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Editorial Office
Secretary: Dominika Niedźwiedź
51-612 Wrocław, al. Ignacego Jana Paderewskiego 35, Poland, tel. 71 347 30 51
hum_mov@awf.wroc.pl
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# AN ANALYSIS OF THE REGULATORY REGION OF THE *IGF1* GENE IN PROFESSIONAL ATHLETES IN YOUTH SPORTS TEAMS

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**KATARZYNA KRYCH-GARSZTKA[1] *, HANNA MIZGAJSKA-WIKTOR[1], ANNA GOŹDZICKA-JÓZEFIAK[2]**

[1] University School of Physical Education, Poznań, Poland
[2] Adam Mickiewicz University, Poznań, Poland

ABSTRACT

**Purpose.** The aim of this study was to search for single nucleotide changes in the P1 promoter sequence of the *IGF1* gene in both high-class athletes and subjects who do not participate in professional sports. The second rationale was to compare the polymorphism frequency in the promoter region in athletes across a variety of sport disciplines. **Methods.** 272 athletes from the regional sports team of Wielkopolska (Poland) took part in the study. 154 athletes practiced team sports whereas 118 trained in strength sports. The control group comprised of 122 individuals who did not practice sport professionally. Genetic material came from epithelium swabs from the oral cavity, which was then subject to DNA isolation and tested with the PCR/SSCP technique. DNA samples showing different migration in electrophoresis were then sequenced. **Results.** The frequency of the polymorphisms was substantially higher ($p < 0.05$) in the athlete group (9.2%) than in the control group (2.4%). A considerably higher frequency of the sequence changes ($p < 0.05$%) was observed in those athletes who participated in strength sports (11.0%) than in team sports (7.8%). Among all the individuals tested, the –147bp –475bp region was the most polymorphic, yet changes within this fragment were not detected in the control group. In the control group the most often change in the nucleotide sequence was observed at position –1089 (T/C), while in the athlete group at position –383 (C/T). Change at position –1089 (T/C), found in eight individuals, is related to a potential binding site of the AP-1 transcription factor. Change at position –361 (G/A), detected in two individuals, is probably the site for the Sp1 transcription factor. **Conclusion.** The conducted study found that single nucleotide polymorphism of the P1 promoter region of the *IGF1* gene is more frequent in athletes than in non-athletes. We believe that the variation in the P1 promoter sequence of this gene is related to an organism's adaptation to physical (especially strength) activity.

**Key words:** *IGFI* gene, P1 promoter polymorphism, athletes, strength exertion, speed-endurance-strength exertion

## Introduction

The first genes significant in human physical performance were identified almost 20 years ago. At present, more than 230 of such genes are known, with *IGF1* being among them [1]. The product of this gene is the insulin-like growth factor I – IGF-I, which consists of 70 amino acids. Its activity is regulated by proteins which bind to it, the Insulin-like Growth Factor Binding Proteins (IGFBPs). The IGF-I factor acts on cells via a membrane receptor which possesses tyrosine kinase activity. It is also able to bind to the insulin receptor causing hypoglycemic effects. The IGF-I protein plays a key role in the majority of the processes regulated by growth hormone (GH). Local synthesis of this factor, and its subsequent autocrine and paracrine secretion, show that IGF-I is a factor that independently induces a number of processes: its synergic action with erythropoietin, especially under hypoxia conditions [2], and its influence on cardiac muscle hypertrophy and its intensified contractility, [3] can be listed among them. IGF-I also activates satellite cells responsible for new muscle fiber formation in skeleton muscles subjected to loading and in the regeneration of damaged muscle fiber [4]. IGF-I also participates in glucose metabolism through the stimulation of glucose reuptake and glycogen storing in muscle cells [5]. The broad spectrum and specificity of action of the IGF-I protein caused it to be recognised as a highly effective doping agent, and the *IGF1* gene is recognized as a marker in determining phenotypes desired in professional sport.

The expression of the *IGFI* gene depends on both environmental and genetic factors [6]. It is conditioned by the type of tissue, the level of certain hormones (e.g. growth hormone, estrogens, parathormone), the kind of amino acids provided by nourishment, and the developmental age of the specimen [7]. Additionally, the activity of the gene may be influenced by growth factors (EGF – epidermal growth factor, PDGF – platelet-derived growth factor, TGF-β1 – transforming growth factor), oncogenes (*c-myb*), tumor suppression genes (*WT1*), and transcription factors: Sp1, AP1, HNF-1£, HNF-3β, C/EBPα and β, LAP protein [8]. One

* Corresponding author.

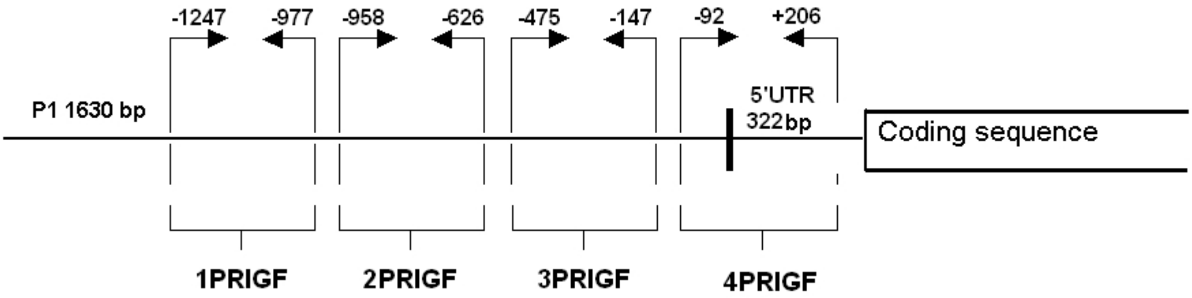


Figure 1. Structure of the P1 promoter of the *IGF-I* gene (prepared by W. Jarosz) Arrows show the localization of primers. Numbers indicate the nucleotides as according to GenBank (AH002705)

of the relevant environmental factors influencing *IGF1* gene expression is physical exertion [9, 10]. It is worth mentioning that the level of IGF-I protein in blood shows large variation among individuals, which reflects the variable expression of the *IGF1* gene.

The *IGF1* gene is localized on chromosome 12 (12 q22–24.1) and occupies over 90 kbps which contains 6 exons, 5 introns, and 2 promoters – P1 and P2, which are localized upstream of the first and the second exon, respectively (Fig. 1). In humans, the main promoter of this gene is P1, from which about 80% of transcripts are initiated. This promoter is a region showing significant sequence polymorphism, i.e. the presence of microsatellite repeats (CA) or change in single nucleotides (SNP, single nucleotide polymorphism). These changes can modulate the binding of transcription factors, which in turn influence gene expression. The relationship between changes in the P1 promoter sequence and the occurrence of various pathological states has been previously demonstrated and confirmed in a number of clinical trials. For instance, a connection between P1 polymorphism and low height in children [11], bone and joint inflammation [12], elevated risk of bone breakage in older women [13], left heart chamber overgrowth [14], increased risk of type II diabetes and heart attacks [15], as well as breast cancer and colon cancer have all been observed [16–18].

In previous studies of the *IGF1* gene and its connection with physical activity, the influence of such physical activity on the mRNA level of this gene in muscles was determined. In addition, many studies analysed the association between physical exertion and the concentration of IGF-I in the blood [19–22]. With reference to the P1 polymorphism, only the connection between the presence of microsatellite 192 bp repeats $(CA)_{19}$ and muscle strength of 67-year-old men and women has been shown [23]. The variation of this promoter in professional athletes has not been previously analyzed. Thus, the aim of our study was to analyse the promoter sequence in individuals who practice sport professionally and in those who do not. A comparison of these sequences will shed light on any possible differences between the two groups and on an organism's various responses to training exertion, which are key in achieving athletic success.

Table 1. Characteristics of the studied group

| Discipline | Number of examined | | |
|---|---|---|---|
| | total | female | male |
| Volleyball | 55 | 27 | 28 |
| Basketball | 44 | 24 | 20 |
| Handball | 55 | 24 | 31 |
| Weight lifting | 19 | 6 | 13 |
| Wrestling | 63 | 18 | 45 |
| Judo | 36 | 16 | 20 |
| Total athletes | 272 | 115 | 157 |
| Control group | 122 | 74 | 48 |
| Total examined | 394 | 189 | 202 |

## Material and methods

A group of 394 individuals was subjected to the study: 272 athletes representing the regional sports team of Wielkopolska (Poland) ranging from 15 to 18 years of age as the experimental group, and 122 individuals from 18 to 19 years of age who do not train professionally in sport as the control group (Tab. 1).

Epithelium swabs from the oral cavity were collected from all tested individuals using a sterile cotton swab and then processed for DNA isolation.

### Molecular studies

Molecular studies were performed at the Biology and Environmental Protection Department at the University School of Physical Education in Poznań, and in the Laboratory of Sequencing at the Adam Mickiewicz University in Poznań, Poland.

### DNA isolation

DNA isolation was performed by binding the DNA to a silica resin using the epithelium tissue collected from mouth, using DNA isolation kit (A&A Biotechnology).

PCR/SSCP analysis

Genomic DNA served as the matrix for amplification by PCR (Polymerase Chain Reaction) of the P1 promoter region and the 5'UTR region of exon 1. Because of the considerable length of the analyzed promoter sequence, it was divided into four regions according to Obrępalska-Stęplowska et al.'s [11] approach. In this division, the 5'UTR fragment of exon 1 is in the promoter region IV (Fig. 1). PCR was performed using four pairs of primers, complementary to four fragments of the studied gene's regulatory region (Tab. 2). The PCR reaction was carried out in a 10 ml solution containing 1 mM primers, 200 μM deoxyribonucleotide triphosphate, 1X PCR buffer and 1.0 U/25 μl Taq polymerase. The reaction was repeated in 35 cycles, each of them consisting of the following steps: denaturation at 95°C for 1 minute (in the first cycle for one and a half minute), annealing done at the proper temperature for each pair of primers for 30 seconds and polymerization at 72°C for 1 minute. PCR was performed in an Eppendorf thermocycler. The products of amplification were analyzed in a 2% agarose gel supplemented with ethidium bromide.

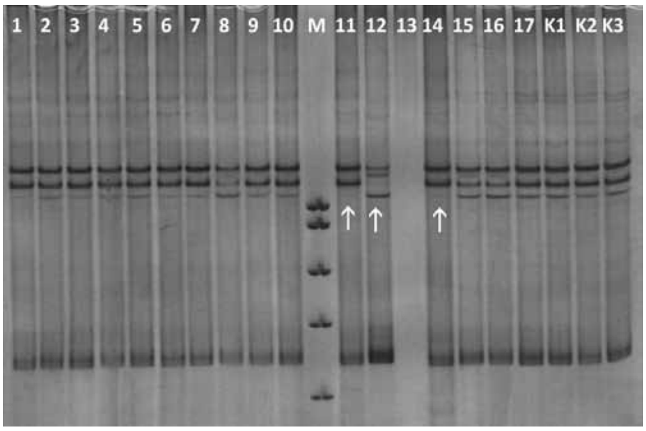


Figure 2. SSCP analysis of the P1 promoter of the *IGF1* gene in athletes (1–17). K1–K3 – control samples, M – molecular weight marker (pUC8 Mix Marker). Arrows indicate DNA fragments with different pattern of migration (photo: author)

The PCR products were then analyzed by the SSCP (Single Strand Conformation Polymorphism) technique. The DNA fragments (5 μl) were chemically denatured using formamide and a DNA loading buffer, and subsequently denatured thermally by incubating at 95°C for 10 minutes. After the incubation, the samples were placed on ice. Electrophoretic DNA distribution was performed in a 10% polyacrylamide gel, in 0.5X TBE buffer, for 22 hours at room temperature (electrophoreses parameters: 200 V, 105 mA, 20 W). The gels were stained with silver salt and then dried. The DNA fragments, whose migration patterns were different when compared to the control group, were then sequenced.

Statistical calculations

In order to determine the level of significance of the differences in the frequency of polymorphism among the analysed groups and promoter regions of the *IGF1* gene, a comparative test of two indicators was performed.

Bioinformatics analysis

Using Alibaba 2.1 computer software, an analysis of transcription factors binding to sites where single nucleotides changes were detected, was performed.

## Results

Molecular studies

DNA analysis using the PCR/SSCP technique (Fig. 2), confirmed by sequencing, found changes in the nucleotide sequence (SNP, single nucleotide polymorphism) in 28 (7.1%) individuals among the 394 tested, i.e. in 25 (9.2%) individuals in the athlete group, and in 3 (2.3%) individuals in the control group. In women, the frequency of polymorphisms was similar to men and was 5.8% and 6.9%, respectively. Most often, the changes occurred in region III (5.5%) of the P1 pro-

Table 2. The characteristics of primers used in PCR for the four studied regions of the *IGF1* gene P1 promoter

| Amplified region | Primer sequence (5' → 3') | Length (bp) | Annealing temperature (°C) |
|---|---|---|---|
| 1PRIGF | AACCCAACCCCCTTCCAAACA<br>GCAAAAGCCCAGAGCAGACATAC | 271 | 55.2 |
| 2PRIGF | ACTTTCTTATCTACTGCTTCACAA<br>TTCCATATAACTCAAACCTCTG | 333 | 52 |
| 3PRIGF | TCATCGCAGGAGAAAAAGTAT<br>GCTGGGCATGAAGACACAAAC | 329 | 53 |
| 4PRIGF | ATGTCTGCGAACCCTGTCACTAAC<br>TATTCCATTGCGCAGGCTCTATCT | 299 | 53.8 |

Table 3. The frequency of polymorphisms in athletes of various sport disciplines with different forms of physical exertion and in the control group

| Discipline | Promoter region | | | | | |
|---|---|---|---|---|---|---|
| | Examined N | I | II | III | IV | Total |
| Team sports | 154 | 2 (1.3%) | 2 (1.3%) | 6 (3.9%) | 2 (1.3%) | 12 (7.8%) |
| Combative sports | 118 | 3 (2.5%) | 4 (3.4%) | 5 (4.2%) | 1 (0.8%) | 13 (11.0%) |
| Total athletes | 272 | 5 (1.8%) | 6 (2.2%) | 11 (4.0%) | 3 (1.1%) | 25 (9.2%) |
| Control group | 122 | 3 (2.4%) | – | – | – | 3 (2.4%) |
| Total | 394 | 13 (3.3%) | 12 (3.0%) | 22 (5.5%) | 4 (1.0%) | 41 (10.4%) |

Table 4. Changes found in the sequence of the *IGF1* gene P1 promoter in athletes and in the control group

| Discipline | Polymorphic/ Examined N | Promoter region | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Volleyball | 5/55 | –1089 (T>C) | –776 (A>G) | –383 (C>T) | –25 (A>T)<br>–22 (A>T) |
| Basketball | 6/44 | –1089 (T>C) | –776 (A>G) | –383 (C>T), –361 (G>A)<br>–383 (C>T), –381 (T>A)<br>–380 (C>T)<br>–383 (C>T) | – |
| Handball | 1/54 | – | – | –361 (G>A) | – |
| Weightlifting | 2/19 | – | – | –383 (C>T)<br>–361 (G>A) | – |
| Wrestling | 3/63 | –1089 (T>C) | –776 (A>G) | –348 (T>A) | – |
| Judo | 8/36 | –1089 (T>C)<br>–1089 (T>C) | –776 (A>G)<br>–776 (A>G)<br>–776 (A>G) | –392 (G>C)<br>–383 (C>T)<br>–383 (C>T) | – |
| Control group | 3/12 | –1089 (T>C)<br>–1089 (T>C)<br>–1089 (T>C) | | | |

moter while less frequent changes were in region IV (1.0%) (Tab. 3). The difference in the frequencies of polymorphisms between these two regions was statistically significant ($p < 0.05$) and was particularly marked for those who took part in strength sports. For athletes, polymorphism was confirmed in all of the four regions analysed, while in the control group it was found only in one, region I, of the promoter. Changes in region III were detected in 14 athletes and consisted of both transition and transversion. In some cases, there were two SNPs detected in this region for one individual. The frequency of polymorphisms, both in region I and in II, was found in 6 individuals where were only transitions. It is worth mentioning that the polymorphism which occurred in region I, at position –1089 (T>C) was a heterozygotic change. In region IV there were polymorphisms only in 2 subjects, and these were transversions (Tab. 4).

In analysing the frequency of polymorphisms found in the tested athletes, when taking into consideration the type of physical exertion they undergo, it was noticed that athletes who take part in combative sports, where strength exertion dominates, polymorphic changes were found more often (11.0%) than in athletes of team sports, where mixed exertion is performed (i.e. strength-endurance-speed) (7.8%). No significant changes were observed in the polymorphic changes frequency in the particular regions of the promoter in athletes who underwent various forms of physical exertion (Tab. 3).

Bioinformatics analysis

Using Alibaba 2.1 computer software, it was found that some sites in the P1 promoter sequence of the *IGF1* gene, which exhibit changes in single nucleotides, are the possible sites of transcription factors binding. It applies to SNP localized in region I of the promoter at position –1089 (T>C), where probably the AP1 transcription factor binds. The III region of the promoter at position –361 (G>A), is supposed to bind the Sp1 transcription factor. As with other SNPs, it has been found that they are localized in close proximity to the transcription factors binding site, e.g. SNP in region III of the promoter at position –348 (T>A) is 3 nucleotides away from the Sp1 factor binding site.

## Discussion

The way in which an organism adapts to physical exertion depends, among others, on the regulation of many genes' expression (e.g. *IGF1*, *ACTN3*, *PPAR delta*, *ACE*). Their polymorphism turns out to be an important factor that influences the level of physical performance. Among those genes, *IGF1* plays a remarkable role because of the broad spectrum and specificity of its action. It is known that the regulatory region of the P1 promoter of this gene is labile. This manifests itself by a significant degree of single nucleotides variation or by the presence of the different number of microsatellite repeats (CA) [17]. Theses changes have been analysed in relation to various pathological states [12–18], but were not studied in athletes. Our analyses of the P1 promoter in a group of 394 subjects confirmed the variation of this promoter in 28 tested individuals (7.1%). The polymorphism was significantly higher ($p < 0.05$) among athletes (25 individuals) as compared to the control group (3 individuals). Change in the promoter sequence may be an important determinant of athletic success, since polymorphic types of the gene promoter may influence its different expression, thus the change in the level of IGF-I protein which is important for an organism's ability to adapt to exertion. Also, our results found that athletes training in combative sports, which are mainly based on strength exertion, had higher P1 polymorphism (11.0%) than in players of team sports, who perform mixed exertion (i.e. strength-endurance-speed) (7.8%). This may be remarkable because other author's have shown the connection between IGF-I protein concentration in the blood with muscle mass and strength. It has been observed that in skeletal muscles subjected to loading, the level of IGF-I mRNA increases, and to be more precise, IGF-I's isoform: MGF (mechano growth factor) [19]. The IGF-I protein is responsible for after-exertion muscle hypertrophy and the regeneration of damaged muscle fibres [20].

With reference to the analysis of the P1 sequence, in order to facilitate PCR/SSCP analyses, the promoter was divided into 4 regions [11]. Thanks to this approach, it was possible to track and compare changes in particular sections. We have shown that region III (from –475 to –147 bp) is the most labile while the least various is region IV (from –92 to + 206 bp). The difference in the frequency of changes between III and IV was statistically significant ($p < 0.05$). The low variability of the sequence in region IV of the P1 promoter results from the fact that the 5'UTR region of exon 1 of the *IGF1* gene, which in our study was amplified together with region IV, is the most conservative fragment of this gene, as was confirmed earlier [24–26]. Many cis elements, which regulate the expression of *IGF1*, are localized in the 5'UTR region. Changes found in the sequence of the P1 promoter may have a functional meaning. It is known that the level of IGF-I protein in the bloodstream is determined genetically and to an equal extent depends on many environmental factors [6]. Thus the polymorphism of this promoter may influence the regulation of its transcriptional activity and further the level of the IGF-I protein in the bloodstream. The P1 promoter region is characterized by the presence of many sequences regulating tissue-specific expression of this gene. Part of them is strongly conservative, e.g. the fragment 5'-CAGCTG-3', also known as the E-box. It is localized just above the main transcription start site in skeletal muscles (position –837 and +76 in relation to the first start site of the transcription). However, it has been found that point mutations in this region can (depending on the developmental state of the tissue) change the level of transcription factors binding [27].

Using the Alibaba 2.1 computer software, we have found that among the 28 polymorphic changes of the P1 promoter that have been identified, 3 changes constitute a potential transcription factors binding site. They are in region I position –1089 (T>C), in region III position –361 (G>A) and in region IV position –25 (A>T). It should be underlined that the sequence in position –1089 (T>C) probably binds the AP1 factor, which in cooperation with other transcription factors plays an important role in growth control, proliferation, cell transformation and its death. [28] It has been previously confirmed that the complex of estrogen and estrogen receptors activates transcription of the *IGF1* gene by a AP-1 protein binding motif [29]. The second SNP at position –361 (G>A) probably binds the Sp1 factor. Studies of the *IGF1* gene in rats showed that mutation in the TTAT region adjacent to the Sp1 factor binding site lowers the expression of the *IGF1* gene [30] SNP at position –25 (A>T) which itself occurs in the region of the hepatic transcription factor HNF-3 (Hepatic Nuclear Factor) binding site (region from –34 to –21). As was shown, HNF-3 protein is a strong transactivator of the P1 promoter, and its binding is inhibited after point mutations at positions +9 and –27 [31].

The variations in the P1 promoter sequence as detected in our study are interesting; however, a question arises whether they do influence the binding of transcription factors and gene expression. The functional meaning of single nucleotide changes in the P1 promoter of the *IGF1* gene was determined in its different positions. For instance, it has been determined that change in the sequence identified at position –1411 (C>T), localized in the region of many transcription factors binding sites, influences the binding of one of the regulatory proteins, i.e. allele T binds c-Jun and allele C binds C/EBP delta. This point mutation was correlated with changes in the functioning of the circulatory system. It has been proven that individuals with hypertension possessing allele T have lower systolic and diastolic blood pressure in comparison with individuals who do not posses this allele [32]. In addition, the connection between the polymorphism in the P1 promoter at position –2995 C>A, which constitutes the site for Oct1/Oct2 transcription factor binding, and a decreased risk of colon cancer has been shown, and this connection was stronger in physically active people [17].

As observed in our study, the differences in the frequency of SNPs occurring in the P1 promoter of the *IGF1* gene between athletes and individuals who do not train sport professionally as well as being dependant on the form of physical exertion they undergo, may suggest their functional importance. One may assume that the detected polymorphic changes in the studied promoter influence the change in *IGF1* gene activity. Its expression is an important determinant in how an organism adapts to physical exertion. However, to assure that such a connection exists, functionality tests should be conducted using a vector with a reporter gene.

## Conclusion

1. The polymorphism identified in the P1 promoter region of the *IGF1* gene is more frequent in subjects with higher physical activity.
2. The polymorphism in the P1 promoter region of the *IGF1* gene has higher frequency in athletes of strength sports in comparison to athletes of team sports.
3. The polymorphism in the P1 promoter region of the *IGF1* gene could be associated with the human body's adaption to physical activity.

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*Correspondence address*

Katarzyna Krych-Garsztka
Zakład Biologii i Ochrony Środowiska
Akademia Wychowania Fizycznego
ul. Królowej Jadwigi 27/39
61-871 Poznań, Poland
e-mail: krych_garsztka@awf.poznan.pl

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# ACE I/D GENE POLYMORPHISM IN ATHLETES OF VARIOUS SPORTS DISCIPLINES

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**JOANNA HOLDYS [1], JAKUB KRYŚCIAK [1], DANIEL STANISŁAWSKI [2], PIOTR GRONEK [1*]**
[1] University School of Physical Education, Poznań, Poland
[2] Poznań University of Life Sciences, Poznań, Poland

ABSTRACT
**Purpose.** Genetic factors play an important role in physical performance. In this study, the polymorphism of the angiotensin-converting enzyme gene (*ACE*) was analyzed in relation to the level of physical fitness, measured by maximal oxygen uptake ($VO_{2max}$). **Methods.** Molecular genetic research on the *ACE* gene was carried out on a group of 154 men and 85 women. All of the subjects were Polish students at the University School of Physical Education in Poznań and included professional athletes representing various sport disciplines and levels of fitness. **Results.** Allele *I* was found to have an advantageous effect on higher maximal oxygen uptake values and, in addition, a characteristic distribution of genotypes was found, where allele II was more common in individuals practicing aerobic sports and allele DD in individuals training anaerobic disciplines. **Conclusion.** No significant associations were found between I/D polymorphism in the *ACE* gene and $VO_{2max}$ values but certain tendencies were found for those individuals with the *ACE* II genotype.

**Key words:** *I/D* ACE polymorphism, maximum oxygen uptake

## Introduction

The angiotensin I-converting enzyme gene (*ACE*), located in region 17q23, is one of the best-documented genes that affect human physical activity. It is an important component of the rennin-angiotensin-aldosteron (RAA) system, which maintains homeostasis of the circulatory system. The angiotensin I-converting enzyme leads to the elevation of arterial blood pressure in two different ways: by activating angiotensin II, one of the most potent factors which constrict blood vessels, and by deactivating bradykinin, a factor which dilates blood vessels.

In 1992, a team of researchers headed by Rigat characterized insertion-deletion polymorphism (I/D) in the angiotensin convertase gene and found its strict relationship with the amount of the free *ACE* found in the blood [1]. This polymorphism is characterized by the presence of two allelic variants differing in length, i.e. the short D and the long I allele, which in the human genome may form the following genotypes: II – the insertion homozygote, ID – the insertion-deletion heterozygote and DD – the deletion homozygote. The difference in alleles results from the presence of a 287 bp fragment in intron 16 of the gene.

The effect of the I/D polymorphism on the *ACE* gene has been found in terms of the incidence of cardio-vascular diseases such as hypertension, myocardial infarction or left-ventricular hypertrophy [2, 3], Jones et al. initiated studies on the effects of *ACE* gene variants on the effort tolerance of humans [4]. The first analysis on the polymorphism of the *ACE* gene aimed at determining whether a specific allele is represented more frequently among athletes when compared to a control group. In 1996, Gayagay with his team confirmed a higher frequency of II and ID genotypes in a group composed of members from the Australian national rowing team, which are required to have very good aerobic capacity [5].

The insertion genotype (II), characterized by low activity of this enzyme in tissue, makes it possible to maintain an advantageous energy balance during intensive and long-term physical exercise. It was observed that athletes practicing disciplines with predominant aerobic energy processes, such as mountaineering, long-distance running and long-distance swimming, seldom had allele D in their genotype. Athletes practicing disciplines that predominantly feature anaerobic metabolism, i.e. sprinters and short-distance swimmers, are characterized by a high level of *ACE* and more frequently feature the DD deletion genotype. The amount of activity of the *ACE* enzyme in the blood of individuals with the DD genotype is approx. two times higher than in individuals with the II genotype [1, 6].

A team headed by Montgomery focused on analysing the effects of I/D polymorphism within the *ACE* gene on aerobic endurance in two simultaneous experiments: on a group of Himalayan mountaineers climbing at altitudes of over 7000 m without oxygen

* Corresponding author.

supplementation and on a group of British army recruits [7]. Particularly interesting results were obtained from the group of Himalayan mountaineers (25 total), for whom the allele distribution was markedly shifted towards the allele I insertion genotype when compared to a control group, composed of men with no respiratory and circulatory diseases but not involved in physical exercise. In 50% of the Himalayan mountaineers, the II genotype was observed, in 40% the ID genotype while in 10% the DD genotype, with the theoretical normal distribution of genotype frequency being 25 : 50 : 25, respectively. In the second experiment, conducted on men recruited by the British Army ($n$ = 123), a relationship was found between *ACE* gene polymorphism and the recruits' response to training, whose objective was to perform the maximum number of repeated elbow joint flexions with a 15 kg load over a specified period of time. Prior to the onset of training, the number of repetitions completed was similar for all participants. However, after completing the training cycle, a considerable increase was observed in the number of repeated flexions performed by 66 individuals with the II and ID genotypes, which was not found in a group of 12 individuals with the DD deletion homozygotes genotype of the *ACE* gene.

Research conducted in 2000 by a team headed by Williams showed that the presence of the insertion allele of the *ACE* gene considerably enhances the mechanical efficiency of skeletal muscles when compared to individuals having the deletion allele in their genotype, which was observed during a 10-week endurance-training period [6]. Similar conclusions were reported by Jones, Montgomery and Woods, who stated that the allele I of the *ACE* gene is connected with lower angiotensin convertase activity and frequently found among the leading athletes of certain sport disciplines such as long-distance running, rowing and mountaineering [4]. Similarly, teams of researchers headed by Myerson and Tsianos observed an increase in the frequency of allele I found with an increase in the length of Olympic distances covered by athletes [8, 9].

It also needs to be stressed that there are studies that have not confirmed the above-mentioned results in terms of the differences found in the distribution of alleles I/D in a group of athletes and a control group not involved in physical training [10, 11].

The authors of some publications tend to believe that the insertion-deletion polymorphism of the *ACE* gene may be a factor that enhances physical fitness, but one that does not effect oxygen uptake levels or the regulation of systole frequency [12]. Zhang, with his team, stated that the presence of the insertion allele of the *ACE* gene is rather connected with an increase in the size of muscle fibre type I (slow-twitch oxidative, i.e. ST fibres). It was suggested that this phenomenon might underlie the mechanic relationship between the presence of insertion alleles of the *ACE* gene with better physical fitness. Similarly, other relationships were observed between allele D and a higher share of fast-twitch muscle fibres type II (FT) [13], greater power of the quadriceps muscle in response to training, and higher anaerobic capacity as well as improved aerobic capacity in short-term effort after undergoing training [14]. Thompson and Binder-Macleod [15] reported two probable mechanisms of the relationship between *ACE* polymorphism and fitness. The first mechanism, as mentioned above, of better respiratory and circulatory efficiency is connected with the function of angiotensin convertase. The other mechanism involves the effect of *ACE* polymorphism on metabolic efficiency. Montgomery et al. [16] and Katsuya et al. [17] in their studies observed a relationship between allele I and fat mass as well as the body's higher anabolic reaction when subjected to exercise. Thus, genotype II may have an advantageous effect on metabolic efficiency by the maximization of aerobic sources of energy.

In literature on the subject, we may also find scientific publications in which the connection between the *ACE* genotype and physical fitness was not confirmed. A team headed by Rankinen summed up their research on a group of men ($n$ = 192) practicing endurance disciplines (cross-country skiing, biathlon, Nordic combined, long- and medium-distance running, road cycling), stating that no overrepresentation of allele I was found in the group of athletes attaining the highest maximal oxygen uptake values (over 80 ml/kg/min). This may suggest that *ACE* gene polymorphism does not play a role in better cardiorespiratory efficiency [11]. In addition, studies on an ethnically diverse group of U.S. army recruits subjected to basic physical training [18] or on a group of twins subjected to weight training [19] did not confirm the effect of the *ACE* genotype on aerobic capacity or find a relationship between allele D with greater muscle power. No relationship was found among 291 world-class Kenyan athletes practicing endurance sports and their ranking [20]. Most scientific reports are contradicted by the results found by Zhao et al. on a group of 67 Chinese men not involved in professional sports subjected to a 20-week training period. They observed higher values of maximal oxygen consumption in individuals with the deletion genotype DD [21] or an even higher increase of $VO_{2max}$ when compared to individuals with genotypes ID and II [11].

From the data presented above, it appears that the effect of different alleles of the *ACE* gene on the value of maximal oxygen uptake is often ambiguous, although its function in the modification of cardiorespiratory capacity is obviously significant. Thus for the authors of this paper it seemed justifiable to conduct studies in this respect on a group of selected Polish athletes.

The aim of this study was to analyze how I/D polymorphism in the *ACE* gene, when taking into consideration the circulatory system and muscle metabolism, may affect various parameters of an organism's physical fitness, such as maximum oxygen uptake $VO_{2max}$. This study was conducted on a group of young individuals, those practicing various sport disciplines that differ in terms of the character of energy metabolism and those leading less active lives. To the best of our knowledge, at the time when this study was initiated, such an analysis had not been carried out among subjects from Poland, and as such, there are no available results which may compared with the analyses presented here. What is more, ethnic differences prevalent among the other studies conducted around the world prevent a simple comparison of results with the ones here that were conducted on the largely homogeneous Polish population.

## Material and methods

### The experimental group and biological material

Biological material for genetic analyses comprised of peripheral blood samples collected from students attending their second and third year at the University School of Physical Education in Poznań. The students were either studying Physiotherapy or Physical Education and included those who were actively practicing sports as well as professional athletes training in various sport disciplines, representing different sports classes and included representatives of Polish national teams, as well as those students who were less active. The study was approved by the Commission of Bioethics at the Karol Marcinkowski University of Medicine in Poznań.

The group subjected to physiological and genetic analyses comprised of 239 Caucasians (154 men and 85 women) aged 18–26 years. Since $VO_{2max}$ is a sex-dependent parameter, all statistical analyses were performed separately for men and women.

In order to verify the effects of the analyzed gene polymorphism on maximal oxygen consumption, depending on the level of physical activity, the participants in this study were then divided into a group of individuals who trained (119 men and 37 women) and those who did not train in any sports (35 men and 48 women). Furthermore, those individuals who did train in sports were then subdivided into three subgroups, each classified by the type of exercise metabolism that predominates in the discipline they practice: (i) speed and strength disciplines (disciplines that predominate in anaerobic energy metabolism) were denoted as Sp-St, (ii) endurance-speed-strength disciplines (disciplines requiring both anaerobic and aerobic energy metabolism) were denoted as E-Sp-St, and (iii) endurance disciplines (those predominating in aerobic energy metabolism) were denoted as E. The division of the sport disciplines was based on the classification system developed by Bellotti et al. [22] and is presented in Table 1, which lists the practised disciplines and the numbers of individuals in them.

Table 1. A division of the sport disciplines into subgroups in terms of the predominate exercise metabolism

| Sex | Sp-St | E-Sp-St | E |
|---|---|---|---|
| M | Short-distance running<br>Long jump<br>High jump<br>Discus throw | Field hockey<br>Tennis, Rugby<br>Football (soccer)<br>Volleyball<br>Basketball<br>Handball<br>Boxing<br>Kickboxing<br>Canoeing | Triathlon<br>Medium-distance running<br>Long-distance running<br>Long-distance swimming<br>Skiing<br>Race walking |
| | *n* = 24 | *n* = 62 | *n* = 33 |
| F | Short-distance running<br>Long jump<br>High jump | Tennis<br>Taekwon-do<br>Volleyball<br>Rowing<br>Canoeing | Triathlon<br>Long-distance running<br>Race walking<br>Mountaineering |
| | *n* = 11 | *n* = 9 | *n* = 17 |

M – males
F – females
Sp-St – speed-strength disciplines,
E-Sp-St – endurance-speed-strength disciplines
E – endurance disciplines
n – size of subgroups

### Physiological analyses

Physiological analyses were conducted at the Laboratory of Functional Examinations at the University School of Physical Education in Poznań, certified by ISO 9001:2000 standards (no. 956-2007-AQ-GDA-RvA).

The maximal oxygen uptake of the participants was determined by using the direct method during exercise tests on a treadmill with the use of a Jaeger Oxycon Mobile spiroerogometer (Germany). During each test, the composition of air inhaled and exhaled by a subject ($VO_2$, $VCO_2$) was analyzed and their heart rate (HR) was monitored using a Polar pulsometer (Finland). The exercise tests were carried out on a treadmill with increasing load, starting from a running speed of 8 km/h, increasing the load by 2 km/h every 3 min, until the moment of maximum individual load was reached.

### Genetic analyses

Genetic analyses were conducted at the Laboratory of Genetic Analyses at the University School Physical Education in Poznań, certified by ISO 2000:9001 standards (no. 956-2007-AQ-GDA-RvA).

DNA for genetic analyses was isolated from 5 ml of peripheral blood collected from the examined individuals onto an anticoagulant (EDTA). DNA isolation was performed using the guanidine isothiocyanate (GTC) method. The I/D polymorphism of *ACE* was genotyped by a polymerase chain reaction (PCR) and electrophoresis was conducted on agarose gel. The DNA was amplified in a volume of 25 µl. Genomic DNA from each examined individual was placed in a separate test tube measuring 4 µl (200 mg) and a 21 µl reaction mixture was added, containing 50 mM KCl, 10 mM Tris-HCl (pH 8.3), 1.5 mM $MgCl_2$, 0.25 mM dNTP, 7.5 pmol each primer and 0.5 unit of Taq polymerase. The primer's sequence was F – CTg gAg ACC ACT CCC ATC CTT TCT, R – gAT gTg gCC ATC ACA TTC gTC AgA T [23]. The 30-cycle reaction was run in a Biometra (Germany) Tpersonal thermocycler. The standard cycle comprised of an initial denaturation at 95°C for 10 min, denaturation at 95°C, annealing at 58°C, synthesis at 72°C and final synthesis at 72°C for 10 min.

PCR products were separated on 1.5% agarose gel (0.75 g agarose on 50 ml gel). Electrophoresis was run at 100 V for 30 min in a Biometra agagel mini horizontal apparatus (Germany). The results were visualized on a UV transilluminator with 2 µl ethidium bromide (5 mg/ml). An example of genotyping for I/D polymorphism in the *ACE* gene is presented in Figure 1.

Statistical analyses

Statistical calculations were performed at the Computer Laboratory of the Faculty of Animal Breeding and Biology at the Poznań University of Life Sciences, with the use of SAS statistical software ver. 9.1 (USA).

The $\chi^2$ test was used to verify the goodness of fit for genotype distributions and the Hardy–Weinberg principle was used for verifying the consistency of the maximal oxygen uptake values. The homogeneity of variance was determined using the Bartlett test. The association between the I/D polymorphism of the *ACE* gene and maximal oxygen uptake ($VO_{2max}$), as recorded for the each of the participants in the experiment, was verified using the ANOVA one-way analysis of variance – the parametric test *t*.

## Results

Table 2 presents the general characteristics of the study's participants including mean values of anthropometric traits, i.e. body weight and height together with age, along with the means and standard deviations.

The means of the minimum and maximum values of maximal oxygen uptake of the participants are presented in Table 3. The highest level of $VO_{2max}$ in the group of men was recorded for a triathlon athlete, while the lowest was for a field hockey player, whereas among women the highest value was also found for a triathlon athlete and the lowest for a non-training individual.

Table 2. General characteristics of the study's participants. The mean values of body weight, height and age are provided

| Sex | *n* | Body weight (kg) | SD | Body height (cm) | SD | Age (years) | SD |
|---|---|---|---|---|---|---|---|
| F | 85 | 59.7 | 5.71 | 169.4 | 6.28 | 21.4 | 1.67 |
| M | 154 | 76.2 | 8.14 | 180.3 | 10.58 | 20.9 | 2.12 |

SD – standard deviation
n – number of participants in the group
F – females
M – males

Table 3. Values of $VO_{2max}$ recorded for women and men in the exercise test

| Parameter | Sex | *n* | Min | Max | $\bar{x}$ | SD |
|---|---|---|---|---|---|---|
| $VO_{2max}$ (ml/kg/min) | F | 85 | 30.60 | 59.80 | 45.61 | 6.63 |
| | M | 154 | 40.30 | 79.00 | 55.13 | 7.06 |

F – females, M – males
n – number of participants in the group
Min – the lowest $VO_{2max}$ value in the group
Max – the highest $VO_{2max}$ value in the group
SD – standard deviation

Table 4. Mean values of maximal oxygen uptake ($VO_{2max}$) in ml/kg/min of both non-training and training groups

| $VO_{2max}$ (ml/kg/min) | Non-training | | | | | Training | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| sex | *n* | Min | Max | $\bar{x}$ | SD | *n* | Min | Max | $\bar{x}$ | SD |
| F | 48 | 30.6 | 58.4 | 42.3 | 5.2 | 37 | 33.8 | 59.8 | 49.9 | 5.9 |
| M | 35 | 42.3 | 62.2 | 50.7 | 4.3 | 119 | 40.3 | 79.0 | 56.4 | 7.2 |

F – females, M – males
n – number of participants in the group
Min – the lowest $VO_{2max}$ value in the group
Max – the highest $VO_{2max}$ value in the group
SD – standard deviation

As mentioned, the men and women were divided into groups of individuals actively practicing sports and those not involved in any form of training, and then in terms of the character of energy metabolism connected with the practiced sports discipline. Mean $VO_{2max}$ values for women and men, depending on the level of physical activity and the character of energy metabolism as per the practiced sports discipline, are presented in Tables 4 and 5. As was expected, women recorded lower values of $VO_{2max}$ when compared to men and those individuals not involved in training had lower values than those who practiced sport. In the training group, the highest values of the maximal oxygen uptake were recorded for athletes of endurance disciplines, while the lowest for representatives of endurance-speed-strength disciplines.

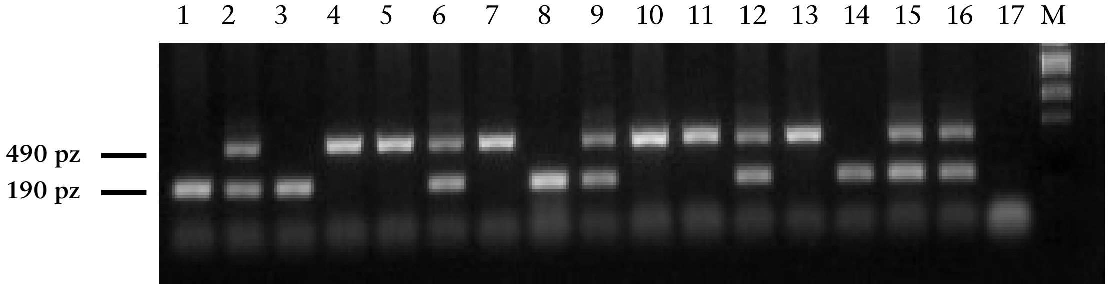


Figure 1. An example of genotyping for insertion-deletion polymorphism in the *ACE* gene using PCR. Products were separated on 1.5% agarose gel with ethidium bromide. Lanes 4, 5, 7, 10, 11 and 13 correspond to insertion homozygotes I/I, lanes 2, 6, 9, 12, 15 and 16 correspond to heterozygotes I/D, lanes 1, 3, 8 and 14 correspond to deletion homozygotes D/D; lane 17 – negative control; M – size marker of *λ*/*Eco*RI+*Hind*III

Table 5. Maximal oxygen uptake ($VO_{2max}$) values in ml/kg/min of the subgroups having different energy metabolism characteristics

| $VO_{2max}$ (ml/kg/min) | Sp-St | | | | | E-Sp-St | | | | | E | | | | | Non-training | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sex | *n* | Min | Max | $\bar{x}$ | SD | *n* | Min | Max | $\bar{x}$ | SD | *n* | Min | Max | $\bar{x}$ | SD | *n* | Min | Max | $\bar{x}$ | SD |
| F | 11 | 39.3 | 56.1 | 49.5 | 4.7 | 9 | 40.2 | 52.0 | 47.5 | 4.5 | 17 | 33.8 | 59.8 | 51.5 | 6.9 | 48 | 30.6 | 58.4 | 42.3 | 5.2 |
| M | 24 | 41.1 | 71.5 | 54.9 | 5.9 | 62 | 40.3 | 62.0 | 53.8 | 4.2 | 33 | 42.3 | 79.0 | 62.4 | 9.0 | 35 | 42.3 | 62.2 | 50.7 | 4.3 |

F – females, M – males, *n* – number of participants in the group
Min – the lowest $VO_{2max}$ value in the group
Max – the highest $VO_{2max}$ value in the group
SD – standard deviation

Table 6. Descriptive statistics and a comparative analysis of maximal oxygen uptake ($VO_{2max}$) between I/D polymorphism genotypes in the *ACE* gene. The analysis of variance did not show statistically significant differences between the mean values of the recorded maximal oxygen uptake in groups represented by genotypes DD, ID and II

| *ACE* | DD | | | | | ID | | | | | II | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | *n* | $\bar{x}$ | SD | Min | Max | *n* | $\bar{x}$ | SD | Min | Max | *n* | $\bar{x}$ | SD | Min | Max |
| F | 23 | 44.06 | 7.45 | 31.30 | 58.40 | 39 | 46.13 | 5.89 | 30.60 | 57.70 | 23 | 46.28 | 7.01 | 33.80 | 59.80 |
| M | 39 | 55.66 | 7.99 | 42.30 | 76.80 | 72 | 55.38 | 6.43 | 40.30 | 74.90 | 43 | 54.21 | 7.26 | 41.10 | 79.00 |

F – females, M – males, *n* – number of participants in the group
Min – the lowest $VO_{2max}$ value in the group
Max – the highest VO2max value in the group
SD – standard deviation

### Results of the association analysis of the investigated gene with $VO_{2max}$ values

The aim of this study was to analyze the association of the investigated polymorphism with the level of recorded maximal oxygen uptake. In the experimental group, the frequency of alleles and genotypes were analyzed together with the distribution of $VO_{2max}$ values. The $\chi^2$ test confirmed the fact that the analyzed parameter was characterized by normal distribution and the frequency of *ACE* genotypes was observed to be within the genetic equilibrium ($\chi^2_{tab;\, n-1=2,\, \alpha=0.05} = 5.991 > \chi^2$ obl. = 1.2004). The homogeneity of variance was verified using the Bartlett test. The differences in the values of the observed maximal oxygen uptake for different polymorphic variants were determined based on the ANOVA one-way analysis of variance with the parametric *t*-test. Descriptive statistics and comparative analysis of the maximal oxygen uptake obtained for the individual polymorphic variants of the gene are presented in Table 6. The differences between the mean values of the maximal oxygen uptake recorded in the three groups with different genotypes turned out to be statistically non-significant.

As was mentioned, in order to verify whether there are any differences in maximal oxygen uptake values with different genotypes, depending on the level of physical activity, the women and men participating in

Table 7. Descriptive statistics and a comparative analysis of maximal oxygen uptake ($VO_{2max}$) values between groups of different I/D polymorphism genotypes of the *ACE* gene in training and non-training women and men. The analysis of variance did not show statistically significant differences between mean values of the recorded maximal oxygen uptake in groups represented by genotypes DD, ID and II in training individuals. In the group of non-training men, a statistically significant difference was found between genotypes ID and DD.

| $VO_{2max}$ (ml/kg/min) | *ACE* | Non-training | | | | | Training | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | | *n* | $\bar{x}$ | SD | Min | Max | *n* | $\bar{x}$ | SD | Min | Max |
| F | DD | 16 | 41.05 | 6.71 | 31.30 | 58.40 | 7 | 50.94 | 3.39 | 46.50 | 56.10 |
| | ID | 23 | 43.52 | 4.60 | 30.60 | 50.70 | 16 | 49.88 | 5.60 | 39.30 | 57.70 |
| | II | 9 | 41.37 | 2.26 | 36.40 | 44.00 | 14 | 49.44 | 7.25 | 33.80 | 59.80 |
| M | DD | 9 | 47.88 | 4.22 | 42.30 | 52.90 | 30 | 58.00 | 7.36 | 49.90 | 76.80 |
| | ID | 15 | 52.43 | 4.67 | 46.80 | 62.20 | 57 | 56.16 | 6.63 | 40.30 | 74.90 |
| | II | 11 | 50.76 | 2.47 | 45.70 | 53.70 | 32 | 55.39 | 7.99 | 41.10 | 79.00 |

F – females, M – males, *n* – number of participants in the group
Min – the lowest $VO_{2max}$ value in the group
Max – the highest $VO_{2max}$ value in the group
SD – standard deviation.

The statistically significant difference in maximal oxygen uptake between the given genotypes (a – at $p \leq 0.05$) are underlined.

Table 8. Descriptive statistics and a comparative analysis of maximal oxygen uptake ($VO_{2max}$) and different genotypes of I/D polymorphism in the *ACE* gene in the groups of women and men not involved in training and those training in various disciplines, subdivided by their energy metabolism characteristics. An analysis of variance showed a statistically significant difference in maximal oxygen uptake between genotypes ID and DD in the group of non-training men. A difference was observed in $VO_{2max}$ between genotypes ID and II in the group of men practicing speed-strength disciplines at $p = 0.07$

| $VO_{2max}$ (ml/kg/min) | *ACE* | Sp-St | | | | | E-Sp-St | | | | | E | | | | | Non-training | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | | *n* | $\bar{x}$ | SD | Min | Max | *n* | $\bar{x}$ | SD | Min | Max | *n* | $\bar{x}$ | SD | Min | Max | *n* | $\bar{x}$ | SD | Min | Max |
| F | DD | 6 | 51.52 | 3.32 | 46.50 | 56.10 | | | – | | | 1 | 47.50 | | | | 16 | 41.05 | 47.50 | 31.30 | 58.40 |
| | ID | 3 | 45.43 | 6.42 | 39.30 | 52.10 | 6 | 47.98 | 5.62 | 40.20 | 52.00 | 7 | 53.40 | 3.22 | 50.00 | 57.70 | 23 | 43.52 | 4.60 | 30.60 | 50.70 |
| | II | 2 | 49.25 | 2.05 | 47.80 | 50.70 | 3 | 46.67 | 0.74 | 46.10 | 47.50 | 9 | 50.40 | 8.99 | 33.80 | 59.80 | 9 | 41.37 | 2.26 | 36.40 | 44.00 |
| M | DD | 6 | 53.97 | 0.86 | 53.00 | 55.20 | 14 | 54.56 | 3.34 | 49.90 | 61.30 | 10 | 65.23 | 8.42 | 52.80 | 76.80 | 9 | 47.88 | 4.22 | 42.30 | 52.90 |
| | ID | 14 | *56.81* | 6.02 | 48.20 | 71.50 | 29 | 53.08 | 4.41 | 40.30 | 58.80 | 14 | 61.89 | 7.38 | 48.90 | 74.90 | 15 | 52.43 | 4.67 | 46.80 | 62.20 |
| | II | 4 | *49.48* | 6.95 | 41.10 | 58.00 | 19 | 54.48 | 4.57 | 44.30 | 62.00 | 9 | 59.94 | 11.8 | 42.30 | 79.00 | 11 | 50.76 | 2.47 | 45.70 | 53.70 |

F – females, M – males, *n* – number of participants in the group
Sp-St – speed-strength disciplines
E-Sp-St – endurance-speed-strength disciplines
E – endurance disciplines, Min – the lowest $VO_{2max}$ value in the group
Max – the highest $VO_{2max}$ value in the group, SD – standard deviation

The statistically significant difference in maximal oxygen uptake between the given genotypes: a - at $p \leq 0.01$ was marked by underlining the two values. The statistically significant difference level of $p = 0.07$ between the genotypes was marked by underlining and italicising the values.

the experiment were divided into groups of those who were and were not involved in sports training. The distribution of genotypes and maximal oxygen uptake values (minimum, maximum and mean value) of the two groups are presented in Table 7. Within these two groups, a statistically significant difference was found in the mean values of maximal oxygen uptake between genotypes ID and DD ($p \leq 0.05$) in non-training men.

The recorded results were also analyzed in terms of the differences in the maximal oxygen uptake values recorded by individuals with different genotypes, depending on the character of energy metabolism that predominates in their practiced sport discipline. The mean values of maximal oxygen uptake in the subgroups of individuals practicing speed-strength disciplines, endurance-speed-strength disciplines, endurance disciplines and those not involved in any form of training are listed in Table 8. In the I/D polymorphism of *ACE*, apart from the one mentioned above between genotypes ID and DD in non-training men, a significant difference was also found at $p = 0.07$ between genotypes ID and II in men representing speed-strength disciplines.

## Discussion

The *ACE* gene has been widely described and analysed in literature. It was shown that I/D polymorphism in intron 16 affects the function of the gene, differentiating the enzymatic activity of angiotensin convertase in the blood [1, 6], which is connected with the regulation of blood pressure and as such, it plays an important role in cardiorespiratory efficiency. There are numerous studies in which allele I was associated with higher $VO_{2max}$ values and having a more-frequent incidence in individuals practicing endurance sport disciplines, such as marathon running, cycling, rowing, long-distance swimming and mountaineering [5, 7, 24]. In turn, allele D was associated with such disciplines as sprint running, short-distance swimming and strength sports, predominating in anaerobic energy metabolism and with lower *ACE* activity in the blood [4, 7, 25, 26]. However, analyses of this polymorphism were also undertaken as many researchers have not been able to confirm the association of the *ACE* gene with $VO_{2max,}$ or able to find it having a general effect on aerobic efficiency [12, 25, 27–29]. Other studies have also found polymorphism having a completely different effect for individual alleles, such as in the observations reported by Montgomery et al. [11, 21, 30–32].

Maximal oxygen uptake values for the *ACE* genotypes in the group of women and men analyzed within this study were similar, with an upward trend found for genotype II in women and DD in men. The division of the experimental group into training and non-training individuals showed a significant difference in $VO_{2max}$ between participants with genotypes DD and ID in the group of non-training men. The further division of those individuals training into the three subgroups of disciplines with different types of exercise metabolism found a difference between genotypes ID and II close to statistical significance ($p = 0.07$) in terms of $VO_{2max}$ in men practicing speed-strength disciplines. In the group of non-training women and those representing endurance and endurance-speed-strength disciplines, the highest value of maximal oxygen uptake was found for women with genotype ID, while in the subgroup of those practicing speed-strength disciplines it was for women with genotype DD. In turn, in the group of men, the highest maximal oxygen uptake values were observed for individuals with genotype II in the subgroup of endurance disciplines, ID in the subgroups of speed-strength disciplines and non-training individuals, as well as II and DD in the subgroup of disciplines with mixed-type metabolism. Despite a lack of statistically significant associations, the results of this study present findings that support those researchers who found an association of allele I with higher maximal oxygen uptake values, which is confirmed by the group of non-training individuals, in which there was no factor modifying their level of fitness. This conclusion was additionally supported by the distribution of genotypes in groups representing sports disciplines predominating in aerobic and anaerobic metabolic processes. Among the 35 individuals taking part in disciplines characterized by anaerobic energy metabolism, only 6 participants had the "endurance" genotype II. Furthermore, among the 50 individuals who practice sports that predominate in aerobic energy metabolism, only 11 had the "sprint-type" genotype DD. Additionally, our observations of the distribution of *ACE* genotypes is similar to those obtained in another study of Polish rowers, which found an association between allele I with endurance performance as well as a predominance of the genotype II in the athletic group when compared to the control group [24].

Studies aimed at uncovering the genotypes that determine physical fitness have been rapidly developing. An analysis of individual polymorphism associations is at present a method of low efficiency in the search for the genetic background of complex characters. Genetic models including several polymorphisms are created to form an optimal profile characteristic for athletes practicing a sports discipline requiring a specific type of exercise metabolism [33]. A specific case of such a profile may be connected with haplotypes, i.e. polymorphisms with considerable linkage disequilibrium, resulting from their being located closely to one another and which are inherited jointly, thus they are considered as one unit and not a single polymorphism. For this reason, several analyses need to be performed covering a spatially narrower range of the genome, subjected then to a comprehensive analysis on a specific aspect of efficiency, e.g. cardiorespiratory or cell respiration efficiency, in order to systematically form a base of genetic profiles that would be advantageous in competitive sports. The results of this study may also contribute to similar analyses conducted on the Polish population, particularly in view of the practical applicability of these results in benefiting Polish athletes.

## Conclusion

No association was found between I/D polymorphism in the *ACE* gene with $VO_{2max}$ values. Allele *I* was found to have an advantageous effect on higher maximal oxygen uptake values and, in addition, a characteristic distribution of genotypes was found, where allele II was more common in individuals practicing aerobic sports and allele DD in individuals training anaerobic disciplines.

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*Coresspondence address*
Piotr Gronek
Zakład Fizjologii
Katedra Fizjologii, Biochemii i Higieny
Akademia Wychowania Fizycznego
ul. Królowej Jadwigi 27/39
61-871 Poznań, Poland
e-mail: gronek@awf.poznan.pl

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# MALTODEXTRIN'S EFFECT ON THE PERFORMANCE OF ELITE MOUNTAIN BIKING ATHLETES DURING SIMULATED COMPETITION AND ON POWER OUTPUT AT THE VENTILATORY THRESHOLD

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CARLOS RICARDO MANECK MALFATTI [1, 2 *], ERIVELTON FONTANA DE LAAT [1, 2], LARISSA TRAMONTIN SOLER [1], IRENE WILMA BRONKHORST [1], CARLA VANESSA PACHECO [1], EDUARDO IRINEU BORTOLI FUNEZ [1], JOÃO LUIZ PAVLAK [3, 4], LUIZ AUGUSTO DA SILVA [3, 4], RAUL OSIECKI [3, 4]

[1] State University of Center-West (UNICENTRO), Irati, Brazil
[2] Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Brazil
[3] Federal University of Paraná (UFPR), Curitiba, Brazil
[4] Federal University of Santa Maria (UFSM), Santa Maria, Brazil

ABSTRACT
**Purpose.** To aim of this study was to analyze the effects of maltodextrin supplementation on cardiovascular and performance parameters during simulated Mountain Biking (MTB) competition as well as the cardiorespiratory and blood glucose (BG) response to a maximal test performed in a laboratory on elite MTB athletes. **Methods.** A total of eight male bikers [age: 28.4 ± 10.6 years; body fat: 9.46 ± 3.76 %; VO2max: 55.31 ± 4.7 mL/kg/min], participated in a double-blind study. The athletes received maltodextrin supplementation (1g/kg) or a placebo (light tangerine juice) 20 min before competition (seven 2 km laps) or before a laboratory maximal test. An incremental exercise test on a cycloergometer was performed to find any alterations in maximal HR, Watts max, $VO_{2max}$, VEmax, and $VO_2$ at the ventilatory threshold (VT), using a gas exchange analyzer. Comparisons between the simulated competition and laboratory variables (maltodextrin vs. placebo) were made using ANOVA and a two-tailed paired Student's t-test, where $p < 0.05$ was considered statistically significant. **Results.** Maltodextrin supplementation reduced 26 s in the mean time spent on completing all laps (Maltodextrin: 9 min and 16 s vs. placebo: 9 min and 35 s; $p < 0.05$). In laboratory testing, maltodextrin raised BG during exercise (Maltodextrin: 104.1 ± 20.9 mg/dL vs. placebo: 88.2 ± 5.3 mg/dL; p < 0.05), power output at the ventilatory threshold (Maltodextrin: 260.8 ± 12.9 vs. placebo: 150.5 ± 8.7; $p < 0.05$) but had no effect on cardiorespiratory variables. **Conclusion.** Maltodextrin was found to enhance athletic performance during MTB competition, showing that it can play an important role in supplementation strategies for these competitors.

**Key words:** supplementation, maltodextrin, cyclist, performance

## Introduction

Mountain biking cross-country cycling (MTB) is a popular alpine outdoor recreational activity and an Olympic sport since 1996, [1] characterized by off-road circuits with continuous climbs and descents on gravel and field paths. The International Cycling Union (UCI) suggests an optimal competition winning time of 105 to 135 minutes and is performed at an average heart rate close to 90% of the maximum, corresponding to 84% of maximum oxygen uptake ($VO_{2max}$) [1, 2]

Mountain bikers' physiological characteristics indicate that aerobic power and the ability to sustain high work rates for prolonged periods of time are prerequisites for competing at a high level in off-road cycling events [2].

However, there are other factors than aerobic power and capacity that might influence off-road cycling performance and therefore, require further investigation. These include off-road cycling economy, anaerobic power and capacity, technical ability and pre-exercise nutritional strategies. The importance of proper nutrition, such as carbohydrate (CHO) supplementation pre-, during and post-exercise, has been shown to increase the amount of work that can be performed [3–5] as well as the duration of aerobic exercise [6, 7]. The elevation of blood glucose (BG) associated with supplementation is suggested to improve aerobic performance through the reduction of muscle glycogen use [7–10] or through the use of BG as a predominant fuel source as glycogen becomes depleted [4, 9, 11].

CHO provides most of the energy for high-intensity endurance exercise (85% to 100% $VO_{2max}$) when compared with other nutrients. Consequently, a high-CHO diet could be more appropriate for athletes competing in endurance events because of greater pre-exercise muscle-glycogen availability in heavily recruited

* Corresponding author.

muscle fibers and due to an enhanced glycolytic metabolism [12].

One frequent way of delivering CHO pre-, during and post-exercise is through the use of sports beverages. However, one of the disadvantages of such sports beverages is their monosaccharide and disaccharide composition, making the beverage very sweet. One alternative is the use of hydrolized soluble starch (maltodextrin), which has a major advantage when compared to mono- and disaccharides as it is not as sweet and, therefore, allows for solutions with concentrations of 10 g per 100 ml or more (10% m/V). Such a concentration is more acceptable than glucose, sucrose or fructose solutions, which are far sweeter. Although being a complex carbohydrate, maltodextrin is considered to be a carbohydrate with a high glycemic index, capable of retaining the glycemic levels of glucose, but with the advantage of preventing the fast accumulation of glucose at the beginning of exercise, which could result in hypoglycemia as a consequence of high insulin secretion [13].

However, the effect of maltodextrin supplementation on athletes' heart rate intensity and performance at different moments of MTB competition has not yet been reported. Therefore, the aim of this study was to analyze the effects of maltodextrin supplementation on heart rate intensity and lap times during competition, as well as power output, and cardiorespiratory and BG response during a maximal laboratory test performed on elite Brazilian MTB athletes.

## Material and methods

A total of eight elite Brazilian MTB athletes [age: 28.4 ± 10.6 years; body fat: 9.46 ± 3.76 %; $VO_{2max}$: 55.31 ± 4.7 mL/kg/min], participated in the double-blind study. Informed consent was obtained for the study in accordance with Resolution 196/96 of the National Health Council in Brazil, which was approved by the local Ethics Committee (prot. n. 03454/2008).

One week prior to competition, the cyclists were evaluated in a laboratory to obtain their physiological and physical parameters. Body mass and height were measured using anthropometrical devices (Welmy Corp., Brazil). Body fat was measured by means of the skinfold technique [14, 15], using a skinfold caliper (Cescorf Corp., Brazil).

For the first simulated competition (based on a Olympic Cross Country competition), the athletes received oral supplementation with a placebo (dose: 1g/kg; light tangerine juice). For the second simulated competition, they received maltodextrin (dose: 1g/kg; DNA Design Nutrition Advanced) dissolved in distilled water 20 min before the competition (seven 2 km laps). Similarly, this procedure was used for the laboratory maximal test, held during a seven-day interval between the two competitions.

The athletes were advised not to train 24-hours before the maximal laboratory test. The maximal laboratory test was performed on a Biotec-1800 cycloergometer (CEFISE, Brazil), at 60 rpm, with an initial resistance set at 50 W, where each 3 min stage was increased by 25 W until the athletes reached exhaustion. Maltodextrin or placebo supplementation was used to verify alterations in maximal heart rate, Wattsmax, $VO_{2max}$, VEmax, $VO_2$ at the ventilatory threshold (VT) using a TrueOne 2400 gas exchange analyzer (ParvoMedics, USA). The heart rate was monitored every 5 s from the beginning to the end of the competition by means of a cardiac monitor (Polar Team System, Finland).

Exhaustion was defined as the point when an athlete was no longer capable of maintaining an appropriate pedaling rate of 55–60 rpm. The highest $VO_2$ value obtained during the last minute of exercise was considered the $VO_{2max}$ [16].

The ventilatory threshold was determined by plotting ventilation ($V_E$) vs. oxygen consumption ($VO_2$) values [17]. Two linear regression lines were fit to the lower and upper portions of the $V_E$ vs. $VO_2$ curve before and after the break points, respectively. The intersection of these two lines was defined as the VT.

Open circuit spirometry was used to analyze the gas exchange data using the TrueOne 2400 Metabolic Measurement System (ParvoMedics, USA). Oxygen and carbon dioxide were analyzed through a sampling line after the gases passed through a heated pneumotach and mixing chamber. The data were averaged over 15-second intervals. The highest average $VO_2$ value during the test was recorded as the $VO_{2max}$ if it coincided with at least two of the following criteria: (a) a plateau in the heart rate (HR) or with HR values within 10% of the age-predicted HRmax, (b) a plateau in $VO_2$ (defined as an increase of no more than 150 ml · min$^{-1}$), and/or (c) a respiratory exchange rate (RER) value greater than 1.15 [16].

Capillary blood samples were used to determine glucose concentrations using an ACCU–CHEK Performa digital glucose meter (Roche, Australia), and an ACCU-CHEK Multiclix lancetator (Roche, Australia), performed at grade 5 on the distal phalange on the right hand's third finger prior to testing (basal), twenty minutes after maltodextrin or placebo consumption and immediately after the end of the maximal test in laboratory. The subjects abstained from food 6 hours before all experiments.

All data are expressed as means ± SEM. The statistical analyses of BG at rest (maltodextrin vs. placebo) and immediately at the end of exercise (maltodextrin vs. placebo) were carried out by one-way ANOVA. The physiological parameters (maltodextrin vs. placebo) analyzed in the laboratory were carried out by the two-tailed paired Student's t-test. Comparisons between each lap (total of 7 laps) during competition and the laboratory variables comparisons (maltodextrin vs. placebo) were made using two-way ANOVA. A value of $p < 0.05$ was considered significant. Post-hoc analysis was carried out, whenever appropriate, through the Student-Newman-Keuls Test.

## Results

During the simulated competition, the athletes recorded heart rates of 180 to 190 bpm, which represents a predominant intensity at 80–90% of $HR_{reserve}$ (Fig. 1). This intensity is in accordance with recent publications showing the cardiovascular demands during competition for elite mountain biking competitors [1, 2, 18].

The two marked areas in Figure 1 found that maltodextrin induced minor cardiovascular demand in the first thirty minutes, allowing the athletes to finish faster in the competition (see end exercise). In relation to the time spent on each lap, maltodextrin supplementation enhanced performance during the simulated competition, reducing ~20 s in mean lap time (CHO: 9 min and 16 s vs. placebo: 9 min and 35 s; $p < 0.05$; Fig. 2), finishing the competition approximately ~3 min faster.

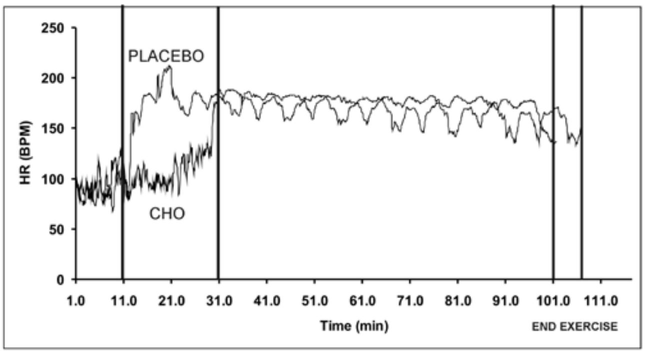
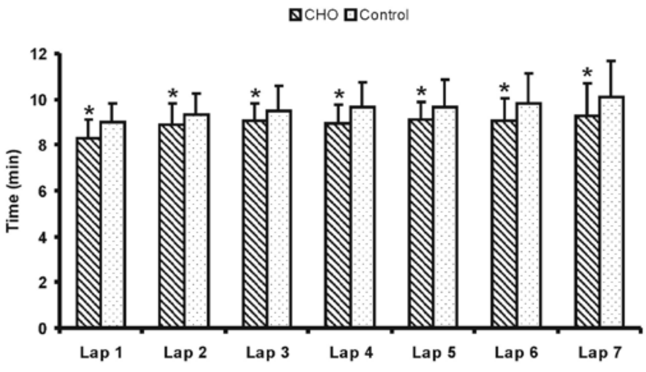



Figure 1. Mean heart rate (data measured every 5 s) observed during simulated MTB competition using maltodextrin (CHO) or a placebo (data are mean; $n = 8$)




* Statistical difference was verified by two-way ANOVA

Figure 2. Time spent on each lap during simulated MTB competition using maltodextrin (CHO) or a placebo (data are mean ± SE; $n = 8$)

Table 1. Physiological responses during the incremental cycloergometer test and competitions situations (means ± SEM)

| | Maltodextrin ($n$ = 8) | Placebo ($n$ = 8) | $p$ value ($t$ test) |
|---|---|---|---|
| Maximal power output (W) | 271.6 ± 9.2 | 260.8 ± 12.9 | 0.2 |
| WVT (W) | 260.8 ± 12.9* | 150.5 ± 8.7 | 0.0001 |
| $HR_{max}$ lab (bpm) | 184 ± 3.0 | 185 ± 3.1 | 0.6 |
| $HR_{max}$ field (bpm) | 186.7 ± 2.7 | 187.1 ± 5.1 | 0.9 |
| $\%HR_{reserve}$ field | 81.9 ± 6.8 | 86.2 ± 7.1 | 0.4 |
| $VO_{2max}VT$ (ml/kg/min) | 33.4 ± 2.0 | 36.2 ± 2.9 | 0.09 |
| $VO_{2max}$ (ml/kg/min) | 54.27 ± 2.9 | 56.35 ± 6.6 | 0.2 |

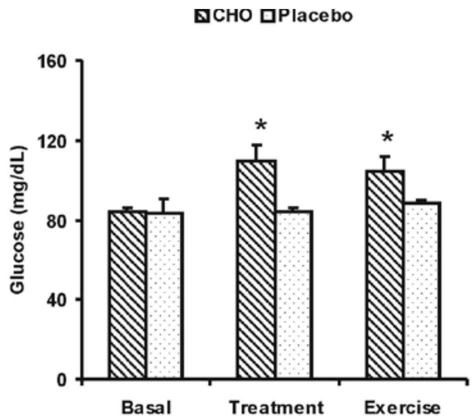
* Statistical difference was verified by a two-tailed paired student's t-test. Data are mean ± SE

WVT – power output at the ventilatory threshold;
$HR_{max}$ lab – maximal HR observed in the laboratory;
$HR_{max}$ field – maximal HR observed during competition;
$\%HR_{reserve}$ field – mean percent of reserve HR observed during competition; $VO_{2max}VT$, $VO_{2max}$ – observed at the ventilatory threshold; $VO_{2max}$ – maximal oxygen uptake

In laboratory tests, maltodextrin increased the BG level when at rest (CHO: 109.7 ± 7.7 vs. placebo: 84.12 ± 2.1 mg/dL; $p < 0.05$) and during exercise (CHO: 104.1 ± 7.4 mg/dL vs. placebo: 88.2 ± 1.9 mg/dL; $p < 0.05$; Fig. 3). In addition, maltodextrin increased the power output at the ventilatory threshold (CHO: 260.8 ± 12.9 vs. placebo: 150.5 ± 8.7 W; $p < 0.0001$; Tab. 1), but did not increase maximal power output or other physiological variables, such as maximal HR during laboratory tests, maximal HR during competition; the mean percent of reserve HR during competition, $VO_{2max}$ at the ventilatory threshold or $VO_{2max}$.

## Discussion

A substantial number of scientific papers have been published describing the relationship exercise intensity and the effects of various CHO supplements during road cycling [19–25], but there are few scientific papers focused on the effect of maltodextrin supplementation in pre-competition or laboratory testing nor how it modifies off-road cycling performance parameters. Recent studies have found that carbohydrate drinks (glucose, maltose and sucrose administrated at 0.65 g/kg before a performance test and then 0.2 g/kg every 15 min during every 1 h of testing), when compared to a placebo (maltodextrin in low doses), increased plasma glucose levels but did not enhance performance during the test (a 1 h test) after glycogen-depletion protocol initiated [26]. The data suggested that although carbohydrate drinks help maintain plasma glucose at a higher level, they have no effects on performance after the glycogen-depleting exercise. In fact, the optimal reserve of pre-exercise glycogen is very important




* Statistical difference was verified by one-way ANOVA

Figure 3. Plasma glucose values during laboratory testing, before supplementation (base), 20 min after supplementation (treatment) and after a maximal test on a cycloergometer (exercise) using maltodextrin (CHO) or placebo (data are mean ± SE; *n* = 8)

during an endurance competition. In other studies, carbohydrate supplementation has been shown to increase the amount of work that can be performed [3–5] as well as increase the duration of aerobic exercises [6, 7]. The elevation of blood glucose, found in the laboratory test, can be associated with improved aerobic performance through the reduction of muscle glycogen use [7, 27, 28] or through the use of blood glucose as a predominant fuel source as glycogen becomes depleted [4, 9, 11].

As was found in this study, maltodextrin supplementation induced better velocity during competition and increased the power output at the ventilatory threshold during laboratory test. The better performance observed during the competition **suggests, but does not prove** that maltodextrin supplementation can induce minor glycogen depletion during such mountain biking competitions [4, 9, 11].

The simulated off-road competition used in the present study consisted of highly intensive exercise, where the athletes achieved a cardiac rate from 80% to 90% of $HR_{reserve}$ during approximately 100 min of the competition. This model of simulated competition is in accordance with a previous study, in which a similar test protocol was used, with the aim of depleting glycogen (60 min at 70% of $VO_{2max}$). In that same study, supplementation with high concentrations of carbohydrates (500 $g^{-1}$), such as maltodextrin with fructose or maltodextrin with glucose, were not able to enhance performance, but improved the pre-competition muscle glycogen levels and plasmatic glucose concentrations [29].

A wide array of articles show the benefits of supplementation with CHO, where many of these papers use glucose and other CHOs before exercise [30, 31]. However, this study found novel data with maltodextrin supplementation used before exercise, which has a smaller glycemic index when compared to glucose solutions and can avoid rebound hypoglycemia and, as such, decrease endurance performance. In a study conducted by the authors of this paper with rats, plasmatic glucose concentration, insulin responses and fatty acid mobilization (analyzed by blood glycerol concentration) were not statistically different when the difference between a glucose polymer (maltodextrin) and a placebo was analyzed [8].

In the laboratory maximal test, maltodextrin induced an increase in power output at the ventilatory threshold but not in $VO_{2max}$ (at the ventilatory threshold) or maximal oxygen uptake. These data suggest that maltodextrin induced positive effects in performance predominately during sub-maximal intensities and can used as part of a nutritional strategy for an athlete's optimized performance during different training phases at sub-maximal intensities as well as during competitions.

## Conclusion

Maltodextrin enhanced performance during Mountain Biking competition, showing that maltodextrin supplementation can be used as part of nutritional strategy for competing athletes. The results from this study suggest further research is needed in analyzing different dosing of maltodextrin and the consequent glycogen levels and their relation to performance and physiological markers during laboratory simulated mountain biking competition.

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*Correspondence address*
Carlos Ricardo Maneck Malfatti, PhD
State University of Center-West
Riozinho, 153; Km 7, 84500-000
Irati – PR, Brazil
e-mail: crmalfatti@irati.unicentro.br

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# THE INFLUENCE OF EXERCISE ORDER ON LOCAL MUSCULAR ENDURANCE DURING RESISTANCE TRAINING IN WOMEN

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**TIAGO FIGUEIREDO [1] *, MATTHEW R. RHEA [2], DEREK BUNKER [2], INGRID DIAS [1], BELMIRO FREITAS DE SALLES [1], STEVEN FLECK [3], ROBERTO SIMÃO [1]**

[1] Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
[2] A.T. Still University, Mesa, Arizona, USA
[3] Colorado College, Colorado Springs, USA

ABSTRACT
**Purpose.** The purpose of this study was to investigate the effects of different exercise orders on the local muscular endurance of trained women. **Methods.** Nineteen women with a minimum of two years experience in resistance training volunteered to participate in the study (age 27.68 ± 5.24 years; body mass 60.31 ± 7.50 kg; height 161.83 ± 7.05 cm; body mass index 22.85 ± 1.85 kg · m$^{-2}$). Data were collected in two phases: 1) determining the one repetition maximum (1RM) for the bench press (BP), machine lat pull-down (LPD), free-weight shoulder press (SP), standing free-weight biceps curl (BC), and triceps extension (TE); 2) the completion of two resistance training sequences including 4 sets of exercise at 60% of 1RM with 2 minute rest intervals between sets with exercises performed until failure: Sequence A (SEQ A) comprised of: BP, LPD, SP, BC, TE while sequence B (SEQ B): TE, BC, SP, LPD, BP. **Results.** The mean number of repetitions per set in BP and TE presented significant reductions ($p = 0.001$ and $p = 0.026$, respectively) when they were the last exercise performed in each exercise sequence. Rating of Perceived Exertion (RPE) was not significantly different between the exercise sequences; however, increases for BC (in SEQ A) and BP (in SEQ B) were observed when they were performed later in the sequences. **Conclusion.** These data indicate that in trained women, local muscular endurance is affected by exercise sequence, with exercises performed later in a workout sequence showing decreased exercise ability due to fatigue.

**Key words:** strength training, performance, local muscular endurance, OMNI scale

## Introduction

The American College of Sports Medicine's (ACSM) position on progression models in resistance training for healthy adults [1] is that it recommends that large-muscle group exercises generally be performed first in a training session. However, this recommendation has been based on evidence category C (evidence from outcomes of uncontrolled trials or observations). ACSM's [1] recommendations for novice, intermediate, and advanced resistance training include the following exercise sequences:

1. large-muscle group exercises before small-muscle group exercises
2. multiple-joint exercises before single-joint exercises
3. higher-intensity exercises before lower-intensity exercises
4. or rotation of upper and lower body, or agonist–antagonist, exercises, which are exercises performed for one muscle group followed by an exercise for the opposing muscle group [1].

Previous acute [2–10] and chronic studies [11–13] have all demonstrated that performing either large or small muscle group exercise at the end of a training session resulted in significantly fewer repetitions or less strength gains compared to when the same exercise was performed earlier in a workout sequence. With the results quite similar between these acute studies for either large or small muscle group exercises in relation to the number of repetitions performed [2, 5–10], it is recommended that exercises stimulating muscle groups needing maximal adaptation should be placed at the beginning of an exercise session regardless of the size of the muscle group. Recently, Bellezza et al. [2] investigated the influence of exercise order and its influence on blood lactate as well as the affective and perceptual responses to acute bouts of resistance training and suggested that a small to large exercise order may have beneficial physiological and psychological outcomes and potentially influence exercise adherence.

The ACSM's position [1] on both exercise selection and order on increasing local muscular endurance shows that the order of exercises may not be as important as fatigue is a necessary component of local muscular endurance training. To the best of the author`s knowledge, no studies have examined the acute effect of exercise order on local muscular endurance. There-

* Corresponding author.

fore, the purpose of this study was to investigate the influence of exercise order on both endurance and the rating of perceived exertion (RPE) in trained women. It was hypothesized that both large- or small-muscle group exercises would be negatively affected in terms of the total number of repetitions performed to volitional fatigue when these exercises were performed later in a training session.

## Material and methods

### Experimental approach to the problem

In order to investigate the influence of exercise order on volume capacity and the RPE of trained women, the subjects performed two exercise sessions separated by 72 hours of rest using a counterbalanced crossover design. The two sessions were composed of the same exercises performed in different exercise order. Sequence A (SEQ A) began with exercises for large-muscle groups and progressed toward exercises for small-muscle groups. Sequence B (SEQ B) began with the exercises for small-muscle groups and progressed toward exercises for large-muscle groups. The performance of SEQ A and B was separated by 72 hours of rest. All exercises in both sequences were performed for 4 sets to volitional fatigue by using the predetermined 60% of 1 repetition maximum (1RM) for each of the exercises. The number of repetitions was recorded for each set of each exercise for both sequences. The RPE and the number of repetitions performed in each exercise as well as sequence were evaluated to examine the differences in the orders in which exercises were performed.

### Subjects

Nineteen women (age 27.68 ± 5.24 years; body mass 60.31 ± 7.50 kg; height 161.83 ± 7.05 cm; body mass index 22.85 ± 1.85 kg $\cdot$ m$^{-2}$) with at least two years of recreational resistance training experience participated in the study. The inclusion criteria consisted of the following: a) all of the subjects must have experience performing all of the selected exercises; b) the subjects did not have any medical conditions that might be aggravated by participation in resistance training; and c) subjects did not use any nutritional supplements or ergogenic aids. All subjects read and signed an informed consent document and were asked to not participate in any resistance training during the study period other than that prescribed as part of this study. The experimental procedures were in accordance to the Declaration of Helsinki and the study protocol was approved by the Research Ethics Committee of the institution where the experiment was performed.

### 1RM testing

After two weeks of a resistance training familiarization period (comprised of 4 sessions), all participants completed 1RM tests performed on two non-consecutive days for all the exercises using a counterbalanced order. On day one the first trial of 1RM tests were performed and then after 72 hours of rest the 1RM retests were repeated to determine test retest reliability. The heaviest load achieved on either of the test days was considered to be the 1RM. No exercise was allowed in the 72 hours between 1RM tests so as not to interfere with the test retest reliability results. To minimize error during 1RM tests, the following strategies were adopted: a) standardized instructions concerning the testing procedure were given to participants before the test; b) participants received standardized instructions on exercise technique; c) verbal encouragement was provided during the testing procedure; d) the mass of all weights and bars used were determined using a precision scale. The 1RM was determined in fewer than three attempts with a rest interval of 5 minutes between each of the 1RM attempts including 10 minutes of rest was allowed before starting the next exercise test. The range of motion for each of the exercises used was similar to Simão et al. [7]. 1RM testing on both attempts, separated by 72 hours of rest, showed intraclass correlation coefficients of BP, r = 0.95; LPD, r = 0.91; SP, r = 0.92; BC, r = 0.95; TE, r = 0.97.

### Exercise sessions

72 hours after the 1RM loads were determined for each exercise, the subjects performed one of the two exercise sessions in a counterbalanced crossover design. The second session was performed 72 hours after the first session. The two sessions were composed of the same exercises performed in two different exercise orders. SEQ A began with exercises for large-muscle groups and progressed toward exercises for small-muscle groups. The exercise order of SEQ A was free-weight bench press (BP), machine lat pull-down (LPD), free-weight shoulder press (SP), standing free-weight biceps curl (BC) with a straight bar, and seated machine triceps extension (TE). SEQ B began with exercises for small-muscle groups and progressed toward exercises for large-muscle groups. The exercise order for SEQ B was TE, BC, SP, LPD, and BP. Warm-up before each exercise sequence consisted of 10 repetitions of the first exercise of the session (BP for SEQ A and TE for SEQ B) at 40% of the 1RM load. A 2-minute rest interval was allowed after the warm-up before subjects performed the assigned exercise sequence. Both exercise sequences consisted of 4 sets of each exercise (60% of 1RM load) with 2-minute intervals between sets and exercises. During the exercise sessions, subjects were verbally encouraged to perform

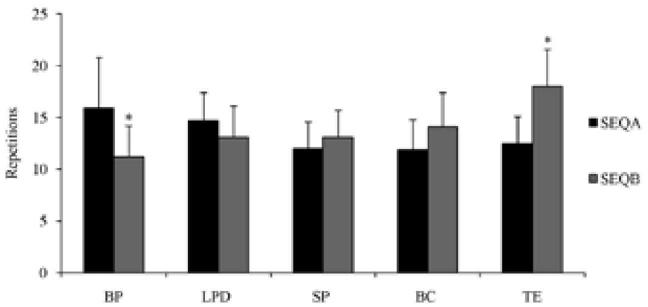
all sets to concentric failure, and the same definitions of a complete range of motion used during 1RM testing were used to define the completion of a successful repetition. No attempt was made to control the velocity in which the repetitions were performed. The total number of repetitions for each set of each exercise was determined. Immediately after completion of the fourth set of each exercise and exercise sequences, the OMNI Scale was used to assess the RPE with emphasis on local fatigue [14].

Statistical analyses

Two-way analyses of variance (ANOVAs) were used to test differences in the mean number of repetitions per exercise and the repetitions per set between sequences. A 1-way ANOVA was used to compare the number of repetitions per set within each sequence. A Tukey post-hoc test was performed where indicated. The RPE at the end of each exercise and exercise sequences was analyzed by a Wilcoxon test. The level of significance was set at $p \leq 0.05$ for all statistical procedures. Statsoft statistical software (version 6.0) was used for all analyses (Statsoft, Tulsa, USA).

### Results

The mean number of repetitions of each exercise for the 4 sets varied significantly between sequences only for BP ($p = 0.001$) and TE ($p = 0.026$). The LPD, SP and BC presented no significant difference between sequences, as defined by $p > 0.05$. (Fig. 1).




SEQ A – sequence A, SEQ B – sequence B, BP – bench press, LPD – lat pull-down, SP – shoulder press, BC – biceps curl, TE – triceps extension, * significant difference found when compared to SEQ A

Figure 1. Mean number of repetitions per exercise in both exercise sequences (mean ± SD)

Comparison between SEQ A and the corresponding SEQ B sets did not demonstrate significant differences for the number of repetitions performed. However, within each sequence, significant differences were observed with the progression of the sets in all of the exercises, with more significant differences found in SEQ A which began with large muscle group exercises (Tab. 1).

The RPE median was not significantly different between exercise sequences (SEQ A: 9 and SEQ B: 9). Increases in RPE for BP (SEQ A: 8 and SEQ B: 9) and BC (SEQ A: 9 and SEQ B: 8) were observed when they were performed later in the sequences (Tab. 2).

### Discussion

An important finding from this study was that exercise order did influence the number of repetitions in the last exercise in each of the sequences, the large muscle group (BP) or a small muscle group (TE), with loads equal to 60% of 1RM. Results found that local fatigue can reduce performance (the mean number of repetitions in 4 sets) in the last exercise of each sequence. For example, the mean repetitions of 4 sets of BP decreased 29% in sequence B when it was at the end of the sequence. Similarly, the mean number of repetitions of TE decreased 30% when it was performed at the end of SEQ A compared to SEQ B when it was performed first in the sequence. This pattern of significant decrease in the mean number of repetitions of the 4 sets, when an exercise was preceded by exercises for the same general body part (the upper-body), was true only in the last exercise of both SEQ A and SEQ B. Additionally, within each of the sequences, significant reductions in repetitions performed per set were found from the first exercise to the end of the exercise sequence. This decrease in the number of repetitions in the successive sets of an exercise appears to be, in part, the result of increasing fatigue as the exercise session progresses.

Two previous studies done by our research group [7, 8] corroborate with the results of this study. Simão et al. [7] compared the effects of exercise order on the number of repetitions and RPE in 14 men and 4 women with 6 months of resistance training experience. The exercise sessions consisted of 3 sets of 10RM for the same exercises that were performed in this study. In that study there were two training sessions, one training session began with large muscle group exercises and progressed to small-muscle group exercises (exercise order: BP, LPD, SP, BC and TE) while the other session first began with small group exercises (exercise order: TE, BC, SP, LPD and BP). Simão et al. [8] also conducted a study that compared two exercise orders in a sample group composed of only trained women. The exercise sequence utilized was BP, SP, TE, leg press, leg extension and leg curl in one sequence, and the exact opposite order in the second exercise sequence. The results of both studies [7, 8] found that performing either large or small muscle group exercises at the end of a training session resulted in significantly fewer repetitions compared to when the same exercises were performed earlier in a workout sequence.

In the present study, the exercises and the sequences adopted are similar to that utilized by Simão et al.

Table 1. Number of repetitions per set in both exercise sequences (mean ± SD)

| | | BP | LPD | SP | BC | TE |
|---|---|---|---|---|---|---|
| SEQ A | First set | 22.0 ± 5.2 | 18.7 ± 2.8 | 15.8 ± 3.1 | 16.2 ± 3.6 | 16.2 ± 3.6 |
| | Second set | 17.4 ± 4.1* | 14.3 ± 2.1* | 12.2 ± 1.6* | 11.6 ± 2.8* | 12.6 ± 3.1* |
| | Third set | 14.1 ± 4.0*† | 13.3 ± 2.1* | 10.3 ± 1.8* | 10.3 ± 1.8* | 10.5 ± 2.4* |
| | Forth set | 10.5 ± 2.4*†# | 12.7 ± 2.1* | 9.9 ± 2.0*† | 9.5 ± 2.2* | 10.8 ± 3.4* |
| SEQ B | First set | 15.5 ± 4.4 | 17.3 ± 4.6 | 16.7 ± 3.5 | 18.9 ± 4.1 | 23.0 ± 3.0 |
| | Second set | 11.1 ± 3.2* | 13.2 ± 2.5* | 13.4 ± 2.2 | 14.2 ± 3.5 | 18.3 ± 3.2 |
| | Third set | 9.6 ± 2.5* | 11.7 ± 1.9* | 11.8 ± 2.1* | 12.2 ± 3.1* | 16.1 ± 2.7* |
| | Forth set | 8.6 ± 2.3*† | 10.2 ± 1.9*† | 10.7 ± 2.2* | 11.3 ± 2.2*† | 14.7 ± 3.1*† |

SEQ A – sequence A
SEQ B – sequence B
BP – bench press
LPD – lat pull-down
SP – shoulder press
BC – biceps curl
TE – triceps extension
* significant difference found from the first set of the same sequence
† significant difference found from the second set of the same sequence
# significant difference found from the third set of the same sequence

Table 2. Rating of Perceived Exertion (RPE) per exercise in both exercise sequences (median)

| | | BP | LPD | SP | BC | TE |
|---|---|---|---|---|---|---|
| SEQ A | Median 4 sets | 8 | 9 | 8 | 9 | 9 |
| SEQ B | Median 4 sets | 9 | 9 | 8 | 8 | 9 |

SEQ A – sequence A
SEQ B – sequence B
BP – bench press
LPD – lat pull-down
SP – shoulder press
BC – biceps curl
TE – triceps extension

[7]. However, there are three basic differences between the two studies: (a) Simão et al. [7] used 10RM resistance while this study used 60% of 1RM to failure, (b) Simão et al. [7] evaluated trained men and women with 6 months of resistance training experience while in this study only trained women with 2 years of experience were evaluated, (c) Simão et al. [7] evaluated the RPE with a Borg scale while this study utilized the Omni scale. Despite these methodological differences, the studies agree that performance decreases in exercises at the end of an exercise sequence. The study results presented here are confirmed by the data from Simão et al. [7], which also indicated a significant reduction in the number of repetitions in the third set when it was compared to the first set, and that more fatigue occurred, as shown by more significant decreases in repetitions per set in successive sets of the same exercise, specifically when the exercise sequence began with large-muscle group and progressed to small-muscle group exercises.

The RPE was used to evaluate the level of local fatigue immediately after the end of the fourth set of each exercise and at the end of the sequences. There were significant increases in the RPE median after the performance of four sets of BP (in SEQ A) and BC (in SEQ B) when these exercises were performed later in the sequences. On the order hand, there was no significant difference in the RPE median between the sequences, confirming the results obtained by Simão et al. [7, 8] and Bellezza et al. [2] which found no significant differences in RPE mean [2, 7, 8] or RPE median [8] for different exercise sequences. In the present and previously mentioned studies [2, 7, 8], each exercise of the sequences were performed to concentric failure in all sets. The validation criteria of the RPE scales have been shown for sub-maximal effort (sets at various percentages of 1RM with sets not performed to concentric failure) [14]. Therefore, it is possible that significant differences in the RPE occur only when a fixed number of repetitions at a predetermined percentage of 1RM are performed, as was done when validating the OMNI-RES scale [14].

A unique aspect of this study, when compared to other acute studies [2–10], is the training intensity that was utilized No previous study investigated the influence of exercise order with low intensities, commonly used when trying to develop local muscular endurance (60% of 1RM or less). The intensities utilized in previous acute studies [2–10] ranged between 8RM [6, 9, 10] and 10RM [2–5, 7] or 80% of 1RM [8], Therefore, this is the first study that analyzed the influence of exercise order on training programs designed for the development of local muscular endurance.

In summary, this study demonstrates that exercise order during a resistance training session, emphasizing local muscular endurance involving upper body exercises, affects the total number of repetitions performed to failure with 60% of 1RM. For both large- and small-muscle group exercises the maximum number of repetitions performed in the last exercise of the sequence decreases in trained women. Higher levels of RPE for the last exercises of the sequences were also observed; however, the results demonstrate that the RPE median immediately following an exercise sequence was not affected by exercise order when all sets are performed to concentric failure. Further research should investigate the influence of exercise order on local muscular endurance in lower body exercises and other exercise orders, as well as the effect of different exercise orders on the performance of women without previous experience in resistance training.

## Conclusion

The present study found that exercise order can influence performance during a local muscular resistance training endurance session performed by trained women. As the exercise session progressed the total number of repetitions performed to failure decreases. This is especially true for the last exercise in a sequence, whether it is a large- or small-muscle group exercise. The implications of this study are relevant in the future design of resistance training sessions with the goal of improving local muscular endurance or in resistance training phases that require moderate intensities. It is suggested that in training programs aimed at improving local muscular endurance, exercises or movements most important to the objective of the training session should be performed at the beginning of the session. This is true regardless whether the exercise is a large- or small-muscle group exercise.

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*Correspondence address*
Tiago Figueiredo
Federal University of Rio de Janeiro
Physical Education Post-Graduation Program
Rio de Janeiro, RJ – Brazil
e-mail: tc-figueiredo@uol.com.br

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# EFFECTS OF FATIGUE INDUCED BY PROLONGED GAIT WHEN WALKING ON THE ELDERLY

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**MARCELO PINTO PEREIRA [1, 2] *, MAURO GONÇALVES [1]**
[1] São Paulo State University, São Paulo, Brazil
[2] Anhanguera College of Rio Claro, Rio Claro, Brazil

ABSTRACT
**Purpose.** Fatigue has been pointed as a fall risk in the elderly; however, the effects of prolonged gait on neuromuscular recruitment and on its pattern remain unknown. The aim of this study was to evaluate the effects of prolonged gait on neuromuscular recruitment levels and spatial-temporal gait variables. **Methods.** Eight healthy older women (age: 72.63 ± 6.55 years) walked at their preferred walking speed for twenty minutes on a treadmill. The Root Mean Square (RMS) from the vastus-lateralis, femoral biceps, tibialis anterior and lateral gastrocnemius muscles were determined at the first and last minute of the test during the moments of Heel Strike (HS), Terminal Stance and Terminal Swing (TS). In addition, coactivation in the knee and ankle as well as the stride cadence and length were measured in the test. The two RMS data (taken at the first and last minute) were compared by means of a Student's t-test. **Results.** Twenty minutes of walking induced fatigue in the subjects, as observed through an increase in RMS, notably during the HS and TS. Coactivation was also influenced by the prolonged gait test. The only gait phase where a risk of falling was enhanced was the HS. Nonetheless, subjects developed strategies to maintain a safe motor pattern, which was evidenced by an increase in stride length and a decrease in stride cadence. **Conclusion.** Tests lasting just twenty minutes on a treadmill were enough to induce fatigue in older adults. However, the level of fatigue was not enough to present a danger or fall risk to elderly individuals.

**Key words:** ageing, fatigue, walking, electromyography, kinematic

## Introduction

Although walking is a human movement pattern that expends the least amount of energy to be performed [1], many aspects play important roles in its performance, such as age and fatigue [2, 3]. Aging is directly related to specific gait adaptations, such as step length decrease [4] and higher mediolateral trunk acceleration [2]. However, these adaptations give rise to greater instability [2, 5].

The instability found in those who are elderly is attributed to the loss of force [6], which is most evident when an individual's muscles are fatigued [7]. The decrease in force in this population segment is due to a reduction in the number of motor units and in neural conduction velocity [8]. The influence of such neuromuscular adaptations can be measured by surface electromyography (EMG), which also allows the evaluation of neuromuscular fatigue. Fatigue can be measured by the amplitude of the EMG parameters. Its effects can be observed through an increase in the Root Mean Square (RMS), that is brought on by the recruitment of new motor units or by a higher activation level of those already activated [9, 10].

EMG can also be used to evaluate coactivation, which is calculated by the agonist and antagonistic ratio. Coactivation is higher in the elderly when compared to younger individuals [11] and it decreases the capacity to produce force during toe-off [5] as well as also increasing heel strike velocity during loading [12]. There is no standard value for this variable; however, increased values represent higher energy consumption [3] and a decreased capacity in controlling movement [12]. In addition, lower coactivation scores have been found to represent a reduction in joint stability [13, 14].

The influence of fatigue on both elderly (an encompassing study was done by Kent-Braun [15]) and younger individuals [16, 17] has been already studied, however it was induced by means of isometric contractions [17] or other movements that are not performed in daily life, such as the seat-to-stand test [2]. Therefore, the effect of fatigue on the elderly induced by functional activities, such as prolonged gait, may better represent the routine movements and adjustments made by this population. In addition, another feature that is still not fully understood is the influence of fatigue on coactivation; recent studies have found that during isometric contractions the co-contraction magnitude is not influenced by fatigue [18]. However, this interaction in the elderly is not clear, especially during gait.

A period of about twenty minutes is recommended

* Corresponding author.

to assess the performance of many body systems of the elderly [19–21], since it represents a sufficient period for registering change without cardiorespiratory risks [20]. As such, the main objective of this study was to evaluate the effect of fatigue on the elderly, induced by gait for a period of twenty minutes. Specifically, the aim of the study was to investigate the effects of fatigue on lower limb neuromuscular recruitment levels, coactivation, and stride spatio-temporal variables. As hypothesized, it was believed that fatigue would cause higher RMS values, would not influence coactivation, and would lead to increased stride cadence and decreased stride length.

## Material and methods

Of a total of 82 invited subjects, 50 agreed to participate in the study. From this subtotal, 19 were not eligible due to the inclusion criteria and another 19 were not considered physically active. Four of the remaining 12 subjects were unable to adapt to walking on the treadmill. Therefore, total participation in this study composed of eight female subjects aged 72.63 ± 6.55 years weighing 63.43 ± 7.98 kg and 1.53 ± 0.05 m in height. All of the volunteers were considered physically inactive (with a score of 6.78 ± 4.50 in a physical activity questionnaire proposed by Voorrips et al. [22], the Modified Baecke Questionnaire for Elderly People). The exclusion criteria were any orthopedic, neurological, visual, vestibular or cardiovascular conditions that would not allow the subject to perform all of the proposed activities. The subjects visited the laboratory on two different occasions, with a minimum of 24 h and maximum of 72 h between the two visits. All of volunteers signed a consent form, approved by the Local Ethics Committee.

During the first visit, the volunteers were familiarized with a Millennium Super ATL motorized treadmill (Ibramed, Brazil), where velocities varying between 1 km/h and 4 km/h were used (with a 0.5 km/h step increase) for 15 min of activity [23].

During the second day of testing, the preferred walking velocity was determined as proposed by Malatesta et al. [24]. The volunteers began to walk at the lowest velocity (1 km/h) which was then progressively increased (0.1 km/h/second) until the subject found a comfortable walking speed. After a 5 min rest period, the same procedure was used, but with an initial walking speed of 4 km/h with progressive speed reduction. Finally, the volunteers' preferred walking speed was determined as the mean of the two tests.

After at least 10 min of rest, the volunteers walked at their preferred walking speed for 20 min or until they voluntarily stopped. During all gait tests, the volunteers used their preferred walking shoes. As a safety procedure, during the entire test the volunteers wore a pelvic belt attached to a special rope that was fixed to the ceiling, with a support capacity of 15 kN. Data was acquired after 3 min of walking in order to take into account for any possible adaptation.

### Kinemetry

Volunteers were filmed with a Panasonic digital camcorder (60 Hz frame rate) positioned perpendicularly to their right sagittal plane. MyoResearch XP software (Noraxon, USA) was used for image acquisition and to simultaneously record EMG data. To determine the gait phases (heel strike), a 2 cm reflexive marker was positioned over the volunteers' right calcaneus, which was then tracked by Peak Motus software (Vicon, USA). The raw digital kinemetric data were filtered by a forth-order Butterworth filter, with a 6 Hz cut-off frequency. The kinematic variables that were determined were stride cadence (strides/min) and stride length (cm).

### Electromyography

Passive Ag/AgCl electrodes (MediTrace, USA), with a 1 cm diameter, were used with the subject's skin prepared (abrasion and cleaning) according to SENIAM. The electrodes were positioned over the vastus-lateralis (VL), femoral biceps (BF), tibiailis anterior (TA) and lateral gastrocnemius (GL). EMG data were acquired using a Telemyo 900 telemetric surface EMG system (Noraxon, USA) with 2000x gain and a 1000 Hz sample rate. Raw data were filtered off-line with a 20–500 Hz band-pass filter.

To identify the Root Mean Square (RMS) of specific gait phases, the entire cycle period (from one heel strike to the next) was normalized at 100% and the raw signal was averaged over 2% periods. Thereafter, for each muscle, the RMS was determined at three different gait phases i) Loading Response (0–10% of the gait cycle); ii) Terminal Stance (30–60%) and iii) Terminal Swing (87–100%) [25], according to the following formula.

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} [f(t)]^2 \, dt}$$

In order to calculate a normalized RMS, all data were normalized by a standard value: the mean RMS of the last five strides (recorded during the entire cycle) at the first minute (MIN1) when data were collected. A schematic of this calculation is shown in Figure 1.

The Coactivation Index (CCI) was determined for the same gait phases as mentioned above and was calculated as follows [26, 27]:

$$\mathrm{CCI} = \frac{2 \times \mathrm{Ant}}{\mathrm{AtTot}} \times 100$$

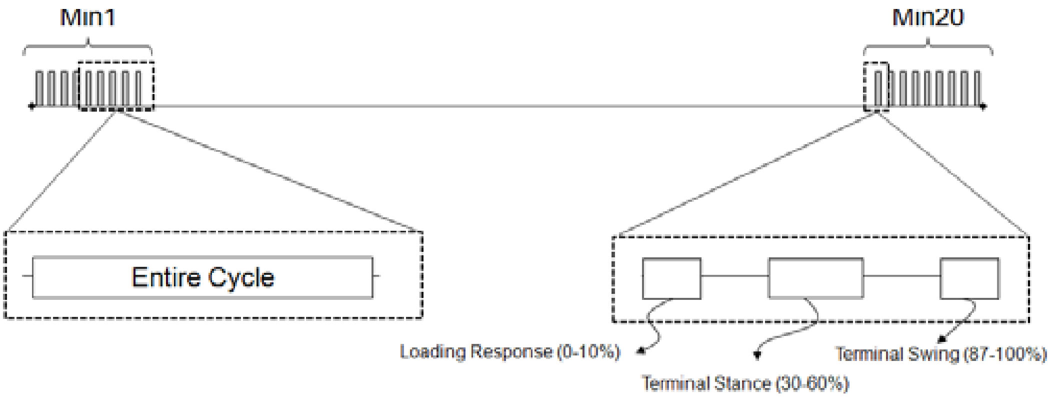


Figure 1. A schematic showing EMG acquisition and processing. Each gray bar represents one step. During the first minute, or MIN1, the RMS value (for each muscle) was determined for the entire stride cycle and during the last five strides (left corner). This value was used for normalizing the RMS values. In addition, three RMS values were determined during the last ten strides at the first (MIN1) and twentieth minute (MIN20): the Loading Response, Terminal Stance and Terminal Swing (right corner). Thereafter, a mean RMS value for each step phase from these last ten steps was determined and normalized as mentioned previously.

where 2 x Ant is double of the antagonistic RMS and *AtTot* is the total muscular activation at a joint (the antagonistic plus agonistic RMS values). Since one muscle can act as agonistic in a specific gait phase and as antagonistic in another, the muscle that presented the higher RMS value during each analyzed period, when compared to its pair (BF vs. VL; TA vs. GL), was considered as the agonistic one. The CCI was determined between VL and BF, and TA and GL.

All of the EMG variables were calculated using specific algorithms in MatLab software (Mathworks, USA). All of the variables were determined from an average of the last ten strides of the first minute (MIN1) and last minute (MIN20) of data collection.

To calculate the activation pattern, EMG data were also filtered with a fourth-order Buterworth filter with a 10 Hz cut-off frequency. The last ten strides of the two test samples, at MIN1 and MIN20, were then averaged and a new average was found for all the subjects.

Statistical analysis

To ensure normal data distribution a Shaprio-Wilk test was used, where the influence of each test stage (MIN1 vs. MIN20) was analyzed by a paired Student's T-test. A $p$ value of 0.05 was considered statistically significant. All data are expressed as mean ± standard deviation.

**Results**

The mean preferred walking speed was found to be 2.64 ± 0.32 km/h. Just one subject was unable to fulfill the entire 20 min test, voluntarily stopping at the twelfth minute of the test. Therefore, for this volunteer, the variables recorded at MIN1 were compared to those recorded at MIN12.

Table 1 presents the RMS and CCI results. During Loading, all muscles with the exception of the GL were higher at MIN20 with a reduction of coactivation in the ankle. During Terminal Stance, TA presented lower RMS values at MIN20 but increased RMS values for VL and GL. During Terminal-Swing, all RMS values of all the muscles as well as the CCI at the knee were

Table 1. The RMS values (% Mean) of the vastus-lateralis (VL), biceps femoris (BF), tibialis anterior (TA) and gastrocnemius lateralis (GL) obtained during MIN1 and MIN20 of the gait test during three different gait phases

| | MIN1 | MIN20 | $p$ – value |
|---|---|---|---|
| Loading | | | |
| VL | 225.45 (58.94) | 252.84 (59.29) | **0.002** |
| BF | 171.66 (88.09) | 189.72 (65.90) | **0.006** |
| TA | 131.91 (63.13) | 169.90 (63.38) | **< 0.001** |
| GL | 112.797 (55.93) | 99.13 (62.00) | 0.780 |
| CCI Knee | 73.22 (13.16) | 76.42 (13.63) | 0.076 |
| CCI Ankle | 72.06 (19.99) | 63.03 (22.14) | **0.004** |
| Terminal-Stance | | | |
| VL | 38.84 (21.86) | 51.01 (27.91) | **< 0.001** |
| BF | 52.28 (34.63) | 58.37 (44.33) | 0.240 |
| TA | 76.17 (33.81) | 60.92 (35.67) | **< 0.001** |
| GL | 123.21 (40.32) | 146.51 (38.55) | **< 0.001** |
| CCI Knee | 77.01 (12.41) | 79.72 (14.02) | 0.195 |
| CCI Ankle | 66.17 (18.21) | 53.76 (19.86) | **< 0.001** |
| Terminal-Swing | | | |
| VL | 219.98 (67.23) | 142.22 (70.94) | **< 0.001** |
| BF | 197.34 (61.54) | 195.08 (82.94) | **< 0.001** |
| TA | 161.66 (48.19) | 123.60 (48.45) | **< 0.001** |
| GL | 73.69 (49.97) | 48.57 (32.23) | **< 0.001** |
| CCI Knee | 84.60 (11.22) | 69.62 (17.14) | **< 0.001** |
| CCI Ankle | 57.07 (24.80) | 56.35 (25.51) | 0.735 |

The values in bold denote statistical significant differences ($p < 0.05$)

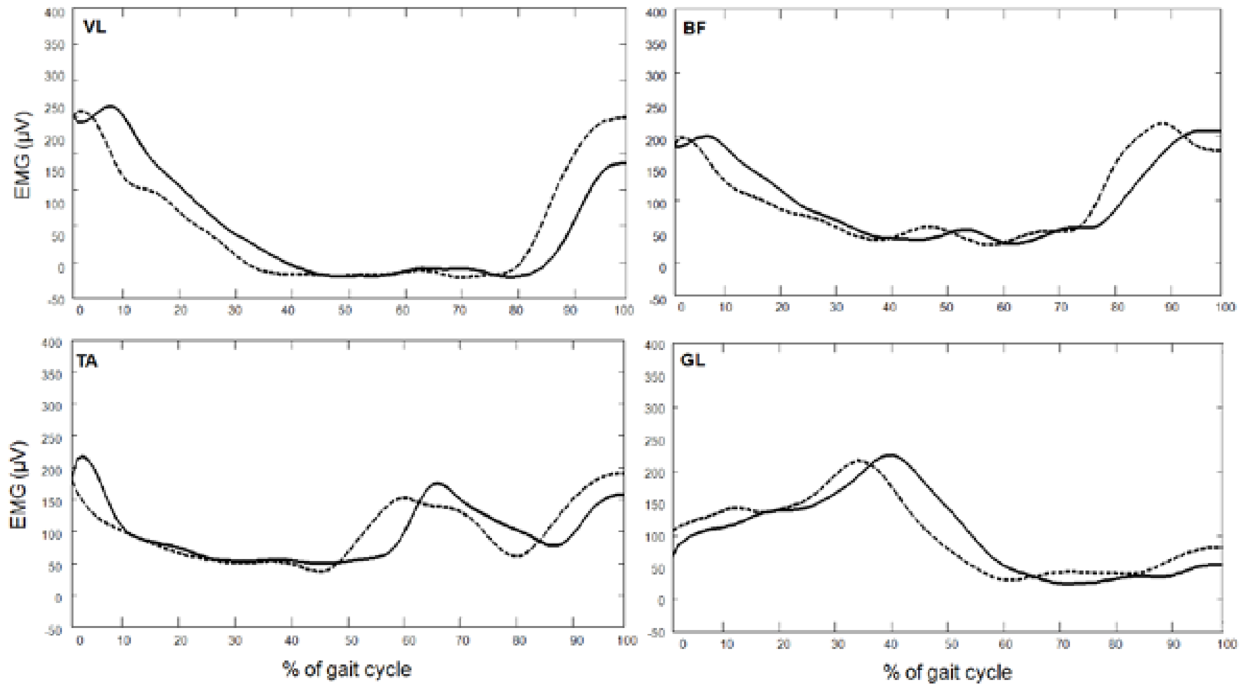


Figure 2. Mean ($n$ = 80 for each minute: 8 volunteers, ten strides) rectified EMG activity (µV) of VL, BF, TA and GL during the entire gait cycle at MIN1 (dot lines) and MIN20 (full lines)

influenced by the gait test, with RMS decrease noted for all muscles.

Figure 2 shows the rectified neuromuscular activation of VL, BF, TA and GL. Besides the magnitude differences already shown in Table 1, a delay in the activation peaks during MIN20 can be observed when comparing it to MIN1 for all muscles. For example, the first peak of VL, during heel strike, occurs at around 5% of the gait cycle at MIN1, while at MIN20 it occurs at around 8% of the gait cycle. Also, for GL, the EMG peak at MIN1 occurs at around 35% of the gait cycle and around 40% at MIN20. However, this analysis is only descriptive, since no statistical evaluations were conducted on this data.

AT MIN20, higher stride length was found when compared to MIN1 (MIN1: 84.42 ± 12.23 cm; MIN20: 87.12 ± 12.35 cm; $p < 0.001$), while stride cadence was lower at MIN20 (MIN1: 53.00 ± 5.23 strides/min; MIN20: 51.50 ± 6.50 strides/min; $p = 0.003$).

## Discussion

The main objective of this study was to investigate the influence of fatigue induced by a functional activity, such as prolonged gait, on neuromuscular recruitment levels and on coactivation levels in the knees and ankles of elderly subjects. What was found was a general increase in muscular activity after fatigue during the landing gait phase with a reduction during the swing phase. Also, a reduction in the coactivation levels was observed in the ankle during the landing phase.

The study's subjects (healthy, elderly adults) usually walked on the treadmill with a preferred walking speed of around 4.64 km/h [28]. However, the mean velocity recorded was 2.64 ± 0.32 km/h. This could be attributed to the physical fitness level of our subjects, since they received overall low scores on the Modified Baecke Questionnaire for Elderly People.

It could be surmised that such a test would not be able to induce fatigue, since twenty minutes of treadmill walking at the preferred gait speed is not an exhaustive activity. However, since the subjects had a low physical fitness level, it was expected that this activity would be enough to induce fatigue. This was confirmed by the increased RMS values for almost all muscles, indicating the presence of neuromuscular fatigue [29]. The increase in the RMS values indicates that new motor units are recruited to maintain muscular tension or a synchronous activation of those motor units already activated [10].

Fatigue also promotes conduction velocity reduction, mainly by the recruitment of type I fibers and by the accumulation of inorganic phosphate and $H^+$ ions [9]. This could explain the EMG peak delays observed in Figure 2. This reduction of conduction velocity could prevent muscles from contracting rapidly, and explain the delay at the observed peaks. However, this analysis was only descriptive and the induction of fatigue can only be properly discussed through RMS data.

During Terminal Swing, the BF muscle presented lower RMS values at MIN20 than at MIN1; therefore a higher heel strike velocity was expected [12], since this muscle is responsible for decelerating the knee extension during this gait phase [12]. This study did not investigate ground reaction forces or heel strike velocity; however, this could explain why the VL and TA RMS values increase during Loading. At this gait phase, with higher velocities of heel strike, these muscles should exert a higher workload to counteract the increased knee flexion and ankle plantarflexion momentum [25]. Since BF and VL presented the same tendency (RMS increase) on Loading, no differences in coactivation were observed in this joint.

However, a coactivation increase was found in the ankle. This can indicate a higher fall risk at MIN20. This coactivation increase can be due to the maintenance of the GL's activation level, contrary to what was observed at the TA. During Loading, the ankle should act as rigid block to support and transfer ground reaction forces to the entire lower limb. Therefore, since lower levels of coactivation implies stiffness in the lower joint [13, 14], we can suggest that at MIN20 these subjects have a less stable joint in comparison to MIN1, indicating a higher fall risk. Hence, even with an increase of VL activation during Loading (maintaining joint preparation to counteract ground reaction forces), fatigue can become dangerous, since the coactivation in the ankle results in a reduction of joint stiffness.

Nonetheless, during the Final-Stance, the subjects were able to adapt enough to maintain a safe gait. Both the TA and GL worked as expected to guarantee enough impulsion: as the GL activation level increased (maintaining muscular tension to counteract fatigue), the subjects reduced TA activity, which reduced coactivation levels in the ankle. A sufficient activation of the GL is necessary during this gait phase to ensure sufficient forward body impulsion and to maintain gait performance [5].

Similarly, during Terminal-Swing, the neuromuscular behavior in the knee at the end of the test showed safe motor strategy. At MIN20, subjects had reduced the recruitment level of the BF, which could increase coactivation in the knee and represent an increased fall risk [30]. However, this reduction accounted for only 2%, far less than the 35% reduction of the VL, which resulted in a reduction of the coactivation level in the knee. The reduction of both the TA and GL also represents a strategy to maintain gait performance, since these muscles are not necessary during this gait phase [25]. This behavior also maintained coactivation levels in the ankle.

Hence, it can be affirmed that such a test, composed of walking for at least twenty minutes, can be used in training or evaluating older subjects and is enough to induce lower limb neuromuscular adaptations but not enough to reduce balance. As mentioned previously, neuromuscular adaptations, such as those observed during the Loading phase, did increase the fall risk. However, the subjects, under more demanding conditions or when they felt unsafe, reduced their step length and increased the step cadence and width [4, 5, 31] in order to increase balance. Therefore, the subject assumed a new motor pattern when they are unbalanced or in hazardous conditions [4, 5, 32]. However, since the subjects increased their step length and reduced their step cadence, it can be affirmed that the neuromuscular adaptations observed at the end of the test were not demanding enough to make the subjects feel unsafe.

Some limitations of this study were the absence of kinetic analysis and the small sample size. However, since the focus of this study was to analyze neuromuscular adaptations, information on ground reaction forces would not produce any new information needed in the discussion. However, additional studies with a larger number of subjects should be conducted in the future.

## Conclusion

It can be concluded that tests involving prolonged gait, such as those which involve at least twenty minutes of walking on a treadmill, are enough to induce fatigue in older subjects. However, in healthy older adults, generally speaking, the level of fatigue is not enough to create a hazardous condition due to the neuromuscular adaptations that were observed which in turn did not lead to an increased fall risk. However, special attention should be given to the Loading phase, as the muscular adaptations that were observed could induce unstable situations. Nonetheless, we can affirm that such a period of walking is safe for elderly subjects and can be used in physical training or for evaluation purposes.

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*Correspondence address*
Marcelo Pinto Pereira
R. Napoleão Laureano, 72
CEP: 13418-160
Piracicaba, São Paulo, Brazil
e-mail: mppereir@yahoo.com.br

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# JUMPING IMPAIRS VISUAL FEEDBACK CONTROL OF BODY POSITION

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**ERIKA ZEMKOVÁ*, DUŠAN HAMAR**
Comenius University, Bratislava, Slovakia

ABSTRACT
**Purpose.** The aim of this study was to evaluate the effects of maximal rebound jumping on sensorimotor tasks that required visual feedback control in positioning the body. **Methods.** A group of 14 university students (age 23.7 ± 2.6 y, height 178.6 ± 9.2 cm, and weight 70.6 ± 11.4 kg) had to hit a target that randomly appeared on one side of a screen by horizontally shifting their centre of mass (COM) in the appropriate direction prior to (as a baseline) and after six 60-second maximal jump exercises. Each response test consisted of 60 targets. The time, distance, and the velocity of the centre of pressure (COP) trajectory between the stimulus's appearance and its hit, by visually-guiding the COM movement on the screen, were registered by means of a FiTRO Sway Check system using a dynamometric platform. During the sets of jumps, the power of the concentric phase of take off was registered using a FiTRO Jumper recorder. **Results**. Results found that after each set of jumping (of around 110 jumps per set), mean response time significantly ($p \leq 0.05$) increased from an initial value of 1616 ± 506 ms to 1825 ± 562 ms till the 4$^{th}$ set, with no further increase towards the 6$^{th}$ set. Similarly, the mean distance of COP covered during the response time increased significantly ($p \leq 0.05$) from a pre-exercise value of 0.449 ± 0.298 m to 0.550 ± 0.295 m after the 4$^{th}$ set which then plateaued towards the 6$^{th}$ set. However, no significant changes in mean COP velocity were detected. **Conclusion.** Rebound jumping negatively affected the visual feedback control in positioning the body. However, after the proprioceptive functions deteriorated to a certain level, there was no further impairment on sensorimotor parameters.

**Key words:** acute effect, center of mass, jumping, task-oriented sensorimotor exercise, visual feedback

## Introduction

Many studies have been carried out to study the effects of different types of exercise on postural stability. For instance, running has been reported to impair postural stability more profoundly than walking [1] or cycling [2]. However, little attention was paid to the intensity and duration of such exercise. Therefore, this study decided to focus on the postural sway response to different forms of exercise and the physiological mechanisms of post-exercise balance impairment (for a review, see [3]).

One of the studies conducted by the authors of this paper [4] proved that despite the same heart rate response, more rapid, intensive, and shorter forms of exercise impair postural stability in the early phase of recovery more profoundly than longer stepwise exercise with a lower contribution to anaerobic glycolysis. Furthermore, prolonged exercise of moderate intensity has been found [5] to cause longer balance disorders as compared to exercise of the same intensity but of a shorter duration. Longer readjustment of postural sway to pre-exercise levels was also observed [6] after upslope treadmill running than after level running which involved different forms of muscle contraction. On the other hand, a comparison of balance parameters after exercises with different activated muscle fibres showed [7] more profound balance impairment after cycling at higher rather than lower revolution rates only in the initial phase of recovery. In the case of resistance exercise, besides the type of exercise and its intensity (of additional load), the rate of movement, the number of repetitions and sets, the muscle mass activated, and the intensity of proprioceptive stimulation all play a role [8].

Fatigue has been generally proposed [9–12] as the principal factor of post-exercise balance impairment. However, such an effect is usually a consequence of prolonged exercise, as shown by Lepers et al. [2], such as after 25 km running or 1 h 44 min cycling, or by Derave et al. [13] where tests were conducted after 30 min of treadmill walking and running. Similarly, it was suggested by the authors of this paper [5] that more pronounced neuromuscular fatigue resulting from prolonged exercise of moderate intensity is responsible for longer balance disorders as compared to exercise of the same intensity but of a shorter duration.

On the other hand, the contribution of hyperventilation or the deterioration of the proprioceptive, vestibular, and visual inputs on such balance impairment has not been well specified. In fact, it has been shown [4] that more pronounced respiration levels, as a result of compensating anaerobic acidosis caused by abrupt intensive exercise, are responsible for the more pro-

* Corresponding author.

found impairment of postural stability when compared to longer stepwise exercise. This assumption was corroborated by close correlations found between the movement of the centre of pressure and level of ventilation in the recovery phase after such an exercise. This finding is in agreement with several authors' reports [14–17] who documented that a higher breathing rate significantly affects postural stability.

Likewise, in another study conducted by the authors of this paper [8] showed that balance impairment in the early phase of recovery after resistance exercise is a consequence of more marked ventilation rather than fatigue. This effect was more evident with exercises performed with the lower (squats and calf rises) than the upper extremities (biceps curls and presses behind neck).

However, the same ventilation levels may be induced by exercises of different muscle contraction intensity eliciting different levels of proprioceptive stimulation. Indeed, a comparison of sway variables after two forms of resistance exercise which lead to the same ventilation levels showed [18] more profound balance impairment after jumping than after calf rises due to a higher intensity of proprioceptive stimulation. This factor was also suggested to be responsible for greater postural sway after running than after cycling [19]. In other words, the intensity of proprioceptive stimulation during exercise also has an important influence on feedback mechanisms that are involved in the control of balance.

On the other hand, there are only few studies available which evaluated the effects of exercise on the visual feedback control of body position. One of the studies, conducted by the authors of this paper [20], showed that the accuracy of visual feedback control in positioning the body, after maximal rebound jumps, is more compromised in the antero-posterior than in medio-lateral direction. However, this was proved through the use of a visually-guided COM tracking task which did not provide information on the visual feedback control of body position after jumping on the basis of different task-oriented sensorimotor exercises. Therefore the aim of this study was to evaluate the effects of maximal rebound jumps on sensorimotor parameters through a visually-guided COM target-matching task.

## Material and methods

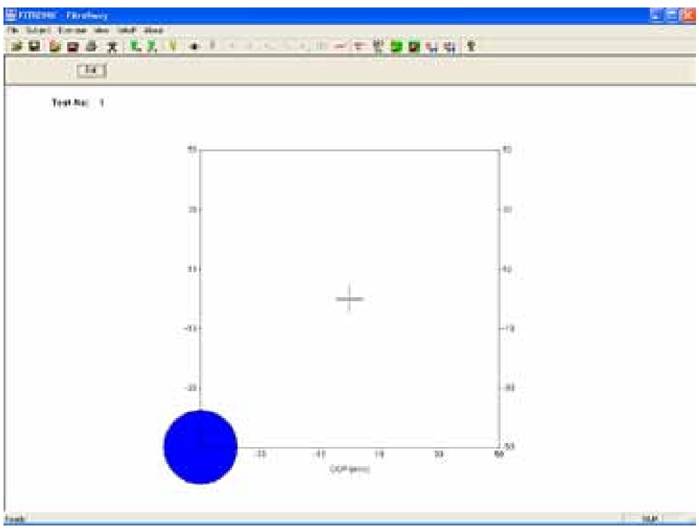
### Subjects

A group of 14 university students studying physical education (age 23.7 ± 2.6 y, height 178.6 ± 9.2 cm, and weight 70.6 ± 11.4 kg) volunteered to participate in the study. All of them were informed of the procedures and the main purpose of the study. The procedures presented were in accordance with the ethical standards on human experimentation.

### Study setting

The subjects' task was to hit a target that randomly appeared on one side of a screen by horizontal shifting their COM in the appropriate direction of where the stimulus was positioned on the screen prior to (as a baseline) and after six 60-second maximal jump exercises (Fig. 1 a, b). Each response test consisted of 60 stimuli. The time, distance, and COP trajectory velocity between the appearance of the stimulus and its hit by a subject's visually-guided COM movement, as seen on the screen, were registered by means of a FiTRO Sway Check (Fitronic, Slovakia) system using a dynamometric platform.

a)



b)

Figure 1. FiTRO Sway Check diagnostic system (a) and the graphic display of an executed task (b)

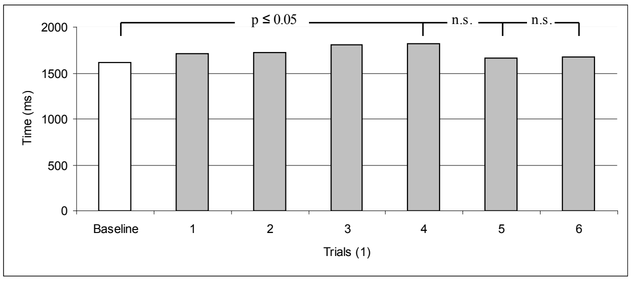


Figure 2. Response time of COP trajectory prior to and after each six 60-second maximal jump exercise

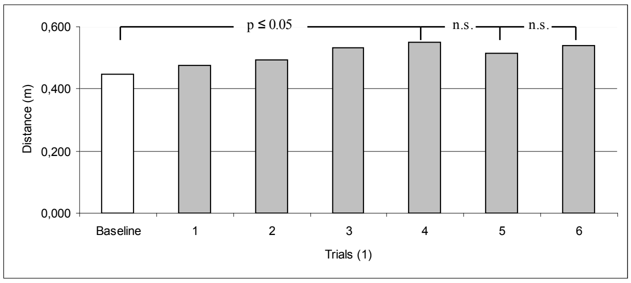


Figure 3. COP trajectory distance prior to and after each six 60-second maximal jump exercise

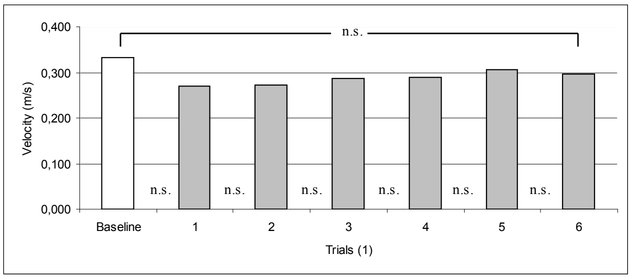


Figure 4. COP trajectory velocity prior to and after each six 60-second maximal jump exercise

During the jump sets, the power of the concentric phase of take off was registered using a FiTRO Jumper (Fitronic, Slovakia) recorder consisting of a contact mat, a serial port interface and a special computer program. The program's calculations are based on the contact time (Tc) and flight time (Tf), as measured by the contact mats, with an accuracy of 1 ms using the formula as follows: Pcon = $((g^2 \times Tf) \times (Tc + Tf)) / 4\ Tc$.

### Statistical analysis

Ordinary statistical methodology including average and standard deviations was used. A paired t-test was employed to determine the statistical significance between the differences between pre- and post-exercise values of the examined abilities; $p < 0.05$ was considered significant.

## Results

The results found that after jumping (of around 110 jumps per set), the mean response time significantly ($p \leq 0.05$) increased from an initial value of 1616 ± 506 ms to 1825 ± 562 ms till the 4$^{th}$ set, with no further increase towards the 6$^{th}$ set (Fig. 2). Similarly, the mean distance of COP covered during the response time increased significantly ($p \leq 0.05$) from pre-exercise values of 0.449 ± 0.298 m to 0.550 ± 0.295 m after the 4$^{th}$ set and then plateaued toward the 6$^{th}$ set (Fig. 3). However, no significant changes in mean COP velocity were detected (Fig. 4).

## Discussion

Theoretically, the impairment of sensorimotor parameters after the maximal rebound jumps may be attributed to a deterioration of both motor and the sensory functions. The effect of impairment on the motor side may be assumed from a decrease in power during the concentric phase of take off (initially from the first to last series of jumps by 10.3% and then by 5.3% in the last 5 seconds of jumping). However, such an assumption is questionable due to the results of other studies finding no correlations between postural sway amplitude and ankle joint pronator muscle strength, [21] and maximum inversion and eversion moments [22]. On the other hand, a fatigue-induced delay in the rate of force development has been associated with an increase in unilateral postural sway amplitude [10]. So, one has to admit that this mechanism played a role in the deterioration of completing a visually-guided sensorimotor task.

It is also possible that the sensory system was affected, namely at the peripheral level, through a change in the spindle excitation threshold of the fatigued muscles. Muscle fatigue induces a depression in the spindle afferent fibre discharge, possibly due to a decrease in γ-motoneurone activation. The gamma system is known to facilitate the alpha motoneurons that control slow-twitch fibres. Assuming a correlation between the activity of the soleus muscle and the COP displacement [12], these fibres are involved in the control of body position. Presumably, it may mainly be a response from the small-diameter III and IV afferents modulating postural reflexes which decreased with repeated contractions [23]. However, besides the impairment of muscle spindle function, the decreased sensitivity of joint receptors and cutaneous mechanoreceptors on the sole, due to their intensive stimulation during jumping, may also be taken in account. The resulting partial reduction of afferent impulses that are utilized in the proprioceptive feedback of body control might also contribute to a less precise perception of COM position and in the regulation of its movement. However, this effect was observed only from the 1$^{st}$ to 4$^{th}$ set of 60-second jumping, after which no further increase in the response time nor in the distance of COP movement occurred. This finding may be explained by a lower susceptibility of the already impaired proprioceptors to further mechanical stimulation during the final 2 sets of jumping. A further reduction of proprioceptive acuity in fatigued legs might be also compensated for by alternative sensory inputs from different body segments, namely the trunk and upper-leg muscles. This shift from an ankle to hip body control strategy is the result of more active contractions that are required to perform the sensorimotor task when fatigued. These contractions could originate mainly from the stretch and vestibular reflexes. Since ankle and calf muscle reflex responses could be delayed due to fatigue, other postural reflexes likely became involved in the regulation of COM movement. These compensatory mechanisms could reduce the further negative effects of jumping on the visual feedback control of body positioning.

These findings are in agreement with results found in a previous study done by the authors of this paper [24], where no linear relationship had been found between post-exercise balance impairment and the level of proprioceptive stimulation. Sway velocity increased 36.6% when compared to to pre-exercise values after jumps dropped to 75% 1MJ. A further 26.0% increase was observed after jumps dropped to 50% 1MJ. However, despite more than double the number of jumps performed when jumps dropped to 25% 1MJ (196 jumps) as compared to 50% 1MJ (81 jumps), sway velocity only slightly increased (on average 8.4%).

As such, it has to be taken into account that not only the type and intensity of exercise, [18] but also height of the jumps [25] and their duration [24] may play a role in the magnitude of balance impairment. Consequently, this may negatively affect performance and increase the risk of injuries.

Landing on one's feet is an important part in sports performance, such as in dancing, gymnastics and aerobics. From biomechanical analyses, it is known that ground reaction forces in aerobics may reach 3-, 4-, and even 5-times that of body weight [26]. Substantially higher peak forces have been recorded in gymnasts' landings ranging from 8.2 to 11.6 times that of body weight [27]. These athletes often land with minimal flexion at the hip, knees, and ankles, which themselves are used as the primary means of attenuating energy during such landings [28]. In addition, gymnasts are exposed to higher ground reaction forces during drop landings from 60- and 90-cm heights (40.3 N/kg and 56.0 N/kg, respectively) than recreational athletes (27.0 N/kg and 37.4 N/kg, respectively) [29].

It may be assumed that repetitive exposure to such high loads may contribute to the incidence of lower limb injuries. These account for 50% [30] to 64% [31] of all injuries suffered, with the most frequent sites of trauma being the ankle [32], followed by the knee [33].

In particular, the functional instability of the ankle joint is a late complication of 10% to 30% of acute ankle sprains [34]. Functional instability is associated with the decreased strength of ankle musculature, impaired proprioception, loss of balance and ligamentous laxity [35]. Decades ago it was postulated [36] that these injuries could have resulted from delayed reflex responses to stress on ankle ligaments as a result of damage to ankle joint receptors at the time of the initial injury. However, recent evidence [37] suggest that the dynamic control of ankle stability is achieved by feed-forward mechanisms of the central nervous system rather than by means of feedback effected by peripheral reflexes.

Caulfield and Garrett [38] have documented that lateral and anterior force peaks occurred significantly earlier in subjects with functional instability of the ankle joint. Significant differences were seen between groups' time-averaged vertical, frontal and sagittal components of ground reaction force. These ranged from 5% (frontal force) to 100% (vertical force) of body mass. According to these authors, the disordered force patterns observed in subjects with functional instability are likely to results in repeated injury due to a significant increase in stress on ankle joint structures during jump landings. They suggest that these injuries are more likely to result from a deficit in the feed-forward control of ankle joint movement. This is also important during the initiation of a vertical jump as the human body´s upward propulsion has been found [39] to depend on the control of forward equilibrium. Due to biomechanical constraints, balance is first lost through a backward shift of centre of pressure. Therefore, the COP is moved forward so as to reach a position favourable to produce a vertical jump.

Tests based on visually-guided COM tracking or on target-matching tasks may provide deeper insight into the changes of postural control induced by exercise. A better understanding of the balance maintenance mechanisms during fatigue [40] may serve as a basis for creating exercise programs focused on the prevention of injuries. Experience has found that task-oriented sensorimotor exercises based on visual feedback control of body position could provide better coordination in stabilizing the body's centre of pressure. Therefore, retraining balance function after lower limb injury using visual feedback exercises could become a promising tool that may complement existing rehabilitation methods.

## Conclusion

Rebound jumping negatively affected visual feedback control of body position. However, after the proprioceptive functions deteriorated to a certain level, there was no further impairment of sensorimotor parameters. More specifically, mean response time and the mean distance of COP covered during the response time increased significantly after four sets of jumps (of around 110 jumps per set) out of six sets, with no further changes in the last two. These findings indicate that there is no linear relationship between post-exercise impairment of postural control and the level of proprioceptive stimulation.

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*Correspodence address*
Erika Zemková
Faculty of Physical Education and Sport
Comenius University
Nábr. arm. gen. L. Svobodu 9
814 69 Bratislava, Slovakia
e-mail: zemkova@yahoo.com

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# SEASONAL VARIATIONS IN THE MORPHOLOGICAL AND FUNCTIONAL DEVELOPMENT OF GIRLS AND BOYS AGED 14–15

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**KRZYSZTOF ZIEMBA [1] *, JULIUSZ MIGASIEWICZ [2]**

[1] Opole University of Technology, Opole, Poland
[2] University School of Physical Education, Wrocław, Poland

ABSTRACT

**Purpose.** During a biological year one can observe the effects of seasonal change on the number of functions and processes in the human organism. The rhythmical seasonal changes of a year are directly connected with a number of the functions of the human body. In humans, the first six months of a year are characterized by increased sympathetic nervous activity, while the next six months are characterized by increased parasympathetic nervous activity. As such, both somatic and motoric changes lead to periods of either high or low physical efficiency. The aim of this study was to assess what changes occur in the morphological and functional development of 14–15 year-old girls and boys across an entire year. **Methods.** The study of the seasonality of motoric fitness described herein was of a longitudinal character and was conducted five times, with a three-month interval between each study (1 – June, 2 – September, 3 – December, 4 – March, 5 – June) during 2004–2005. The study was conducted at the No. 1 and No. 7 Lower Secondary Schools in Opole, Poland, where 452 students (216 girls and 236 boys) participated in the study. **Results.** The results of this study found that there are two phases of increased levels of physical efficiency, which are particularly pronounced in March and June. From the results of this study as well as from results obtained from other available studies, it was found that the transition periods between seasons, especially during the transition between the first and second half of the year, are particularly unfavourable to the human organism. Having assessed these particular periods of the year (on the basis of a participant's training load), it seems necessary to emphasize that this transition is the most pronounced between the autumn and winter seasons. Significant seasonal changes were found in the general metabolism of the body, which is the most visible in regards to somatic development. An increase in the body's height and weight among teenagers starts abruptly in the spring season, reaches its peak in the summer, then it decreases in the autumn season and goes up again in winter. The study shows that from April till September a build-up of tissues occurs in the human organism, while from October till March the body stabilizes and uses its accumulated reserves. In the spring, the human body regenerates its central nervous system as it is influenced by sun and warmth and produces particular substances which function as links in the energetic and regenerative processes of nerve tissue. **Conclusion.** Seasonal changeability in the human organism leads to differences in levels of physical fitness. It is necessary to emphasize the character of seasonal changes on the physical fitness of boys and girls at the age of puberty. Through analysing intersexual variability of motoric skills it is possible to determine the exact direction of these differences. In tests that measured hand movement as well as body agility and flexibility, the female subjects achieved better results, particularly after the winter season. In regards to the scores achieved in the remaining Eurofit tests, the male subjects were at the forefront when compared to the females. On the basis of the research material presented in this article, it is claimed that the seasonal rhythm of the physical efficiency of the human body is also reflected in changes of motoric fitness. Thus, it can be considered appropriate to continue studies in this field in order to understand all and any phenomena and regularities.

**Key words:** seasonal changeability, morphological and functional development, physical fitness, motoric fitness

## Introduction

The seasons play a large role in the formation of a number of functions of living organisms, including the human organism, as they are subject to the revolution of the Earth around the Sun which naturally creates the various seasons of the year. The inclination of the Earth's axis to the circular orbit around the Sun leads to the seasonal cyclicity of almost every component in the environment. Seasonal fluctuations of temperature are of significant importance for humans, plants and animals, but these temperature fluctuations are less influential than those exerted by light. Cyclical changes in air humidity, atmospheric pressure and wind speed are also emphasized as contributors in a number of biological phenomena. The amplitude of these fluctuations is not significant, but it is necessary to emphasize that they differ across different seasons: in winter these fluctuations are four times larger than in the summer. Moreover, in the winter season one may observe lower fluctuations of atmospheric electricity and therefore, depending on the season, the level of electrical conductivity of the air decreases. The same occurs with the ionization of the air and the percentage of ozone contained therein. These stimuli induce and regulate a number of phe-

* Corresponding author.

nomena and processes of a cyclical nature, which are referred to as a "seasonal character of nature" or "seasonality".

In the case of humans, seasonality is highly pronounced and its characteristics are quite visible. However, at this point it is necessary to emphasize that in the case of the human population and the human body, the mechanism of influence of the above stimuli is more complicated. While creating their own microenvironment (clothes, living space, breeding animals, growing plants, changes in duration and intensity of lighting, etc.), people modify their actions towards the above mentioned providers of biological time, namely through either limiting or strengthening their influence. Undoubtedly, the seasonality of living organisms is a product of a number of stimuli each composed of different founding factors, whose intensity is interrelated with the particular season of the year. With the above viewpoint in mind, every biological year can be divided into the following seasons:

– biological winter (16 Nov – 15 Feb);
– biological spring (16 Feb – 15 May);
– biological summer (16 May – 15 Aug);
– biological autumn (16 Aug – 15 Nov).

Working on the above division, Hildebrandt [1, 2] distinguished two phases of the year, namely:

– biological spring and summer (16 Feb – 15 Aug);
– biological autumn and winter (16 Aug – 15 Feb).

The aim of this study was therefore to assess the changes in the morphological and functional development of humans during the cold and warm seasons of the year. This study used a study sample of girls and boys aged 14–15 years. Hypothetically, it was assumed that the colder seasons of the year (autumn, winter) would cause a decrease in the level of physical fitness among the participants in the study.

Having verified the study hypothesis and the very aim of the study, the following research questions were formulated:

– Does the period of puberty have any influence on the assessment of morphological and functional development of the study's participants?
– Do the observed changes depend on the sex of the study's participants?
– Which of the motoric skills subject in the study were the most vulnerable to change?

## Materials and methods

The study participants consisted of 452 students (216 girls and 236 boys). Due to the fact that not all of the study participants completed all of the motoric tests and somatic measurements as planned, only the results achieved by those participants who did not miss any tests and measurements were included in statistical analysis. As a result, only 430 full measurements were recorded, composed of 212 from the female subjects and 218 from the male subjects.

The study of seasonality on motoric fitness described herein was of a longitudinal character and was conducted five times with three-month intervals between each study (the 1st in June, 2nd – September, 3rd – December, 4th – March, 5th – June) conducted during 2004–2005. The study was conducted at the Lower Secondary School (Gimnazjum Publiczne) No 1. and No 7. in Opole, Poland. These schools are attended by teenagers from a sizeable town district. The above-mentioned schools boast a well-developed sports infrastructure such as gyms, football pitches and vast sport grounds. In accordance with the assumptions underlying this study, only the most basic somatic features and motoric skills were subjected to measurements. Using an anthropometer, the body height was measured to an accuracy of one tenth of a cm, while body weight was measured with electronic scales to an accuracy of 0.1 kg. The same equipment was used and its precision was verified throughout all the stages of measurements. An assessment of the functional development was conducted with the use of the Eurofit Physical Fitness Test Battery [3]. To test endurance a multi-stage shuttle run race was used until the subjects reached exhaustion. A detailed description of the particular tests and the method of their measurements can be found in the publication titled: *The EUROFIT Physical Fitness Test Battery*. Taking into consideration dimorphic diversification, the study groups were divided on the basis of sex.

The following methods of statistical analysis were used in the analysing the research material:

Indices of weight and height were calculated on the basis of data derived from the somatic measurements [4]:

$$\text{Rohrer's index: } \frac{\text{body weight [g]}}{\text{body height}^3 \text{ [cm]}} \times 100;$$

$$\text{BMI index: } \frac{\text{body weight [g]}}{\text{body height}^2 \text{ [cm]}} \times 100;$$

The most basic statistical indices were calculated for all tests of seasonal motoric skills and somatic characteristics. On the basis of these indices the student's t-test was used to determine the statistical significance of differences between the averaged results achieved by both girls and boys.

To assess the dimorphic differences, the Mollison's index was used [5], where:

$$WM = \frac{\bar{x}_{\text{girls}} - \bar{x}_{\text{boys}}}{s_{\text{boys}}}$$

where $\bar{x}$ is an arithmetic average of a particular feature, $s$ is the standard deviation of a particular feature. Diagnostic features are synonymous with the values whose differences exceed 100% of the deviation used in the study. A symbol of "+", which can be found at the value of deviation, means that mean values are higher for girls than the ones recorded for boys. The symbol "–" means that mean values are higher for boys [6].

A juxtaposition of changes was calculated in the recorded scores of the various studies, in particular, the motoric tests (in percentage terms).

**Results**

A description of the changes (in percentage terms) in the somatic features recorded for girls and boys in the particular studies (as based on the seasons of the year) enables one to conclude that both body height and weight show similar tendencies for change. However, the values of body height are considerably higher. The biggest increase of body height among girls was 1.53 % (Fig. 1) and 2.99 % among boys (Fig. 2). Similar tendencies were observed in the case of body weight, where its increase among girls was 0.55 % (Fig. 1) and 0.82 % among boys (Fig. 2). Analysis on the seasonality of these changes enables one to conclude that the biggest changes were recorded in the summer, while the smallest changes were recorded in the autumn (0.42% among girls as in Fig. 1, and 0.59% among boys as in Fig. 2). An overview of the available specialist literature [7–9] and on the basis of the data recorded finds that the transition periods between particular seasons of the year are particularly unfavourable for the human organism, especially during the transition between the first and second half-year. Having assessed the particular periods of the year (based on the participant's training load), it seems necessary to emphasize that this transition is the most pronounced between the autumn and winter seasons [10–20].

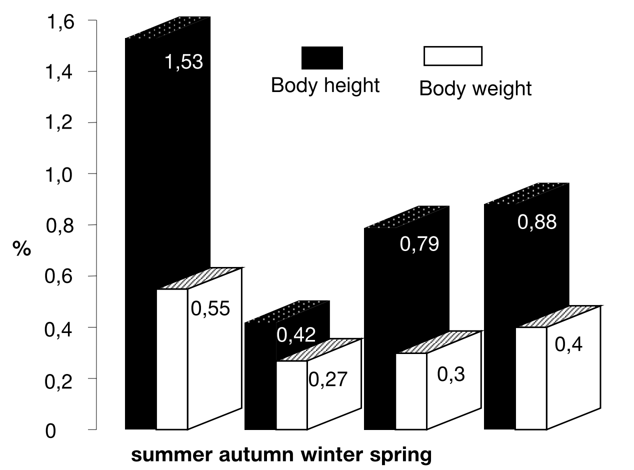


Figure 1. Changes in the values of the basic somatic features among the girls throughout the particular seasons

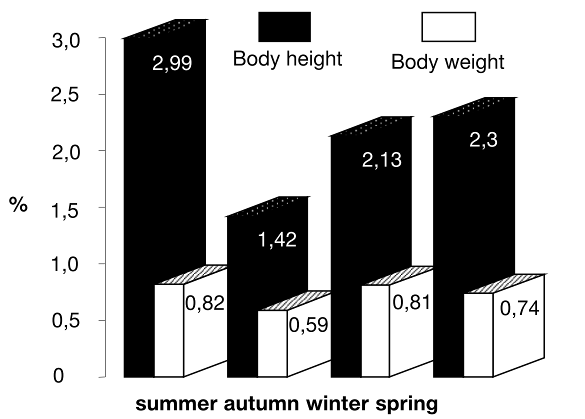


Figure 2. Changes in values of basic somatic features among the boys throughout the particular seasons

The results enable one to conclude that the boys showed a bigger increase of height during the summer season when compared to increases of weight. However, the values recorded during the different seasons were constant, which enables one to conclude that there occurred a steady increase in both height and weight among the boys. In regards to the girls, a small increase was observed in the Rohrer's index after the summer vacation period (between the 1st and 2nd studies), which can be related to the larger weight increase when compared to height (Fig. 3).

The averaged values of the BMI index of the girls and boys in the study increased steadily and systematically during every season of the year (Fig. 4). The dynamics of this index seem to be quite interesting. In regards to the girls, the biggest increase was recorded in the summer (between the 1st and 2nd studies) and spring (the 4th and 5th studies), while for the boys the biggest increase was recorded in the autumn (between the 2nd and 3rd studies) and winter seasons (between the 3rd and 4th studies) (Fig. 4).

The changes in the results achieved by both girls and boys in the particular motoric tests differ considerably. The values of scores achieved by the boys are considerably higher than the results achieved by their peers of opposite sex. The arrangement of the results is particular interesting, such as those that reflect the level of explosive force (measured by a standing long jump) and static force (measured by a dynamometer). The biggest increase in scores achieved by the boys in the standing long jump occurred after the summer season (13%) (Fig. 5), while the biggest increase achieved by the girls occurred after the autumn season (6%) (Fig. 6). A comparison of the charts showing the changes in the particular motoric skills among girls and boys of the same age enables one to draw attention to those values (in percentage terms), which differ greatly from the remaining values recorded in the particular tests during the relevant seasons of the year. It is noteworthy that the summer holiday season (more than 3% of the results) as well as the Christmas and midterm winter break period (more than 2% of the results) exert adverse influence upon the level of explosive force among the girls (Fig. 5). A decrease in results in the standing long jump (1.5%) among the boys may be observed only in the winter season (Fig. 6). It is also noteworthy that the change in the level

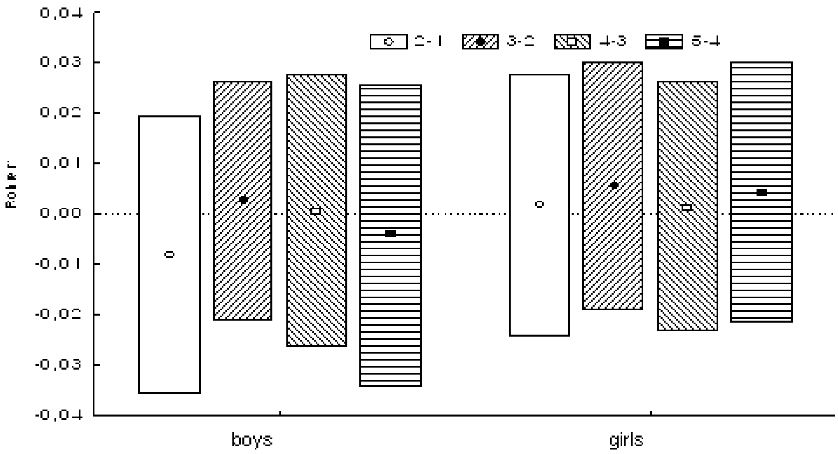


Figure 3. Dynamics of changes in the Rohrer's index among girls and boys throughout the particular seasons

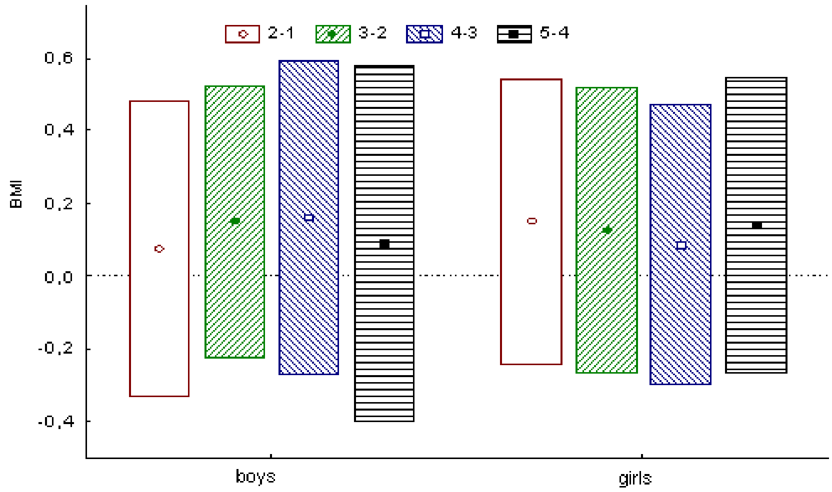


Figure 4. Dynamics of changes of the BMI index among girls and boys throughout the particular seasons

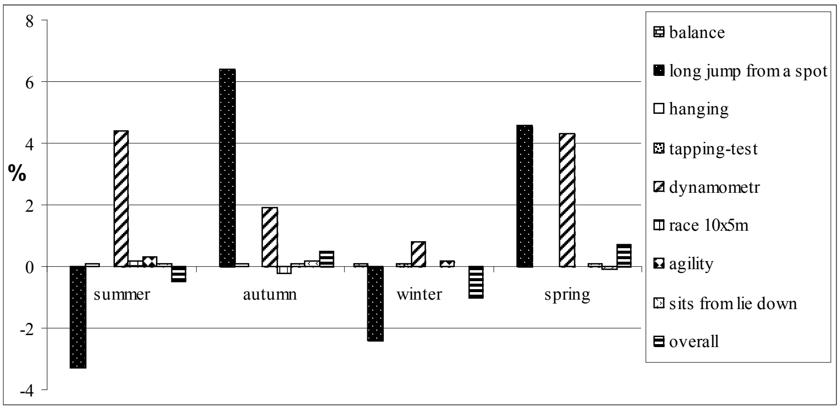


Figure 5. Changes in the scores recorded during motoric tests in the subsequent studies on the group of girls

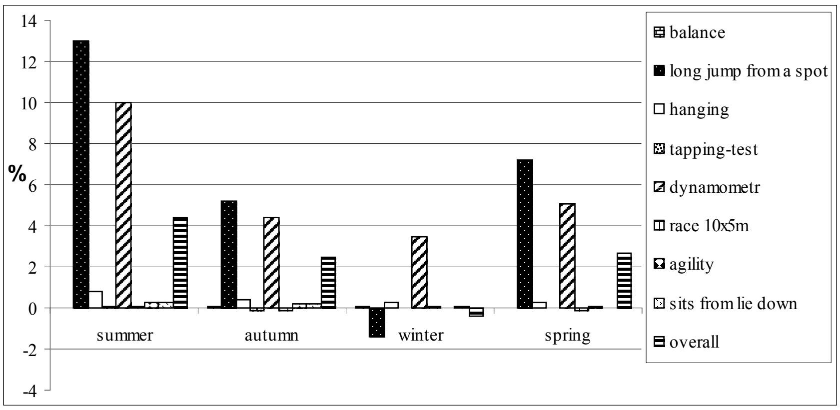


Figure 6. Changes in the scores recorded in the motoric tests in the subsequent studies on the group of boys

of overall endurance (measured by a 20 m shuttle run race) differs considerably more in the changes recorded in the remaining tests. However, this phenomenon is characteristic only for the boys. In regards to the girls, the level of overall endurance changes from season to season, and is alternatively negative or positive. Changes in the scores recorded in the remaining motoric tests (by both girls and boys) remain at stable low levels.

## Conclusions

The diverse dynamics of physical development among the 14–15 year old teenagers subjected in our study is associated with the period of puberty, which brings about changeability in their somatic build.

Boys entering the period of puberty show more dynamics in regards to the increase of body height and weight when compared to the girls.

The dimorphic diversification reflected in the motoricity was the most visible in the range of explosive force of the lower limbs, overall endurance, hand screw force, muscular endurance in the shoulders, and of trunk strength, where boys achieved considerably better results. In regards to speed and coordination tests, girls achieved better results than boys.

The biggest tendency for change among the girls and boys was recorded in the range of lower limb strength, overall endurance and hand screw force.

The seasons of the year exert significant influence on the results of the measurements. Biological spring and, in particular, biological summer play an important role in the development of young human organisms. A decrease in motoric fitness is the most visible during autumn, only to reach its peak during winter.

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*Correspondence address*
Krzysztof Ziemba
ul. Bierkowicka 9b
45-843 Opole, Poland
e-mail ziemb1@op.pl

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# EFFECTS OF HATHA YOGA ON THE SHAPING OF THE ANTERO-POSTERIOR CURVATURE OF THE SPINE

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**MAŁGORZATA GRABARA*, JANUSZ SZOPA**
The Jerzy Kukuczka University of Physical Education, Katowice, Poland

ABSTRACT
**Purpose.** The purpose of this study was to assess the influence of hatha yoga exercises on the shaping of the antero-posterior spinal curvature in first-year students of the University of Physical Education in Katowice who participated in hatha yoga classes. **Methods.** 72 women and 46 men took part in the study. Hatha yoga classes were held once a week for 90 minutes over a period of 15 weeks. Measurements of the subjects' spines were performed twice, first before the start of the classes and then after all the classes were finished. The students were divided into three groups, the first composed of all the participants in the study, the second of students whom attended the yoga classes and practiced hatha yoga in their free time, whereas the third group was composed of students for whom hatha yoga was their only form of physical exercise. The inclination of the antero-posterior curvature of the spine, i.e. the thoracic kyphosis and lumbar lordosis angles, were measured with a Rippstein plurimeter. **Results.** The results found that after 15 weeks of yoga, a decrease in the thoracic kyphosis angle (ThKA) and lumbar lordosis angle (LLA) occurred in most of the subjects. Differences between the values of these angles before/after yoga were statistically significant in women ($p < 0.001$), whereas in men, only a decrease of the thoracic kyphosis angle was statistically significant ($p < 0.001$). After completing the hatha yoga classes, the majority of students (50–62%) were found to have correct angular values of the thoracic kyphosis and lumbar lordosis when compared to the measurements taken before the start of classes (40–45%). **Conclusion.** An assessment on the shaping of the anteroposterior curvature of the spine finds that hatha yoga exercises have a positive impact on one's body posture in the sagittal plane.

**Key words:** physical recreation, hatha yoga, curvature of the spine, thoracic kyphosis, lumbar lordosis

## Introduction

Body posture in the sagittal plane is very difficult to assess due to its permanent variability as well as due to a lack of precise evaluation standards. Body posture also depends on the physical and mental state of an individual as well as in their movement habits. However, proper body posture can be determined by the shaping of the anteroposterior curvature of the spine. It can also be used to measure the efficiency of one's kinetic abilities, muscular balance and motor coordination [1].

If poor body posture is recognized, frequently in the case of children, corrective gymnastics are usually recommended for correction. However, maintaining correct body posture is a life-long effort as all spinal overloads caused by an improper body position can lead to serious ailments and chronic pain. Thus, regular physical activity composed of appropriate physical exercise which enhances core stability and articular mobility can help develop habits that maintain correct body posture.

Hatha yoga is, according to Polish standards, an official form of physical recreation. However, yoga is vastly different from conventional physical exercise, which itself is frequently composed of repetitive movements done at a certain rate with the whole or part of the body. Instead, hatha yoga is based on slowly assuming a particular body position (asana), holding it, relaxing the body and then slowly returning to the original body position. In attempting each asana, a yoga practitioner tries to achieve an optimal body position by placing specific body limbs both in relation to their body and to the ground through the use of their proprioceptors. Some authors also indicate that hatha yoga can be used as a corrective treatment for poor body posture [2]. Many yoga practitioners develop an ability to maintain correct body posture, increase their articular mobility and improve muscular strength and efficiency. There are many more benefits of practicing hatha yoga, one of which is that specific asanas can improve the functioning of the whole body, as well as its particular systems and organs [3–9].

Under the hypothesis that hatha yoga exercises improve body posture, especially in the sagittal plane, the aim of this study was to assess whether practicing hatha yoga did indeed develop habits of maintaining correct body posture in regards to the correct anteroposterior curvature of the spine. The study sample composed of first-year students at the Jerzy Kukuczka

* Corresponding author.

University of Physical Education in Katowice, participating in obligatory hatha yoga classes as part of their PE curriculum.

## Material and methods

The study sample consisted of 72 female and 46 male first-year students studying Sport and Tourism Management at the Jerzy Kukuczka University of Physical Education in Katowice. The subjects took part in obligatory hatha yoga classes once a week for 15 weeks. Two measurements of the subjects' spines were carried out, first before the start of the classes and then after all the classes were finished. Students who missed more than one class during the 15-week period were excluded from the study.

The mean and standard deviation values of the participants' ages (women: 19.8 ± 0.88 years; 19.7 ± 0.79 years) were similar, having a coefficient of variability at around 4%, which pointed to near sample homogeneity.

Some students (36% of women and 61% of men) also practiced other sports or forms of physical exercise apart from hatha yoga (with women practicing on average 2.4 times a week, men, 3.8 times a week). Of those involved in other forms of physical exercise, women most often practiced aerobics, swimming and volleyball; while men most often practiced football, strength sports, combat sports, cycling, volleyball and basketball. In addition, 18% of women and 11% of men declared practicing yoga exercises in their free time outside of the obligatory class, on average 1.6 times and 2 times a week, respectively.

With regard to the students' participation in other sports or physical recreation activities the study sample was divided into three groups: Group I was composed of all students; Group II was of students who practiced no other forms of sports or physical recreation, but those who practiced hatha yoga in their free time; and Group III was of students who did not participate in any other form of physical exercise. For Group III, the 90-minute hatha yoga classes were their only form of physical exercise.

Measurements of the antero-posterior curvature of the spine were performed using a Rippstein plurimeter (Dr. Jules Rippstein, Switzerland). The thoracic kyphosis angle (ThKA) was measured with a zeroed meter at the seventh cervical vertebra (C7) and the upper part of the thoracic spine. The kyphosis angle was then measured by drawing a curve along the kyphosis to the top of the lumbar lordosis. Measurement of the lumbar lordosis angle (LLA) was done again with a zeroed meter placed at the lumbosacral and then drawing a curve along the lordosis to the top of the lumbar lordosis (Fig. 1). A value of 30° ± 5° was accepted for both angles as the correct spinal angle [10, 11].

Statistica ver. 9 statistical analysis software (Stat-

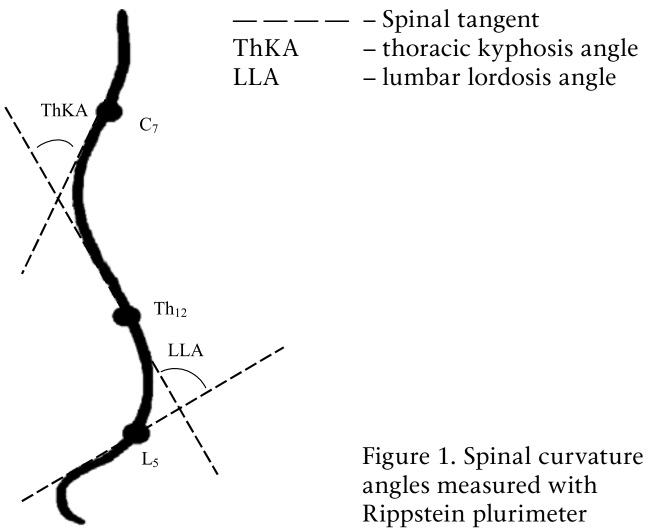


Figure 1. Spinal curvature angles measured with Rippstein plurimeter

soft, USA) was used to calculate the means, standard deviation ($\bar{x}$ ± SD) as well as to analyze the measurement of the thoracic kyphosis and lumbar lordosis angles, with a t-test used for both measurements, with a level of statistical significance set at $p < 0.05$. Both the level of statistical significance ($p$) and the t-value ($t$) are provided.

## Results

Measurements of the spine's antero-posterior curvature before the start of the hatha yoga classes (Measurement I) found that the majority of students had incorrect body posture in their sagittal plane, with the remaining students having the correct thoracic kyphosis angle (ThKA) and lumbar lordosis angle (LLA) (Fig. 2, 3). The plurimeter measurements taken after completing the hatha yoga classes found improvement, with more than 50% of the subjects having the correct angles (Fig. 2, 3). The measurements therefore indicated a positive impact of hatha yoga classes on the improvement of body posture in the sagittal plane.

Analysis of both measurements of the antero-posterior spinal curvature angles show that in the majority of students the thoracic kyphosis angle (ThKA) and the lumbar lordosis angle (LLA) decreased after 15 weeks of hatha yoga classes (Tab. 1, 2). The differences in both angle values between the first and second measurements were statistically significant in all three groups of women; whereas in the groups of men only the thoracic kyphosis angle decreased significantly.

The study results found that hatha yoga had a beneficial effect on the reduction of the thoracic kyphosis angle, which offsets having a rounded back (kyphosis). Having the correct curvature of the thoracic spine in turn affects the correct positioning of the head and shoulder girdle, in expanding the chest, as well as it

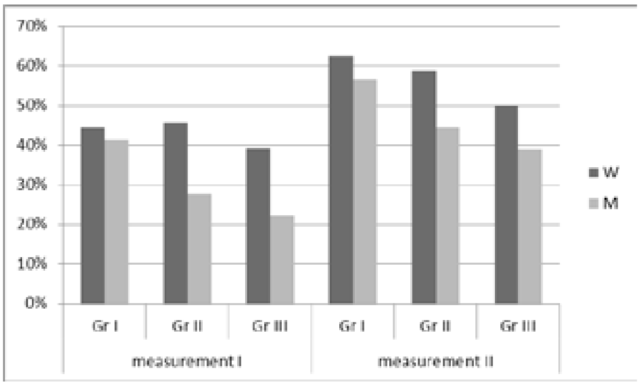


Figure 2. Thoracic kyphosis angle (ThKA) in women (W) and men (M) measured before (Measurement I) and after hatha yoga classes (Measurement II)

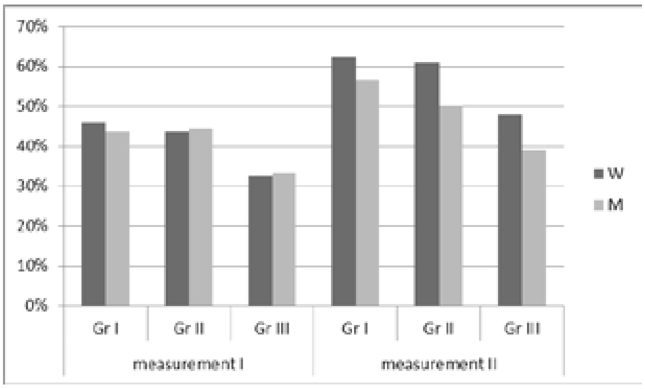


Figure 3. Lumbar lordosis angle (LLA) in women (W) and men (M) measured before (Measurement I) and after hatha yoga classes (Measurement II)

having an effect on the correct shaping of lumbar lordosis. With regard to the examined subjects, this turned out to be highly desirable, as it was found that 31% of women and 37% of men in the study featured excessive thoracic kyphosis (at an angle of 40° and more).

Moreover, excessive lordosis (at 40° or more) was observed more in women (22%) than in men (6.5%). Within the group of men, 33% had a more flattened lumbar lordosis, with an angle that was below 21°, thus for this group a further reduction of lumbar lordosis would not be advisable. The analysis found that hatha yoga's influence on the flattening of the lumbar lordosis was statistically significant only in Group I ($p$ = 0.04), whereas no significant differences were found in the other groups of men (Tab. 2). On the other hand, there was a statistically significant decrease in the lumbar lordosis angle in women. It should be emphasized that an excessive flattening of the lordosis usually leads to an overloading of the intervertebral joints and to pelvic anteversion, while a shallowing of the lordosis causes an overloading of the vertebral and intervertebral discs.

Table 1. Means and standard deviation ($\bar{x}$ ± SD) of the thoracic kyphosis angle (ThKA) of the first-year students at the Jerzy Kukuczka University of Physical Education in Katowice before beginning hatha yoga classes (Measurement I) and after their completion (Measurement II). Statistically significant differences at $p < 0.05$ are in boldface

| Subject groups | | Measurement I (ThKA) | Measurement II (ThKA) | $t$ | $p$ |
|---|---|---|---|---|---|
| | | $\bar{x}$ ± SD | $\bar{x}$ ± SD | | |
| Group I | women $n$ = 72 | **34.65 ± 6.884** | **31.35 ± 5.771** | 5.44 | 0.000001 |
| | men $n$ = 46 | **37.33 ± 7.743** | **32.02 ± 6.137** | 6.97 | 0.0000001 |
| Group II | women $n$ = 46 | **34.57 ± 6.575** | **32.00 ± 5.914** | 3.38 | 0.001488 |
| | men $n$ = 18 | **39.00 ± 8.623** | **32.00 ± 6.843** | 4.53 | 0.000295 |
| Group III | women $n$ = 36 | **34.86 ± 5.856** | **32.14 ± 5.617** | 2.93 | 0.006089 |
| | men $n$ = 14 | **37.43 ± 6.903** | **31.64 ± 6.476** | 4.21 | 0.001028 |

Group I: all students; Group II: students who practiced no other forms of sports or physical exercise besides doing additional hatha yoga in their free time; Group III: students who did not participate in any other form of physical exercise excluding the hatha yoga classes

Table 2. Means and standard deviation ($\bar{x}$ ± SD) of the lumbar lordosis angle (LLA) of the first-year students at the Jerzy Kukuczka University of Physical Education in Katowice before beginning hatha yoga classes (Measurement I) and after their completion (Measurement II). Statistically significant differences at $p < 0.05$ are in boldface

| Subject groups | | Measurement I (LLA) | Measurement II (LLA) | $t$ | $p$ |
|---|---|---|---|---|---|
| | | $\bar{x}$ ± SD | $\bar{x}$ ± SD | | |
| Group I | women $n$ = 72 | **32.88 ± 6.838** | **30.65 ± 5.68** | 3.88 | 0.000233 |
| | men $n$ = 46 | **26.57 ± 7.802** | **24.72 ± 4.246** | 2.15 | 0.037373 |
| Group II | women $n$ = 46 | **33.70 ± 6.514** | **31.41 ± 5.663** | 3.47 | 0.001144 |
| | men $n$ = 18 | 26.17 ± 6.697 | 25.00 ± 4.887 | 1.1 | 0.288207 |
| Group III | women $n$ = 36 | **33.64 ± 6.525** | **31.25 ± 5.684** | 3.04 | 0.004424 |
| | men $n$ = 14 | 25.86 ± 6.479 | 25.00 ± 3.803 | 0.69 | 0.502969 |

Group I: all students; Group II: students who practiced no other forms of sports or physical exercise besides doing additional hatha yoga in their free time; Group III: students who did not participate in any other form of physical exercise excluding the hatha yoga classes

## Discussion

Yoga makes the body more flexible, strengthens muscles and, above all, is conducive to spinal elongation and in maintaining correct body posture. Yoga practitioners consciously work with their bodies to properly align their body, so that that the obtained yoga position becomes ever more stable and comfortable.

With those affected by a flattened antero-posterior curvature of the spine, as was found in many of the study's participants, hatha yoga would be beneficial as such exercises strengthen excessively extended muscles, e.g. thoracic spine extensors, and extend excessively contracted muscles, e.g. ischio-crural and pectoral muscles. However, one of the most important aspects of practicing yoga is postural re-education, i.e. the development and maintenance of correct body posture, which is often hindered by a number of improper postural habits.

The study results explicitly point to an improvement of body posture in the sagittal plane. Measurement of the antero-posterior curvature angles of the spine following the completion of the hatha yoga classes found that a greater percentage of subjects maintained correct body posture in the sagittal plane. This was manifested by a significant reduction of roundback, i.e. a decrease in the thoracic kyphosis angle, in all of the groups and in the group of women, a decrease in the lumbar lordosis angle.

The results of the present study correspond to those of Greendale et al. [12], who studied 118 men and women above the age of 60 and found a statistically significant reduction of hyperkyphosis (above 40°) in subjects attending yoga classes three times a week for 24 weeks when compared to a control group.

Yoga exercises are of particular significance in the development of correct body posture in children. They can be recommended as a component of PE classes or as separate remedial-compensatory classes. Śleboda [2] confirmed the therapeutic and educational value of relaxation and concentration exercises with integrated elements of hatha yoga as well as general kinesiology education, aimed at improving the body posture and agility of 8-year-old boys and girls. The beneficial effects of yoga on body posture were also noted in a study of fifteen 10-year-old children. After 6 months of practicing yoga, a significant correction was observed in shoulder and hip asymmetry, a reduction of head protrusion as well as the disappearance of such symptoms such as contracture of the pectoral muscles and back extensors [13]. All of these research results confirm the positive effects on hatha yoga on body posture, regardless of a subject's age and gender.

Performing each asana requires concentration and control of the body's position in order to avoid breaking the proper movements when entering a pose. Isometric contractions of the muscles enhance proprioceptive stimulation of the parts of the body that are involved, which in turn has a positive influence on their functioning. Stimulating such receptor can improve the functioning of the whole system, for example, through biofeedback. Furthermore, performing asanas can also release muscle tension, strengthen the ligamentous-capsular system and synovial tendon sheaths, as well as remove fascial restrictions [3]. Thus, hatha yoga can be effectively used not only as a corrective exercise, but in kinesiotherapy and as a form of preventive treatment [14].

Furthermore, analysis on the curvature of the spine in the sagittal plane of a basic hatha yoga pose (tadasana, the so-called Mountain Pose) in those who had been practicing yoga for a longer period of time found that this basic position elongates the spine, reduces flattening of the antero-posterior spinal curvature, expands the chest, improves proper head posture (in the so-called Frankfurt plane), prevents an unnatural retraction of the shoulder blades and is conducive to correct pelvic posture.

Nonetheless, proper body posture in the sagittal plane may depend on the time and frequency of regular hatha yoga exercise [9]. The present study did not examine the relationships between proper body posture and participation in additional sports or physical exercise due to significant differences in the identified study sample groups. In addition, it should be noted that the lowest number of differences between the angular values in the two measurements were found in Group III, comprising of students who did not participate in any other form of physical exercise. It should also be stressed that different forms of physical exercise or sports each feature different motor tasks. This particularly relates to those training competitively in sport, whose goal is to solely attain the best results in a sport and not maintain proper body posture.

In summary, body posture in the sagittal plane is an individual feature of every person and may depend on a variety of factors, above all, the type of physical exercise that is performed.

## Conclusion

Before beginning their hatha yoga classes, about 40–45% of the subjects had correct angular values of the thoracic kyphosis and lumbar lordosis. After completing the 15-week hatha yoga classes about 50–62% of subjects were found with the correct spinal curvature angles. The study revealed a positive impact of hatha yoga on proper body posture in the sagittal plane. A significant decrease in the thoracic kyphosis angle was found in the studied male students. In the studied female students, both the thoracic kyphosis and lumbar lordosis angles were reduced.

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*Correspondence address*
Małgorzata Grabara
Katedra Turystyki i Rekreacji
Akademia Wychowania Fizycznego
ul. Mikołowska 72
40-065 Katowice, Poland
e-mail: Malgorzata@Grabara.pl

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# THE IMPACT OF TRAINING ON THE 500 M ROWING ERGOMETER TIME AND AN ASSESSMENT OF THE APPLIED TEST'S RELEVANCY

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ROBERT PODSTAWSKI *, DARIUSZ CHOSZCZ, STANISŁAW KONOPKA
University of Warmia and Mazury, Olsztyn, Poland

ABSTRACT
**Purpose.** The purpose of the conducted research was to determine the impact of training on the time spent covering a distance of 500 m on a rowing ergometer as well as an examination of the representativeness of the adopted sample in developing a method of providing an accurate and reliable assessment of the obtained results when measuring the short-term endurance capacity in a female student population. **Methods.** The research was conducted on 96 full-time female students at the UWM in Olsztyn using a "Concept II Indoor Rower" rowing ergometer, where the impact of regular training on the time of covering the 500 m distance was analysed. The results of the research were statistically analysed in order to examine the conformity of the obtained distributions in the time spent in covering the simulated distance, the subjects' mass and height, an adopted *CPI* value (height/body mass ratio), *BMI* index and the female students' slenderness ratios all within normal distribution. Mathematical (regressive) models describing the impact of the adopted factors on the time of covering the simulated distance were then developed. **Results.** On the basis of the obtained results and the developed mathematical relationships, it was noted that with further repetition of the exercise, the mean time of covering the 500 m distance on a rowing ergometer (based on the results obtained between the 1st to the 10th trial) decreased from ca. 15–20 s. The phenomenon of shortening the covered time may be caused by an improvement in the level of short-term endurance capacity as well as becoming familiarized with the movements (learning) performed on the rowing ergometer. **Conclusion.** A one-time attempt at covering the 500 m distance on a rowing ergometer, at the fastest pace possible and performed once a week, was found to improve the endurance capacity level of the studied subjects. The developed method found herein can be applied as an accurate and reliable test in assessing the time of covering the simulated 500 m distance on a rowing ergometer when determining short-term endurance capacity.

**Key words:** motor fitness, sample of female students, rowing ergometer

## Introduction

The rowing ergometer is a device that is commonly used in sports centers, fitness studios, and rehabilitation clinics as well as in applied research on the physical performance of rowers [1]. The effectiveness of this device in health, utilitarian or sports purposes comes from the fact, among others, that it provides a form of complex and versatile exercise, which almost affects the entire muscular system of the human body. Therefore, the usage of a rowing ergometer provides the possibility of improving one's motor skills, which is one of the main aspects behind an individual's overall motor potential [2].

This device can also be used to measure the motor ability of people in large-scale studies conducted at schools and universities. Regardless of the purpose of research, in each of the case studies, the level of fitness can be interpreted differently depending on the applied differentiating factors (such as somatic, physiological, coordination, and even psychological predispositions) that can have a varying degree of influence on the obtained results [3–6]. In continuation of the earlier conducted studies on the ability to cover a distance of 500 m on a rowing ergometer, future tests should be expanded to include additional physiological and somatic parameters as well as perform testing on the impact of training on the times of repeated ergometer attempts [7–9].

Therefore, in the experiment presented in this study, attempts were made to evaluate the changes recorded during the time needed to cover a distance 500 m on rowing ergometer as quickly as possible and at a fixed frequency of training. At the same an attempt was made to assess whether the effort performed on the rowing ergometer at weekly intervals may have a positive impact on the level of short-term endurance capacity of untrained, young women (people not participating in professional sport). An analysis of this assumption was also made with regard to certain selected somatic parameters. Since each of the fitness tests used here must meet the basic criteria of selection, the study also examined the validity and reliability of the sample population in regards to the students at the University of Warmia and Mazury in Olsztyn.

Therefore the following methods were used in determining the accuracy and reliability of the tests: that the accuracy of the test's content was in accordance

* Corresponding author.

with other experts in regards to its operational compliance, as well as the theoretical definitions developed by the experts in this area [10–12]; also used was an attempt to examine the factorial validity of the test using a parametric set of sequence in order to determine the functional variation that may occur in repeated trials [13].

**Material and methods**

The experiment composed of 96 female students attending the University of Warmia and Mazury in Olsztyn, who expressed willingness to voluntarily participate in the experiment. The average age of the students participating in the study was 21.1 years old (from 19 to 25 years old). These students fully completed 10 trials, each composed of rowing 500 m on a rowing ergometer. The sample selection in this research was guided by the following main criteria: it is known that student study participants are optimal for this type of research due to their developed anatomical profile and their stabilized central and peripheral nervous systems [14] (during such a period there is also a relative balance between the stimulation and inhibition processes [15]). In addition, in this study, those who competitively practiced sports were not included as these persons were found to be defined in categories characterized by the highest rate of biological development (in height and weight) among all students [16], where their strong participation in such sport activities could be an important factor that could impair the obtained results.

In order to ensure that matching conditions existed during the experiment, especially during each of the repeated trials, participants engaged in the trial every Friday (with a weekly rest period) and in the exact same training conditions. In addition, the subjects pledged that in the days preceding the trial they would not drastically change their lifestyle or habits. This mainly applied to performing physical exercise, as the experiment was to be performed at the same time for the following 10 weeks, i.e., each test subject performed the test once a week, composed of covering the 500 m distance as quickly as possible on a rowing ergometer. Besides the trial attempts, the students performed no other form of physical exercise.

Before determining the relationships between the studied variables, the recorded results were examined for any grievous errors [8, 17]. In addition, a sample was used in order to extrapolate whether the analysis could be carried out on the entire student sample population. The results were analyzed statistically using WINSTAT (Winstat, Germany) [18] and Statistica PL (Statsoft, Poland) [19, 20] software. Statistical calculations were carried out at a significance level of $\alpha = 0.05$. The $H_0$ hypothesis was verified to find if the resulting time distribution spent in completing the 500 m distance on the rowing ergometer, during the first attempt, was consistent with having normal distribution. Also tested was the consistency of the resulting empirical distribution of weight and height, and the adopted coefficients of *CPI* (ratio of the students' height to weight), *SI* (slenderness) and *BMI*. Also examined was whether the number of female students admitted in the study was sufficient enough to be treated as representative sample. To determine whether the sample was representative or not, the dependencies provided by Grenia were used [21].

As the authenticity of the obtained results can be described in equally applicable means by several differing models [22–24], it was decided in order to determine the effect of the independent variables (covariates) on other variables (dependent), several functions were tested with the attempt at keeping them as simple as possible yet contain the most amount of information [25]. As a criterion for assessing the fit of the model to the empirical data, the following values were used: the (F) statistic value as the probability of crossing over group variances, multiple correlation coefficients, the percentage of explained variability, the standard residual deviation and the coefficient of random variation. In addition the effect of the structural parameters of significance was determined [25–28].

**Results**

The designated sample size of the trials (with the assumption of an average error rate not exceeding 1.5%) was calculated at 70 people, which was smaller than the true sample size of this study (96 people), therefore it can be treated as a representative sample. The results of the study in regard to the time spent in covering the simulated distance on a rowing ergometer when compared to normal distribution patterns are presented in Table 1. However, the obtained test results on the accuracy of the empirical distributions of the other variable (*m*, *h*, *CPI*, *BMI* and *SI*) with their normal distributions are given in Tables 2–6.

It was found that the empirical distribution of the simulated time to complete the distance of 500 m on a rowing ergometer is consistent with normal distribution, with a mean value of 122.8 s and a standard deviation equal to 7.34 s, and their dispersion in the range of 35 s.

It was found that the empirical distribution of the study participant's body mass is consistent with normal distribution, with a mean value of 58.5 kg and a standard deviation equal to 6.75 kg, and their dispersion in the range of 40 kg.

The test results found that the empirical distribution of the study participant's height is consistent with normal distribution, with a mean value of 167.3 cm and a standard deviation equal to 6.03 cm, and their dispersion was in the range of 30 cm.

Table 1. The accuracy of the test results obtained in an empirical distribution of the time spent completing 500 m on a rowing ergometer with normal distribution

| Interval (s) | Interval average (s) | Empirical size (–) | Theoretical size (–) | Test results | |
|---|---|---|---|---|---|
| 105–108.5 | 106.75 | 3 | 2.5 | The $H_0$ hypothesis: the empirical distribution has normal distribution with the parameters | $\bar{x} = 122.8$ i $s = 7.34$ |
| 108.5–112 | 110.25 | 3 | 4.3 | | |
| 112–115.5 | 113.75 | 11 | 8.5 | With the adopted level of significance | $\alpha = 0.05$ |
| 115.5–119 | 117.25 | 13 | 13.6 | | |
| 119–122.5 | 120.75 | 19 | 17.4 | The calculated statistic value | $\chi^2 = 3.295$ |
| 122.5–126 | 124.25 | 13 | 17.8 | | |
| 126–129.5 | 127.75 | 12 | 14.5 | The probability of exceeding the calculated statistic value | $p(\chi^2) = 0.348$ |
| 129.5–133 | 131.25 | 14 | 9.5 | | |
| 133–136.5 | 134.75 | 7 | 4.9 | If $p(\chi^2) > \alpha$ – then there is no reason to reject the $H_0$ hypothesis. | |
| 136.5–140 | 138.25 | 1 | 3.0 | | |

Table 2. The accuracy of the rest results obtained in an empirical distribution of the subjects' body mass (*m*) in the trials of completing the simulated 500 m with normal distribution

| Interval (kg) | Interval average (kg) | Empirical size (–) | Theoretical size (–) | Test results | |
|---|---|---|---|---|---|
| 42–46 | 44 | 1 | 3.1 | The $H_0$ hypothesis: the empirical distribution has normal distribution with the parameters | $\bar{x} = 58.5$ i $s = 6.75$ |
| 46–50 | 48 | 10 | 6.9 | | |
| 50–54 | 52 | 19 | 14.2 | With the adopted level of significance | $\alpha = 0.05$ |
| 54–58 | 56 | 22 | 20.9 | | |
| 58–62 | 60 | 21 | 21.9 | The calculated statistic value | $\chi^2 = 3.60$ |
| 62–66 | 64 | 11 | 16.3 | | |
| 66–70 | 68 | 7 | 8.6 | The probability of exceeding the calculated statistic value | $p(\chi^2) = 0.308$ |
| 70–74 | 72 | 1 | 3.21 | | |
| 74–78 | 76 | 3 | 0.9 | If $p(\chi^2) > \alpha$ – then there is no reason to reject the $H_0$ hypothesis. | |
| 78–82 | 80 | 1 | 0.2 | | |

Table 3. The accuracy of the test results obtained in an empirical distribution of the female study participants' height *h* in the trials of completing the simulated 500 m with normal distribution

| Interval (cm) | Interval average (cm) | Empirical size (–) | Theoretical size (–) | Test results | |
|---|---|---|---|---|---|
| 150–153 | 151.5 | 3 | 2.5 | The $H_0$ hypothesis: the empirical distribution has normal distribution with the parameters | $\bar{x} = 167.3$ i $s = 6.03$ |
| 153–156 | 154.5 | 3 | 4.3 | | |
| 156–159 | 157.5 | 11 | 8.5 | With the adopted level of significance | $\alpha = 0.05$ |
| 159–162 | 160.5 | 13 | 13.6 | | |
| 162–165 | 163.5 | 19 | 17.4 | The calculated statistic value | $\chi^2 = 7.083$ |
| 165–168 | 166.5 | 13 | 17.8 | | |
| 168–171 | 169.5 | 12 | 14.5 | The probability of exceeding the calculated statistic value | $p(\chi^2) = 0.132$ |
| 171–174 | 172.5 | 14 | 9.5 | | |
| 174–177 | 175.5 | 7 | 4.9 | If $p(\chi^2) > \alpha$ – then there is no reason to reject the $H_0$ hypothesis. | |
| 177–180 | 178.5 | 1 | 3.0 | | |

It was found that the empirical distribution of the study participant's *CPI* value is consistent with normal distribution, with a mean value of 2.89 cm · kg$^{-1}$ and a standard deviation equal to 0.284 cm · kg$^{-1}$, and their dispersion was in the range of 1.5 cm · kg$^{-1}$.

The test results found that the empirical distribution of the study participant's *BMI* value is consistent with normal distribution, with a mean value of 20.91 kg · m$^{-2}$ and a standard deviation equal to 2.2 kg · m$^{-2}$, and their dispersion was in the range of 12 kg · m$^{-2}$.

It was found that the empirical distribution of the study participants' slenderness ratio is consistent with normal distribution, with a mean value of 43.2 cm · kg$^{-0.33}$ and a standard deviation equal to 1.63 cm · kg$^{-0.33}$, and their dispersion was in the range of 9 cm · kg$^{-0.33}$.

Besides the subsequent repetitions on the rowing

Table 4. The accuracy of the test results obtained in an empirical distribution of the female study participant's *CPI* value (their ratio of height to weight) in the trials of completing the simulated 500 m with normal distribution

| Interval ($cm \cdot kg^{-1}$) | Interval verage ($cm \cdot kg^{-1}$) | Empirical size (–) | Theoretical size (–) | Test results | |
|---|---|---|---|---|---|
| 2.15–2.30 | 2.225 | 3 | 1.8 | The $H_0$ hypothesis: the empirical distribution | $\bar{x}$ = 2.89 |
| 2.30–2.45 | 2.375 | 2 | 4.0 | has normal distribution with the parameters | i s = 0.284 |
| 2.45–2.60 | 2.525 | 10 | 8.9 | With the adopted level of significance | $\alpha$ = 0.05 |
| 2.60–2.75 | 2.675 | 13 | 15.1 | | |
| 2.75–2.90 | 2.825 | 21 | 19.5 | The calculated statistic value | $\chi^2$ = 1.493 |
| 2.90–3.05 | 2.975 | 16 | 19.1 | | |
| 3.05–3.20 | 3.125 | 17 | 14.3 | The probability of exceeding the calculated statistic value | $p(\chi^2)$ = 0.684 |
| 3.20–3.35 | 3.275 | 9 | 8.1 | | |
| 3.35–3.50 | 3.425 | 4 | 3.5 | If $p(\chi^2) > \alpha$ – then there is no reason to reject | |
| 3.50–3.65 | 3.575 | 1 | 1.5 | the $H_0$ hypothesis. | |

Table 5. The accuracy of the test results obtained in an empirical distribution of the female study participant's *BMI* value in the trials of completing the simulated 500 m with normal distribution

| Interval ($kg \cdot m^{-2}$) | Interval verage ($kg \cdot m^{-2}$) | Empirical size (–) | Theoretical size (–) | Test results | |
|---|---|---|---|---|---|
| 17.0–18.5 | 17.75 | 10 | 13.2 | The $H_0$ hypothesis: the empirical distribution | $\bar{x}$ = 20.91 |
| 18.5–20.0 | 19.25 | 24 | 19.5 | has normal distribution with the parameters | i s = 2.200 |
| 20.0–21.5 | 20.75 | 31 | 25.6 | With the adopted level of significance | $\alpha$ = 0.05 |
| 21.5–23.0 | 22.25 | 15 | 21.4 | The calculated statistic value | $\chi^2$ = 4.888 |
| 23.0–24.5 | 23.75 | 10 | 11.5 | The probability of exceeding the calculated | |
| 24.5–26.0 | 25.25 | 3 | 3.9 | statistic value | $p(\chi^2)$ = 0.087 |
| 26.0–27.5 | 26.75 | 1 | 0.9 | If $p(\chi^2) > \alpha$ – then there is no reason to reject | |
| 27.5–29.0 | 28.25 | 2 | 0.1 | the $H_0$ hypothesis. | |

Table 6. The accuracy of the test results obtained in an empirical distribution of the female study participant's slenderness ratio (*SI*) in the trials of completing the simulated 500 m with normal distribution

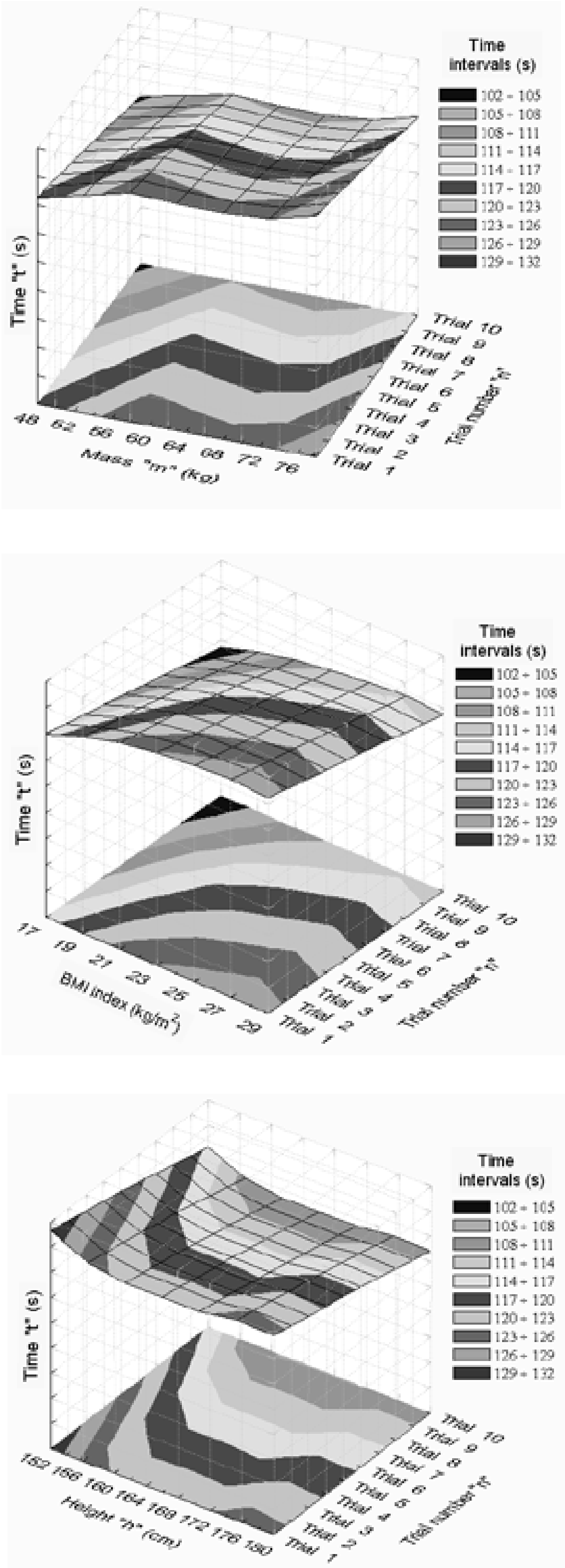
| Interval ($cm \cdot kg^{-0.33}$) | Interval verage ($cm \cdot kg^{-0.33}$) | Empirical size (–) | Theoretical size (–) | Test results | |
|---|---|---|---|---|---|
| 38.5–40.0 | 39.25 | 4 | 2.4 | The $H_0$ hypothesis: the empirical distribution has normal distribution with the parameters | $\bar{x}$ = 43.20, i s = 1.626 |
| 40.0–41.5 | 40.75 | 10 | 11.9 | With the adopted level of significance | $\alpha$ = 0.05 |
| 41.5–43.0 | 42.25 | 27 | 29.1 | The calculated statistic value | $\chi^2$ = 0.518 |
| 43.0–44.5 | 43.75 | 32 | 32.3 | The probability of exceeding the calculated statistic value | $p(\chi^2)$ = 0.472 |
| 44.5–46.0 | 45.25 | 20 | 16.2 | If $p(\chi^2) > \alpha$ – then there is no reason to reject | |
| 46.0–47.5 | 46.75 | 3 | 4.1 | the $H_0$ hypothesis. | |

ergometer, the other covariates that had an effect on the time needed to complete the simulated distance of 500 m are shown in Figure 1. On the basis of the performed statistical analysis it was found that, besides the subsequent trial on the rowing ergometer ($n$), the largest variable that had the most significant influence on the amount of time needed to complete the distance ($t$) was the slenderness ratio ($SI$). That is why it was also adopted as a covariate. Among the tested functions the best-fitting model for the empirical studies was one of second degree polynomials (Tab. 7).

Since the coefficients of the regression equations significantly differ from zero, there is a relationship that describes the covariates' (dependent) effect, i.e., another subsequent trial ($n$) and the slenderness ratio ($SI$) on the dependent variable ($t$). Therefore, the model describing the effect of the independent variables on the time needed to cover a simulated distance of 500 m by the students participating in the experiment takes the equation of (1):

$$t = 8.428906 \cdot SI - 2.539610 \cdot n - 0.120228 \cdot SI^2 + 0.019811 \cdot n^2 - 0.017717 \cdot SI \cdot n - 16.168104 \quad (1)$$

On the basis of the derived mathematical dependencies and on an analysis of the correlation matrix it



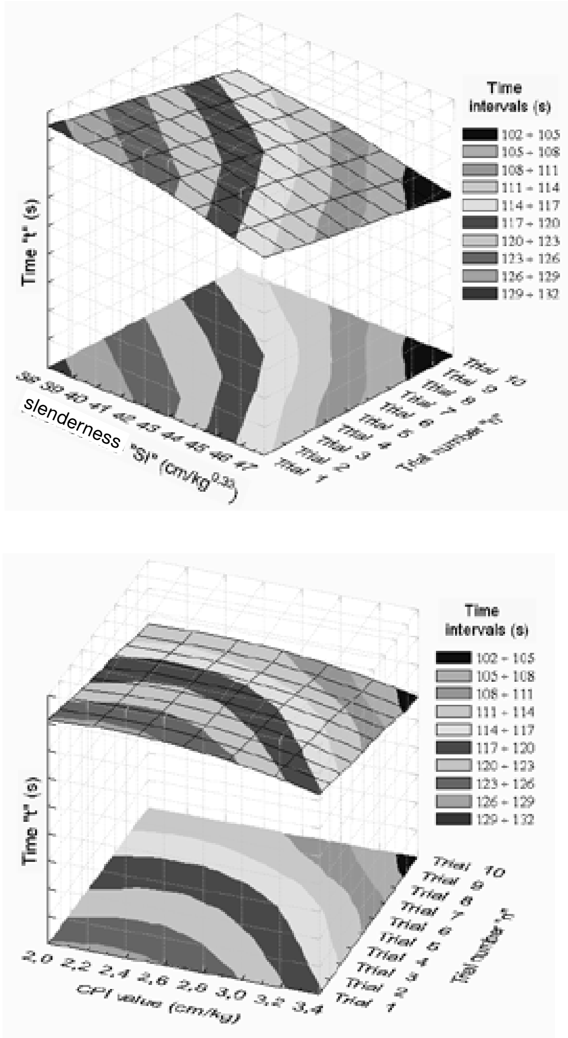




Figure 1. The effect of the research factors on the time needed to complete a simulated rowing distance of 500 m

can be concluded that there is a high correlation between the time in completing each trial and each subsequent repetition (–0.737) and a slightly lower, but also very important, correlation between the time to complete the trial and the slenderness ratio (–0.539). Negative correlation coefficients indicate that both the subsequent attempts of each of the trials and an increase in the slenderness ratio cause a clear reduction in the time needed to complete the simulated 500 m distance. An interactive link was also found between the covariates, i.e., the subsequent attempt at each of the trials with the slenderness ratio of the participant. A more detailed analysis on the effect of the covariates on the response variable equation was performed through a stepwise regression analysis, with the results shown in Table 8.

Following the stepwise procedure, equation (1) becomes:

$$t = 8.526347 \cdot SI - 1.562273 \cdot n - 0.120228 \cdot SI^2 + - 20.780752 \quad (2)$$

After the reduction, the polynomial form that was obtained was far simpler and thus easier to interpret the found relationships. Equation (2) is well matched to the empirical data. The percentage of explained vari-

Table 7. A summary of the results of second degree polynomial regression

| Variable (attribute) | | Average value | Standard deviation | Coefficient of variation (%) |
|---|---|---|---|---|
| Subsequent trial attempts | $n$ (–) | 5.50 | 2.8795 | 52.35 |
| Slenderness ratio | $SI$ (cm · kg$^{-3}$) | 42.86 | 1.9717 | 4.60 |
| Time to complete distance | $t$ (s) | 114.74 | 6.1014 | 5.32 |

Correlation matrix

| | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | –0.000 | –0.737 |
| 2 | –0.000 | 1.000 | –0.539 |
| 3 | –0.737 | –0.539 | 1.000 |

Assessment of fit equation

| | |
|---|---|
| Calculated Snedecor's $F$ value | 209.750 |
| Probability of exceeding the calculated statistic value $F$ $p$ ($F$) | 0.0000 |
| Percentage of explained variability | 84.39 (%) |
| Multiple correlation of coefficient R | 0.91860 |
| Residual standard deviation $S_e$ | 2.442 |
| Coefficient of random variation $W_e$ | 2.13 (%) |

Verification of hypothesis on the significance of the regression coefficients:
* The adopted significance level $\alpha = 0.05$
If $p(F) \geq \alpha$ – there is no reason to reject the $H_0$ hypothesis: the regression coefficients of the equation insignificantly differ from zero
If $p(F) < \alpha$ – reject the $H_0$ hypothesis in favor of the alternative $H_1$: the regression coefficients of the equation significantly differ from zero

Table 8. The compiled results of the regression analysis after the stepwise second degree polynomial procedure

| Variable (attribute) | | Average value | Standard deviation | Coefficient of variation (%) |
|---|---|---|---|---|
| Subsequent trial attempts | $n$ (–) | 5.50 | 2.8795 | 52.35 |
| Slenderness ratio | $SI$ (cm · kg$^{-3}$) | 42.86 | 1.9717 | 4.60 |
| Time to complete distance | $t$ (s) | 114.74 | 6.1014 | 5.32 |

Assessment of fit equation

| | |
|---|---|
| Calculated Snedecor's $F$ value | 350.974 |
| Probability of exceeding the calculated statistic value $F$ $p$ ($F$) | 0.0000 |
| Percentage of explained variability | 84.31 (%) |
| Multiple correlation of coefficient R | 0.9182 |
| Residual standard deviation $S_e$ | 2.4294 |
| Coefficient of random variation $W_e$ | 2.12 (%) |

Verification of hypothesis on the significance of the regression coefficients:
* The adopted significance level $\alpha = 0.05$
If $p(F) \geq \alpha$ – there is no reason to reject the $H_0$ hypothesis: the regression coefficients of the equation insignificantly differ from zero
If $p(F) < \alpha$ – reject the $H_0$ hypothesis in favor of the alternative $H_1$: the regression coefficients of the equation significantly differ from zero

ation is over 84% and the multiple correlation coefficient reaches a value of about 0.92. Similarly, the standard deviation of residuals is relatively small while the random variation coefficient is slightly above 2%.

On the basis of the derived mathematical dependence (2) and the observations made, it can be stated that the covariates having the greatest impact on the response variable was the slenderness ratio (*SI*) of those who engaged in the trial and the subsequent attempts (*n*).

The average duration of the rowing trial of those whose slenderness ratio was $SI = 47$ was about 15 seconds shorter than those who were the most obese ($SI = 38$). The average time of completing the simulated distance of 500 m during the first trial was about 14 s longer than a person performing their 10$^{th}$ trial. Taking into consideration that the coefficient of variation of the time needed to finish the simulated distance and that the slenderness ratio are not significantly different (of a value of 5%), it can be concluded that the relative effect of these variables is comparable.

## Discussion

Research to date on the factors that determine the efficiency of ergometer rowing was aimed at high-performance athletes and only in distances of 1000 m [5], 2000 m [3, 4, 6, 29, 30] or even longer [31]. This probably stems from the fact that, as of now, no professional (prestigious) competitions are held at a distance of 500 m in ergometer rowing. The 500 m distance is frequently found in local competitions which are mostly held for children, adolescents and the elderly (over 60 years of age). As a result, no research has been carried out on the relationships between anthropometric and physiological parameters and the time needed to complete a distance of 500 m in ergometer rowing, besides the research found herein. This raises the significance of this study, particularly in regard to its possible use in research conducted on a large population group of people who do not train professionally in sport.

The results of those studies in distances of 1000 m and 2000 m found differences in the obtained results that were mainly dependent on the participants' weight, age and gender. Rowers (both women and men) having a higher body weight (HWT – High Weight Team) had better results than rowers with a lower body weight (LWT – Low Weight Team) [3]. Studies on physiological parameters found that the obtained results strongly correlated with maximal oxygen uptake ($VO_{2max}$), the involved percentage of slow-twitch fibers, body weight, and the production of lactic acid and the body's tolerance level for acidity [32, 33]. In turn, with trials carried out on a distance of 6000 m, rowers that were distinguished by a higher percentage share of lean body mass and increased total lung capacity had better outcomes [31]. However, in the case of study subjects that did not competitively or regularly row, the situation was totally reversed, where individuals with less body mass had better results. The differences in the obtained results by professional athletes of large body mass and of people practicing only recreational physical activity may be due to a greater percentage of lean muscle tissue (lean body mass) relative to the amount of adipose tissue (fat body mass), which resides in a greater percentage.in the bodies of individuals who do not practice sport.

Considering Mleczko's finding [34], which states that the basis behind motor skills classification are specific structures, functions and processes in the body that are involved with "energy-information", it should be emphasized that human motor potential is primarily determined through energetic (metabolism) and information (perceptual, cognitive and mnemonic) processes [10]. This assumption allows us to place endurance capacity within the group of general fitness abilities, and therefore those that are driven primarily by the level of one's energetic-metabolic processes and motivation [35]. Inline with the above statements is also a theory shared by Szopa, who, together with other experts, place endurance capacity in a group that is characterized by structural-energetic processes, and thus in some way ties itself to the concept of "endurance capacity" as presented by Raczek [36].

These above statements are of primary importance in the classification of the trails in completing the distance of 500 m on a rowing ergometer, due to the nature of the energy conversion processes as it is one that is anaerobic [9], but when considering the duration of the exercise test, one that is an exercise of short term endurance [37, 38]. In addition to the explicit description of the time-space structure of the human body on a rowing ergometer, one draws attention, in accordance with Szopa [39], to the intensity and load of overcoming the resistance that exist in such exercise trails. Therefore, both the exercise intensity and the effort needed in overcoming the resistance (load) increase when trying to shorten the time in finishing the 500 m distance on the rowing ergometer, but each of the respective values increase or decrease simultaneously.

In the research presented in this study, the attempt at assessing the relevancy of the test used in men was also confirmed in women, with the proceedings of the entire test concluding with similar results [9]. Such a parametric sequence test, used to determine the variability of the functions that played a role in each of the subsequent rowing trails by each of the participants found a gradual improvement in all of the students' results after about 7–8 trails. The occurrence of a systematic improvement in all of the obtained results in each of the students may indicate a high degree of reliability and validity of the analyzed experiment. Since after 7–8 trail repetitions did the obtained results begin to stabilize, and that any subsequent iterations did not differ significantly, it can be said that exercising once a week on a rowing ergometer for a distance of 500 m is enough to raise the level of endurance capacity in the studied individuals at least to a certain limit.

## Conclusion

Based on the obtained findings, made observations and the performed statistical analysis, the following conclusions can be made:

1. All of the covariates (the height to weight ratio, *BMI* index, *SI* slenderness ratio and subsequent test attempts) had a significant impact on the dependent variables (time to finish the distance *t*). The model that best suited the empirical data of the test was a second degree polynomial, and the covariate that provided the best fit was the *SI* slenderness ratio and subsequent test attempts.
2. Since approximately 16% of the variation was not explained and that it was found that there was a significant correlation between the time

to complete the distance for the first attempt and then every subsequent attempt, it may indicate the influence of other parameters, such as somatic, physiological or even psychological ones. Therefore, research should be continued and its scope extended in order to include new relevant variables that may affect the time needed to complete the simulated distance of 500 m on a rowing ergometer, such as the effect of the length of the upper and lower extremities and the trunk.

3. The presented method used in the conducted research and studies can serve as an algorithm to develop the results of other research performed on short-term endurance capacity.

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*Correspondence address*
Robert Podstawski
Studium Wychowania Fizycznego i Sportu
Uniwersytet Warmińsko-Mazurski
ul. Prawocheńskiego 7
10-720 Olsztyn, Poland
e-mail: podstawskirobert@gmail.com

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# INDIVIDUAL VARIATION OF BOWSTRING RELEASE IN HIGH LEVEL ARCHERY: A COMPARATIVE CASE STUDY

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HAYRI ERTAN [1] *, AXEL J. KNICKER [2], RUHI A. SOYLU [3], HEIKO K. STRÜDER [2]

[1] Anadolu University, Eskisehir, Turkey
[2] German Sport University Cologne, Germany
[3] Hacettepe University, Ankara, Turkey

ABSTRACT

**Purpose.** The muscle-contraction strategy between the predominant forearm and pull finger used in archery is defined as a response to the fall of the "clicker" by active contraction of the m. extensor digitorum (MED) and the gradual relaxation of the m. flexor digitorum superficialis (MFDS). However, one archer with a long-term high performance history makes use of an entirely different strategy, which is thought to have positive effects on her performance. The purpose of this study was to make a more detailed analysis of the contraction strategy performed by this particular top-level archer and to consider the advantages this strategy may have on bowstring behaviour after release. **Methods.** A high level (world-class) archer volunteered to participate in this study. The subject has been ranked in the top 20 in the world and as one of the top 3 archers in Europe for almost two decades. The subject has a personal best score of 1354 points (pts) in a qualification round as well as receiving 168 pts in an 18-arrow match. The subject engaged in a single test session consisting of 12 shots. EMG activity of the MFDS and MED were quantified. **Results.** The subject's MFDS was found to be clearly relaxed even ~ 100 ms after the snap of the clicker was heard. The subject also showed a gradual relaxation of the MED after the snap of the clicker. **Conclusion.** The study results found that this different type of contraction-relaxation strategy can be used in the drawing arm with success, as it may avoid causing a lateral deflection of the bowstring.

**Key words:** archery, muscular contraction-relaxation, EMG

## Introduction

To fire an arrow in archery, an archer pushes the bow with an extended arm, which is statically held in the direction of the target, while the other arm exerts a dynamic pulling of the bowstring from the beginning of the drawing phase until it is released through dynamic execution [1]. The release phase must be well balanced and highly reproducible in order to perform well in competition [2].

The bowstring is released when an audible signal is received from a device called a "clicker" which is used to check draw length [1]. Thanks to this device, every arrow can be drawn to an exact distance, and therefore a standard release can be obtained. The clicker is reputed to improve an archer's score and is used by nearly all target archers. The archer should react to the clicker as quickly as possible and for this reason a contraction and relaxation strategy in the forearm and pull finger muscles should be developed for repeatable performance.

Ertan et al. [3] identified a contraction-relaxation strategy used in archery during the response to the snap of the clicker, which was executed by a majority of archers irrespective of their performance level. This study described the response to the snap of the clicker as an active contraction of the m. extensor digitorum (MED) and gradual relaxation of the m. flexor digitorum superficialis (MFDS) in all subject groups (high level, beginner archers and non-archers). This active contraction of the MED was defined as the predominant forearm and pull finger muscle contraction strategy that is used in archery. However, one particular archer with a long history of high level performance showed a different strategy, which is thought to have had a considerable positive effect on her performance.

The purpose of the current study was to carry out a more detailed analysis of the contraction strategy performed by this particular top-level archer [3] and to consider the advantages that her strategy might have on performance.

## Material and methods

### Participant

A high level (world-class) archer volunteered to participate in the study. Before the taking of measurements, the subject was informed about the possible risks associated with the experiment. Written informed consent

* Corresponding author.

was obtained from the athlete before participating in the study. The study conformed to the ethical requirements of the 1975 Helsinki Declaration. The subject, whose competitive results are shown in the study, has been ranked in the top 20 in the world and as one of the top 3 archers in Europe for almost two decades. The subject had participated in 4 Olympic Games, 4 World Championships, 8 European Championships and several internationally recognized tournaments. The subject has a personal best score of 1354 pts in a qualification round (composed of four distances) and 168 pts in an 18-arrow match.

Materials

The measurement test sites were prepared as according to SENIAM's recommendations [4]. Ag/AgCl electrodes with a centre-to-centre distance of 2 cm were placed longitudinally along each muscle. The electrodes were placed on the muscle belly and the positive and negative electrodes were positioned parallel to the muscle fibres of the MFDS and MED. The reference electrode was placed on the olecranon process of the ulna [3, 5], which was found to be a relatively neutral test site [6] and suitable for archery shooting as it does not disturb the archer when shooting. The pass band of the EMG amplifier, sampling rate, maximum intra-electrode impedance and CMMR were 8–500 Hz, 1000 Hz, 6 kOhms and 95 dB, respectively.

Design and procedure

The subject engaged in a single test session consisting of 15 shots, the first three being trial shots. EMG activity of the MFDS and MED were quantified. Prior to shooting, the maximum voluntary contraction (MVC) of the MED and MFDS of each subject were determined by EMG as base variables. The subject was instructed to contract the aforementioned muscles to maximum effort against a stable resistance by forming a three-finger hook as is required when holding the bowstring. The MVC of the muscles was recorded.

The angle between the proximal and distal interphalangeal joint was not changed during the isometric contractions of the aforementioned muscle groups. The EMG amplitudes were normalized according to the maximum contraction effort (absolute amplitude) within a 100ms time-window of the highest activity recorded during the MVC.

The snap of the clicker triggered a 5V Transistor-Transistor Logic (TTL) signal, which was registered simultaneously with the myoelectric signals. According to the rise of the TTL signal, two one-second periods were identified as pre-clicker and post-clicker intervals. The respective EMG data sets of each of the twelve shots were fully-wave rectified and filtered (a moving average filter with a 100 ms time-window). Figure 2 shows the processed (averaged, rectified, filtered and normalized) EMG data for each muscle group separately.

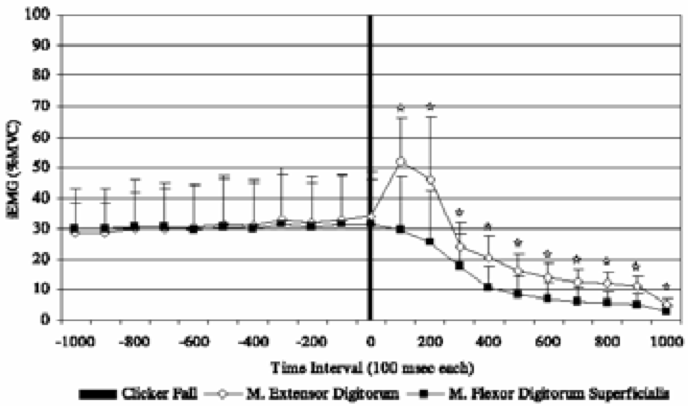
Mean scores were calculated during the subject's 12 shots. One-way analysis of variance (one-way ANOVA) was conducted to compare the MED and MFDS activity during each time interval. ANOVA was followed by Tukey posthoc comparisons to determine the intervals where significant differences did occur. A probability of $p < 0.05$ was selected to indicate statistical significance.

## Results

During the final moments of the full draw phase the archers' finger flexors and extensors showed an almost isometric contraction pattern indicating that the final drawback of the bowstring is obviously regulated by the shoulder and back muscles. As soon as the arrow had been drawn beyond the clicker device, extensor muscle activation increased and the fingers actively released the bowstring and arrow. It is evident that the timing and intensity of muscle activation show variations specific to an athlete's performance level. Novice archers increase muscle activity prior to release with a steady and continuous increase of extensor activity throughout the pre- and post-clicker phase and a delayed relaxation of finger flexors after the snap of the clicker. More experienced archers have developed an activation strategy which is characterized by a comparable level between flexor- and extensor muscles prior to the clicker signal but a pronounced active extension of the fingers in response to the clicker signal (see Fig. 1).

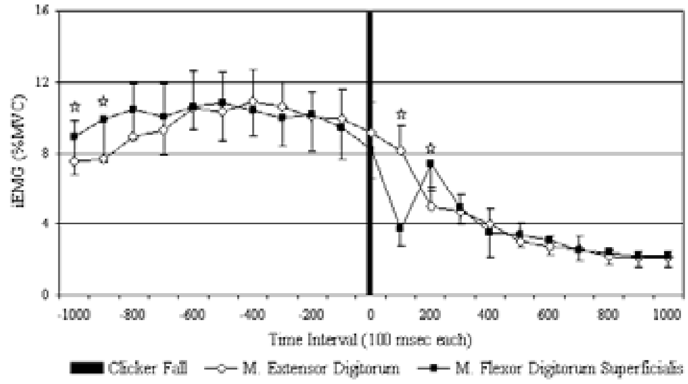
Comparing the activation patterns of this particular top-level archer to those of the different performance level groups reveals obvious differences [3].

The subject of this study presented a clear relaxation of the MFDS approximately 100 ms after the snap of the clicker. She also showed a gradual relaxation of the MED after the snap of the clicker. In other words,




* denotes a statistical significant of 0.05 between the MED and MFDS

Figure 1. IEMG values for elite archers
(the figure is taken from Ertan et al. [3])




* denotes a statistical significant of 0.05 between the MED and MFDS

Figure 2. IEMG values for the elite female archer

there was no active contraction of MED. Throughout the entire shot, the normalized values of the MED and MFDS were significantly different ($p < 0.05$) at the time intervals of –1000, –900, 100, 200 ms (Fig. 2). However, an active contraction of MFDS was observed approximately 200 ms after the snap of the clicker and just after the period of sudden relaxation. From high-speed film observation it is known that the bowstring travels past the fingertips within a time period of about 60 ms [2]. The activation of the archer's MFDS consequently does not further influence bowstring travel.

## Discussion

The contraction and relaxation strategy in the forearm muscle during the release of the bowstring is critical for accurate and reproducible scoring in archery. Up until now, two different approaches to this strategy were proposed in previous studies [2, 7–10].

The first approach suggested that an archer should release the bowstring through a sudden relaxation of the muscles that maintain the flexed position of the fingers around the bowstring rather than attempting to affect the release moment by willingly extending the fingers through concentric antagonistic muscle action [9]. An active extension of the pull fingers is proposed to produce lateral deflections of the bowstring and to produce less consistency in shot-to-shot performance [10].

The second approach suggested, based on representative experimental data, was the relaxation of the flexors and an active contraction of the extensors [3]. Muscular coordination between the agonist and antagonist muscles of the forearm [11] is essential in this strategy and requires a relatively long training period [2, 7, 8].

The specific archer in this study responded to the snap of the clicker by the relaxation of the MFDS and without an active involvement of the MED. The subject's contraction-relaxation strategy is different from those of other archers as described in earlier findings. In the subject's strategy, the release of the bowstring is accomplished by only relaxing the MFDS. Therefore, the force of the string on the fingers is sufficient to produce the extension of the three finger hook.

The relaxation of the muscles directly after the snap of the clicker makes the tension of the bowstring the only mechanism to open the fingers, which then provide no further resistance. An active, muscle driven extension of the fingers, as observed in other archers, could allow the fingers to drag against the bow string sideways and thus force it to deflect from a straight path until arrow delivery. It is most likely that the muscle activation strategy developed by this study's particular athlete avoids a deflection of the bowstring and considerably contributes to the repeatability and reliability of her performance.

Archery shooting is a good example of the isometric contractions present in the forearm muscles of the drawing arm. Before the snap of the clicker, the archer is not supposed to change the range of motion of the proximal and distal inter-phalangeal joints. To do so, the muscles involved in this specific movement pattern must be held at a constant length instead of being allowed to lengthen or shorten. However, the range of motion of the proximal and distal inter-phalangeal joints may be allowed to change, but to do so, requires responding to a specific stimulus by coordinating agonist and antagonist muscles which necessitates a long training period.

## Conclusion

The current literature on forearm contraction-relaxation strategies for the drawing arm states, in general, that a response to the snap of the clicker requires an active contraction of the MED and relaxation of the MFDS. The performance level of a subject may also influence some change in such a strategy (refer to Ertan et al. [3] for more detail). However, the current findings prove that a different type of contraction-relaxation strategy can be used in the drawing arm as it may avoid causing a lateral deflection of the bowstring.

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*Correspondence address*
Hayri Ertan
Anadolu University
School of Physical Education and Sports
26470 Eskisehir, Turkey
e-mail: hayriertan@gmail.com

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# VITAL VALUES AS PERCEIVED BY MAX SCHELER AND JOSÉ ORTEGA Y GASSET

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**KATARZYNA SALAMON-KRAKOWSKA**
University School of Physical Education, Wrocław, Poland

ABSTRACT
Contemporary mass culture is such that it now demands that one takes care of their body. The cult of the body has dominated our actions to such an extent that, oftentimes, the value of a person is perceived in terms of his or her physical perfection. However, the modern cult of the body cannot be seen as a revival of the ancient Greek concept of kalos kagathos. Today's culture, while coaxing people into tending to their body's needs, mystifies that very care. The question therefore arises whether the cult of the body upholds the value of body or whether it, in fact, denies it.
Facing such a paradox, one may first question what significance the body itself has. Here, Max Scheler's concept of nobleness seems to be an alternative to the extremes represented in the philosophy of the body by both the traditional schools, more in line with Plato, and between those with more contemporary, somatocentric tendencies. As such, this antagonism between the noble and the ordinary constitutes one of the core issues in the demonstration of a human's vital values, values connected with maintaining life and health, in both the physical and mental aspects.
This paper aims at presenting the range and specificity of such vital values and their influence on human activities. Scheler draws a clear demarcation line between those values which are vital and those which are hedonistic and utilitarian. His concept of vital values assumes that they encompass the widely understood ideas of physical culture, health promotion and ecology. He does not reduce the vital values when compared to those hedonistic, but underlines their autonomy and grants them a high standing in the hierarchy of values. While considering Scheler's philosophy of vital values, this paper will also set them in the context of Ortega y Gasset's speculation on values.

**Key words:** axiology, physical activity, body, nobleness, vitalit

## Introduction

Modern man has been beset by an omnipresent demand to take care of his body. Those residing in the world of mass culture, apart from what we may call a small group of "heroic" outsiders, may not ignore its demands for fear of being accused of disrespecting themselves. Mass media, various opinion-forming circles, food-producers, the manufacturers of cosmetics and food supplements, as well as fashion designers and those in business aimed at promoting a so-called healthy life-style, all compete in inventing new arguments and reasons for our bodies to receive ever more attention. However, this idea is nothing new, where in order to maintain the integrity of being a human, requires one to equally mind both the body and the soul. Yet the modern cult of the body cannot be seen as a revival of the ancient Greek concept of *kalos kagathos*. Today's culture, while coaxing people into taking care of their bodies, mystifies that very care.

Therefore, the question arises whether the cult of the body upholds the value of body or whether it, in fact, denies it. A person convinced about the importance of so-called "body care", which in fact involves the interference with, and a modification of, the body, paradoxically denies his or her original intention. Human corporeality becomes commodified in the process, acquiring a value only after having met specific requirements. Thus, the value of the body becomes itself a paradoxical notion: is a body itself a value, does it have a value or, perhaps, is it valuable? When does a body have any value? Is the value of a body determined by anything specific? If so, what requirements need to be met to give value to a body?

Max Scheler's concept of nobleness, when taken into consideration, provides an intellectual option which prevents us from plunging into any of the extreme views on human bodiness, either stemming from the more traditional, Platonic schools of thought or those stemming from more contemporary, somatocentric ideologies. Unlike other axiological theories, Max Scheler's typology of values is not burdened with too many ontological or ideological resolutions. Although Scheler assumes that values have an objective and normative status (that is, values are binding), he abstains from determining their ontological status. He does not determine the definitions of values or any specific classification of their kinds or modalities. Rather, he indicates the centres of where the values appear, which opens his approach to an empiric characterization of human preferences and choices. Max Scheler belongs to a group of axiological objectivists, hence to him values are objective characteristics discovered by humans in objects. However, values, although discovered in objects, are not things unto themselves, nor are they features of things, nor do they come from the mental states of human beings. Values are simple and primary qualities and, as such, they remain indefinable. Jan Galarowicz, a researcher on Scheler's ethics, finds that "values are specific qualities that cannot be narrowly identified in the properties of things. As ideal beings they determine the importance and value of humans, of their acts, things, the states of things, etc." [1, p. 79]. Admittedly, Scheler ascribes values to a status of ideal beings, but at the same time, he precludes their association with those ideas coming from the Platonic mind-set [2].

## Typology of values according to Max Scheler

Max Scheler distinguishes five kinds of values which are also described as value modalities (*Wertmodalitäten*). The first modality refers to hedonistic values (also known as hedonic or pleasurable). Sensual, hedonic values concentrate on the opposites of pleasant and unpleasant. They are connected with sensual sensations, such as the feelings of pleasure, pain and suffering. The second modality refers to utilitarian values which deal with the useful and the harmful. It must be mentioned here that the latter one is sometimes omitted by Scheler. The third modality refers to vital values which concentrate on the opposites of what is noble and ordinary. Vital values manifest themselves in feelings of bravery and paltriness, health and illness, power and weakness, ascents and drops in stamina, and they are all connected with maintaining life and health, in both the physical and mental aspects. Scheler characterizes this modality in the following way: "All values of this modality, if they are values in themselves, are the qualities which deal with the opposites of 'what is noble' and 'what is ordinary' [or maybe 'what is good' in the very specific meaning of the expression where it equals to 'what is suitable' (das Tüchtige) and is not opposite to 'what is evil' (das Böse), but rather similar to 'what is unsuitable' (das Schlechte)]" [3, p. 1539]. The fourth modality refers to spiritual values that are sometimes referred to as cultural ones. According to Scheler, spiritual values also include aesthetic values that focus on opposites such as beauty and unsightliness, values of "pure knowledge cognition" as well as values of legal order that focus on the opposites of right and wrong, honourable and dishonourable, just and unjust. The fifth and last group refers to holy (religious) values.

As was said before, vital values, also known as values of life, are determined by the opposites of what is noble and what is ordinary. Scheler's intention was to stress that the vectors of "noble" and "ordinary" are values present in living organisms. "Therefore", Scheler writes, "on one hand they are typical not only of people, but also of animals, plants and even of all living creatures, whilst on the other hand, things (Dingen) are never entitled to them, as values of what is pleasurable and what is useful" [3, p. 1517].

Yet a discourse on the characteristics of vital values would not be complete without presenting Ortega y Gasset's standpoint. Being Scheler's friend and admirer at the same time, Ortega y Gasset developed his own interest in vitality. At the turn of the 20th century, philosophy became increasingly polarized into, as it then appeared at the time, two extreme aspects of reality: one of "sense" and the other "life", representing two opposites at a philosophic crossroad [4]. The philosophers of that time were faced with a necessity in declaring themselves either for the rational side, which saw reality as a scheme, or for the irrational side, escaping any sort of conceptualization. A researcher on Ortega's works, Stanisław Cichowicz, characterized Ortega's point of view in the following way: "Neither vitality, nor rationality, that was the answer for those who wanted to follow the paths of Ortega [...]. Therefore, his way led in the middle... The philosopher himself pronounced the moderate "azimuth" as ratio-vitality, thus showing he was preserving the most valuable aspects of the extremes" [4, p. 86]. Ortega y Gasset often stressed the "self-sufficiency of vital phenomenon" [5, p. 79], where life is a value of its own and does not have to serve any other purpose in order to for it to be considered valuable. According to Ortega, "life does not have to resort to extra-vital deliberations, either theological or cultural ones, in order to choose and hierarchize values" [5, p. 79]. As Ortega explains, an example that can prove the above theory can be a herd of horses, where we always perceive individuals that are more perfect and those less perfect. Perfection or the lack of perfection is internally hidden in each form of life. Only the skilful eye of an expert can easily distinguish the hierarchy found inside a herd. Yet the hierarchy is not established by an outside observer, it is an immanent part of the structure. There is something about horses that lets us, irrespective of their utilitarian intended use, observe the measure of their perfectness. As Ortega y Gasset writes, that between these two opposite poles, "we can easily find a point, where a vital form unequivocally inclines to perfection and a second one, which inclines to degeneration. Below that point all individuals of the species seem "evil" to us, their biological potential deteriorates. And reciprocally, anything above that point is of "pure blood", an animal and species become "noble". The above described situation is an example of two absolutely vital values, a positive one and a negative one, one of honour and the other dishonour" [5, p. 79].

**Rank of values versus *ordo amoris***

Max Scheler's typology of values is itself a part of a hierarchy of values. According to Scheler, a certain value gains its position within a hierarchy thanks to the acts of feelings and preferences, emotionally-cognitive acts, which result in particular commitments. Scheler claims that the emotional sphere of a life of a human is not, as had been believed, a kingdom of chaos and coincidence, but rather characterized by an order which is called by philosophers "ordo amoris". The cognitive recognition of this world of values is not due to the sanity of will, as was perceived by Kant, but thanks to emotional cognitive mastery. Therefore, values are accessible through emotional acts which allow us to capture their characteristics as well as the relationships between them. According to Max Scheler, neither senses nor the mind are capable of perceiving the hierarchic character of the world of values. The hierarchic character of the world of values reveals itself within "ordo amoris". Within a so-called feeling, Max Scheler differentiates a state of active experience i.e. "feeling something" (Fühlen von Etwas) from "a state of feeling" (Gefühlzustand), it being a passive experience. The difference between the two states is not limited to their degree of activity. What sets them apart is the sense of purpose that can be ascribed to active experience only. An emotional state is noticeable and explainable (it is almost always possible to give a reason for a certain emotional state), but it is never of a cognitive character, as only through feeling something can we transmit a meaning. Max Scheler explains that these "emotional states, as such, refer to sensual experience, whilst both vital and pure psychic and spiritual feelings can be of intentional character. Feelings that are purely spiritual have to be of such a character that is out of nature" [2, pp. 267–270]. The ranking of the vital sphere is emphasized in the above quote. All that is vital, as being potentially intentional, along with what is a psychic and spiritual, stand opposed to sensual feelings. Having made all the distinctions, we may venture to claim that vitality is closer to the spiritual sphere than to sensual one. The four levels of an emotional life of a human, as distinguished by Max Scheler, are the sensual, vital, psychic and purely spiritual and they all fully correspond to the typology of values.

Max Scheler presented five criteria in recognizing the rank of a value. The first is permanence. The longer the value lasts, the higher its value is. At the same time the permanence of a value is not tantamount to the permanence of its bearer (the value of a sculpture does not depend on the durability of the material it has been made of). Max Scheler stresses that the lowest values are the most "ephemeral" while the highest values have their share in eternity. The second criterion that gives a value its rank is its scope. The higher the value, the less divisible it is, hence spiritual values have an advantage over material ones. The third criterion refers to the "founding of values". Values require foundation for their existence, for example, where the ontic foundation for sustenance is bread. The more a value can serve as a foundation for another value, the higher it is ranked. Therefore a vital value that serves as a foundation for a utilitarian value is superior to it. It stays in line with the natural ethical intuition of a human, as everyone agrees that possessing assets (a utilitarian value) remains of no importance if we are faced with a fatal disease (a vital value). "Who, being also truly unhappy, could possibly envy a paralytic's 'exhilaration'?" [3, p. 1527]. The fourth criterion of Scheler is a "depth of satisfaction". The deeper the satisfaction resulting from a value's implementation, the higher the value is ranked. Scheler stresses that the depth of satisfaction has nothing in common with pleasure, although pleasure can be the result of the satisfaction one experiences. "The pleasure we experience is because we feel the value is called 'a deeper one' than others only when its existence (*Dasein*) appears to be independent on feeling other value and the 'pleasure' connected with it" [3, p. 1528]. The insignificant and inconspicuous pleasures we feel when walking or having fun with friends can serve as an example of such a situation. Such pleasures may be a source of satisfaction, but only when we feel satisfied in "a more central", as Scheler says, realm of our life. The last and fifth criterion attributes the value's rank to its absoluteness. The more constant and accessible the value is, the higher it will appear to be. Scheler's values also appear to be ranked higher when deeper satisfaction is felt while implementing a value and less when it serves as foundation for other values.

**Deformation of vital values**

Unlike other typologies of values, Scheler acknowledges the existence of vital values but he clearly sets them apart from hedonic or utilitarian values. At the same time, his concept of vital values assumes the widely understood ideas of physical culture, the promotion of health and ecology. Yet Scheler does not reduce vital values merely to hedonic values, he recognizes their autonomy and grants them a prominent standing in the hierarchy of values, saying that, "Vital values are a completely independent modality of values and cannot be reduced to the values of what is pleasurable, what is useful or to spiritual values" [3, p. 1540]. Neglecting this autonomy, according to Scheler, is a "major flaw" of past ethical concepts. However, this is not the only threat he saw to vital values. In his book *Resentment vs. Morality*, Scheler analyses the phenomenon of perverting axiological hierarchy. This process mainly affects vital values, which begin to be subordinated to utilitarian values, where, "if we use the term 'noble' to describe qualities responsible for the values of living organisms, we subordinate whatever is **'noble' to what is 'useful'**" [6, p. 190]. Although Scheler associates this unfortunate deformation with the expansion of industry and commerce that was happening during his times, and hence the domination of a middle-class mentality, yet it seems that the phenomenon in question was not symptomatic only at the turn of the 20$^{th}$ century. The perception of vital values as ancillary to utilitarian values is characteristic of modern times as well. The author of *Resentment vs. Morality* foresaw our thoughts and writes, "All of physical exercise is given only the value of 'recreation' after working hours or to regain power for newer, more useful work, they are not given any values, as all physical exercise is beneficial only when it serves the purpose of being a 'respite' from work or when it helps us prepare for new, useful tasks, and not as vital forces, which are valuable themselves" [6, p. 196]. Does this not sound familiar? Modern fitness clubs are overcrowded with those who come to get back into shape and at the same time want to be ready for the next day's work, where they spend several hours of working in an office or in a bank. Corporate leaders leave the gym satisfied without realizing the nobility of physical exercise. Proud of being disciplined, sure of their rightness or even the necessity of their actions, they subordinate their vitality to practical, utilitarian reasons. There are numerous reasons for contemporary man to take care of his body and just as many different forms of physical activity. However, it must be stressed that few who take up sport and exercise appraise the more noble values found in it.

Inspired by Scheler's philosophy, Ortega y Gasset in his essay *El origen deportivo del Estado*, differentiates thusly two kinds of activity: one that can be described as animalistic, characterized by primordiality, creativity, vitality but most important of spontaneity and disinterestedness. The second kind of activity is activity thoroughly human, of a utilitarian nature. The latter one is secondary, making mechanical use of the first activity. As Ortega y Gasset notices, utilitarian activity itself cannot be of a disinterested nature yet it is not creative. What is worse, it stabilizes and disables the potential and creativity of the first, primal activity [7]. Both forms of activity appear regularly in the lives of humans. The life of a human appears to us as a great effort, an effort which, similar to an activity, presents itself in two forms. The first one is that of necessary effort, an effort we cannot escape, an effort that is imposed on us by the fact that we exist, and is most commonly referred to as work. Ortega finds that, "work is opposed to another kind of effort, which does not originate from any imposed need, but it comes into being as the result of the free and noble impulse of vital powers, be it called sport" [5, p. 83]. Therefore sport, although sometimes perceived as an unnecessary effort (*superfluo)*, appears to remain the noblest form of effort, of course only when it is performed when one wants to receive pleasure from it. Hence, if certain conditions are met, it can be assumed that physical activity is an equivalent of primal activity. Therefore, we can discuss the nobleness of effort only when the effort affirms itself, becoming a source and a goal at the same time. According to Ortega y Gasset, "with work a vital character of an act makes an effort meaningful; in sport, however, its result acquires nobleness thanks to its spontaneity. It is a luxurious effort, an excess of internal energy, which we take up making the most of it and never expect any reward. And that is why a sporting effort has been always perceived as a luxury" [5, p. 83]. As such, a vital value that is submitted to a practical goal ends with its degradation. When a physical effort is taken up for reasons different from those that simply involve accomplishing an effort, when we can consider it as "pleasurable vs. not pleasurable" or "useful vs. useless", it consequently equates vitality with the values of hedonism or usefulness. If performed because of heterogenic reasons, sport cannot possibly become anything more but a mean of satisfying a need, a need to look good, to be thin, to be fit, to possess new skills (one can also imagine a need to learn how to play golf for purely snobbish reasons). But when a physical activity is taken up as a consequence of our affection of nobleness, only then an endless affirmation of the activity and disinterestedness appears.

## A noble man versus an ordinary man

Let us remind ourselves that Max Scheler laid the values of what is noble and what is ordinary as the groundwork for vital values. Nobleness should be understood as a synonym of aptitude, while ordinaryity comes closer to being inapt, unfit. Therefore the question arises, what is a noble man capable of? What is he fit for? Ortega y Gasset, inspired by Scheler's speculations, provided his own definition of nobleness, "for me, nobleness is synonymous to a life full of effort and sacrifices, being always ready in perfecting oneself, to moving from what there is to still bigger responsibilities and new goals" [8, p. 72]. A noble life, understood in this way, is definitely the polar opposite of an ordinary life. As we shall see shortly, both nobleness and ordinaryity influence a man's attitude to his bodiliness. In *The Revolt of the Masse*, while discussing the concept of nobleness, Ortega finds that people are mostly unable to take up an effort by themselves. They do it only when forced by an external necessity. That is the case of an ordinary man, one who takes up an activity only when pressured by external coercion. We realize that we regularly admire the few people who "can summon up the spontaneity and the luxury of an effort" [8, p. 72]. Ortega continues by writing that, "These are the chosen ones, the noble ones, the only ones who know how to be active, not only re-active, for whom a life is a constant strain, a never ending training (*áskesis*). They are the ascetics." [8, p. 72]. Who can nowadays remember that the Greek term ἄσκησις (aesthetics) originally meant "training"? Following the word's etymology, Ortega y Gasset equates asceticism with training. But does that mean they are the same? Assuming so, let us outline where the athlete meets the ascetic. Undoubtedly, both asceticism and training are associated with sacrifice and self-control. Both an ascetic and a trainee must find the inner strength to cope with the regime they impose on themselves. One might say that in the case of an athlete, their training regime and the numerous limitations resulting from it are purely external and imposed, and as such, we could not refer to it as to self-limitation. However, it seems that even if we initially may talk about external limitations, the process of internalization is inevitable and as a result whatever was external therefore becomes internalized. As a result, all coercive limitations become liberating self-limitations.

Let us come back to considering nobleness and ordinarity. A noble man can be said to be able to make sacrifices through the affirmation of his activities. A noble man is able to stick to his decisions, having enthusiasm on his side. A noble man is the one who imposes strict rigors on his activities, in both moral and vital realms, which brings us back to the tradition Greek tradition of *arete*. In order to become strong, a noble man limits himself and accepts these limitations voluntarily. A noble man is the one who understands the liberating power of self-limitation. Therefore, what might be an ordinary man? An ordinary man is unable to make sacrifices or do effort that would originate from him. If it happens that such a man does not waste his life on pleasures, it most certainly is not the result of a conscious decision but from a lack of opportunity. An ordinary man creates the pretence of activity while in reality he remains only re-active. His re-activity is only a response to external factors, in the same way that the movement of a billiard ball is only a re-action to the hit of a cue. One may wonder whether the causality that is so typical of the physical world is not a characteristic of ordinary man. An ordinary man lacks enthusiasm and persistence and is therefore unable to feel admiration or exhilaration. Sublimity is unfamiliar to him. An ordinary man lacks the noble passion that can be easily turned into a fiery one. An ordinary man misses his life's mark with every step. Anyone can declare vital values, but only the noble man will extol them in a perfect manner, and hence has the chance to become a "hero". An ordinary man will confine himself to his illusions which will never reveal the essence of vitality. An ordinary man is impossible to admire, his stillness and stagnation inspires no one. He lacks the luminous glow that beams in a noble man. Everything remains matte and motionless within the fumes of the ordinary.

### A hero: a noble epitome of vitality

In his ethical treatise, Max Scheler not only hierarchized values but he also assigned a specific role model to each modality. A role model differs, according to Scheler, not only from the bellwether we encounter in the world of animals but also in the case of a leader. A leader differs from the role model in such a way that he is aware of his role and aims at performing it. A person who is a role model is neither aware of their role nor do they desire it. Role models, unlike leaders, do not even have to be real people, "as the relation between role models and people, for whom they perform, is perfect" [1, p. 94]. The idea of a "model" is entirely axiological. Someone who is a role model does not affect people in the same way that a leader does. A role model influences the perception of values not by means of verbal declarations, but by actions. A role model is someone who we wish to follow, someone we want to emulate. Max Scheler quotes five models which refer to the five modalities of his hierarchy of values. So the "master of pleasure" links his life with hedonic values, the "leading spirit of civilisation" realises utilitarian values, the "hero" realises his potential in vital values, and the "genius" mainly focuses on spiritual values. "The saint" is connected with the highest level of values, those which are religious in nature.

Let us observe the hero who made vital values essential in his life. A hero is a man who proclaims himself in favour of nobleness, where "he is the man of power and volition. The essential virtues of a hero include the presence of mind, composure, bravery, decisiveness, battle spirit. He is also characterised by a beautiful body, dignified manners, agility in games, self-discipline [...]" [1, p. 96]. It is worth observing how a man passionate about life becomes a hero. A man who prefers vital values would then at the same time prefer nobleness, and by means of nobleness he becomes a hero. A noble man cannot, by nature, ignore values that exceed the value of life. A noble man is a man of honour and, as such, is capable of sacrificing his own life in defending that honour. It is someone who declares himself on the side of vital values and never stops being their glorifier, even when he sacrifices his life in defending his homeland. The same can be said about athletes; where among such a group we may encounter both the noble and ordinary ones. One might ask how to tell a noble and an ordinary athlete apart. The answer is simple, where only a noble sportsman is capable of strictly following the rules of the game. Nobleness always means playing fair. A noble athlete will never break the rules of a game as he will always act in the name of justice, which as we already know, belongs to legal values. It may easily happen that a noble sportsman becomes a hero worth following.

**Nobleness as a vital value – nobleness as a moral value**

Positioning vital values in, as it can be said, the middle of a hierarchy not only forces them to prominence but also emphasizes the fact that a body is not "only" a body. Their central position suggests that the importance of vital values comes from their relativity. One might say that vital values give certain properties to utilitarian and hedonic values, and that they themselves are derivative from the spiritual realm. If we removed vital values from the hierarchy, it would again become an antithesis of the sensual and spiritual. Vital values are what provide the hierarchy with a kind of organic unity. Although, according to Scheler, a body is neither an ontic nor an axiological bearer of vital values (a body plays such role only with reference to hedonic values), that within the context of vital values a body seems to be more that just a means or a tool for their realisation. Following Scheler's intentions, we can observe that vital values, for the first time, combine the spiritual order with a bodily order in a clear manner. This clarity is called nobleness. Declaring oneself for the cause of nobleness may be the first opportunity, within Scheler's values, that would enable a man to become a moral subject. This aspect is noticed by Roman Ingarden, who points out that nobleness is "a decisive moment" which determines the other elements of moral values, "a quality determinant of values" [9, p. 225]. According to Ingarden, if we want to discuss the moral value of an act, we need to find a general "quality determinant", common in all moral acts. Ingarden stresses that such a factor does not exist in Kant's formal ethics or in Max Scheler's conclusions. Let us remember that in the ethics of Kant, a formula exists where the categorical imperative is what decides whether a given act is of moral value, and hence whether the act is considered to be moral, but only if the rule we follow is in force. Max Scheler believes that an act is moral only when, through preference, we are able to recognize a hierarchy of values. Therefore, our acts prove that we can give priority to higher values over the lower ones. As was mentioned before, Ingarden considers both attitudes inadequate. Although he does not question the necessity in meeting the above-mentioned requirements, he still assumes the existence of something "morally specific" in every moral act. Ingarden perceives nobleness as *specificum*, but at the same time he makes it clear that he is aware of the triviality that can be ascribed to his suggestion, "With reference to the nobleness of an act one may say it is an empty cliché. It may only be true that each value we discuss as a moral value, can be referred to as 'noble', that a moral value means that an act is noble in itself" [10, p. 326]. Roman Ingarden emphasizes that noble acts, in the case of man, have a "transforming function", which means that every morally valuable, noble act of man influences him as a person and gives him dignity. It seems that with such a view, Ingarden comes close to the intentions of Max Scheler, who could easily state that in giving priority to higher values over lower ones we turn out to be noble or possibly even become noble. Nobleness has two appearances. The term may be used when we deal with vital values as well as moral ones, which are not separated categorically but nevertheless, do not cease to be the key issue within the science of morality. If nobleness appears to me to have a higher value than pleasure, then through the choices I make I opt for variants which are different than if the two values were reversed. Scheler writes, "If you 'prefer' what is noble to what is pleasurable, then you can *reach* to experience a completely new *worlds of goodness*, otherwise unattainable" [3, p. 1519]. We choose to prefer some values over others but this does not mean that such a hierarchy depends on our preferences. The hierarchy of values does not set them apart, if any conflict appears it refers to what is good and remains secondary to aprioric preferences. The very act of having a preference is previous to the choice we make. Therefore, the clearer our preferences are to us, the less we are exposed to feelings of weakness and perplexity when we make a choice. It commonly happens that we do not have enough time for thought prior to acting. Hence, decisions are made prior to choosing, prior to acting. It would not be an abuse to either Max Scheler or to Roman Ingarden if we were to state that a noble man is the least prone to conflict, and as Ingarden points out, "nobleness results in a certain internal unity of a man" [10, p. 326].

Józef Tischner suggests that only with vital values can deserting one's own act of preference be called infidelity to oneself [11]. Let us one more time use the example of giving priority to nobleness over pleasure. If nevertheless, despite our prior preferences, it happens that we choose pleasure over nobleness, then, according to Tischner, "a sense of infidelity, some inappropriateness" will remain [11, p. 357]. In the case of a noble man, the exclusiveness of experiencing "the world of goodness" is exactly that, that only at the level of vital values can something be seen as meaningful and which can be confirmed. The subject is himself responsible in the inadequacy of his choices.

It can therefore be justifiably said that vital values are the turning point in Scheler's hierarchy. If a man opts for nobleness he consequently opens himself up to all other levels of values. If someone is noble he cannot be blind to other higher values without discrediting nobleness itself, but he also understands that a certain "world of goodness" correlates to specific values. Access to this world is granted or taken away depending on his accordance, or the lack thereof, with the act of preference and the act of will. Nobleness, therefore, is the key towards opening the gates that conceal the greatest treasures a human being can possess.

## Conclusion

If Max Scheler differentiates between the values that are based on acts and those that are based on functions, it implies that vital values cannot be brought down to the values of living functions. Scheler wrote that life is not a set of living functions of the body or an "empirical idea"; it is instead a "real essence". On the one hand, it signifies the independence between the two values, but on the other, it signifies the two values being founded in what is higher to them. It appears, however, that vital values are founded in spiritual values differently than, for instance, the way hedonistic values are related to utilitarian ones. The very act of having some values founded in others, within such a hierarchy, is not only a formal and abstract act, but is dependent every time on the nature of what is being founded, as well as in what it was founded. We may risk saying that the higher the value the more it anticipates the value in which it is founded.

Therefore, if taking care of our body does obscure the successive levels of values' modalities, and is only used in trying to fulfil them, then taking care of one's body can certainly be considered an extension of what is noble.

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*Correspondence address*
Katarzyna Salamon-Krakowska
Zakład Filozofii i Socjologii
Katedra Podstaw Fizjoterapii
Akademia Wychowania Fizycznego
al. I.J. Paderewskiego 35
51-612 Wrocław, Poland
email: katarzyna.salamon@awf.wroc.pl

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# THE BODY AS A VALUE IN THE AXIOLOGY OF DISABLED PERSONS

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**KRZYSZTOF PEZDEK**
University School of Physical Education, Wrocław, Poland

ABSTRACT
The body adopts the specific contents, functions, and places of the axiological system in persons with a disability. It can adopt the contents of ultimate, instrumental, vital, utilitarian, cultural, moral, religious, and other values. It can represent, for example, cognitive, judging, motivating, and expressive functions. Moreover, the body itself can take a central or peripheral place. It is the recognition of these various contents, functions and places of the body in the axiological system of disabled persons that allows us to identify their needs and goals, as well as to assess the methods of achieving them. Therefore, it is through this knowledge that we can understand an individual with a disability in the widest possible context, which takes into account the biological, psychological and social dimensions of their behavior.

**Key words:** value, system, hierarchy, disability

## Introduction

The actions of a conscious human being are determined by a system of values to which he or she constantly defers to while making choices, evaluations, plans for the future or in confronting their plans with various everyday situations. Such an axiological plane sets the broadest boundaries of human existence, embracing biological, psychological and social spheres. However, not all values possess the same meaning for every individual. There are values which influence many aspects of his or her functioning, sometimes occupying a central position in their axiological system. Other values are marginalised as they occupy a peripheral place and therefore do not greatly influence the functioning of an individual.

It seems that in the axiological system of persons with a disability, the body constitutes a fundamental value. It can influence the behaviours and attitudes of disabled persons both constructively and destructively. It constitutes a value which the disabled take into account while determining their needs and goals and the possibility of how to achieve them. It is, therefore, responsible to a considerable degree in the outcome of their actions as well as in their social functioning.

The aim of this article is to present the various contents, functions and places that the body occupies in the system of values of people with disabilities. The natural context will also be shown, taking into account the relations, dependencies and mutual influences between the body and other values in the axiological system of people with disabilities.

## Material and methods

In attaining the above mentioned objective, methods of analysis, observation and the systematic method were used. This author analysed the terms that constitute the theoretical basis for reflexion on the body in the axiological system of people with a disability. Specifically, what the terms of values, system, hierarchy, etc. are and what they mean. Then, based on the observations of behaviours and attitudes of people with a disability, the content, function and place of the body in their axiological system is presented. The systematic method seems necessary here, as it allows us to approach the studied phenomenon not only from a point of internal relationships, influences and dependencies between these elements, but also holistically taking into account the natural context of such occurrences and the development of certain values.

There is no one harmonising definition of the term "value". Nevertheless, in the prevailing definition a value is basically understood as "something that is strived for and realised for the sake of a goal" [1, p. 527], or as an element taken into account while making a decision [2]. Thus, values are strictly connected with needs, aspirations and motivations. They can take on the form of material goods, ideas, thoughts, attitudes, concepts, mental states or certain physical states and features. The issue of values is most often studied in social sciences, such as philosophy, sociology, pedagogy, psychology, culture science or economy [3–9].

It is not hard to notice that the above quoted definitions approach values from an objective point of view.

However, equally important seems to be the relating to values from a subjective point of view as well. The subject of values can be a rational, self-conscious and autonomous human being. Man endowed with such qualities is called a person in philosophical literature [10, 11]. Only persons can take full responsibility for their deeds and their consequences. Therefore, they can be responsible to themselves or to other people (society) for modifying their own system of values. It is, however, necessary to distinguish the term of a person from the secular and religious approach. In Christian religion, a human being becomes a person at the moment of being conceived, and therefore such qualities as rationality, self-consciousness and autonomy are possessed not in an actual but in a potential sense [12]. Therefore, a person in such a reflexion could be, among others, a disabled accountant, as he possesses his own axiological system to which he relates to while identifying his own needs, making choices or realising concrete goals. On the other hand, an infant or an individual suffering from a permanent consciousness disorder whose existence is entirely dependent on other people is not a person. In this case we cannot speak of an axiological system which could be the basis for any goals. Such an approach to understanding the axiological system corresponds to the definition of what a system is, as given by the Polish bioethicist Kazimierz Szewczyk. According to this scientist, a system should be understood as "a functional whole of many related elements serving the realisation of a common goal" [13, p. 212]. For people with a disability, a common goal may be the return to physical ability, finding work, finishing their education, starting a family, etc.

In classifying values, researchers most often divide them into: (1) ultimate; (2) instrumental; (3) for the sake of content; (4) for the sake of place. In addition, they assign various functions to values, such as the cognitive, evaluating, motivating and expressive [14].

Ultimate (autotelic) values constitute a goal in themselves whereas instrumental ones are the means leading to the fulfilment of a goal. Obviously, determining what is an ultimate and what is an instrumental value is a relative matter, dependant on a given situation. In literature, values are also differentiated for the sake of content. With this approach, they are divided as vital, hedonistic, utilitarian, economic, social, cultural, aesthetic, cognitive, spiritual, moral, political and religious values. Both the number and the range of classification used here depend on the preferences of particular researchers. Additionally, values in an axiological system can hold a central or peripheral place. Central values have influence on the change of a greater number of an individual's attitudes and behaviours than peripheral ones. They constitute the core of what interests and actions particular people have; therefore, they determine the direction of their development to a considerable extent. Peripheral values, on the other hand, are not concerned with the main course of functioning and do not greatly influence the life of individuals.

An individual's knowledge of their own system of values provides them with a basic source of information about themself and the reality of how one functions. Thus, the cognitive function of values is especially important as, on the basis of this knowledge, can a conscious man make decisions and choices. We have, in addition, a motivational function of values as well. Moreover, all decisions and their consequences should be carefully analysed and evaluated by an individual as well as confronted with their whole axiological system and with the system adopted by their society. This is the evaluating function of values that gives information whether the decisions made are indeed part of the hierarchy of values of an individual or society and can therefore be realised without problems or, instead, be modified, as they may enter into conflict with the good of other people or society. Along with the above mentioned functions of values there also exists the expressive function. Thanks to it we can gain knowledge about the emotional state of a person fulfilling certain needs, tasks or goals. Thus, we can know what actions can give an individual satisfaction, or, on the contrary, lead to frustration and stress.

The classification presented here is not complete or expansive, as the content, functions and the place of values are constantly being modified, dependant on the changes occurring in the biological-psychological-social environment of an individual. Nevertheless, each attempt at classifying values creates, at the same time, a hierarchy. As such, vital, hedonistic, economical and utilitarian values are traditionally classified as lower values. Higher values, on the other hand, are cultural, spiritual, moral, religious, etc. As an example, it is worthwhile to quote the hierarchy of values proposed by Max Sheller. According to him, the lowest class of values is hedonistic, then utilitarian, vital, spiritual (cultural) and at the highest level there are religious values [15]. Władysław Stróżewski, on the other hand, placed vital values at the bottom, then cultural values, moral values and at the very top of the hierarchy, religious values [16]. However, each conscious individual tries to create their own hierarchy which becomes a basic factor when deciding on the direction of his or her development.

An especially vital feature here is also the systematic approach to values. Each system consists of many subsystems or elements which create a net of dependencies, relations or mutual influences [17]. It is similar to the elements of an axiological system in which particular elements themselves enter into mutual relations, dependencies and influences. Through the systematic approach values can complement and strengthen each other but also exclude and weaken each other. They can create new values or obstruct them, rendering their creation impossible. Each value occupies, in an axiological system, a certain place (central or peripheral), which gives it a content (e.g. vital, cultural), a function (e.g. cognitive, motivational) and marks its development perspectives. However, this place can change and then the function and content of a value will also undergo modifications. The systematic approach is therefore a holistic approach, taking into account not only the values themselves, but above all, taking them into consideration in many various contexts.

**Discussion**

The body can be perceived by people with a disability as an ultimate value. As such, it becomes a value in itself, a carrier of desired abilities, skills and functions which through various reasons (e.g. illness, accident) have become unattainable, either temporarily or permanently. The body can also be understood, by those who are disabled, of containing metaphysical values, imputing a supernatural power or one of even divine origin. Therefore, it often becomes a cultural or a religious symbol, becoming a cult object, or, on the contrary, a despised and hated one. In such an approach, as features of the body are not ultimately defined or cognizable, they, with their symbolical power, support the disabled in making decisions by taking into consideration their actual abilities and the conditions of their functioning. On the other hand, they can express desires which cannot be realised in concrete actions, because they surpass the rational convictions of an individual. Thus, the disabled usually choose one of two ways of acting. The first way of acting is they undergo intensive rehabilitation, hoping to regain their optimal ability as fast as possible. In this case, the value of the body motivates them, giving them a prospect of entirely obliterating their pain and suffering as well as regaining lost abilities. A good example illustrating the above consideration could be a disabled athlete whose disability does not constitute a great obstacle in the realisation of their dreams of sporting success [18]. The overriding goal becomes accomplishing abilities that should be understood not only in a biomedical, but also in a social understanding [19]. A person without legs will never be able-bodied in the biomedical sense, as transplanting the lower extremities is still not possible in modern medicine. However, it does not mean that this person will not be able to achieve their full ability as an athlete, competing with the best contenders in national and international sporting events. At the same time, by improving his or her physical condition, such a person increases their opportunities to take part in social life. Thus, such a person usually completes some form of education, learns a profession, finds a job, starts a family, takes responsibility for bringing up their children, etc. Nevertheless, a person with a disability would not have been able to achieve these goals without a modification of the axiological system they had so far, giving to some values new content and functions, and accepting a new hierarchy of values. It applies to both lower values (e.g. vital, in the form of intensive rehabilitation) and higher ones (e.g. cultural, in the form of education).

The second possible way of acting for someone who is disabled is withdrawal, often giving up their rehabilitation. The disabled who act as such perceive the body as a carrier of ultimate values, but those values paralyse their actions towards regaining health, completing education, finding a job, starting a family and others. Many constructive actions lose sense for them, as they ascribe the opportunity to develop and realise oneself only to abled people (whether biomedically, socially, legally, etc.). For this reason, some who are disabled reduce their participation in social life to an existential minimum. Sometimes even that may seem to be too much, so they ask for assistance in euthanasia or suicide. These people are not able to modify the cravings and goals they have in order to adapt to the circumstances in which they are now in. In this case, the idea of the body as an ultimate value destabilises their attitudes and behaviours, showing at the same time a dissonance between the disability and so called "normality", constituting a determinant of proper functioning in society. In the confrontation between those two axiological systems, the first one usually is defeated, becoming incoherent with the image of what a body looks like as accepted by the majority of the members of their society.

Although the idea of the body in the category of ultimate values seems not to be entirely explicit and cognizable, from the perspective of instrumental values, it takes on the content of concrete needs, aspirations, attitudes, goals, etc. It can be finding or keeping a partner, making new friends, being employed in a responsible position, etc. In each of the above mentioned situations it must be proven that the body is subject to a form of relative self-control, on the individual's part, and does not constitute an obstacle which could prevent an individual from fulfilling his or her tasks. Such an idea was visualized by Kazimierz Szewczyk, where, according to him, "physicality constitutes a kind of a vehicle or a car, which moves and which is used by the soul, as its passenger or even its owner" [13, p. 142]. This vehicle should, by each of us, be maintained in such a state as to be able to reach its destination, even if the cost of subsequent repairs and spare parts increasingly rises. Its total immobilization means the end of the journey and its ultimate termination.

In the available literature on the subject, there are numerous examples of such instrumental treatment of the body by the disabled [18, 20]. However, the common denominator for all of the described cases is a departure from the body, understood in a metaphysical and religious sense, by imputing it with supernatural features, and by concentrating on its utilitarian qualities. Thus, somebody can accept the fact that their problems with motor coordination will probably prevent them from being a professional climber. Nevertheless, their problems are not able to obstruct their want of physical activity. Therefore, hiking is still possible, as well as taking part in mountain expeditions, though they may have to acquire additional equipment or make use of other people's help. In this example, such an ultimate value is not the possession of an able body in the biomedical sense of meaning, but in this context of mountain hiking, it is instead to have an able body in the social sense. As such, the body is used here only as a means in the realisation of a goal, it is this "vehicle" in which every person moves (whether faster or slower, more or less comfortably). Therefore, an instrumental approach to the body assumes that people with a disability are the same as able-bodied people, i.e. each conscious human being has a possibility for optimal psychophysical development, only if they correctly identify their needs and goals and adapt them to what possibilities they have in their realisation. Among both the disabled and the able-bodied there are often people who are too weak, as far as strength, skill or knowledge is concerned, to fulfil a chosen task. Subsequently they experience considerable disappointment and frustration, not because they have not proven themselves as people, but because they have decided to realise needs and goals beyond their abilities. The responsible factor might be a lack of humility, excessive ambition, insufficient knowledge, the lack of a sense of responsibility, or simply human conceit and egotism. Thus, needs and goals should be modified and sometimes forsaken in such a way that they are coherent within one's own, as well as society's, system of values (in an ideal situation).

However, there are those who are disabled who consider themselves helpless and dependent on the help of others. It happens in particular when everyday activities become too hard to accomplish, such as when going to the toilet or making a meal becomes a considerable challenge. In such a state it is difficult to think of one's development, instead, an effective obstacle for development turns to shame, a lack of respect for oneself and an utter loss of dignity. The body in this aspect is perceived as a source of illness and degeneration and not as a space for actual and potential abilities. When a person with a disability starts to perceive his or her own body or its particular organs as degenerate they then begin to perceive their whole life as being unhappy. In such a situation it is obviously difficult for a disabled person to reformulate their system of values by themselves in such a way that the idea of the body would not obstruct their development, but instead support it and motivate them to look for new opportunities for self-realisation. Therefore, help for the disabled should be undertaken by other people and by institutions whose workers are properly trained in identifying the contents, functions and places of values which have considerable influence on the psychophysical state of someone who is disabled.

As in the instrumental approach, the body is used as a tool in the realisation of definite goals, where in the hierarchy of values those goals are situated far higher than the value of the body itself. It can be education, travel, increasing their level of being self-sufficient, winning an Olympic medal or fulfilling the role of a spouse or parent. Therefore, if cultural values become a goal, e.g. completing education, the body then adopts the content of vital, hedonistic, utilitarian and other values. They usually take the form of practical activities, such as eliminating pain or overcoming different barriers: architectural, urban, communicative, psychological, legislative or financial. Therefore, self-realisation in the sphere of lower values should not necessarily be understood only in the biomedical sense, but also in the social one. Although lower values most strongly accent the physiological aspect of a human being's functioning, within their boundaries an individual prepares for their functioning in the sphere of higher values, e.g. aesthetic, legal, cognitive, moral, religious and others. Therefore, when using the systematic perspective, values should not be considered in isolation and without taking into account their influence on each other. When lower values are in the centre of interest of an individual, then higher values also certainly coincide with them as peripheral values. When, however, we deal with the instrumental approach, they are usually placed within a broader context of ultimate values. Thus the overriding feature of an axiological system is its dynamics and openness to change.

It has already been mentioned that in the axiological system of people with a disability, the body can take a central or peripheral place. Placing a value in a certain position shows its natural context, defined through the net of relations, dependencies and mutual influences into which it enters with other values. Thus, the body can occupy a central place in various contexts, among others, biomedical (recovery, keeping fit, regaining lost skills and abilities), utilitarian (self-care and autonomy of a disabled person, or regaining a position in their family, peer group, school or career), aesthetic (restoring or correcting beauty), agonistic (competition with other individuals) as well as hedonistic (experiencing pleasure). The common denominator for all the above mentioned contexts is the fact that a considerable majority of the actions undertaken by an individual focuses on a concrete form of activity with their body, which is turn is a determining factor in their whole life. It can be intensive rehabilitation, taking care of one's beauty, doing sport, etc. The remaining values are mainly used by an individual in order to strengthen the actions they undertake or when there is a risk of their weakening. For example, let us consider the body in the context of rehabilitation. It can take on the content of an ultimate value (a healthy body) or an instrumental one (an able body). These, in turn, coexist with other values important for the disabled. We can have a healthy, able, and beautiful body (aesthetic value), a strong body (a vital value), a self-serving body (utilitarian value), a body capable of starting a family (a cultural value), a helpful body (a moral value), a body adoring God (a religious value), etc. The overriding goal of these values is in supporting an individual during the process of rehabilitation. It can be achieved by having a patient focus not on the therapy itself, but on the values that could be realised after its completion. So after completing rehabilitation the body will not only be healthy and able but also beautiful, self-relying, capable of starting a family, etc. Since those values relate to the concrete needs and plans of a patient, they show the natural boundaries of his or her rehabilitation. Neglecting them can therefore make the therapy less efficient or even entirely unfeasible.

The body in the axiological system of the disabled can also take a peripheral place. Then the central place is occupied by cultural values (education, work), moral (social activity) and others. Here, a suitable example can be the story of Piotr Pawłowski, the physically disabled editor-in-chief of the magazine *Integration* [21]. As an able-bodied person he dreamed of becoming a professional basketball player when a spine injury destroyed those dreams. After evaluating his needs, goal and abilities, Pawłowski decided to concentrate on completing his education, learning foreign languages and on social activism. The fact that he was almost 100% paralysed (a tetraplegic), seemed to provide him with additional motivation. In his axiological system, the body ceased to be perceived as a central value, fully determining one's actions. For him the most important thing became education: "I knew that life among people requires physical ability that I do not possess. Education was to make up for this" [21, p. 5–14]. After his graduation another goal appeared: creating a magazine integrating the milieu of the disabled. "A bedroom in my house was changed into an editorial office", he reminisced, "For the first issues I and Bolek wrote all of the texts, using several pennames. Each of us was writing with one finger, he with his finger in his right hand, I with a small wooden pencil attached to the left one" [21, p. 9]. As a social activist, Pawłowski helped the disabled with legal, psychological, professional, medical and other problems. At the same time he continued with his private life, became married and strengthened his family and social ties. It could be surmised that realising the above mentioned goals would not have been possible if, in Pawłowski's system of values, the body occupied the central position, dominating other values. It was his departure from the body as the ultimate, central value and then considering the body in categories of peripheral instrumental values that resulted in such creative work for his own development and for other people's development. Knowledge of the various aspects of the body in an axiological system of persons with a disability influences their functioning both in their private and social life. For this reason, the cognitive function of values seems especially important. By getting to know his or her own body, man constructs an axiological picture of reality which sets the boundaries of their individual existence. Thus, if a disabled person perceives his or her own body in positive categories, he or she also perceives reality in such categories. However, if the knowledge disheartens and frightens him or her, the world would then seem terrifying. Hence, the axiological construct constitutes the most basic knowledge of the world available to man. Some scientists even question the differences between facts and values in the context of their cognitive function. Such a hypothesis can be formulated both on the basis of an analysis of facts and on the basis of an analysis of the expectations expressed through values [14, 22].

Thus, the motivational function of values allows individuals to formulate goals adequate to their situations, needs and own abilities. It is strictly connected with the knowledge of reality that an individual possesses. The body efficiently becomes motivated to action only if it coexists with goals that can be attained. If a person is convinced that a goal is not possible to attain, even if the goal is in fact almost achievable, he or she will not be motivated enough to attempt at reaching it. One should also remember that setting goals means setting a hierarchy of values. Therefore, these values usually occupy the central place in the axiological system of an individual, which are tied to attainable goals (which does not mean that they always constitute the ultimate goals of actions, since they can be an intermediate goal). On the other hand, the values connected to the goals whose realisation is not very probable or entirely impossible usually has a more distant place within the system.

The evaluating function of values affects, above all, the establishment of recognizing the consequences of an individual's actions. If a person wants to define the consequences of their actions, he or she should take into account not only their own interests but also those of other people, i.e. society. There are some social standards that regulate behaviours towards the body which are found in traditions, customs, legal norms, regulations, etc. Individuals confront these standards with their own spontaneous decisions. The result of this confrontation can be the separation from what one wants and conceding to what is socially acceptable. A person with a disability may want to murder another man but will realise the weighty consequences of their deed and therefore give up such a plan, in fact yielding to the interests of the community.

The last function that should be mentioned is the expressive function, which the body can realise in the system of values of people with a disability. Thanks to it, individuals can manifest their emotions and attitudes towards various facts, phenomena or states of affairs. Analysing an individual's system of values can therefore lead to predicting the direction of a person's activities, and towards stating, with high probability, what gives them pleasure and satisfaction (positive emotions) and what does not (negative emotions). Therefore, when a person with a disability is performing an activity and shows dissatisfaction and frustration due to experiencing pain and suffering, we have a clear signal that we should introduce some modifications in our behaviour or that the system of that person's values should undergo some change.

## Conclusions

In this article, the contents, functions and places of the body in the axiological system of people with a disability was presented. In addition, it was showed that the body does not exist as an autonomous and fully independent value, as it cooperates with other values, building certain relations, dependencies and mutual influences. Hence the systems of values constitute dynamic wholes, prone to changes and modifications. Thanks to this feature we can formulate particular values in such a way that they do not act dishearteningly on the disabled, but conversely, so that the new contents and functions given to them will enable the discovery of paths of self-realisation not known before.

However, in this respect, those who are disabled should receive the necessary support from other people and from proper institutions. This support can clearly be given by providing support with their rehabilitation, giving legal help or removing architectural barriers. Nevertheless, a candid conversation with the disabled person about the issues that are important to them is also important. It can be a conversation about family, hobbies, religion, politics, and plans for the future. It can be conducted by any person knowing the system of values that exist in a person with a disability or by possessing the necessary interpersonal skills. The effectiveness of this conversation increases with the amount of influence that the interlocutor has on the disabled person. Thus, it can be physiotherapist, a doctor, a family member, an employer, a life partner or another disabled person. However, one should remember that the goal of the conversation should be in adapting the system of values of the person with a disability to their needs, goals and the possibility of how to achieve them, as well as to the system of values that exists in society. Thus, the partner in the conversation should adopt the role of a trustworthy custodian, who does not impose their own point of view but relates with respect and humility to the values of others even in they are personally controversial or in oppositions to their own convictions [23]. As Tadeusz Kotarbiński mentioned, a trustworthy guardian is a "good person, with a kind heart, sensitive to the needs of the others and ready to help" [23, p. 378]. One can trust him or her entirely and entrust one's problem to them as there exists the understanding that they would do everything possible to help in a difficult situation.

Undoubtedly, owing to the identification of the particular values that coexist with the body, it is easier to understand the attitudes and behaviours adopted by the disabled. It is also easier to motivate them in the realisation of everyday duties and making rational plans for the future.

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*Correspondence address*
Krzysztof Pezdek
Zakład Filozofii i Socjologii
Katedra Podstaw Fizjoterapii
Akademia Wychowania Fizycznego
al. I.J. Paderewskiego 35
51-612 Wrocław, Poland
e-mail: kpezdek@interia.pl

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# CORPOREALITY IN MARTIAL ARTS ANTHROPOLOGY

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**WOJCIECH J. CYNARSKI *, KAZIMIERZ OBODYŃSKI**
University of Rzeszów, Rzeszów, Poland

ABSTRACT
The aim of this paper is to discuss the subject as well as the problem of corporeality in the anthropology of martial arts. The authors wish to begin with the concept of corporeality as it is found in the available literature on the subject. The main issues which require additional contemplation are: the anthropology of the psychophysical progress, the humanistic theory of Eastern marital arts and the sociology of fitness culture. Anthropological research on martial arts attempts to explain the place and meaning as well as the significance and value of humans practicing the various psychophysical forms of East Asian martial arts. Therefore, emphasis must be placed on the numerous varieties of martial arts and the resulting examples and cultural values found therein. Through such a perspective can corporeality's place and importance be examined. Among the classifiable models found in somatic culture, one of the most fundamental is the model of asceticism and self-fulfillment. Historically significant and still relevant is also the example of fitness, connected with treating the body as it were an instrument.
Within the context of martial arts being used as a psycho-educational form of education, the body fulfills, above all, the role of a tool to be used on the way towards enlightenment and wisdom. It is utilized specifically in spiritual progress. Improving one's physical abilities is therefore an ascetic journey of physical perfectionism and technical accomplishment all towards achieving spiritual mastery. In some cases, spiritual development is described in terms of energy (qi, ki) and connected with the capacity of one's health. Yet, the motivation for participating in martial arts more often comes from the body itself and its psychophysical health rather than moral and spiritual improvement. However, in our era of globalizing and commercializing almost all aspects of culture, some confusion can emerge from the polymorphic treatment of corporeality in martial arts as is now practiced around the world.

**Key words:** human body, patterns and values, psychophysical progress, ascetic pattern

## A literature review

Non-ideologically determined physical exercise, or sport for all, has been practiced from the beginning of civilization to today for pleasure, splendor, emotion and other themes. Nonetheless, a lifestyle based on entertainment, leisure, appearance and the consumption of specific services has now become, in a way, an enforced standard of living. This is in part of an era of cultural globalization, which through the media, imposes specific paradigms of behavior and conduct consistent with the dominant ideology of postmodernity (liberal and progressive). A pop culture lifestyle is especially disseminated through television and lifestyle magazines [1].

Malacrida and Low [2] summarize in their book the sociology of the body, as well as the sociology of health and illness, elements of social theory on the concepts of the body and the ideology of "gender". Here, such an outlook is dominated by a feminist perspective and extrapolates its interpretations as such. The content is fairly consistent with what is found in other new books [3–5] The impact of popular ideology on the current dominant theories found in cultural academia and in the different subjects of the humanities is clearly visible [6, 7].

The religious, Christian model applied within the framework of corporeality is less prevalent. However, analysis on this subject can be found. Here, attention is drawn to the dangers of reducing human self-consciousness to corporeality [8, 9], a reduction named by Pawłucki [10] as corporealism, which stands opposed to the idea of personalizing pedagogy in both sport and health. Bodily exercise, which lacks a deeper moral meaning, does not establish humanistic knowledge and wisdom, which is exactly something that should be conveyed by its instructors. It is in this way that a religious facet of corporeality is manifested, where "the human body is an ideal meeting place for theology and science because it displays the fullest spectrum of the manifold wisdom of God" [11, p. 39].

The humanistic-oriented sociology of physical culture, when analyzing issues concerned about the body as a social fact, takes into account the religious characteristics of the body, its symbolic elements as well as the problems with controlling the body, such as in covering or exposing it, situational behavior, socially accepted forms in presenting the body as well as

* Corresponding author.

physiological responses (yawning, sneezing, etc.) [12]. Corporeality, understood through a socio-cultural prism, is also a study of the ways on how we use the body, the preferences of specific physical (also known as somatic) models, reflection on autotelic and instrumental values as well as on the axiological sphere, and on the ontology of man as a corporeal being [13].

These concepts and analysis trends are concerned with the numerous forms of physical exercise, especially in sports and recreation. As such, they also relate to martial arts and the practitioners of such psychophysical forms of self-improvement. However, analysis of the corporeality found in martial arts requires special consideration, as it is different from other forms of physical exercise due to the values, objectives and methods used.

In popular and "commonsensical" opinion, it is believed that the main point of practicing East Asian martial arts is that they serve as a form of self-defense, in protecting one's life and health, which in particular means protecting the body. Martial art training, at least in the initial stage, consists of learning falls and moves in order to properly fall onto the ground or onto other hard surfaces in both training and in the various life situations. However, this interpretation does not only best befit the purpose and value of martial arts training, but indicates a lack of understanding of its deeper meaning. In addition, an attempt at using a hermeneutical analysis of the language found in Asian traditions of words connected to energy and the "corporal quality of energy" [14, pp. 131–132, 273], called in schools as taiji quan, qigong, aikijutsu or hapkido (qi, chi or ki), does not explain the goals of these traditions (besides the obvious health reasons).

As indicated by researchers of Asian philosophy, the aspect of physical fitness as a virtue in the canon of ethical warriors [15] or as a bond between ethics and aesthetics, as in Zen Buddhist tradition, is just a fragment of what the way in martial arts entail. Such a way involves various systems of psychophysical training, from the meditative-religious tradition of martial arts (in Japanese bujutsu) to the way of the warrior (budō), which was concluded long ago from the fieldwork and observations of Michael Maliszewski [16, 17] from the Chicago School.

According to this author, a complete approach to the issue at hand calls for the adoption of, from a research perspective, an **anthropological study of psychophysical progress** [18]. Therefore the "way" (progress) of martial arts can be defined as follows: **the way of martial arts** (Japanese budō) is various forms of physical, or to be more precise, psychophysical, instruction, which on the basis of the tradition of the warrior's code and in training fighting techniques, leads to psychophysical mastery and self-fulfillment. At the same time these are processes of education and positive asceticism. Positive asceticism combines bodily exercise with conscious self-discipline; it focuses on moral and spiritual progress [19, pp. 20–21]. "Both yoga and Asian martial arts provide a prescription in achieving spiritual progress through using the proper form of implementation. The philosophy of Asian countries is almost identical to religious practices through the expression of body movement and active self-expression in a variety of ways. It is a manifestation of ancient Asian thought and spiritual culture which holds that spiritual development is closely connected with exercise of the body" [19, p. 148]. The difficulty of clearly classifying martial arts within the sphere of physical culture stems from the necessity in understanding it holistically. It is a discipline on the outskirts of psychophysical culture, based on tradition, where there is no clear division between what is spiritual or physical.

### Corporeality in the anthropology of psychophysical progress

In the spirit of the new systematic paradigm between man, culture and society, we perceive human psychophysicality as something too comprehensive, with its higher-order needs, goals and aspirations, as well as in its spiritual development. This kind of perspective is founded upon the basics created for studying the cultural phenomenon of martial arts theory, a humanist theory of martial arts and of adequate anthropology [19–21]. **Martial arts anthropology** is a form of anthropology of psychophysical progress, similar to the social philosophical concepts of Erich Fromm [22] and his idea on the creation of a new science about man.

Martial arts anthropology does not apply to combat sports, in which competitive domination has replaced the tenant of finding a moral way towards self-improvement (transgression, transcendence). There are schools and systems (educational programs) that combine the way of martial arts with sport. However, many experts point to a discrepancy between the purposes of sport and martial arts [23, 24, 19].

The specificity of Asian physical culture determines its ascetic qualities. Asceticism must be understood here as a way of observing ethical principles and in practicing psychophysical exercises with the goal of, above all, spiritual development. Physical perfection enables or allows one to achieve spiritual mastery [25]. Despite the different philosophical conditions (ontological assumptions) of Indian yoga and Chinese Taoism, both have developed similar psychophysical practices, in which meditative, breathing, static and dynamic exercises are used to strengthen the body and in finding a state of inner harmony and liberation or sanctification. The ascetic principles between Chinese kung-fu and Zen Buddhism are also similar [15].

A similar understanding between the path of meditation and psychophysical training was found in the works of a pair of Korean-American interpreters of martial arts philosophy, Daeshik Kim and Alan Back. Although they write on the ethics of martial arts, they do not explicitly differentiate corporeality nor do they emphasize its role. "The way to go" is a way of practice, and therefore one of exercise, fighting, compliance with the set rules, etc., but the body and corporeality are not particularly exposed here [24, 26].

It is debatable whether this is indeed philosophy, or simply philosophizing. Nonetheless, a conversation on this subject could be expounded through the use of practical biosophy (as understood by Fromm [22]), which is a wisdom of life attained by the masters of different philosophical beliefs. To what extent is Asian biosophy original, as exemplified in Chinese and other East Asian martial arts? "The way of kung-fu is, contrary to our belief, something which we would not find in the spiritual history of Europe. The ideal of self-improvement, striving for excellence, was already known in the philosophy of the ancient Greeks. Both the Greeks and Romans, like the Chinese, valued the art of living wisely and well, and in resisting evil. They understood the value of focusing on one goal, no matter how simple it may be. They noticed that in human development, the pursuit of a goal may be more important than in attaining it" [27]. However, it seems that the metaphysical understanding of sport and, in particular, the spiritual improvement of oneself in conjunction with physical exercise has become totally lost in Western culture [28].

The psychophysical customs of East Asian martial art systems also confront the so-called mind-body problem. The experience of uniting one's own body, mind and spirit, resulting from the specific practice of biosophy (the philosophy of life, or wisdom of life) points to a holistic anthropological paradigm. Philosophical wisdom, including Eastern philosophies, is more practically oriented and less theorized than academic philosophy. Experience from bodily practice, in other words within the field of physical culture, allows for better understanding the rational and intuitive as well as natural and cultural, somatic and spiritual aspects of humanity. A system without values, morals, ontological and teleological analysis would be incomplete. The Delphi oracle's statement of "know thyself", invoked by Socrates and Goethe, is especially close to the ideas of Taoism and Shinto, which co-created the philosophical context found in samurai imagination. Similarly, the Stoic's "ataraxia", a higher state of harmony with nature, is close to the Taoist concepts of balance, such as in yin-yang and of "wu-wei", of knowing when not to upset a state of harmony.

## The models, values as well as dimensions of martial arts

The general references proposed by Dziubiński and Krawczyk [12] on the models of Western somatic culture and to the actual Asian martial arts practiced in Europe can be presented as follows:

1. The aesthetic model, which contributed to the dominant contemporary ideal of harmony, strength and physical fitness in the aesthetic canons of beauty of the body, sporting trends and a lifestyle of sport. The aesthetic values of martial arts are one of the themes of interest by not only athletes but also the organizers of large events and of filmmakers in the martial arts genre. This raises a digression that the harmonious build of those engaged in various universal forms of martial arts simply look better than the representatives of other sports.
2. The hedonistic model, related to (in this context) to kinetic experiences. Here, kinetic movement is treated as source of recreation, and this is the motivation of many to take part in martial arts. A European does not need to practice martial arts with any religious solemnity or to combine his training with meditative focus or experience any religious rituals. Nevertheless, there does appear a kind of "samurai spirit" that is found in practicing martial arts not just for happiness and entertainment, but for self-improvement.
3. The ascetic model, which originally meant a depreciation of the body and bodily needs. It currently functions in the ideologies of self-realizing psychophysical systems (the modern teachings of the Catholic Church, religious decrees, the philosophy of martial arts, especially the Japanese understanding of budō etc., with its high demands in ethics and self-discipline) which are contrasted to the consumerism of rich, Western societies. The asceticism of budō came from the soteriology of Zen Buddhism, which became an ideology behind many Japanese martial arts. Budō is essentially a "spiritual way", through which the practice of physical exercise derived from the tradition of Buddhist and Taoist monasteries and Zen meditation allow one to achieve an internal (psychophysical) sense of unity and harmony of the macrocosm. Overcoming one's own weakness (the main slogan found in karate-dō) and the mystical components are what constitute the origins of martial arts from the Far East.
4. The hygienic model, which realizes existential and utilitarian objectives, was disseminated largely due to the work of educational and health services. It is associated with preventive health care and the development of physical fitness in youth. One of the physical education and health systems is, for example, jujutsu, popularized in Poland and in Europe since the early twentieth

Table 1. The varieties of sports within the system of social structure and the main motivators for its participants [30, p. 87]

| | | |
|---|---|---|
| Sport – as entertainment for bored gentlemen | Active participation | Fall of feudalism, rise of capitalism |
| Sport – as entertainment for the masses, pop-culture spectacle | Business, taking part in a spectacle | Capitalism and real socialism |
| Professional work, achieving an objective | Economic objectives | Capitalism |
| Professional work, achieving an objective | Political and economic objectives | Real socialism |
| **Psychophysical culture** | Self-realization activity | Postmodern society |
| **Health culture** | Activity for broadly defined health reasons | Postmodern society |
| Corporeal culture (physical recreation | For pleasure, beauty, emotion or other motives | From ancient times to today |

century. Currently jūdō, karate, kendō and aikidō are part of school programs not just in Japan. They foster an integration of the body and mind by improving concentration, motor coordination and improve the overall condition of the body, which develops the so-called positive health potential.

5. The fitness model continues chivalry and military traditions. Today it seems to be useful especially for the armed forces and as an idea compensating the civilizational phenomenon of a lack of physical fitness and exercise, causing overall atrophy and a number of lifestyle diseases. Asian military tradition in martial arts is also a valuable part of cultural heritage which is quite widely used in the army, police and other uniformed services.
6. The agonist model, which affirms the category of bravery, expressed in fighting and sport competition. Agonistic behavior was originally limited to a social class, one of aristocratic sport. Together with the ideas of purely amateur sport and the principles of fair play, this model created the canon found in contemporary axiological sport. Asian martial arts accept in a large part the concept of international competition and often take on the ideas of Olympism. However, some martial art schools and organization strongly reject the paradigm of sports rivalry.

The variety found in martial arts finds that they are practiced for health, self-defense, self-expression, self-fulfillment, sport, recreation, for improving one's character or for rehabilitation. Its students find in it a fragment of the rich culture of the Far East, one of physical exercise combined with a spiritual ritual, a code of ethics, the religious and philosophical or even ideological practices of the various schools of martial arts, their traditional medicine and the teaching language used by its teachers. This broad cultural context requires a particular system in order to distinguish it in matters of perception as well as in its research possibilities [29].

The **seal-realization** model, in the context of one's own corporeality and the self-consciousness of one's identification, is a part of the concept of the evolution of sports culture in relation to the systems of social order and the main motivation for its participants [30] as well as the more general concept of the "anthropology of spiritual progress" found in human psychology. It is a manifestation perceived by postindustrial society and postmodern culture while at the same time one that is psychophysical and of health (health understood in a holistic context) and consistent with the value-objectives (categorized by Merton) and "self-realization" motives and for "broadly defined health". Far Eastern concepts of psychophysical education are a part of, or are, in health and psychophysical culture and in the lifestyle of self-realization, an active lifestyle that is creator of post-industrial and postmodern societies. (Tab 1.).

This model can be described as an ascetic psychocultural model, as human activity is specifically directed here in moral and spiritual development. Positive asceticism is the practice of physical exercise, where the strive for perfection is the only vehicle of physical progress in the highly ethical, humanist way of humanity [25]. This model is apparently now featured in Far Eastern psychophysical customs, such as yoga, meditation methods, qigong, taiji quan, as well as in the way of martial arts (budō). Its aspects are divided here differently, from health to education and utilitarian motives.

The **ascetic aspect** and shūgyō are concerned about the body as an instrument of introspection and self-discovery, one of experience and the study of martial arts through their practice, in order to overcome pain and weakness. The ethical and ascetic way of the warrior is similar to religious practices. It combines the trainings of the body, spirit and mind; it builds utilitarian skills and allows for spiritual development. It motives are different than those in sport. The process of learning its ways (in Japanese shūgyō) is through active, physical or rather psychophysical, participation. Shūgyō, within the field of budō, can also be: 1. Bodily exercise, as a form of positive asceticism (improving the body for moral and spiritual advancement); 2. The process of learning and the practical teaching of the system of a particular form of martial arts; 3. The epistemological method used, dependent on the possibility of scientifically interpreting the psychophysical problems of this kind. Epistemology is used here in the sense of it being a way of learning martial arts and of self-discovery, used in the study methodology of martial arts [19]. Here, the way of learning is done through exercising one's body.

The **educational aspect** of martial arts was especially stressed by Jigorō Kanō. According to this educator, corporeality is supposed to be one of means of education [31]. Naturally, it is to be used in conjunction with education, morality, and cultural tradition. An unusual value in the psychophysical education of budō stems just from this fact, that martial art schools implement an educational system and not just technical training (fighting skills).

The **utilitarian value** of martial arts is one that martial arts theorists focus on [32–34]. They emphasize the use of the body in fighting, as a main instrument, as a weapon, tool or method of fighting. It is this unique theme, the effectiveness of martial arts techniques, which was one of the main causes of its global popularity. However, can their description correspond to a more external word, one either more physical or technical?

The first authors practicing in Japan under the guidance of eminent budō experts had the opportunity to see the utilitarian value (the application of various techniques in self-defense and fighting in life-threatening situations) which had a second or even third meaning. The way of martial arts is more in teaching character and a specific way of life, a combination of dialogue and life encounters, as defined by Martin Buber, especially between the student and the teacher. It is a process of personal growth and in the learning about the culture heritage of ancient masters (as a specific institution of military tradition). This particular **cultural aspect** appears to be more important for the Japanese in promoting their own national tradition, and in the exporting and selling abroad of the noble messages of their forefathers.

Does the modern form of martial arts, as practiced throughout the world and as a result of centuries of evolution, owe its popularity only to its ability in perfecting fighting techniques? Or could there be something else? Undoubtedly, many people are interested in in just the fighting aspect and the effectiveness of self-defense of the many subsystems of martial arts, or in other words, the technical-tactical tidbits packed into a crash courses on martial arts. For these people, the utilitarian value of these forms of martial is backed by the goal and motivation of exercise. However, in the traditionally-oriented ways of martial arts there is a process of evolution in the objectives and methods of its participants, where psychophysical exercise is increasingly used to attain a wider form of perfectionism. Changing its military objective into one that is "non-military" leads to a modification of the methods and preferred training used in its teaching techniques [35].

The cultural tradition and the richness of movement, the aura of mystery and exoticism, the imagery of martial art masters battling against archetypal heroes, these are the modern day myths that the media and numerous other sources propagate which resulted in the globally popular phenomenon of martial arts. The **global popularity aspect** gained, thanks to the democratization and commercialization of its culture, a lot through the culture of the body, as we would have said for Eichberg [14]. The elite form of ancient martial arts has gone under the process of globalization, wherein human corporeality is found in all the continents, races and religions of the world, of which all can experience this form of ancient practical knowledge. This kind of phenomenological analysis is also found in those countries where martial arts are emerging [36, 37] and in the fact that global scientific discourse on martial arts acknowledges its globalized culture [38, 39].

The health aspect comes from the presence of medical knowledge within the content of the educational school systems within traditionally oriented forms of organization. Martial arts are not only a way to defend the body (self-defense) but also a way of strengthening the body, in overall wellness, as well as it in having preventive and therapeutic effects [40]. They provide a high level of overall fitness as well as develop the positive health potential of the body. The motivation for doing such more often comes from its effects on the body and psychophysical health than from moral or spiritual improvement factors.

Training for health and for self-improvement and not for the occasional feeling of satisfaction, or in attaining self-defense skills, improving concentration, or emotional self-control etc., results from an appropriate level of knowledge in the field of physical culture (exercise and sports). The popularity of this kind of psycho-cultural form also comes from the growing needs of self-realization as found in the populations of more developed countries. It is not irrelevant to today's openness in cultural dialogue and in the reaping of valuable non-European cultural patterns that led to the controversial New Age movement as well as it being carried out by a fairly large group of researchers (beginning with Eliade) in a form of long-standing cultural dialogue.

On the other hand, a certain problem may be the occurrence of axiological chaos (a confusion of different traditions, values and negative values). The former elite educational systems have, as mentioned before, come under the process of democratization and commercialization, sometimes to extreme forms [41]. In addition, some forms have become politicized [42]. Extreme commercialization, linked together with mass culture, has caused degradation in the axiological potential in the way of martial arts and other forms of psychophysical improvement. Martial arts are brought down to the level of purely brutal fighting (in film, fights in cages, etc.) [39] or are presented as magic rituals, whose exotic packaging is helpful in only selling it as a product. Undeniably, the **ritual aspect** accompanied martial arts from its beginnings, as in the case of sumō. However, today these rituals and forms of magic are no longer important.

Continuing, the realization model, which binds physical progress with auto-creation objectives, is the least noticeable in media presentations. The trends that result from either its exotic nature or from its extreme commercialization end up in losing martial arts' deeper meaning. Nonetheless, self-identification through corporeality is in this case particularly noteworthy. Physical exercises help its practitioner in better understanding his own self and in the everyday individual processes of aspiration in fighting against one's own weaknesses [7].

## Conclusion

The way of martial arts, through a psychophysical educational system, has the body primarily used as a tool in the way to enlightenment and wisdom. It is especially useful in spiritual progress. Improving one's physical skills is therefore an ascetic way, which through physical perfection and technical accomplishment, leads to spiritual mastery.

In some cases, spiritual development, described in terms of energy, is associated with health potential. However, the motivation in this case comes from the body itself and from psychophysical health, not moral and spiritual improvement.

The utilitarian value comes from the use of the body as a weapon. Connected with it is the fitness model, the treating the body as an instrument, which is still historically significant and present in its modern-day form. The desire in strengthening the body and in gaining useful skills does not, of course, preclude the pursuit of other objectives.

Among the classifiable models found in somatic culture, the most original is the model of asceticism/self-realization. However, in the era of globalization and commercialization most areas of culture, misperception can stem from the models and polymorphic treatment of corporeality as found in arena of globally practiced martial arts.

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*Correspondence address*
Wojciech J. Cynarski
Katedra Nauk Humanistycznych
Uniwersytet Rzeszowski
ul. Piłsudskiego 30
35-959 Rzeszów, Poland
e-mail: ela_cyn@wp.pl

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2. Tekst prac empirycznych wraz ze streszczeniem, rycinami i tabelami nie powinien przekraczać 20, a prac przeglądowych – 30 stron znormalizowanych formatu A4 (ok. 1800 znaków ze spacjami na stronie). Strony powinny być ponumerowane.
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7. The main body of text in empirical research articles should be divided into the following sections:

**Introduction**
The introduction prefaces the reader on the article's subject, describes its purpose, states a hypothesis, and mentions any existing research (literature review)

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This section is to clearly describe the research material (if human subjects took part in the experiment, include their number, age, gender and other necessary information), discuss the conditions, time and methods of the research as well identifying any equipment used (providing the manufacturer's name and address). Measurements and procedures need to be provided in sufficient detail in order to allow for their reproducibility. If a method is being used for the first time, it needs to be described in detail to show its validity and reliability (reproducibility). If modifying existing methods, describe what was changed as well as justify the need for the modifications. All experiments using human subjects must obtain the approval of an appropriate ethnical committee by the author in any undertaken research (the manuscript must include a copy of the approval document). Statistical methods should be described in such a way that they can be easily determined if they are correct. Authors of comparative research articles should also include their methods for finding materials, selection methods, etc.

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The results should be presented both logically and consistently, as well as be closely tied with the data found in tables and figures.

**Discussion**
Here the author should create a discussion of the obtained results, referring to the results found in other literature (besides those mentioned in the introduction), as well as emphasizing new and important aspects of their work.

**Conclusion**
In presenting any conclusions, it is important to remem-

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We wstępie należy wprowadzić czytelnika w tematykę artykułu, opisać cel pracy oraz podać hipotezy, stan badań (przegląd literatury).

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W tej części należy dokładnie przedstawić materiał badawczy (jeśli w eksperymencie biorą udział ludzie, należy podać ich liczbę, wiek, płeć oraz inne charakterystyczne cechy), omówić warunki, czas i metody prowadzenia badań oraz opisać wykorzystaną aparaturę (z podaniem nazwy wytwórni i jej adresu). Sposób wykonywania pomiarów musi być przedstawiony na tyle dokładnie, aby inne osoby mogły je powtórzyć. Jeżeli metoda jest zastosowana pierwszy raz, należy ją opisać szczególnie precyzyjnie, przedstawiając jej trafność i rzetelność (powtarzalność). Modyfikując uznane już metody, trzeba omówić, na czym polegają zmiany, oraz uzasadnić konieczność ich wprowadzenia. Gdy w eksperymencie biorą udział ludzie, konieczne jest uzyskanie zgody komisji etycznej na wykorzystanie w nim zaproponowanych przez autora metod (do maszynopisu należy dołączyć kopię odpowiedniego dokumentu). Metody statystyczne powinny być tak opisane, aby można było bez problemu stwierdzić, czy są one poprawne. Autor pracy przeglądowej powinien również podać metody poszukiwania materiałów, metody selekcji itp.

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Przedstawiając wnioski, należy pamiętać o celu pracy

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**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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Jaskólska A., Bogucka M., Świstak R., Jaskólski A., Mechanisms, symptoms and after-effects of delayed muscle soreness (DOMS) [in Polish]. *Med Sport*, 2002, 4, 189–201.

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> Rodriguez F.A., Moreno D., Keskinen K.L., Validity of a two-distance simplified testing method for determining critical swimming velocity. In: Chatard J.C. (ed.), Biomechanics and Medicine in Swimming IX, Proceedings of the IX$^{th}$ World Symposium on Biomechanics and Medicine in Swimming. Université de St. Etienne, St. Etienne 2003, 385–390.

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> Donsmark M., Langfort J., Ploug T., Holm C., Enevoldsen L.H., Stallknech B. et al., Hormone-sensitive lipase (HSL) expression and regulation by epinephrine and exercise in skeletal muscle. *Eur J Sport Sci*, 2 (6), 2002. Available from: URL: http://www.humankinetics.com/ejss/bissues.cfm/, doi: 10.1080/ 17461391.2002.10142575.

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