants, (2) to compare the growth and functional status of track and field athletes by discipline and of other athletes by sport, and (3) to estimate the contributions that age, body size and adiposity have to variation in functional capacities. An indicator of maturity status was not available for male athletes.

Material and methods

Subjects

The sample included 190 boys 10.54 to 15.45 years of age who were participants in sport schools in the Lower Silesia region (Wrocław, Jelenia Góra, Wałbrzych, Bogatynia, Zgorzelec) in 2004. Most were involved in track and field (n = 136) while the remainder (n = 54) were distributed among four team (basketball

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17, football 20, handball 5, volleyball 3) and four individual (swimming 3, tennis 3, karate 2, skiing 1) sports. Track and field disciplines included general athletics (n = 43), sprinters (n = 36), middle distance runners (n = 12), distance runners (n = 31), jumpers (n = 8) and throwers (n = 6).

The youth had been training for one to two years prior to the study for about 1.5 hours per session, twice a week. Younger athletes (< 13 years) can be viewed as beginners in their respective sports, while older athletes (14–15 years) are further along in their training. The project was approved by the local Ethics Committee. Parents provided informed consent while each athlete provided assent. All athletes were notified that the project was voluntary and that they could withdraw at any time. The identities of individual athletes were anonymous in the analyses.

Variables considered

Variables considered and protocols for assessment were the same as in the paper dealing with female athletes [8]. Briefly, information for each athlete included their experience in the sport, hours of training per week, height, weight, three skinfolds, relative fatness estimated with the near-infrared interactance (NIR) method using a Futrex analyzer apparatus calibrated for youth (model 5000A/ZL), and four indicators of functional capacity: static strength – sum of right and left grip strength, muscular power of the lower extremities – standing long jump, muscular power of the upper extremities – 2 kg medicine ball throw, and running speed – 20 m sprint with a running start (5 m). The BMI was calculated and skinfolds were summed to provide an indicator of subcutaneous adiposity.

Analysis

Descriptive statistics (means, standard deviations) were calculated by age group for the total sample; given the small number of 11 (n = 10) and 12 (n = 16) athletes, the sample was combined into a single group. Age-specific means for height, weight, BMI, better grip and standing long jump were compared with the corresponding means from a 1999 national survey of the growth and physical fitness of Polish youth [9]. The national survey used the EUROFIT test battery; grip strength of the preferred hand was used [10]. For comparison, it was assumed that the better grip strength between right and left hands was that of the preferred hand.

Multiple linear regression analysis was used to estimate the relative contributions of age, height, weight, the interaction of height and weight, and either the sum of three skinfolds or an estimated % Fat based on the NIR method to each indicator of function in athletes aged 11–13 years and 14–15 years. Since male athletes as a group tend towards earlier rather than later maturity, the younger group approximates the interval leading up to and including the growth spurt leading up to peak height velocity (PHV), while the older group approximates the interval after PHV for most boys [3]. Mean age at PHV among 25 boys from the Wrocław Growth Study and Wrocław Longitudinal Twin Study who were involved in several individual and team sports was 13.6 ± 0.9 years [11], while mean age at PHV in 21 boys from Warsaw who were involved primarily in track and field, rowing and swimming was 13.1 ± 1.0 years [12].

Separate regressions were done using the sum of skinfolds and % Fat. Though related (partial correlation controlling for age, r = 0.70), the two estimates are not identical indicators of adiposity. Skinfolds reflect subcutaneous fat, while % Fat is a global estimate of adipose tissue as a percentage of body weight. The sum of skinfolds is not related to age (r = 0.11), while % Fat is negatively related to age (r = –0.39, p < 0.001) in this sample of young athletes. The height × weight interaction term was derived from centered scores [(height – mean height) × (weight – mean weight)]. The regression protocol was the same as used in the study of female athletes [8]. The analysis permitted all variables to enter into the equation, and then the variables that met the criterion for elimination (backward elimination) were sequentially removed. In this protocol, the variable with the smallest partial correlation with the dependent variable was considered first for removal; if it met the criterion for removal (p > 0.10), it was removed. The procedure was repeated for the other potential predictors until those variables that did not meet the removal criterion remained in the equation. Standardized regression coefficients (β) permit comparison of the estimated contributions of each independent variable to the explained variance. The coefficients are not related to the scale of the raw data and are interpreted without scale. Positive and negative coefficients indicate, respectively, an increase and decrease in function associated with change in the particular independent variables.

The Statistical Package for the Social Sciences (SPSS) version 14.0 was used for all analyses.

Results

Descriptive statistics for the total sample are presented by age group in Table 1. The smaller samples of athletes aged 11–13 years should be noted. The years of training increase with age though not linearly, while training time

Table 1. Characteristics (means and standard deviations) of male athletes by age group

Variable	Age Groups, years							
	11–12 (*n* = 25–26)		13 (*n* = 23–27)		14 (*n* = 74–75)		15 (*n* = 62)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age, yrs	11.6	0.7	13.0	0.3	14.1	0.3	15.0	0.3
Training, yrs	1.6	0.8	2.7	1.2	2.2	1.5	3.1	1.7
Training, hrs/wk	1.9	0.3	1.8	0.4	1.8	0.3	1.7	0.3
Height, cm	149.4	9.6	163.7	8.5	169.1	8.1	175.4	7.4
Weight, kg	38.3	8.9	49.2	9.7	54.2	8.7	61.9	9.8
BMI, kg/m^2	16.9	2.2	18.2	2.5	18.8	1.9	20.1	2.7
Sum skinfolds, mm	21.0	5.9	25.0	8.5	21.7	5.7	25.0	9.9
Fat, %	19.2	5.1	15.7	5.6	11.9	4.8	12.2	6.6
Sum R+L grip, kg	46.0	16.8	63.9	16.3	76.9	15.7	85.8	18.5
Standing long jump, cm	166.9	20.8	190.1	18.3	199.7	24.4	209.0	27.0
2 kg throw, m	5.1	1.8	6.7	1.3	7.7	1.6	8.7	1.8
20 m run, sec	3.30	0.25	3.16	0.23	3.04	0.40	3.05	0.44

per week is reasonably constant across the age groups. Body size increases while three of the functional indicators improve, on average, from 11 through 15 years of age. Performance in the 20 meter dash improves (lower time) between the ages of 11 and 14 and is stable to 15 years. The mean sum of skinfolds changes relatively little across age, while % Fat declines from the ages of 12 through 14 and then increases slightly at 15 years.

Compared to the national sample of Polish youth in the 1999 fitness survey, athletes 11–12 years old are, on average, similar in height to the reference but athletes 13–15 years old are taller (Fig. 1). Mean weights are similar to the reference (Fig. 2). Mean BMIs are thus lower than the reference except at 15 years of age (Fig. 3).

The athletes are also stronger in grip strength (Fig. 4) and more powerful in the standing long jump (Fig. 5).

Results of the MANCOVA comparing track and field athletes by discipline and age-adjusted means and standard errors are summarized in Table 2. All variables except the standing long jump and 20 m sprint differ significantly by discipline. Although height differs among disciplines, none of the post hoc pairwise comparisons are significant. The difference in height between middle distance and distance is of borderline significance (p = 0.09). Boys in general athletics and throwers do not differ in weight and BMI, but both groups are significantly larger in size than distance runners. Other pairwise comparisons are not significant.

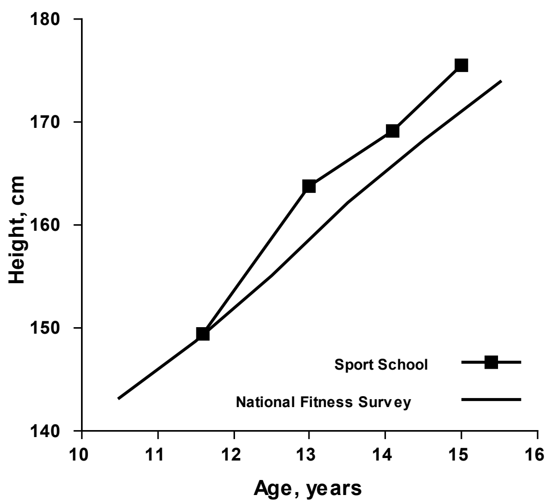

Figure 1. Mean height of male athletes plotted relative to mean height of boys in the 1999 national survey of growth and physical fitness of Polish youth [9]

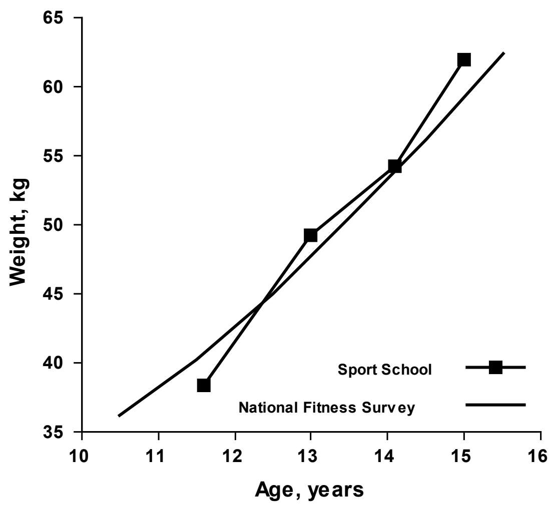

Figure 2. Mean weight of male athletes plotted relative to mean weight of boys in the 1999 national survey of growth and physical fitness of Polish youth [9]

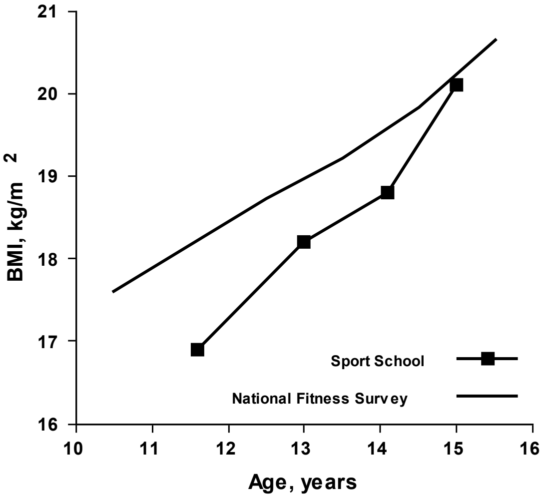

Figure 3. Mean BMI of male athletes plotted relative to mean BMI of boys in the 1999 national survey of growth and physical fitness of Polish youth [9]

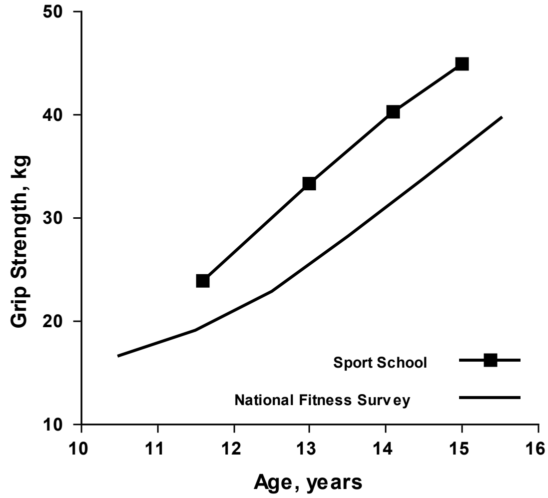

Figure 4. Mean grip strength of the dominant hand of male athletes plotted relative to mean grip strength of the dominant hand of boys in the 1999 national survey of growth and physical fitness of Polish youth [9]

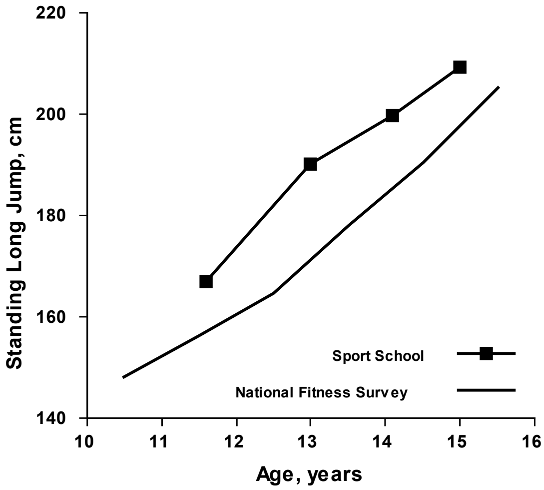

Figure 5. Mean standing long jump of male athletes plotted relative to mean standing long jump of boys in the 1999 national survey of growth and physical fitness of Polish youth [9]

Table 2. Characteristics of male track and field athletes by discipline. Means and standard deviations for age and training history and age-adjusted means and standard errors based on MANCOVA with age at the covariate

	Sprints (*n* = 36)		Middle Distance (*n* = 12)		Distance (*n* = 31)		Athletics (*n* = 43)		Jumps (*n* = 8)		Throws (*n* = 6)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Age, yrs	14.1	1.2	14.1	0.8	13.8	1.4	13.9	1.1	14.5	0.4	13.3	1.9		
Training, yrs	2.3	1.5	2.6	1.5	2.7	1.6	2.1	1.4	2.6	1.6	1.5	0.5		
Training, hrs/week	1.8	0.3	1.8	0.3	1.8	0.3	1.8	0.4	1.8	0.4	1.9	0.2		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*F*	*p*
Height, cm	168.6	1.3	166.7	1.2	165.1	1.4	169.8	1.2	173.7	2.8	172.3	3.2	2.58	< 0.05
Weight, kg	54.2	1.5	51.4	2.6	48.5	1.6	56.4	1.4	55.7	1.4	64.1	3.7	4.62	< 0.01
BMI, kg/m^2	18.8	0.4	18.3	0.6	17.6	0.4	19.4	0.3	18.3	0.8	21.4	0.9	4.03	< 0.01
Sum skinfolds, mm	22.5	1.2	20.5	2.1	20.0	1.3	24.7	1.1	19.5	2.5	31.6	3.0	3.88	< 0.01
Fat, %	12.0	0.9	12.7	1.5	10.5	0.9	13.5*	0.9	10.2	1.9	19.4	2.2	3.57	< 0.01
Sum R+L grip, kg	74.4	2.7	67.2	4.7	65.8	2.9	80.7	2.5	73.8	5.7	83.2	6.7	3.85	< 0.01
Standing long jump, cm	207.1	3.9	189.0	6.8	196.0	4.3	200.9	3.6	202.2	8.4	195.9	9.7	1.42	ns**
2 kg ball throw, m	7.8	0.3	7.3	0.4	7.0	0.3	8.0	0.2	7.8	0.5	8.8	0.6	2.45	< 0.05
20 m sprint, sec	2.92	0.05	2.88	0.09	2.99	0.06	3.01	0.05	2.75	0.11	3.07	0.13	1.41	ns

* *n* = 34 for the sample in athletics; ** ns = not significant

Throwers have a significantly larger sum of skinfolds than distance and middle distance runners and jumpers. Throwers also have a significantly larger % Fat than distance runners, sprinters and jumpers. Other pairwise comparisons for skinfolds and % Fat are not significant. Among functional measures, only grip strength differs significantly between general athletics and distance runners. All other pairwise comparisons indicate no significant differences among athletes by discipline.

The results of the MANCOVA comparing other athletes by sport and age-adjusted means and standard errors are summarized in Table 3. Only height and the 2 kg ball throw for distance differ significantly among groups, and only two pairwise comparisons indicate differences. Basketball players are significantly taller than soccer players, and the small combined sample of handball and volleyball players (other team sports) throw the 2 kg medicine ball significantly farther than soccer players.

Comparisons of track and field athletes and athletes in other sports are summarized in Table 4. Participants in other sports have significantly more experience, while track and field athletes spend significantly more

Table 3. Characteristics of male athletes in other sports. Means and standard deviations for age and training history and age-adjusted means and standard errors based on MANCOVA with age at the covariate

	Basketball (*n* = 17)		Football (*n* = 20)		Other Team[1] (*n* = 8)		Individual[2] (*n* = 9)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Age, yrs	14.0	0.8	13.4	1.4	13.8	1.4	14.3	1.2		
Training, yrs	2.5	1.6	3.1	1.5	2.3	1.0	3.3	1.9		
Training, hrs/week	1.6	0.3	1.7	0.3	1.7	0.5	1.7	0.3		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*F*	*p*
Height, cm	170.9	1.7	162.6	1.6	166.0	2.4	166.9	2.5	4.13	< 0.05
Weight, kg	55.2	2.0	51.0	1.8	56.7	2.8	57.1	2.9	1.65	ns*
BMI, kg/m²	18.7	0.6	19.1	0.5	20.4	0.8	20.2	0.8	1.52	ns
Sum skinfolds, mm	22.0	2.1	22.7	1.9	29.7	3.0	29.5	3.1	2.51	ns
Fat, %	13.9	1.3	16.7	1.2	18.1	1.9	18.7	1.8	1.87	ns
Sum R+L grip, kg	79.1	3.7	68.8	3.4	72.7	5.2	71.3	5.4	1.37	ns
Standing long jump, cm	194.6	5.7	182.0	5.2	192.4	8.0	192.4	8.3	1.02	ns
2 kg ball throw, m	7.6	0.4	6.6	0.4	8.5	0.6	6.8	0.6	3.15	< 0.05
20 m sprint, sec	3.40	0.08	3.47	0.07	3.26	0.11	3.45	0.12	0.86	ns

[1] The sample includes sport school participants in handball (5) and volleyball (3)
[2] The sample includes sport school participants in swimming (3), tennis (3), karate (2), skiing (1)
* ns = not significant

Table 4. Characteristics of male athletes in track and field and in other sports. Means and standard deviations for age and training history and age-adjusted means and standard errors based on MANCOVA with age at the covariate

	Track and Field (*n* = 135–136)		Other Sports[1] (*n* = 54)			
	Mean	SD	Mean	SD	*F*	*p*
Age, yrs	14.0	1.2	13.8	1.2	0.65	ns*
Training, yrs	2.3	1.5	2.8	1.6	4.14	< 0.05
Training, hrs/week	1.8	0.3	1.6	0.3	9.35	< 0.001
	Mean	SE	Mean	SE	*F*	*p*
Height, cm	168.0	0.7	167.1	1.1	0.46	ns
Weight, kg	53.4	0.8	54.8	1.2	0.94	ns
BMI, kg/m²	18.7	0.2	19.4	0.3	4.03	< 0.05
Sum skinfolds, mm	22.6	0.7	24.6	1.1	2.64	ns
Fat, %	12.4**	0.5	16.1	0.7	17.33	< 0.001
Sum R+L grip, kg	73.6	1.4	74.4	2.2	0.08	ns
Standing long jump, cm	199.4	2.0	190.4	3.2	5.63	< 0.05
2 kg ball throw, m	7.6	0.1	7.3	0.2	1.37	ns
20 m sprint, sec	2.96	0.03	3.41	0.04	77.85	< 0.001

[1] The sample included sport school participants in basketball (17), football (20), handball (5), volleyball (3), swimming (3), tennis (3), karate (2), skiing (1)
* ns = not significant; ** *n* = 127 for the sample in track and field

time in weekly training. Participants in other sports have a significantly higher BMI and % Fat, while track and field athletes perform significantly better in the standing long jump and 20 m sprint. Height, weight, sum of skinfolds, grip strength and the 2 kg ball throw do not differ between the groups.

The results of the regression analyses are given in Tables 5 and 6. Among athletes aged 11–13 years, the variance explained is generally similar with either the sum of skinfolds or % Fat among the independent variables: grip strength (85% – 82%), 2 kg ball throw (72%) and standing long jump (48% and 50%). A slightly larger amount of variance in the 20 m sprint is explained when % Fat (20%) rather than the sum of skinfolds (15%) is among the predictors. Nevertheless, the sum of skinfolds and % Fat have a negative influence on each of the functional indicators. For grip strength and ball throw, weight has a positive influence while fatness has a negative influence. Predictors for the standing long jump vary. With skinfolds among the independent variables, significant predictors are age (positive), weight (positive) and skinfolds (negative), while with % Fat among independent variables, significant predictors are weight (positive), height × weight interaction (negative) and % Fat (negative). Height (positive) and skinfolds (negative), and weight (positive) and % Fat (negative) are significant predictors of the 20 m sprint.

Body size and adiposity explain a smaller percentage of the variance in the four functional tests among athletes aged 14–15 years (Tab. 6). % Fat has a negative influence on all functional tests while the sum of skinfolds has a negative influence on three tests. Skinfolds do not appear among the predictors for the 20 m sprint. Percentages of variance accounted for by the independent variables are reasonably similar for grip strength (69%, 64%) and the 2 kg ball throw (51%, 58%). However, significant predictors vary depending on whether skinfolds or % Fat is included among the independent variables. Weight and the height × weight interaction contribute positively to grip strength while skinfolds have a negative influence, whereas weight contributes positively to grip strength while height and % Fat con-

Table 5. Significant predictors of functional capacities and estimated R^2 in the total sample of 11–13 year old athletes based on multiple regression analyses including either sum of skinfolds (n = 52–53, left) or percentage fat (n = 47–48, right) among the predictors as an indicator of adiposity

Variable	Predictors	β	p	R^2	Adj R^2	p	Predictors	β	p	R^2	Adj R^2	p
Grip strength	Weight	1.129	< 0.001	0.86	0.85	< 0.001	Weight	0.950	< 0.001	0.83	0.82	< 0.001
	Skinfolds	–0.343	< 0.001				% Fat	–0.215	< 0.01			
Standing long jump	Age	0.337	< 0.01	0.51	0.48	< 0.001	Weight	0.456	< 0.01	0.53	0.50	< 0.001
	Weight	0.639	< 0.001				Ht X Wt	–0.304	= 0.07			
	Skinfolds	–0.400	< 0.01				% Fat	–0.395	< 0.01			
2 kg ball throw	Weight	1.025	< 0.001	0.73	0.72	< 0.001	Weight	0.898	< 0.001	0.73	0.72	< 0.001
	Skinfolds	–0.275	< 0.01				% Fat	–0.234	< 0.01			
20 m sprint*	Height	0.442	< 0.01	0.17	0.15	< 0.01	Weight	0.324	< 0.05	0.23	0.20	< 0.01
	Skinfolds	–0.259	= 0.07				% Fat	–0.465	< 0.01			

* Signs of the coefficients were reversed because a lower time was a better performance.

Table 6. Significant predictors of functional capacities and estimated R^2 in the total sample of 14–15 year old athletes based on multiple regression analyses including either sum of skinfolds (n = 136–137, left) or percentage fat (n = 132–133, right) among the predictors as an indicator of adiposity

Variable	Predictors	β	p	R^2	Adj R^2	p	Predictors	β	p	R^2	Adj R^2	p
Grip strength	Weight	0.891	< 0.001	0.70	0.69	< 0.001	Height	–0.230	= 0.06	0.65	0.64	< 0.001
	Ht × Wt	0.097	= 0.09				Weight	1.132	< 0.001			
	Skinfolds	–0.409	< 0.001				% Fat	–0.458	< 0.001			
Standing long jump	Age	0.173	< 0.05	0.19	0.17	< 0.001	Height	–0.381	< 0.05	0.30	0.28	< 0.001
	Weight	0.330	< 0.01				Weight	0.861	< 0.001			
	Skinfolds	–0.390	< 0.001				% Fat	–0.771	< 0.001			
2 kg ball throw	Weight	0.807	< 0.001	0.52	0.51	< 0.001	Height	–0.357	< 0.01	0.59	0.58	< 0.001
	Skinfolds	–0.270	< 0.001				Weight	1.216	< 0.001			
							% Fat	–0.587	< 0.001			
20 m sprint*	Height	0.310	< 0.05	0.05	0.03	< 0.05	% Fat	–0.344	< 0.001	0.12	0.11	< 0.001
	Weight	–0.297	< 0.05									

* Signs of the coefficients were reversed because a lower time was a better performance.

tribute negatively. For the 2 kg ball throw, weight contributes positively and skinfolds contribute negatively, whereas weight contributes positively while height and % Fat contribute negatively. More of the variance is explained in the standing long jump when % Fat rather than the sum of skinfolds is among the independent variables (28% and 17%, respectively). % Fat and height contribute negatively and weight contributes positively to the jump, while skinfolds contribute negatively and age and weight contribute positively to the jump. With the sum of skinfolds among predictors, only 3% of the variance in the 20 m sprint is explained; significant predictors are height (positive) and skinfolds (negative). With % Fat among predictors, 11% of the variance in the sprint is explained and % Fat is the only significant predictor, exerting a negative effect.

Discussion

Trends in body size of male athletes attending sport schools were generally consistent with observations for adolescent male athletes in several sports [1–3]. The mean heights of the Polish athletes tended to vary between the age-specific medians and 75th percentiles of reference data for American youth, while mean weights tended to be slightly above the reference medians except at 11–12 years old [13]. As a result, mean BMIs were slightly, but consistently, below age-specific reference medians except at 15 years old. The data were consistent with the notion that young male athletes tend to be taller than average and to have body weights that approximate the average; hence, they tend to have less weight-for-height.

Studies of body composition of young athletes generally focus on % Fat. This is probably due to the fact that fat-free mass (FFM) has a growth pattern that is similar to height and weight so that variation in FFM in young athletes varies with body size [3]. More recently attention has shifted to bone mineral due in large part to advances in DEXA technology [14]. Reference data for body composition are lacking. For comparative purposes, densitometric estimates of % Fat for non-athletic youth in the early 1960s through mid-1980s provide a reasonable reference for the general population [15, 16]. The data pre-date the obesity epidemic which surfaced in the late 1980s in most of the developed world.

NIR was used to estimate % Fat in the present study. The validity of NIR relative to the densitometric estimates of % Fat has been questioned, specifically due to the somewhat larger standard errors of estimate. The problem apparently relates to the equations for deriving % Fat provided by the manufacturer [17]. Allowing for

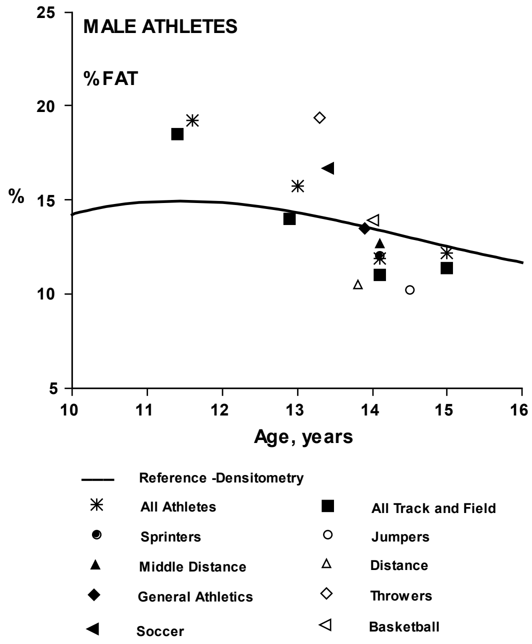

Figure 6. Estimated mean % Fat based on NIR for male track and field athletes by age group and age-adjusted estimated mean % Fat for track and field athletes by discipline and the combined sample of athletes in other sports plotted relative to estimated % Fat based on densitometry in non-athletic youth. Derivation of the non-athlete reference and source studies are reported in Malina et al. [15] and Malina [16]

this limitation, % Fat for males athletes was compared to the reference based on densitometry in Figure 6. Differences between the total samples of track and field athletes and athletes in other sports were small across the age range. Relative fatness declined with age from 11–12 years to 14 years. Age-adjusted mean % Fat varied by discipline and sport. It was, on average, above the reference in throwers and soccer players, at the reference for general athletics and basketball players, below the reference for middle distance runners and sprinters, and well below the reference for distance runners and jumpers. % Fat in sprinters was in the mid-range of estimates for other samples of adolescent sprinters, but % Fat in middle distance runners was consistently above estimates for other samples of adolescent middle distance runners [6, 7].

The percentage of variance explained by body size and adiposity in each of the functional indicators was greater in athletes 11–13 years (Tab. 5) compared to athletes 14–15 years (Tab. 6). In both age groups, however, adiposity expressed either as the sum of skinfolds or % Fat exerted a negative influence on the functional indicators. Greater proportions of the variance were explained by the size and adiposity in grip strength, and the

2 kg ball throw compared to the standing long jump and 20 m sprint. Among athletes 14–15 years old, more of the variance in the jump and sprint was accounted for when % Fat in contrast to the sum of skinfolds was included among the independent variables. This likely reflects differences between relative fatness and skinfolds. % Fat declines during male adolescence due to the rapid growth of muscle mass at this time; hence, fat as a percentage of body mass declines. In contrast, fat mass and skinfolds, especially skinfolds on the trunk increase with age across adolescence [3].

Overall, the results of the regression analyses were similar to estimates in samples of adolescent males in general [3]. Although height, weight and adiposity accounted for significant portions of variation in the four functional indicators, a considerable amount of variation was not explained by body size and fatness in this sample of male athletes, especially in the standing long jump and 20 m sprint. Unfortunately, a measure of biological maturity status was not available for the sample. This is of relevance because maturity status, size and adiposity contribute to the explained variance in a variety of functional indicators in adolescent males in general [3] and adolescent soccer players [18, 19]. Strength and performance are affected by motivation, quality of instruction and practice and other factors. Although experience in the sport school programs increased with age in this sample of male athletes, the amount of time spent in training per week was similar across age groups. This would seem to imply a need for more refined indicators of the duration and intensity of training in the sport schools to estimate any potential influences on functional capacity.

The study was limited to four indicators of functional capacity. There is a need to expand observations to other indicators, e.g., aerobic endurance, anaerobic capacity, agility, etc., and also to sport-specific skills in team (basketball, soccer, etc.) and individual sports (tennis) and to more technical skills in track and field and swimming. There is also a need to include an indicator of biological maturity status given its impact on the growth and performance of adolescent boys [3].

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PROFESSIONAL BURNOUT IN FEMALE AND MALE PHYSICAL EDUCATION TEACHERS – A FOUR-PHASE TYPOLOGICAL MODEL*

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ABSTRACT
Purpose. The best-known concept of professional burnout is the Maslach tri-dimensional model. According to the author, a burnout process starts by increased emotional exhaustion, followed by reduced personal accomplishment and, ultimately, depersonalization. Progressing with time, the syndrome is manifested differently in various individuals. Recognizing the tri-dimensionality of the phenomenon, Golembiewski suggests a reverse direction of symptom occurrence and proposes an eight-phase model of the phenomenon intensification. The two different approaches to the dynamics of the burnout process have been called *facing theories*. The problem of *facing theories* has been solved by developing a concept based on data clustering, in consequence, arriving at a typological model where the four-phase model of professional burnout represents a special variant. The premises of the general model are as follows: tri-dimensionality of the syndrome, temporal continuity of the process, macro-path specific for a given profession (a cluster of individual paths), the effect of external factors. **Basic procedures.** The study was carried out between May 2006 and June 2007. The number of PE teachers was $N = 1563$: females $N = 686$ (43.9%); males $N = 877$ (56.1%). *The Maslach Burnout Inventory* (*MBI*) was employed. Statistical methods: data clustering (K-mean method), U Mann Whitney test. **Main findings.** With the use of the four-phase model, two macro paths illustrating the dynamics of burnout in female and male PE teachers were plotted. The different courses of burnout paths were determined by a significantly higher depersonalization level in men ($p < 0.001$). **Conclusions.** Initially (phase T1), females and males reacted to professional stress with emotional exhaustion (the Maslach's path) or reduced personal accomplishment – in both genders, in phase T1, the path bifurcated. At a high emotional exhaustion level, women began to depersonalize their pupils (phase T2) and get burned out (phase T3; $N = 98$, 14.3%). The second macro-path of female teachers terminated in phase T2. One macro-path of male teachers was identical with the macro-path characteristic of females (T0-T3), while the other illustrated burnout in young male teachers – with reduced personal accomplishment at school (T1), cynicism increased (T2) and the effect was burnout (T3, $N = 99$; 11.3%).

Key words: professional burnout, four-phase typological model, macro-path, PE teacher

Introduction

Teachers tend to burn out while doing their job, a problem which has been studied for many years now. Since the number of researchers who deal with effects of professional stress has increased, they tend to specialize in studying the problems of teachers of different subjects [1, 2]. The first papers on the burnout syndrome in physical education teachers were published in the 1990s [3], and the interest in the issue continues nowadays. During a poster session at the ECSS Congress in 2008, three research reports on the issue [4–6] were presented. In the same year, a scale to diagnose the syndrome in PE teachers in secondary schools and universities [7], as well as Otero López's paper [8] were published. In Poland, the *subject taught* variable was introduced for the first time by Tucholska [9]; she characterized, among others, a group of PE teachers in comparison to the results of the cross-sectional study. A thorough research on the phenomenon of burnout in PE teachers has been carried out by Brudnik [10–13] and Pec [14, 15].

Irrespectively of the correlated studies which included in the model either factors leading to or protecting against burnout, some longitudinal research was conducted. Its objective was to detect existing regularities when the phenomenon was increasing [3, 16, 17]. Among Polish PE teachers, no longitudinal research has been conducted yet. However, an attempt to describe the syndrome progressing over time has been made by applying the four-phase typological model, worked out on the basis of the two theoretical concepts proposed by Maslach and Golembiewski [11].

Christine Maslach defines the syndrome of burnout as a tri-dimensional phenomenon progressing over time. This is the syndrome of physical and emotional exhaustion which leads to a negative self-evaluation and negative attitude towards work, as well as a lack of interest in problems of the people one is in contact with due to one's professional duties (e.g. patients, customers,

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or others one is in charge of). Burned out persons are those who, during a measuring session (*Maslach Burnout Inventory*), obtained above average results [18] in each of the three dimensions of the syndrome – emotional exhaustion (EE), a reduced or even negative sense of personal accomplishment (PA; reverse scale) and a tendency to depersonalise people around them (DP).

Looking for the possible applications in burnout prevention, Noworol and Marek [19] assumed that representatives of each professional group, due to the specific stress resulting from the character of workload and job environment, burn out individually. Based on Maslach's theoretical assumptions, Noworol proposed a general theoretical Phase Model, which through the introduction of time dimension allowed for the construction of four-dimensional space, "where the burnout process is a certain stochastic function characteristic of each person representing a given profession." [20, p. 30].

$$[1] \qquad O_{nZ} = F_Z(\text{EE, PA, DP}, t; p),$$

where:

F_Z – function describing the course of burnout process;
O_{nZ} – person No. n representing a profession from group Z;
EE, PA, DP – variables of burnout syndrome;
t – time;
p – probability (after: [20, p. 30]).

The stochastic function F_Z is characteristic of a given group of professions Z. According to Noworol, by applying function F_Z, it is possible to determine exactly the course of burnout in representatives of different professions.

Figure 1 shows graphically the ways of burning out in relation to a group of professions, where the curved lines indicate a stochastic process of burnout of a given person in a given profession (micro path). The curves which indicate the burnout process in qualified staff of different groups of professions (macro path) result from the bundle of micro paths of representatives of a given profession. It should be noted that the process does not develop in a linear way. The wavy graphs indicate the evolution of the syndrome as a resultant of external factors occurring on the career path and coping processes conditioned by the individual resources. In this approach, the burnout process is a consequence of professional stress.

The stochastic process expressed by the formula *[1]* has no major significance, either for the explanation of burnout or its prevention. In the attempt to construct a model which has a practical application both from

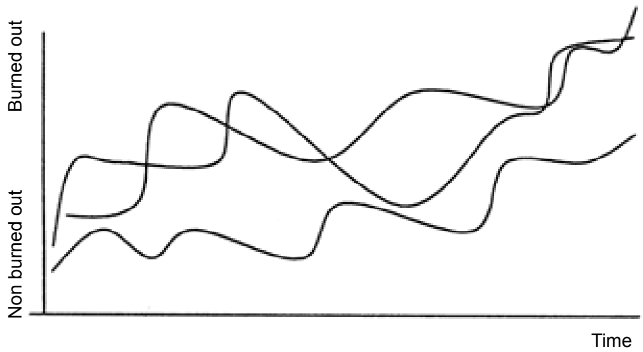

Figure 1. Graphic visualization of the general stochastic model of the professional burnout syndrome; horizontal axis – work time t, vertical axis – burnout level [20, p. 30]

cognitive and utilitarian points of view, the projection of a general model – in any point of time – was done onto the tri-dimensional space of Maslach's model W = (EE, PA, DP) [20].

Maslach claims that the burnout process begins from increased emotional exhaustion, which is followed by reduced personal accomplishment. As a consequence of increased mental exhaustion and disillusionment with one's career, a progressive process of depersonalization begins, which means distancing oneself from the specific stress that is caused by another person and his/her problems and in this way leading to burnout [21].

Emotional exhaustion → negative sense of personal accomplishment → depersonalization

Robert Golembiewski, in making use of Maslach's theory suggests a reverse sequence of the appearance of symptoms, which means an opposite direction of the course of burnout paths. According to him, depersonalization, also perceived as an effect of stress causing the lowering of the sensitivity threshold and, in consequence, the occurrence of dissociating behaviours, is the factor which occurs first. As a result of people distancing themselves from someone, with whom they are in a professional relationship and who is suffering from burnout, the affected individual experiences a reduction in the self-esteem and self-evaluation of his professional accomplishments. As a result of the growing – through an increase in other symptoms – syndrome, the employee begins to react in the emotional sphere, thus burning out emotionally [22].

Depersonalization → negative sense of personal accomplishment → emotional exhaustion

The burnout process described by Maslach and Golembiewski can be represented as two paths with an identical sequence of occurring symptoms, but with opposite vectors. Two different approaches to the syndrome evolving with time were called *facing theories* [23]. The concept of *facing theories* was applied to construct a general typological model of burnout in qualified staff.

The general typological model explaining the burnout syndrome was created on the basis of Golembiewski's eight-phase model [19]. A coherent interpretation of apparently contradictory *facing theories*, describing both the phenomenon of burnout in a different way and at the same time the application of the approach in practice, were possible thanks to Noworol's theoretical concept based on data clustering. The method allows for a presentation of the burnout process on a typological model, thus a statistical analysis of the results in each point of time of Noworol's model is based on data clustering [20]. The model can be used to plot a macro path of burnout typical of a given profession or an organization employing qualified staff.

Assumptions of the general typological model of burnout in the qualified staff's careers:
- Tri-dimensionality of the syndrome resulting from the definition adopted by Maslach;
- Continuity of the burnout process over time;
- Macro path of burnout specific for a given profession, which consists of individual paths (micro paths) of representatives of this professional group (Fig. 1);
- Possible influence of external factors which can modify the image of burnout (organizational behaviours, culture, management style, etc.) [20].

A particular case of a typological model is a four-phase model of burnout (Fig. 2). In this approach the burnout syndrome was presented as a process progressing over time and comprising four main stages. These are: phase T0 – non-burned out, the successive two complex phases T1 and T2 showing various stages, intermediate phases of the syndrome, and phase T3 – burned out.

The process of burning out can have different courses, which means that it is specific for a given person (micro path) or professional group (macro path) (Fig. 1). On the basis of the four-phase typological model, *facing theories* are explained through two separate paths characteristic of two families of professions. Maslach's path describes the burnout process in social professions, for example, a physician, nurse, or teacher, whereas Golembiewski's path explains an increase in the syndrome mainly in managerial professions [20, 23] (Fig. 2).

Based on the results of the research carried out among Polish physical education teachers, it has not been possible to plot, using the four-phase typological model, a complete macro path showing the burnout process in teachers of this subject. Phase T2 adopted after Noworol's model [11] requires further explanation.

The aim of the study is to plot a macro path of burnout in both female and male physical education teach-

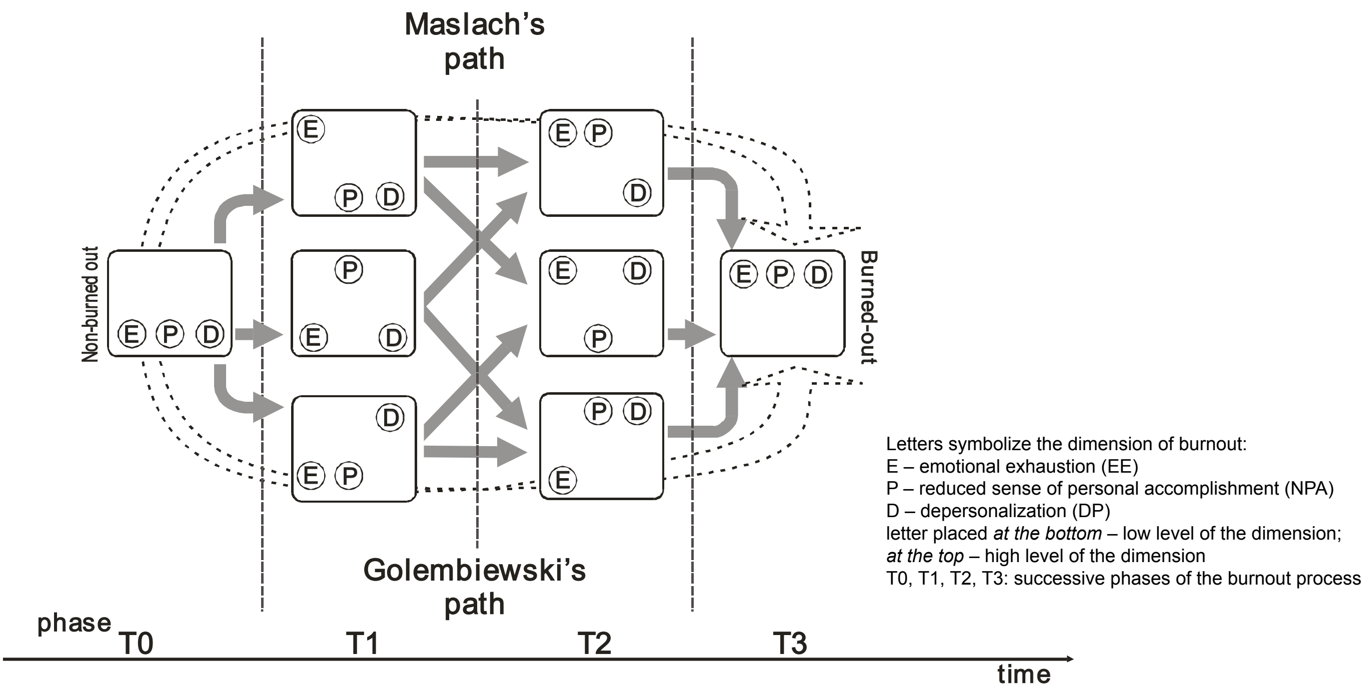

Figure 2. Structure of the four-phase typological model of professional burnout with the plotted Maslach's and Golembiewski's paths [23, p. 58]

ers. A hypothesis has been advanced that the course of the macro path of burnout in the subjects is in line with Maslach's emotional path which explains the burnout phenomenon in social professions.

Material and methods

A diagnostic survey among female and male PE teachers (N = 1563) employed in primary schools (grades IV–VI), lower, and upper secondary schools was carried out between May 2006 and June 2007 using a random sample selection. The geographical area covered by the research comprised three regions: Opole, Greater Poland, and the Subcarpathian region; i.e. their main cities, province towns and districts.

For the diagnosis of burnout, the *Maslach Burnout Inventory* (*MBI*) questionnaire adapted to Polish conditions was used (Noworol 1993, typescript). The MBI questionnaire was used to determine the burnout level as a consequence of chronic emotional stress at work. It consisted of 22 statements grouped into three subscales: emotional exhaustion EE – 9 items; sense of personal accomplishment PA (reverse scale NPA) – 8 items; depersonalisation DP – 5 items. Each subject rates the statements on a seven-point scale determining frequency of occurrence of a given state. The scale ranges from 0 – *never*, to the value 6 – *every day*; intermediate values of frequency are: *once/a few times a year*, *month*, *week*. The material was worked out with the use of data clustering (Mc Quin K-mean method) and U Mann Whitney test. Calculations were done by M. Rutkowski, GEM Kraków.

Results

The number of the physical education teachers involved in the survey was: N = 1563 including N = 686 women (43.9%), and N = 877 men (56.1%); respondents from the Opole region: N = 584 (37.3%), Greater Poland: N = 448 (28.7%) and the Subcarpathian region: N = 531 (34.0%). Teachers working in regional capitals, province towns and districts were respectively N = 367 – 23.5%; N = 915 – 58.5% and N = 281 – 14.0% of the sample. The mean age of the subjects was 38.1 years (women: 38.4 years; men: 37.9 years), mean work experience at school was 13.9 years (women: 14.5 years; men: 13.4 years) (Tab. 1, 2).

The variable of gender determines the structure of burnout in PE teachers. Men more often have a tendency to distance themselves and to treat pupils as objects (DP) (U Mann Whitney test: $Z = -4.910$; $p < 0.001$). In the case of the other two dimensions of the syndrome (EE, NPA), no statistically significant differences were observed.

Before analysing the burnout process, six homogenous clusters were differentiated in both female and male groups. Each cluster included subjects who had similar values of the three dimensions of the syndrome: emotional exhaustion (EE), a negative sense of personal accomplishment (NPA) and excessive tendency to depersonalisation (DP) (Tab. 1, 2).

A. Non burned out PE teachers – low mean values of dimensions EE, NPA, DP:
   - women: cluster V (N = 223; 32.5%);
   - men: cluster VI (N = 218; 24.9%);
B. PE teachers in intermediate phases of burnout (various patterns of burnout consistent with A and C):
   - women: cluster: I, II, IV (N = 355; 51.8%);
   - men: cluster: II, III, IV, V (N = 560; 63.8%);
C. Burned out PE teachers – high mean values of dimensions EE, NPA, DP:
   - women: cluster: III, VI (N = 108; 15.7%);
   - men: cluster I (N = 99; 11.3%).

By means of the four-phase model of qualified staff's burnout (Fig. 2), macro paths showing the dynamics of the syndrome in female PE teachers were plotted (Fig. 3), whereas Figure 4 shows the phenomenon in male subjects. In both cases, based on the data obtained, two paths of burnout were drawn.

The starting point of the macro path in female PE teachers (phase T0) is cluster V (N = 223; 32.5%; $\text{age}_{M = 38.3}$) including respondents who are satisfied with their profession (low mean values of dimensions EE, NDP, DP). The first phase of the syndrome (T1) is represented by clusters IV and II that split in phase T1 of the macro path, which suggests a possibility of two patterns in the case of female burnout (Tab. 1, Fig. 3).

Cluster II, explaining phase T1 of the first macro path of female burnout, includes women (N = 187; 27.3%; $\text{age}_{M = 39.2}$) who, in accordance with Maslach's concept, in the face of professional stress react with mental tension leading to emotional exhaustion ($\text{EE}_{M = 14.30}$). These are female teachers who, regardless of the feeling of tension, have a good contact with their charges and

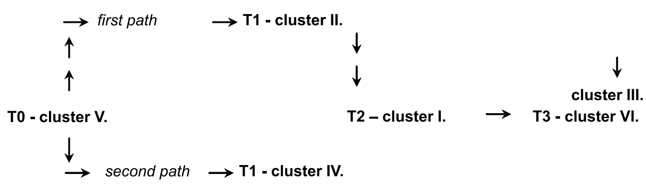

Figure 3. Macro paths of professional burnout in female PE teachers (N = 686) plotted on the four-phase typological model

Table 1. Professional burnout in female PE teachers (women $N = 686$); data clustering

Clusters	Professional burnout in female PE teachers $N = 686$						Age	Work experience
	dimensions	M	Me	SD	min	max	M	M
Cluster I $N = 53$ 7.7%	EE NPA DP	28.06 8.21 5.30	26.00 8.00 5.00	5.976 3.543 3.630	21 0 0	45 15 14	41.7	18.6
Cluster II $N = 187$ 27.3%	EE NPA DP	14.30 8.30 2.84	14.00 9.00 2.00	3.282 3.651 3.026	8 0 0	21 14 18	39.2	15.2
Cluster III $N = 75$ 10.9%	EE NPA DP	18.79 20.01 5.00	19.00 19.00 4.00	3.168 4.431 4.255	13 13 0	25 32 17	36.2	12.4
Cluster IV $N = 115$ 16.8%	EE NPA DP	7.90 19.51 2.53	9.00 19.00 2.00	3.286 4.847 2.667	0 13 0	14 35 13	37.7	12.4
Cluster V $N = 223$ 32.5%	EE NPA DP	5.25 5.61 1.78	6.00 6.00 1.00	3.038 3.622 2.508	0 0 0	11 13 12	38.3	14.6
Cluster VI $N = 33$ 4.8%	EE NPA DP	32.94 19.21 6.12	32.00 19.00 4.00	4.657 3.935 5.165	26 11 0	43 30 18	39.5	15.3
Total $N = 686$ 100%	EE NPA DP	12.73 11.10 3.03	11.00 10.00 2.00	8.787 7.206 3.429	0 0 0	45 35 18	38.4	14.5

Table 2. Professional burnout in male PE teachers (men $N = 877$); data clustering

Clusters	Professional burnout in male PE teachers, $N = 877$						Age	Work experience
	dimensions	M	Me	SD	min	max	M	M
Cluster I $N = 99$ 11.3%	EE NPA DP	20.72 19.34 7.25	20.00 19.00 7.00	4.061 4.457 4.402	14 12 0	32 36 19	37.5	13.1
Cluster II $N = 157$ 17.9%	EE NPA DP	16.31 6.08 4.09	16.00 6.00 4.00	3.821 3.456 3.356	10 0 0	28 13 18	39.6	15.5
Cluster III $N = 86$ 9.8%	EE NPA DP	9.44 25.21 4.27	9.00 24.50 4.00	3.664 4.999 3.418	2 19 0	18 40 15	36.0	11.3
Cluster IV $N = 238$ 27.1%	EE NPA DE	8.83 13.29 3.15	9.00 13.00 2.50	3.745 2.693 2.864	0 8 0	17 19 14	36.6	11.9
Cluster V $N = 79$ 9.0%	EE NPA DP	31.73 11.06 8.35	31.00 11.00 7.00	5.257 5.575 5.916	23 0 0	47 26 26	40.9	17.0
Cluster VI $N = 218$ 24.9%	EE NPA DP	5.07 3.75 1.70	5.00 4.00 1.00	3.188 2.799 2.569	0 0 0	12 10 12	37.9	13.3
Total $N = 877$ 100%	EE NPA DP	12.70 11.28 4.00	11.00 10.00 3.00	8.739 7.740 4.087	0 0 0	47 40 26	37.9	13.4

a sense of fulfilment at work. In phase T2, a macro path which originally followed Maslach's path is the first to change direction. The increasing emotional exhaustion ($EE_{M = 28.06}$) releases, as a mechanism of defence, depersonalising behaviours ($DP_{M = 5.39}$). Cluster I, representing phase T2 of the syndrome, includes mentally tired female teachers who more and more often underestimate their pupils' problems, although they are still professionally active and happy about their pedagogical accomplishments (N = 53; 7.7%, $age_{M = 41.7}$). The last link of the process – phase T3 – is cluster VI (N = 33; 4.8%; $age_{M = 39.5}$) which includes burned out women: Female teachers emotionally exhausted to a considerable extent ($EE_{M = 32.94}$), discouraged and tired of work at school ($NPA_{M = 19.21}$), and perceiving their pupils, who they liked some time ago as a source of problems ($DP_{M = 6.12}$) (Tab. 1, Fig. 3).

The other macro path of burnout in female PE teachers plotted on the four-phase typological model finishes in phase T1. Cluster IV (N = 115; 16.8%; $age_{M = 37.7}$) represents the process of increasing discontent in female subjects and gradual loss of job satisfaction ($NPA_{M = 19.51}$); the mean values of the other two dimensions of the syndrome (EE, DP) remain below the mean value (Tab. 1, Fig. 3).

While analysing burnout in female PE teachers, cluster III (N = 75; 10.9%; $age_{M = 36.2}$) draws particular attention as it – together with VI – explains the final stage, i.e. phase F3, plotted on the model of the macro path for female burnout. The cluster comprises entirely burned out female teachers (age categories: 23–29 years: 18.7%; 30–39 years: 48% of subjects), which suggests that these women – while burning out – took the shortest emotional direction as per Maslach's path. Female respondents deprived of defensive mechanisms, such as the ability to maintain distance from difficult pupils (or superiors), have to face school difficulties which in their opinion are impossible to overcome. These are persons who at the beginning of their career came across particular difficulties or took up the job not because they wanted to become teachers, but because there were no other possible professional career options (Tab. 1, Fig. 3) [24, p. 20].

Successively, two macro paths explaining burnout in male PE teachers were plotted on the four-phase typological model, which is shown in Figure 4. Phase T1, like in the case of women, is explained by two clusters. The two paths which are sequences of four clusters terminate in cluster I (N = 99) which comprises burned out teachers (phase T3).

The first macro path of burnout in male PE teachers is analogous to the first macro path in women (T0-T3)

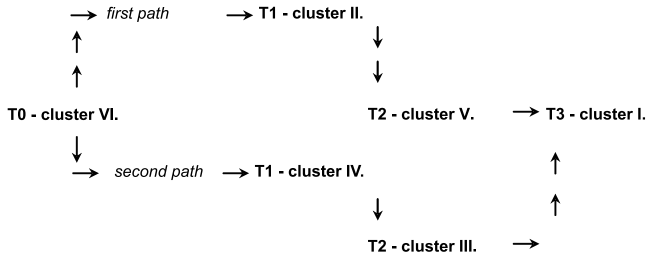

Figure 4. Macro paths of professional burnout in male PE teachers (N = 877) plotted on the four-phase typological model

(Fig. 3). Male teachers included in cluster II (N = 157; 17.9%; $age_{M = 39.6}$) while burning out – phase T1 – react to professional stress with emotional tension ($EE_{M = 16.31}$) (Tab. 2, Fig. 4). Phase T2 is explained by cluster V (N = 79; 9.0%; $age_{M = 40.9}$) – a picture of increasing emotional exhaustion ($EE_{M = 31.73}$) accompanied by a constant intermediate level of job satisfaction ($DP_{M = 8.35}$). As a result of increasing disillusionment of working with youth, male teachers burn out – phase T3 (cluster I.; N = 99; 11.3%; $age_{M = 37.5}$) (Tab. 2, Fig. 4).

The other macro path of burnout in male PE teachers consists of a sequence of clusters which shows the way followed by burned out teachers whose first reaction to occupational stress is disillusionment and a sense of dissatisfaction at work (phase T1).

The first signals of unfulfilled expectations of respondents disappointed with school reality ($NPA_{M = 13.29}$) occured among teachers included in cluster IV (N = 238; 27.1%; $age_{M = 36.6}$). A successive phase of burnout T2 is illustrated by cluster III (N = 86; 9.8%; $age_{M = 36.0}$) – teachers have no signs of mental exhaustion, but their increasing discouragement towards pedagogical work is followed by cynicism and a considerable tendency to treat pupils as objects ($NPA_{M = 25.21}$; $DP_{M = 4.27}$) (Tab. 2, Fig. 4).

The macro path seems to be characteristic of young men, which is indicated by the mean age of male PE teachers burning out according to the following pattern: cluster IV, (T1) $age_{M = 36.6}$ (age category 23–29 years: 29.0%; 30–39 years: 38.7% of subjects); cluster III, (T2) $age_{M = 36.0}$ (age category 23–29 years: 33.7%; 30–39 years: 34.9%) (Fig. 3). The position of cluster III in phase T2 of Golembiewski's path indicates a considerable rate of increase in psychophysical exhaustion and, in consequence, an immediate occurrence of all the symptoms of the syndrome (cluster I; N = 99; 11.3%; $age_{M = 37.5}$) (Tab. 2, Fig. 4).

To sum up, the burnout process in male PE teachers can follow one of two courses, i.e. the above defined macro paths (patterns), thus cluster I (N = 99) includes the burned out men who ended up there after having covered two different macro paths (Fig. 4).

Discussion

The burnout syndrome progresses with time, which is one of the assumptions of the four-phase typological model of burnout in qualified staff, however, it should be emphasized that this research is not a longitudinal study.

Due to the results obtained, it was possible to plot the independent macro paths of burnout in the professional group of physical education teachers, illustrating different courses of the process in female and male teachers. The different courses of macro paths for women (*N* = 686) and men (*N* = 877) were determined by a greater tendency of male PE teachers to treat pupils as objects ($p < 0.001$) and, as one can suppose, another way of coping with difficult situations occurring during school work.

The macro path of burnout typical of female PE teachers has the following course:

Non burned out teachers T0
→ emotionally exhausted T1
→ emotionally exhausted, and detached from professional problems T2
→ burned out teachers T3

whereas in the case of a vast number of young female PE teachers, the first reaction to the stress generated by school work is a loss of job satisfaction (Fig. 3). There is good reason to believe that young female PE teachers who are burning out faster, burn out following Maslach's emotional path.

In the case of male PE teachers, the burnout process can follow one of the two macro paths:

– macro path typical of male PE teachers:
Non burned out teachers T0
→ emotionally exhausted T1
→ emotionally exhausted, and detached from professional problems T2
→ burned out teachers T3

– macro path typical of young male PE teachers:
Non burned out teachers T0
→ disappointed with their job T1
→ disappointed and detached from professional problems T2
→ burned out teachers T3

Additionally, this study explains the incomplete macro path of burnout in female and male PE teachers plotted on the four-phase typological model (*N* = 256; women: *N* = 144; men: *N* = 112) [11, p. 13, Fig. 7!]. The macro path indicates phases: T0-T1, signalling the beginning of the burnout process in teachers (phase T1), from a gradual loss of sense of competence and job satisfaction (NPA). Comparing the macro path plotted without taking into consideration the variable of gender (*N* = 256) with the patterns of burnout in women (*N* = 686) and men (877) worked out on the basis of the research presented here, it was noted that both in the case of female and male PE teachers, the second macro path (women T0-T1; men T0-T3) representing the form of burnout in younger teachers (Fig. 2, 3) somehow becomes an inherent element of the macro path of PE teachers in view of the identical course of the paths in phase T1.

The results of the research carried out in 2003 revealed a slightly higher level of emotional exhaustion (EE) in women ($p < 0.05$) [11]. More detailed, successive studies showed that women and men react differently to difficult situations taking place while working at school. A female teacher's reaction to childrens' bad behaviour was the gradual loss of a sense of personal accomplishment (NPA); pupils' aggression increased emotional exhaustion (EE) in women. Men, in the face of lack of discipline, had a tendency to depersonalise their pupils (DP) [12]. Poor sports facilities explicitly generated burnout in women (EE, NPA, DP), whereas for male PE teachers the main problem was to work when there were two groups of pupils having lessons simultaneously in the gym (NPA, DP). For women it is important to work in a favourable emotional and social school atmosphere, which includes maintaining good relationships with pupils' parents (NPA) [12]. The presented results indicate that external factors, such as pupils' behaviour, school sports facilities, perceived importance of the subject, and emotional and social atmosphere at school can, in the case of PE teachers, modify the picture of burnout in women and men, determining in this way the course of macro paths of the syndrome.

Other studies dealing with the problems of burnout in the professional group of PE teachers, in spite of the ambiguity of their results, seem to confirm the importance of the variable of gender. Ogul and Tinazci [6], indicating slight differences in burnout in Cypriot female and male PE teachers, noted that women got emotionally exhausted more easily, whereas from the very beginning, men were more at risk from burnout syndrome ($p < 0.05$). The findings of research on stress and burnout in PE teachers carried out by Lee et al. [25] suggest conducting separate analysis for groups of women and men.

On the basis of the results obtained, it is difficult to arrange unequivocally the sequence of clusters in macro paths representing burnout in Polish female and male teachers of physical education. In spite of that, in both cases typical courses of macro paths were traced; they follow Maslach's emotional path in the first phase of the progressive syndrome. Moreover, other variants of professional burnout were discovered, as well. Another especially interesting finding, apart from distinctive typical macro paths for women and men, is a course of macro paths typical of burnout in young women and young men.

Conclusions

On the basis of the results obtained, the following conclusions have been reached:

1. In the professional group of physical education teachers, the variable of gender differentiates the courses of macro paths of burnout.

2. Typical macro paths of professional burnout in female and male PE teachers follow Maslach's path only in the first phase of the process.

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ZOMBIES AND MUSCLE MEMORY: RETHINKING SOMATIC CONSCIOUSNESS AND THE MIND-BODY PROBLEM

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ABSTRACT
In this paper I am going to argue on the existence of somatic consciousness, which has a special importance in resolving the mind-body problem. The discussion will include such issues as the range of somatic consciousness and the possibility of improving such an idea not only by interdisciplinary scientific studies but also through contemporary analytic philosophy of mind.

Key words: consciousness, somaesthetics, mind-body problem, muscle memory, zombie

Introduction

Consciousness has been carefully studied in the field of philosophy of mind. However, its discourse has strongly emphasized the importance of the mind while overlooking or misunderstanding the importance of the body. The reason for this imbalance is the strong traditional tendency to focus on the spiritual mind over the material body in the history of philosophy. Yet, no matter how deeply dogmatic this point-of-view is, we cannot just keep excluding the whole discourse of this tradition in the philosophy of mind. Besides the fact that this view has some clear points in explaining what consciousness is, the outlook of the philosophy of mind is deeply rooted in our common understanding of consciousness in terms of culture, religion, and science. In this paper, I wish to revise the view of those philosophers of mind by adopting in it Richard Shusterman's idea of somatic consciousness [1] rather than simply reject the whole discourse of philosophy of mind.

I believe this alterative attempt opens up a proper place for somatic consciousness within philosophy of mind and also surely enriches our general understanding of consciousness in the discipline of philosophy of mind. Before I scrutinize the reason why somatic consciousness has its importance in the problem of mind and body, let me begin with what the mind-body problem is and how philosophy of mind has inherited insufficient attention to the body.

The Mind-Body Problem

The problems of mind-body and consciousness are the crucial issues in the discourse of philosophy of mind. The mind-body problem was introduced in its modern form by Descartes and his contemporaries in the 17th century and because of this origination the problem has always brought with it the consideration of dualism. Descartes thought the mind and body were separate so if we make a movement like drinking a cup of coffee, it can be explained by examining the mind because our body is just something that executes the order of our mind. However, if they are indeed totally separate, how can the mind actually exercise its power over the physical world of our body? And how can we explain the relationship between body and mind in this sense? If the body follows the decisions of the mind, it means they should have a certain relation. The mind-body problem has been argued in various schools of philosophy. Roughly we can divide them into monism and dualism. Even though the details of their arguments are slightly different from each other, and some forms of monism seem similar to dualism, it is still possible to draw a line for basic understanding. To put it simply, dualists believe the mind and body are separate entities, but monists believe they cannot be divided because they are one.

Nowadays, dualism has almost lost its validity, while physicalism, which is monistic has taken over in its place. We can say the reason for this is that classical dualism's explanation for the causal relationship between mind and body is often blindly dependant on God. With our realization of scientific understanding and weakening religious belief, people have come to need a better explanation. However, it is not fair to say that for dualism the most primary aspect is only the existence of God, if we were to also consider contemporary dualists. The clearer reason for the falsity of dualism is "some shared set of assumptions about the mental and physical" world [2, p. 6]. Dualism still remains strong in commonplace perception because of its explanatory convenience. Although dualism is not the main focus of this discussion, it is necessary to review briefly its main views and explain how it made such a strong impact on our intellectual world. Although the details and axis of the separation for dualists are not quite identical, most dualists might be reluctant to embrace "somatic consciousness" because, while "somatic consciousness" is both bodily and mindful consciousness, dualists believe in the division between *body* and *mind*. This dualism includes a tacit hierarchy which sees *mind* higher than *body*, therefore *mind* is more important.

As matter of fact, this mind-body dualism has a very long historical background in philosophy. We have always been interested in what happens to our mind and body after death and how they are different from inert objects. This question attracted ancient philosophers in both the Occident and the Orient, and their task was to figure out what is this thing which moves the body and keeps it alive. Pre-Socratic philosophers, such as Parmenides, the Eleatics and Plato, the major founders of Western thought, are considered as the inventors of the dualistic view on body and mind and although it is not pure dualism in the strictly modern understanding of the term, this platonic scheme was adopted into early Christianity by Plotinus.

Cartesian dualism is considered the first modern attempt to show this problem more cleary. The logic is that we can literally (if we have ability to move our body) touch or hit our body but we cannot physically hit the mind, and in that sense, both cognition and emotion are also untouchable. This statement is very compelling but this strict Cartesian dualism is faced with a two-fold question. If the mind is entirely mental, how does it exercise its power over our physical world? And how does the body undertake its tasks? Schopenhauer is famously quoted as claiming "the world knot", which surely provides an insightful view of the problem, but not a lucid answer [3, p. 9]. It may even create more complexity in the problem; as, what is the world knot? We do not wish to make such a difficult problem even more knotty. Then, why do we not forget about the mental, spiritual aspect and just put everything into the physical world? In such a way we do not have to worry about this perplexing body-mind problem anymore.

Contemporary Trials to Solve the Body-Mind Problem

Some logically well trained philosophers further developed this thought and established the idea of physicalism. Although there are various views of physicalism, it is hard to say that all physicalists are monists in the strict sense of the word. For example, Galen Strawson insists that his position is physicalist but his view is commonly classified as property dualism or neutral monism. Physicalists believe everything can be explained as a physical activity or phenomenon, so we can still say it is basically monistic [4–6].[1] This physicalism, especially its revised version, such as emergentism, somehow holds a central place in philosophy of mind but even physicalists still have ardent debates debate on the body-mind problem. Emergentism is a type of physicalism and therefore it should be monistic, but since emergentism embraces qualia (raw feel, what-it-is-like [7]) which have difficulty in being explained in only physical terms, emergentism is not purely monistic [8]. Paradoxically, physicalism has more validity when it opens possible place for mind, which is not physical, but if physicalism is in line with its own tenet, then it must be able to explain the mind or the body-mind relation only as a physical entity. Once they admit there is no physical entity such as qualia, the physicalists' answer is just "something near enough", and it may be enough for the philosophers who have studied *a certain near enough tradition of philosophy* [8].

There can be another simple solution for this. What if there is no relation between the mind and body? Epiphenomenalists believe our mental states are just epiphenomena which are side effects of the physical state of the world and therefore the mind does not have any relation to the body. The problem of epiphenomenalism is that its very concept is contradictory. If epiphenomena do not relate to the physical world, how can we have the idea of epiphenomenalism and how can someone actually explain what epiphenomenalism is in our physical world?

Our use of the terms *body* or *mind* is vague and also our bodily understanding of *body* and *mind* is even more unclear in most of our everyday life. There is no simple answer, or maybe there is no definite answer, to this question because our view of body, mind, and their relation is continuously changing, being revised and influenced by cultural, historical events, scientific discoveries and also some intellectual trend of the era. In all probability, it is not important *whether body and mind are separate* (*or not*) *or mind is physical* (*or not*). Indeed, we do not have to decide which philosophical tradition is better to solve this problem. The obvious thing is that

[1] Galen Strawson claimed physicalism should entail panpsychism which holds the view that all matter or all objects have a mental aspect and moreover they have a unified center of experience. William James, who built the foundation of pragmatist philosophy of mind, also held a pioneering view of panpsychism [6, 9].

although none of them succeeded in giving a definite answer, they certainly enriched our discourse on *body* and *mind* and *the body-mind problem* and moreover, this problem may even be better left definitively unsolved. The more important thing is not to find a definite answer or to choose a philosophical stance but to take a broad view of the whole discussion of this problem.

The obvious problem which philosophy of mind should deal with is to balance the view on the body-mind problem by careful investigation into the *body* and also providing place for the *body* in its discipline. We can find this bias even in its name – *philosophy of mind*. It is not *philosophy of mind and body* although its central concern is to define the relation between mind and body. The *Body* is used supplementary to explain the mind and it has not been fairly examined. How can philosophers of mind find the right answer to the problem if they have this strongly biased stance on the problem itself? It may be possible but they in fact may have to first deal with their problematic orientation. But it does not mean we should just ignore the whole discourse of philosophy of mind. Although they have problems in their orientation to make it a truly independent discipline of philosophy, we can still use their way of thinking in the process of dealing with the mind-body problem and enrich our understanding of the mind-body problem. What I want to suggest in order to eliminate this deficiency in philosophy of mind is a sufficient investigation into the body to make the discourse balanced. That is to say, philosophers of body and mind should be focused on the *body* not as a cold material thing but as something which has conscience, sentience and qualia since just the opposite way of thinking has been dominating philosophy of mind.

Embodied consciousness is also claimed by various scholars such as Mark Johnson, George Lakoff, Alva Noë, and neurologist Antonio Damasio [10–13]. Although they made clear points against dualism and the pointless superiority of mind it is still possible to find a narrow and somewhat biased view in their attempts because it seems like they are reluctant to challenge their own professional orientation and also, unfortunately, they focus on the mostly conceptual or scientific explanation to the body-mind problem. This kind of theoretical approach is also effective because in this way they can show the value of somatic study to many philosophers of mind since they still share the stance that it is more important to win the theoretical debate than to find a better way to improve “body consciousness”. But if the body really is important in philosophy, a better philosophical attempt should be its taking into consideration how to improve it in the first place. The thing which forms “somatic consciousness” and turns it into the trully meaningful somatic consciousness, should not be explained by only theoretical scientific reasoning but also by bodily experience and somatic understanding. In that sense Shusterman’s somatic consciousness actually widens the range of consciousness by emphasizing the *body’s* cultural, educational, and practical dimensions and I believe it can be one of the most proper ways in correctly placing *body* and *consciousness* in our philosophical life.

However, there are two problematic tendencies in Shusterman’s wide and insightful view on body and mind philosophy. The first one is his neglect of the contemporary analytic philosophy of mind. Although he started his career as a hardcore analytic philosopher, it seems that his orientation in research actually goes in the opposite direction[2]. Moreover, in his book *Body Consciousness*, where he presented his philosophy of mind, Shusterman mainly discussed six important body philosophers: three continental philosophers such as Foucault, de Beauvoir, and Merleau-Ponty, charismatic philosopher Wittgenstein, and two important pragmatists William James and John Dewey. One might argue whether Wittgenstein can be considered a hardcore analytic philosopher, although many contemporary analytic philosophers are inspired by his philosophy, but still he is more influential in philosophy of language and not very much in philosophy of mind. It is difficult to see him joining the current mainstream hardcore philosophy of mind if he were still alive.

In that sense William James has more of a chance in this field and actually his interpretation is considered one of the major views in the contemporary philosophy of mind[3]. However, in Shusterman’s book, his attempt was not focused on those arguments in the contemporary philosophy of mind and it seems as if he ignored their arguments on purpose. It seems that his main concern was to find a link between Damasio’s neurology and James’s philosophy of mind. Indeed, he thinks

[2] Shusterman did his D.Phil. in Oxford under the supervision of the analytic philosopher J.O. Urmson. Shusterman was also the editor of *Analytic Aesthetics* (1989). The very first academic philosophical education of Shusterman was at the Hebrew University of Jerusalem with the hardcore realist Eddy Zemach. Even before his major philosophy of body and mind book, *Body Consciousness*, Shusterman dealt with the problem while developing his own terminology, “somaesthetics” [14, 15].

[3] This James’s view which grew out of his “neutral monism (which could be also considered as a kind of dualism)” [5, 6] is also called “parallelism” or “strong emergentism”. This powerful view can be considered the origin of both David Chalmers’ property dualism [16] and also Richard Shusterman’s anti-dualistic (but which should not be a radical one) pragmatist philosophy of mind [1].

"Damasio offers a scientifically updated version of James's argument" [1, p. 151]. And it is also hard to find a discourse on the contemporary analytic philosophy of mind in his other texts that relate to philosophy of mind. It seems he is almost reluctant to deal with the contemporary analytic philosophy of mind.

Probably, his tendency started with the academic guilt of being an analytic philosopher who inevitably inherited a narrow and rigid tradition. However, if his philosophy of body and mind – somaesthetics – claims to be "an interdisciplinary field of theory and practice broadly defined as the critical study and meliorative cultivation of the soma," [17, p. 15] it needs to consider the contemporary views in philosophy of mind as they ultimately are aiming at the same goal.

The second problematic inclination that Shusterman's somatic consciousness has is that its focus is mainly on the living body or the world in which we live in but not on the dead corpse or in the imaginary world of ghosts because his use of "the term 'soma' indicates a living, feeling, sentient body rather than a mere physical body that could be devoid of life and sensation." [1, p. 1]. Since we should deal with our *embodied world* first, one might argue that it is not a serious problem to omit the dead corpse or ghosts, which only invoke the image of "mere physical body", or of non practical metaphysics or spiritualism. However, it should not be forgetten that death is a part of life as well as life being a part of death; therefore, when we think about life, the issue of death always comes along with the main issue of life. Indeed, the philosophy of body and mind has a deep relation with our curiosity of what we are going to be after our life ends. Originally, the mind derives from ψυχή which is the ancient Greek notion for soul or spirit and the term was also used to discriminate a dead corpse from a living body. For example, Plato defined death as the separation of the soul from the body, which also provided one of the original roots of dualism.

Since we have already adopted a useful solution to the body-mind problem, it is not just the question of choosing the side of "dualism" or "monism", it is "somatic consciousness" that can challenge this meaningless fight waged over the centuries, we do not want the major function of the term "somatic consciousness" to be a weapon to defend "monism" or "holism" against "dualism". It seems that a more useful way to use its open but clear meaning is to actually to try a new project that other concepts could not be able to challenge, which means not only trying to do interdisciplinary research but also in trying to close the gap between philosophical schools.

Is there any way to bridge the gap between practical philosophy and the philosophy of the imaginary world, between a humanistic meliorative view and objective metaphysical realism, and between life and death? Since this question considers a wide range of fields, it is impossible to develop a detailed argument here. However, it is probably not a bad idea to show a possible direction for the next step. What, I am going to attempt is to make a quite extreme mixture of the thoughts of the most powerful living body philosopher Richard Shusterman and the hardcore analytic zombie dualist David Chalmers. However, this attempt may be still asymmetrical because the main goal of this attempt is a revised version of the practical and meliorative thinking of pragmatism of which William James and Richard Shusterman are also a part of. I should also mention that the main reason of my attempt is not just to become a winner of this philosophical debate by claiming that a "better open concept can actively deal with the body-mind problem" but also because of an academic guilt that one does not want to have by choosing one side with non-philosophical favoritism.

Zombies and Somatic Consciousness

The famous philosophical zombie argument which was argued by David Chalmers shows how the body is treated in philosophy of mind, especially in physicalism, which is dominant in recent philosophy of mind. This argument mainly claims that if zombies are conceivable; physicalism is logically flawed because physicalists believe mental states (or mind) can be explained in terms of physical phenomena such as behavior or neural activity, whereas zombies obviously have a certain behavior but they do not have mind [16, 18]. There are various debates, including denial of the argument itself, on this problem [19]. For example, John Searle criticized Charmers' dualism because it is "not the current view among the professionals in philosophy, psychology, artificial intelligence, neurobiology, and cognitive science" and "the only substance dualists (…) are those who have a religious commitment to the existence of a soul" [20, p. 414]. According to Searle's criticism, the zombie argument seems to be an element of old traditional dualism which gets its support only from a kind of religious commitment and moreover, it seems conceivable, one might argue, that this whole zombie scenario was just something roughly coined to attack physicalism.

Although I think "zombies are conceivable", it seems that there is no good reason for trying to further investigate Charmers' dualism. However, it is still interesting to note why this example gained such attention and how this experiment actually appeals to us. The success of the thought experiment seems to have a more useful goal other than supporting his dualism which I am going to develop here. It is not the most important thing that zombies are conceivable or not. The more important thing is that this idea of zombies is based on the view that without a conscious mind the human body is like a *zombie*. Can we try a slightly different zombie thought experiment which does not use explicit consciousness but the most implicit and also weak consciousness which is the most similar to zombie consciousness? This experiment requires not only our mindful consciousness but also the sense of light or lower consciousness, which is directed toward zero consciousness, like zombie's and, what is the most important, the *imaginative mind* which lets us somatically imagine what it is like to lose consciousness, like in a zombie.

Let us imagine becoming a zombie. We do not have thoughts. We do not have beliefs. We do not have feelings. We do not have consciousness. Suddenly, our legs and arms are moving slowly toward a certain direction. Our brain has not made any orders to move them. Someone must be controlling our bodies. Now, in our imaginary world we have become zombies. When did we get the idea of becoming a zombie? Recall the moment we started thinking about becoming a zombie. Actually, it is difficult to have a clear image of becoming a zombie by eliminating all thoughts or beliefs since thoughts and beliefs are abstract notion. Probably we gain a clearer image of being a zombie by thinking of our body parts executing orders from someone else's mind. It is because we have muscle memory which is analogous to the memory we use for imagining the state of a zombie. It seems as if the zombie appeal was effective not because of metaphysical validity but because of an imaginative quasi-empirical muscle memory. Now, I am going to find the theoretical place for this imaginative muscle memory in Richard Shusterman's artful muscle memory argument which does not yet include the imaginative dimension in it [17]. I wish this could be also a step for a cooperative movement between two opposite philosophical schools, namely *mind centered dualism* and *body centered pragmatism*. By doing this I believe they can eventually reduce any unnecessary hostility and also find applications for each other. However, this cooperative step should be based on a very careful scrutiny which includes respect for their important philosophical claims so that it does not produce another thoughtless melting pot which does not convey their original views.

Empirical Muscle Memory and Imaginative Muscle Memory

Shusterman sees muscle memory as implicit memory and defines "(m)uscle memory (as) a term commonly used in everyday discourse for the sort of embodied implicit memory that unconsciously helps us to perform various motor tasks we have somehow learned through habituation, either through explicit, intentional training or simply as the result of informal, unintentional, or even unconscious learning from repeated prior experience." [17, p. 5]. He analyses muscle memory dividing it into six different forms, in terms of: 1. "continuing personal identity" which is "remembering implicitly who one is", 2. locative identity which "is remembering *where* one is", 3. interpersonality (or intersomaticity) which concerns our being with "other bodies", 4. social institution which "recalls the distinctive social role", 5. "performative memory" which "we perform with effortless spontaneity", 6. trauma which one has from "intense shock or pain" and then he explains "how these problems of muscle memory can be treated by disrupting such memory through heightened, explicit consciousness involving methods of somaesthetic attention and reflection." [17, pp. 6–10].

Shusterman's "six forms of muscle memory" mainly focus on the empirical dimension of muscle memory, since they originated from "prior experience" and because his diagnosis is focused just on the experiential dimension, the treatment he suggests misses the quasi-empirical dimension which is not directly experiential (explicitly and also implicitly) but conceivable in our imagination. The quasi-empirical muscle memory which functions for the zombie thought experiment requires not only experiential memory but also sensual muscle imagination which makes connection between the prior muscle experience and our imagination.

Although his muscle memory and its pathology are focused on experiential muscle memory, in the detail of his argument, we can find a potential claim for sensual imaginative dimension of muscle memory. For example, he noticed "intersomatic" forms of muscle memory whose subjects "include non-human companions like animals." "Intersomatic" forms of muscle memory seem to offer the place of sensual imagination and also sensual imaginative muscle memory. However, since an intersomatic form of muscle memory develops by "ways of being with and reacting to certain other bodies", it requires "the presence of other bodies." So, according to Shusterman's analysis of muscle memory, if the body is something we have never (normally) been with, such as "zombies", or we have not ever experienced "the zombie state", there is no way we can have a kind of muscle memory which arises from sensual imagination of the zombie state or of any other non presentational body.

Besides having ontological validity, sensual imaginative form of muscle memory seems to deserve reconsideration for its important practical function which gives metaphorical clues for us to realize and describe what kind of state we are in. This is also the case of the sensual imaginative form of muscle memory which can actually improve our experiential practices. Sometimes we complain about not being able to move our body like we want; then our body is out of control and we feel as if somebody else is controlling our body in an unexplained way. Let us define this state as a quasi-zombie state. There is a good example of this state. To learn swimming it is important not to tense body parts but for a beginner it is hard to let his body relax, so he fails to float on the water. He might feel as if somebody was pulling him down thus hindering him to go forward, but there really is no one who prevents him from advancing. Eventually, he will learn to swim and he will feel that he is really alive. For some people learning to swim is not a difficult task, so some of you may have difficulty in understanding why he should feel "really alive". Then, think about any other difficult physical work which made you suffer from the inability to control your body. Similar experiences of difficulty in controlling the body frequently occur in the process of learning other kinds of sport and also in our everyday life.

We can even think of various levels of states between this quasi zombie state and the living body state. As I mentioned earlier, you might have stronger zombie-like feeling when you have less control of your body and when you are less conscious of your body. That is to say, if you have less body consciousness, the body becomes more zombie-like, whereas if you have more body consciousness, the body gains vitality. Then it seems like we can actually diminish the zombie-like state and increase the living body state by increasing body consciousness. Besides this particular case, we can also try a more detailed analysis of ontology and pathology of this imaginative muscle memory combined with Shusterman's analysis of empirical muscle memory. Since I have only a limited space to develop this idea, I will show only a few cases here.

1. The concept is – imaginative muscle memory can be a tool used for learning death. It is impossible to study death by experiencing it or using the report of someone who has experienced it (Although James actually used a case for his study, it cannot be taken too seriously here). Therefore, it seems to be impossible to use muscle memory to learn what it is like to have a muscle memory of death. However, we can use imaginative muscle memory to learn it by using some death-like experience, such as suspended animation, a coma, and asphyxia.

2. One can have a clearer idea of life by understanding imaginative muscle memory. Since both pain and death have a negative image, it is easy to correlate one with the other, although pain is not part of death or unconsciousness. Indeed, when we are not conscious like zombies we cannot feel any pain. After a serious operation, such as cancer, which requires general anesthesia, the patients realize they are alive for the first time when they feel pain and then when they can actually see the cancer affected part of the body cut off by the surgeon. They feel relieved and are thankful to be able to feel pain again. How can they feel alive suffering from pain which does not have any direct relation with their experience of the painless state during the operation and the dead cancer which they could not see when it was being cut off by the surgeon? At that time somehow they correlate the pain and the dead cancer with the success of the operation and when one makes the connection between those two, it is imaginative muscle memory.

3. We can also apply imaginative muscle memory to various art works. One of them can be a dance. Popping, which is an important break dancing skill, could be a good example for this. When dancers reach a certain level, their movements begin to look like a robots' or marionettes'. To be able to achieve the difficult skill of popping, they need to control not only their movement and their breathing but also imaginative muscle memory which robots or marionettes might have. This dimension of imaginative muscle memory can be used in meditative practices, such as yoga. For example, one can practice a tree pose or a camel pose better when they use imaginative muscle memory.

I have briefly presented three cases which are only a small part of what the imaginative muscle memory affects and there are various cases with two or three characteristics of the above mentioned cases present all together in one case. Unfortunately, I will leave any further analysis for another time, but at least, I believe, that my current analysis has safely proved there is an imaginative dimension of muscle memory.

Conclusions

Shusterman's somatic consciousness can be an alternative solution for the mind-body problem, therefore, it has its importance in the problem of mind and body. However, we observed his experiential muscle memory has ontological limitation, which implies that we need to improve the muscle memory argument as a revised one which has some ontological place for the imaginative sensual form of muscle memory. In the process of doing that I tried a slightly radical combination between healthy somatic pragmatism and imaginative zombie theory.

Indeed, William James – a creative thinker, pragmatist, psychologist and also the father of American physiology – could be the pioneer in this radical cooperative trial since he was a supporter of two extremely opposite parties, body (physical object) centered associationism which inspired James to develop the idea of "the stream of thought" [9, p. 239] and mind centered spiritualism which claims that our behavior is caused by our soul. In his representative work *The Principles of Psychology*, James said,

"[T]he Soul manifests its faculty of Memory, now of Reasoning, now of Volition, or again its Imagination or its Appetite. This is the orthodox 'spiritualistic' theory of scholasticism and of common-sense. Another [way] is to seek common elements *in* the divers mental facts rather than a common agent behind them, and to explain them constructively by the various forms of arrangement of these elements, as one explains houses by stones and bricks. The 'associationist' schools have thus constructed a *psychology without a soul* by taking discrete 'ideas' (…) If we strive rigorously to simplify the phenomena in either of these ways, we soon become aware of inadequacies in our method. Any particular cognition, for example, or recollection, is accounted for on the soul-theory by being referred to the spiritual faculties of Cognition or of Memory" [9, pp. 1–2].

James's claim is important not only for insightful cooperative thinking between the scholastic spiritualism and constructive associationism, but also for the courage of not abandoning his academic responsibility of studying spiritualism which subject to various criticism on his research subjects such as "mystical experience", "mental healing", "telepathy", or even "haunting", for which he still found a useful instrument for his body-mind philosophy [21, 22]. I believe his creative and insightful mind could provide a proper guide for human development into the future along with Richard Shusterman's sharp analysis of our living world. Fertile human development should consider the borderline examples, imaginative thinking and abductions which bring to us new solutions and the potential for the new forms of science.

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CORPORALITY, SPORT AND EROTICA*

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ABSTRACT
The article analyzes interrelations that exist between sport and eroticism. It rejects the propagation of sex through sport and the propagation of sport through sex. The author of the paper asks the question whether erotica is a phenomenon which only recently is valued in sports or whether it is a epiphenomenon. We believe that the topic "corporality, sport and erotica" could be discussed from various aspects, the esthetical, ethical, philosophical, psychological, sociological, sexological, gender and commercial could be included. We can say beforehand that the esthetical aspect plays the largest role when addressing such a topic. Both eroticism and beauty are important categories of esthetics. A naked and exposed body (when considering sport and athletes) can often express much more than a covered body. The naked body has the ability to show the dynamics of sports both authentically and truthfully. Erotica in sport, as it is portrayed through the rules and esthetical nature of each individual sport and through the accepted taste and norms of both athletes and spectators, can be considered a cultural relic of sport itself.

Key words: corporality, sport, erotica, categories of esthetics, beauty, sensuality

Introduction

The aim of this paper, keeping in mind the associations between sport and erotica, is to analyze the interrelation between these two important phenomena, i.e. not the propagation of sex through sport nor the propagation of sport through sex. Another aim of this work is to ask the question whether erotica is a value shaping a phenomenon of modern sport or if it is only its epiphenomenon. An epiphenomenon is a secondary phenomenon accompanying some thing or process, which is basically not influenced by the presence of a given phenomenon. The last aim of this work is to answer the question – what are the causes of erotica's penetration into sport as well as the search for erotica in sport. This is a very important question, as when the causes of some phenomenon, affair or action is known, we can foresee the consequences of such a phenomenon. Sport, or in that case any another related science, will seriously start to deal with the interrelation between sport and erotica only if it is evident that erotica does in fact influence sport. As of now, this influence is only speculated on or talked about unofficially.

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The basic aspects of "sport and erotica"

We believe that the topic "corporality, sport and erotica" could be discussed from various aspects: the esthetical, ethical, philosophical, psychological, sociological, sexological, gender, commercial and others. In this paper we shall discuss very briefly only three aspects of "corporality, sport and erotica", which we consider the most fundamental.

The esthetical aspect

We can say beforehand that the esthetical aspect figures as the most dominant aspect of the topic at hand from some points of view. Eroticism and beauty are important categories of esthetics. Beauty could be characterized as the harmony, symmetry, complexity and impressiveness of something which forms a whole. Both beauty and eroticism are defined by their own and separate ideas. "Erotic and esthetic mean two things; if we want to assimilate them, it means we do not want to understand the nature of them." [1, p. 85]. Eroticism and beauty are important values of many human activities and belong by nature to sport, whether we look at it from a historical or current point of view. In the creative and undistorted perception of a sports event, sport motility and the athletic body, each of them is understood as a part of the other two but not dependant on the others. If modern sport is able to stimulate a person esthetically, it is also more or less able to stimulate them erotically.

When speaking about beauty and erotica in sports, it is common to associate it with the corporality of sport, which involves the body, shapes, movements and gestures of an athlete. Yet, this is only a partial picture. It is created on the basis of an initial impulse, most often as a visual perception. However, the entire process of perception does not end on the visual que. According to Michelangelo, man first perceives "the visible beauty, but from this beauty it is the human soul which uplifts to the beauty itself and by force of visible beauty the man perceives the pure, divine, immortal beauty." [2, p. 135]. In other words, it is important for the eye to be first steeped in beauty and eroticism and only thus the hedonistic need of a human could be satisfied at the same time.

Ethos, the spirit of sport, goes together with a sport's esthetical and erotic expressions. If we can divide the beauty of sport into the sensual and spiritual, we can divide the erotica into sensual and spiritual. In such a context Jirásek used an excellent set of esthetical terms. "Elegance and grace, harmony, rhythm, the purity of movement, individual creativity and interpretation, are the values which underline the kinetic art." [3, p. 17]. The art of sport and erotica establish the relations which inspire the intelligent creator of artistic, sport and erotic values, yet but do not scandalize it.

Eroticism of sport derives from the corporality of athletes and it is identified with the sensuality (and sensuousness) of the human body. Vulgar and aggressive erotica is in today's modern sport promoted by nudity, which changes the sensual into sexual. However, we do not accept such a development in sport, with an example illustrating what was said above. There is a page in the Slovak sport newspaper *Šport* with classifieds offering sex service of not only women but also men. This kind of advertising is pornographic. The texts and pictures on this page have the style of a porn magazine [4]. We consider such erotica vulgar, inadequate and, what is more, irrelevant to sport and to the daily newspaper *Šport*, as well.

The naked and exposed body (in that of sport and athletes) can often express more than a covered one. The naked body has the ability to show the dynamics of sports both authentically and truthfully. Sports clothing also have their esthetical aspects and are also advantageous from the technical and methodological points of view. For example, the coach of a high jumper can interpret the movement and find any technical mistakes of an athlete easier if he/she can see the particular areas of the body as authentically as possible. The exposure of an athlete's body allows us to marvel at the impressiveness of what sport performance there is in sport. This is possible through the esthetical expression (interpretation) of human corporality in the athlete. Also, the first people, Adam and Eve, were represented in "erotic clothes".

When speaking about the process of the gradual exposure of an athlete's body, we find the first such examples in ancient times. It is known that then athletes used to engage in some sport disciplines completely naked. However, in those times nudity was perceived in a different way. Several years ago we performed a case study which involved an athlete, a runner to be exact. We chose an area which we hoped would not causes any undesired attention. With our "experiment" we did not want to elicit any unwanted curiosity, voyeurism or morally shock any accidental spectators. The athlete ran approximately 2 km only in his shoes, without any clothes. The result of this case study was quite banal, irrelevant but telling. Such sport discipline (and we suppose that every sport discipline) requires appropriate and, nowadays, scientifically tested clothes. The esthetical and ethical needs of the athlete do not play a main role when it comes to choosing garments in sports competitions, but objectively tested and validated principles as well as norms which determine what sportswear is worn. If an athlete is driven by their own erotic needs while choosing what to wear, it means that he or she is trying to satisfy their need of becoming a spectacle.

Erotica in sport, as it is portrayed through the rules and esthetical nature of each individual sport and through the accepted tastes and norms of both athletes and spectators, can be considered a cultural relic of sport itself. If comparing it to biological or sexual sexism we can only speak about a simple "natural" instinctive or commercial matter.

An important factor for esthetical thinking and esthetical relation is taste. The gentle and only indicative form of erotica in sport must not be offensive to taste. "In esthetical relation of beauty we take into consideration nobleness, too." [1, p. 85]. Vulgar, obtrusive and vacuous eroticism in sport is therefore an offence to taste, because of the lack of nobility.

The ethical aspect

Ethics is just as much a part of sport. We can say that the ethical aspect is one of the most discussed topics in sport, and even beyond this arena. Huizinga, while analyzing the role of sport in social culture, critically notes that sport is distancing itself from culture. "Sport has been completely profaned and does not relate to the structure of society organically, even if the performance is ordered by government. It is more an independent display of agonal instincts than a worthwhile factor for society." [5, p. 353]. Whenever we talk about the "unification" of sport and erotica, we do it only in private, in unofficial discussions, never at a convention or in other open forum.

The ethical aspect is another very important element in the analysis of the relationships between sport, corporality and erotica. We need also mention the plurality of ethical attitudes in regards to the plurality of ethical concepts, which are based on such attitudes. The spectrum of these attitudes begins with an uncritical acceptance. Then comes an indifference to this matter and ends up with *a priori* rejection of any erotica and cult of the body in sport.

The primal expression of ethical understanding of this topic is by it being made taboo. Sport by itself was in the past considered immoral and did not have any support from society. However, creating taboo of any existing topic is hypocrisy. Pretending that there exists no relation between sport and erotica is an example of such hypocrisy. In such a context we can try to make an analogy. Freud describes how child sexuality was understood in his times and from a medical point of view on this issue. Allowing for such sexuality to exist meant it was "an attack on one of the strongest human prejudices." Childhood should be "innocent", without any sexual desires. If people noticed manifestations of children's carnality, they would consider them as signs of degeneration, corruptness or as freaks of nature [6, p. 28].

An interesting factor in the ethical aspect in the relationship between sport and erotica is sport arriviste. In a terminological dictionary sport arriviste (German *Arrivierte*) is defined as an unhealthy ambition, arrogance, careerism, frantic effort to stand out from society, an uncontrolled effort to become number one in a sports team, or some sport discipline, over-ambitiousness, a will to succeed. Sport arriviste has, therefore, signs of some overblown, extremely strong desire to win no matter what; it shows signs of over-competitiveness, an unhealthy desire to distinguish oneself and to be the best, even if it means using unfair practices, tools, or by breaking the rules of fair play. One of these "forbidden" practices is the erotic propagation of corporality values and the sensuality of the athlete [7, p. 204]. The forms of corporality propagation are mainly body language gestures and its nakedness.

Nakedness is "an exciter" for moralists and puritans. Therefore, they denounce it wholly. The erotic side of sport and any erotic correlations always bring forward the potency of provocation. Provocation itself is not immoral, it is obviously morally indifferent. However, if the form of provocation purposefully focuses on the ethical feelings of some group of spectators, the ethical value becomes very disputable. We can say that in sport nakedness is considered as a form exposing of the body, its parts, proportions, force, but not as a form of "artistic" sports act or as pornography. Not every manifestation of nakedness is perceived as a manifestation of sexuality. "It is not necessary to perceive the nakedness under the terms of sexuality. It is not the nakedness that is a question of morality, but imagination which is aiming at sexual levels of nakedness." [5, p. 11]. The exposure of athlete's bodies (both male and female) should contribute to the understanding of the beauty and spirit of sport as well as to the beauty and soulfulness of human. The body and its gestures combined with a touch of eroticism can be understood as a means of communication between the athlete and the spectator and with the other co-actors of a sport event. Probably there is some specific self-satisfaction present in athletes while exposing themselves in front of spectators. Such self-satisfaction is gladly accepted as a variegation when participatiing in sport events. We do not support the notion that such exposure can be understood as a public aphrodisiac for spectators. If it sexually excites a person in the audience, it is not the consequence of such an expression in sport, but the consequences of a spectator's desires.

The issue of the nakedness of the body, eroticism and sensuality does differentiate genders from the ethical point of view. The gender perception of a given topic is subordinated by the culture of a given society. Many societies consider themselves modern and progressive in the full sense of these words, although, in reality, prejudice prevails and stereotypes continue to dominate in many modern societies. The norms of women and men are applied to both erotica and sport to judge what is not right, because it is immoral, provocative, tempting and aimed against traditional values. Straková pointed out this problem in general [8, p. 407–408]. "In our society it is not appropriate even nowadays to satisfy the woman's needs independently, or to treat them as a part of her personality without any sense of guilt. The autonomous female sexuality is still, in our society, connected to the terms like shamelessness, unsoundness, or immorality and, in extreme cases, evokes the sense of guilt among girls and women." We can compare it to an analysis of the word shyness made by Max Scheler in 1923. According to him, shyness can be divided into two different forms: "physical shyness, in other words, the vital shame where the sexual shyness is only the strongest vital shyness (…), the other one is spiritual shyness, in other words, spiritual shame (…). Both forms are used only when "I" defend myself from the whole sphere of general." [9, p. 85]. In that matter, the human being, whether woman or man, can feel shyness as well in the dictation of moral norms.

The protagonists of modern-day sport are people of different age and health. Children and seniors, the able and disabled, all of them engage in sport. The sport and erotica relation is alway present in its moral form. We believe that this relation between sport and erotica is relevant only (or mainly) for sport done by able adults and young people, through responsible athletes, both women and men. Sport and erotic cultural forms are only permissable in the sport of adults. These reasons lead us to think that erotica in sport is inadmissible for children and adolescents from the moral and legal points of view; the infiltration of erotica in sport could be perceived as an instigation of pedophilia and would be a flagrant threat to the moral development of young athletes.

The sport and erotica relationship is suitable mainly for young athletes who use it to form their own esthetical and ethical perspectives. Erotica is natural for adolescents as it expresses their personal and inner needs, as well as their need for external communication. With all due respect to seniors who take part in sport, any erotic symbols used would be distasteful, offensive, comical, and what is more, they could exhort to gerontophilia.

A similar problem occurs in disabled athletes taking part in sport. Here, the relationship of sport and erotica could also be offensive, tragicomic, cynical, or even deviant, therefore it is applicable only to able-bodied athletes. It is possible that the level of infiltration of erotica in sport depends on the kind and the degree of disability present and on the visibility of this health impairment or disability. From this point of view, one could surmise if erotica and sport are tolerable in the case of deaf athletes.

The philosophical aspect

At the end of our paper we wish to describe several possible philosophical takes on the erotica and sport relationship. Mainly we think that "erotic" is subjective. The same object, the same behavior is perceived by every person in different erotic ways. Our optical system is "adjusted" individually. The same happens to our erotic perception. If we want to see something in a given thing, we mainly have to want to see it. The dimension and quality of erotica in sport, to some extent, depends on the individual. If we want to understand each other, we have to be quite empathic.

Erotica is also objective, otherwise there would not *de facto* be any reason to discuss it. It is obvious that erotica exists in sport; what we do not know is what it actually is, how it is identified, what the real expressions of it are. Sport is a cultural activity in which there are strict and exact rules. Sport has a system character, therefore, the same strict and exact rules should be valid also in its subsystems. We cannot determine the rules of tolerable existence of erotica in sport with a scientific consistency. In spite of that, we believe there are given "common" criteria of eroticism in sport, mainly the social convention. Contemporary sport is a proof that these (unwritten) criteria are respected.

The word erotica itself derives from the name Eros. According to original ancient Greek mythology, and as it is well known, it was the name of the god of love who had a dignified position in mythology. Gods were not all born at the same time, but they came into being one after another. "For the Greeks, Chaos was the first god, followed by Earth or Gaia, while Eros came third." [10, p. 115]. Hand in hand with the topic of sport and erotica goes along the topic of sport and love. Yet, not for this reason alone did we return to ancient times. Making use of what is known from these times, we want to point to the creative power of erotica. Each god represents some principles. From the very beginning, Eros had creative and eternal power. According to the ideas of ancient Greeks, immortality for gods was only guaranteed when they came into the world and when they deserved such immortality. According to the ideas of Plato, which are presented in the dialogues included in the Symposium, Eros leads the human soul from the desire of beautiful bodies to the desire of spiritual beauty. He uplifts this beauty up to a cognition of what the idea of beauty is [11, p. 707–708].

Conclusions

We suppose that in the philosophical aspect the form of coexistence between sport and erotica and the variability of the course of genesis of this coexistence must be distinguished. In the former case, "sport" erotica arises as a natural but unplanned product of sport; it arises spontaneously. In the latter case we reflect the moment of "sports" erotica as a consequence created by an unexpected situation (the simplest example could be a defect of an athlete's garment). The phenomenon of "sports" erotica appears in sport also as a natural and calculated product of playing a sport. The basic reason why comes from animal nature and social substance and natural character. We understand these moments of sports erotica are a result of a satisfied need in seeing, feeling and experiencing eroticism in sport. Yet, not everybody has this ability. *Esse est percipi* – to be is to be perceived. Erotica occurs in sport only when its existence is perceived by a spectator or any other sport protagonist. The world around us only exists if it is in fact perceived by us.

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PUBLISHING GUIDELINES – REGULAMIN PUBLIKOWANIA PRAC

The Editorial Office of *Human Movement* accepts original empirical as well as comparative research papers on human movement science from varying scientific fields (including sports medicine, exercise physiology, biomechanics, kinesiology, sociology, psychology, pedagogy) covering education in health, physical education, recreation and tourism, rehabilitation and physiotherapy. The Journal also invites such contributions as letters to the Editor, reports from scientific conferences and book reviews. The publication of submitted contributions to *Human Movement* is free of charge.

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Conclusion

In presenting any conclusions, it is important to remember the original purpose of the research and the stated hypotheses, and avoid any vague statements or those not based on the results of their research. If new hypotheses are put forward, they must be clearly stated.

Acknowledgements

The author may mention any people or institutions that helped the author in preparing the manuscript, or that provided support through financial or technical means.

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