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ANTROPOMOTORYKA

Vol. 23, nr 61

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VOL. 23, NR 61 **CRACOW – WROCLAW 2013**

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VOL. 23, NR 61 **KRAKÓW – WROCŁAW 2013**

ADRES REDAKCJI

al. Jana Pawła II 78, 31-571 Kraków
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FROM EDITORS • OD REDAKCJI

NEW YEAR 2013 AND A NEW ISSUE OF KRAKOW-WROCLAW "ANTROPOMOTORYKA"

NOWY 2013 ROK I NOWY NUMER KRAKOWSKO-WROCŁAWSKIEJ „ANTROPOMOTORYKI"

It is the New Year already. We are publishing another issue of our Krakow-Wroclaw magazine. Our thoughts, however, are focused on the end of 2013, when this year's last quarterly English edition is scheduled to come out. Judging from the difficulties encountered at the end of 2012, completing this task will not be easy. Nevertheless, we accept the challenge!

Allow me to express my heartfelt wishes first and foremost to all our co-workers that all our creative endeavors are successful, as they determine the future shape of *Antropomotoryka.* I congratulate everyone on the quality of the texts submitted to date for publication. I believe this will continue to improve. Let's hope that our readers are already noticing this. In the 61st quarterly issue – which is yet more proof of this quality – the editors have successfully assembled a collection of interesting and valuable scientific papers. We hope that the English language will not make reading the texts difficult and that the content of the material will be clearly conveyed. Keeping our readers in mind, the editors strive to make the English texts not only comprehensible in Poland, but also comprehensible for the scientists in English-speaking countries. Without a doubt, this will contribute to a better promotion of Polish studies of physical culture.

What can be found in the 61st issue of *Antropomotoryka*? The issue comprises nine scientific studies, including eight articles in the original papers section. The subject matter of the articles can be grouped into four thematic categories:

1. Role of physical activity in rehabilitating persons with various functional disabilities

This category contains two papers. The first one is entitled *Sensorimotor training and the changes in bioelectric activity in select muscles in visually impaired women over 50 years old.* The aim of the conducted research was to evaluate the changes in bioelectrical activity of muscles in visually impaired women aged between 50 and 65 years following a single sensorimotor training with Thera-Band stability trainers. The study confirmed the importance of rehabilitation and proved that undergoing sensorimotor training was beneficial for improving the body balance of visually impaired women by decreasing the bioelectrical activity of the soleus and tibialis anterior muscles.

In the second paper, *The role and use of Frenkel's exercises in rehabilitation*, the author proves the significance of these therapeutic exercises, to some extent already used successfully in the 19th century, in improving the physical fitness of elderly persons.

2. The role of physical activity in improving physical health during different periods of ontogeny

This section contains three research papers that were qualified for publication in the 61st issue of the magazine. The authors not only drew the reader's attention to the well-known relationship between high physical activity and health, but also to the methods for (first and foremost) measuring the quality and intensity of work performed during physical effort.

In the article *Physical activity and mobility of preschool children living in urban settings in the opinion of their parents*, the aim of the study was to investigate the level and type of physical activity ("mobility") of preschool children. The research involved implementing a diagnostic survey method along with a questionnaire that was prepared by the authors and distributed among the parents of the studied preschool children.

On the basis of the discovered correlation between mobility, selected indicators of lifestyle, and motor skills, the study revealed a diversification in the level of physical fitness and some of the motor skills depending on gender and the level of mobility declared by the parents of the preschool children.

On the other hand, the measurements of physical activity with the GT3X+ accelerometer, as presented in the article entitled *Assessment of energy expenditure of secondary school students during physical education classes including selected activity types*, indicate a low quality of physical effort during physical education classes in Poland. The study found that students' energy expenditure during monitored classes equaled 176 kcal in boys and 157 kcal in girls. For almost half the duration of these classes, effort intensity was no greater than 3 MET, according to the IPAQ scale. In considering effort intensity and energy expenditure, classes involving team games were found to be the most beneficial.

The paper *Influence of physical activity on body composition and podometric features of young men* raises the issue of overexertion during performed exercises. The results allowed the authors to draw the conclusion that students who declared a higher level of physical activity were characterized by considerably higher levels of fat-free mass and lower levels of fat mass as compared to students whose physical activity was low. The foot arch is slightly better in students with a high level of physical activity, which may indicate a positive influence of exercise on feet, as sport selects and eliminates persons with feet dysfunctions.

3. Various aspects of improving sports training

The aforementioned subject matter was discussed in two studies. In the first one, entitled *The effective use of intellectualization in teaching selected dispositions to play and its influence on reducing injury rates of lower limbs in adept football players*, the author presents the results of the research conducted with students at the Athletic Championship School in Krakow, and proves that intellectualization of a teaching process improves its effectiveness. The research revealed that lower physical strain and a conscious analysis of movements during a game in a group of football participating in experimental training sessions could result in reducing injuries of lower limbs.

The article *Changes in tactile information during sports training in basketball players and swimmers* raises a very interesting and unique issue. The study aimed to evaluate the changes in tactile information in two sports disciplines (basketball and swimming) that take place in different training environments and in which the participants' skin is subjected to different external stimuli. The researched group comprised sportspersons engaged in competitive sports training. Esthesiometric measurements were taken from 36 basketball players, 32 female swimmers, and a control group consisting of 32 women, all aged between 19 and 20 years. The study revealed changes in tactile threshold in sportspersons during professional sports training. These changes depended on applied external stimuli characteristic for each sports discipline.

4. Intergenerational variability of strength abilities in preschool children and during primary school education in the context of long-term tendencies for changes in body height and non-verbal intelligence

The issue addressed concerns intergenerational variability of motor strength abilities fundamental to one's health on the basis of the American Health Related Fitness concept. Even though the issue itself is not original, the authors present the matter in an extremely interesting way. The comparative analysis regarded variability of basic indicators of motor fitness (measurements of strength abilities), psychological development (the results of the Raven test), and somatic growth (measurements of body height) within 30 years in 3 areas in Malopolska: a village, small city, and big city. The studied range and direction of intergenerational changes in the indicators of somatic growth and psychological development allowed the authors to observe that the dynamics of changes over time is similar only in functional and structural features, while it varies due to gender and the sociological and cultural factors of the inhabited environment.

Furthermore, the reported variability over time in social gradients in physical, psychological, and motor development indicates a decrease of these gradients, but at the expense of the development of children living in big cities, which (surprisingly) slowed. The results of the conducted research may prove that an urban environment in Malopolska no longer provides suitable conditions for somatic growth and (again, surprisingly) for children's intellectual development as well. The intergenerational variability in social gradients may be evidence of social advancement of Polish villages during the transformation of the political system.

The issue is concluded with an engaging discussion in the review papers section on the importance of the immune system for professional sports. Readers can learn about interesting changes in the immune system indicators occurring after exhausting, intensive physical activity. The study revealed lymphocytosis followed by lymphocytopenia, monocytosis, an increase in the number of neutrophil granulocytes and in the total amount of leukocytes (WBC), a decrease in the concentration of immunoglobulin A (IgA) in saliva, an increase in cytokines in serum, and a decrease in the phagocytic activity of neutrophil granulocytes. Apart from the aforementioned changes, the study also revealed an increase in the activity of natural killer cells (NK) immediately following the effort, and revealed that their number dropped below the rest value during the restitution period. It is assumed that physical activity influences the immune system through several mechanisms; the ones most commonly mentioned include: an increase in the concentration of steroid hormones (adrenalin, noradrenalin, cortisol, and growth hormone), muscle damage, and a decrease in the concentration of glutamine in blood due to psychological stress.

What more can be said in this (necessarily brief) recommendation of articles published in the 61st issue of *Antropomotoryka*? I believe that another New Year's wish should be expressed: that the completion of creative work, which has received positive reviews, brings the authors satisfaction and that – I am sure of it – this work may result in a better rank given to our magazine in its next evaluation by the Ministry of Science and Higher Education.

To you, dear readers, I wish that the value of the research results published in our quarterly is confirmed. I am certain that we are not the only ones who would like to see the articles from *Antropomotoryka* quoted by our readers in their studies published around the world.

Edward Mleczko
Editor-in-Chief
Antropomotoryka-Kinesiology

INFORMATION FOR THE AUTHORS

1. "Kinesiology" ("Antropomotoryka") is an official scientific quarterly of the International Association of Sport Kinetics – IASK, published at the University School of Physical Education, Cracow, Poland under the auspices of the Committee Rehabilitation, Physical Education and Social Integration the Polish Academy of Sciences.
   The magazine presents the results of original research work and experiments in the field of human motoricity and related sciences. It also publishes review articles, opinion articles and discussion of scientists evaluating the current situation and perspectives of scientific development of human motoricity.

2. Materials for publication (one copy of computer printouts) should be sent together with the compact disc at the following address: Redakcja "Antropomotoryki", Akademia Wychowania Fizycznego, al. Jana Pawła II 78, 31-571 Kraków, tel. 12 683 12 78, tel/fax 12 683 10 76 or at the e-mail address: antropomotoryka@awf.krakow.pl.

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   - "Antropomotoryka" accepts demonstrative, original, experimental, and historical papers, information about conferences, reports from congresses and conferences on human motoricity, short summaries of works published in foreign periodicals and book reviews on human motoricity. Original works are accepted in English.
   - The works of particular scientific value submitted and accepted for publication earlier on in a foreign scientific periodical can also be submitted for publication in the "Antropomotoryka", however, on condition that the Author obtains a permission from the publisher of the periodical.
   - All papers should be no longer than 22 pages with 1800 letters per page (i.e. 30 lines 60 points each). They should be in double-spaced or 1,5 spaced typewriting on one side of the paper only.

4. Rules of constructing the work:
   - The accompanying letter should contain both home and office addresses and the information at which address to send the correspondence.
   - Empirical works should contain the following information: title, name(s) of the author(s), key words in Polish and in English, brief summary in Polish, summary in English (as mentioned above), introduction, material, methods, results and discussion, conclusions and bibliography.
   - The number of key words should be from 3 to 15.
   - The summary has to contain: the purpose of the work, material, methods, results and conclusions.
   - The first page should contain the information in the following order: title, name(s) of the author(s), scientific degree(s) of the author(s) and the professional affiliation, including the address, key words, brief summary in Polish and in English. The summary should not contain less than 200 and no more than 250 words.
   - The reference materials should be listed on a separate sheet of paper. Only the aterials the Author refers to in the text may be included. They should be numbered using Arabic numerals and placed in the order they are quoted in the work (not in the alphabetic order). Each item of the reference materials should be written in a new verse. The surname(s) of the author(s) of the quoted work should be followed by the initials of their first name(s), then the original title of the magazine where the work was published should be given. The abbreviation of the title of a magazine should be taken from the Index Medicus (or International Committee of Medical Journal Editors: Uniform Requirements for manuscripts submitted in biomedical journals. N Engl J Med 1997; 336, 309–315).

Examples:

a) works printed in magazines:
   - Casella R, Bubendorf L, Sauter G, Moch H, Michatsch MJ, Gasser TC: *Focal neuroendocrine differentiation lacks prognostics significance in prostate core needle biopsies*. J Urol, 1998; 160: 406–410.

b) monographs:
   - Matthews DE, Farewell VT: *Using and Understanding Medical Statistics*, ed 3, revised. Basel, Karger, 1966.

c) chapters in textbooks:
   - Parren PWHI, Burton DR: *Antibodies against HIV-1 from phage display libraries; Mapping of an immune response and progress towards antiviral immunotherapy*; in Capra JD (ed.): Antibody Engineering, Chem. Immunol. Basel, Karger, 1997, 65: 18–56.
   - Kokot F: *Fizjologia nerek*; w. Zieliński J, Leńko J (eds): *Urologia*, Warszawa, PZWL, 1992, 1: 9–20.

All the illustrations have to be of high quality. Graphic material should be submitted on white sheets of paper. Copies of photographs and photographs should be submitted on glossy paper. The consecutive number of the photograph should be written with a soft pencil on the back side of each photograph as well as an arrow marking its top edge. Only black and white pictures are printed. Scales and pictures should be placed on separate pages and numbered with Arabic numerals. The headings, descriptions and suscriptions under the pictures and above the scales should be written in Polish and English.

Example in Polish:

Tabela 1., Ryc. 1., Objaśnienia, Chłopcy

Example in English:

Table 1., Fig. 1., Commentary, Boys

Please, use round parentheses. Physical or chemical formulae should be written clearly. This refers particularly to indices and exponents.

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The reference materials should be given in the order of quotation.

[1] Żekoński Z, Wolański N: *Warunki społeczno-bytowe jako czynniki rozwoju człowieka w Wolański N* (red.): *Czynniki rozwoju człowieka*. Warszawa, PWN, 1987, 68–88.

[2] Malarecki I: *Zarys fizjologii wysiłku i treningu sportowego*. Warszawa, Sport i Turystyka, 1975.

[3] Bouchard C, Malina RM: *Genetics of physiological fitness and motor performance*. Exerc. Sport. Sc. Rev. 1983; 11: 112–115.

[4] Szopa J: *W poszukiwaniu struktury motoryczności: analiza czynnikowa cech somatycznych, funkcjonalnych i prób sprawności fizycznej u dziewcząt i chłopców w wieku 8–19 lat*. Wyd. Monograficzne, Kraków, AWF, 1983; 35.

While quoting the reference materials in the text, only square parentheses with the number of the quoted item in Arabic numerals should be given. When quoting two or more works the square parentheses should contain the chronological order of their publication.

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   - All the materials are evaluated and anonymously reviewed.
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   - The article (with a written statement – see: *General conditions*) should be sent with a cover letter signed by a senior reasercher, who is responsible for the content of the of the article.
   - The Author gets a free copy of "Antropomotoryka – Kinesiology" in PDF format. The magazine in book form can be ordered on condition of payment at the e-mail address: joanna.stepien@awf.krakow.pl when the corrected proof copy is returned.
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   - Summaries in Polish and English can be found at the following Internet addresses: www.awf.krakow.pl; link: wydawnictwa, czasopisma, antropomotoryka, and www.journals.indexcopernicus.com.

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1. „Antropomotoryka" („Kinesiology") jest oficjalnym, recenzowanym kwartalnikiem naukowym Międzynarodowego Stowarzyszenia Motoryki Sportowej – IASK, wydawanym w Akademii Wychowania Fizycznego w Krakowie pod patronatem Komitetu Rehabilitacji, Kultury Fizycznej i Integracji Społecznej PAN. W czasopiśmie przedstawiane są wyniki oryginalnych badań i doświadczeń w dziedzinie motoryczności człowieka oraz dziedzin pokrewnych. Zamieszczane są również prace przeglądowe, poglądy oraz dyskusje oceniające obecny stan i perspektywy rozwoju dorobku badawczego szeroko pojętej antropomotoryki.

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scripts submitted to biomedical journals. N Engl J Med 1997; 336; 309–315).

Przykłady:

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   - Casella R, Bubendorf L, Sauter G, Moch H, Michatsch MJ, Gasser TC: *Focal neuroendocrine differentiation lacks prognostic significiance in prostate core needle biopsies*. J Urol, 1998; 160: 406–410.

b) monografie:
   - Matthews DE, Farewell VT: *Using and Understanding Medical Statistics*, ed 3, revised. Basel, Karger, 1996.

c) rozdziały w książkach:
   - Parren PWHI, Burton DR: *Antibodies against HIV-1 from phage display libraries; Mapping of an immune response and progress towards antiviral immunotherapy*; in Capra JD (ed.): *Antibody Engineering.* Chem Immunol. Basel, Karger, 1997, 65: 18–56.
   - Kokot F: *Fizjologia nerek*; w Zieliński J, Leńko J (red.): *Urologia*, Warszawa, PZWL, 1992, 1: 9–20.

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Tabela 1., Ryc. 1., Objaśnienia, Chłopcy

Table 1., Fig. 1., Commentary, Boys

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[1] Żekoński Z, Wolański N: *Warunki społeczno-bytowe jako czynniki rozwoju człowieka*; w Wolański N (red.): *Czynniki rozwoju człowieka*. Warszawa, PWN, 1987; 68–88.

[2] Malarecki I: *Zarys fizjologii wysiłku i treningu sportowego*. Warszawa, Sport i Turystyka, 1975.

[3] Bouchard C, Malina RM: *Genetics of physiological fitness and motor performance*. Exerc Sport Sc Rev, 1983; 11: 112–115.

[4] Szopa J: *W poszukiwaniu struktury motoryczności: analiza czynnikowa cech somatycznych, funkcjonalnych i prób sprawności fizycznej u dziewcząt i chłopców w wieku 8–19 lat*. Wyd. Monograficzne, Kraków, AWF, 1988; 35.

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ORIGINAL PAPERS
PRACE ORYGINALNE

SENSORIMOTOR TRAINING AND THE CHANGES IN BIOELECTRIC ACTIVITY IN SELECT MUSCLES IN VISUALLY IMPAIRED WOMEN OVER 50 YEARS OLD

TRENING SENSOMOTORYCZNY A ZMIANY AKTYWNOŚCI BIOELEKTRYCZNEJ WYBRANYCH MIĘŚNI U SŁABOWIDZĄCYCH KOBIET PO 50. ROKU ŻYCIA

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Key words: EMG, sensorimotor training, visually impaired women, proprioception
Słowa kluczowe: EMG, trening sensomotoryczny, kobiety słabowidzące, propriocepcja

SUMMARY • STRESZCZENIE

Aim of the study. The purpose of this study was to assess the changes of the bioelectrical activity of muscles in visually impaired women aged between 50 and 65 years under the influence of one-time sensorimotor training with Thera-Band stability trainers.

Material and methods. The study included the experimental group E, comprised of 30 women aged between 50 and 65 years with category II and III visual impairment, and the control group C containing 30 women of similar age with normal sight. The measurements were taken prior to and after exercising with Thera-Band stability trainers, with the subjects standing freely or maximally leaned forward and backward, both with eyes open (EO) and eyes closed (EC). The EMG signal was registered with the four-channel method using superficially placed electrodes. The following four muscles were examined: tibial anterior muscle, soleus muscle, and the medial and lateral head of gastrocnemius muscle.

Results. Significant reduction in the bioelectrical activity of tibial anterior muscle ($P < 0.05$) and soleus muscle ($P \leq 0.05$) was documented in both studied groups after sensorimotor training, along with only isolated significant changes in the activity of the gastrocnemius muscle in the control group. In addition, statistically significant differences were observed in the experimental group in relation to the tibialis anterior: ($P \leq 0.05$) and the soleus ($P \leq 0.05$ or $P < 0.01$) compared to the control group. Further statistical analysis conducted in group E revealed significant variance in the model of changes in the tibialis anterior muscle activity ($Chi^2ANOVA = 125.845$, $P < 0.001$) in all measurements. In contrast, significant variance in the model of changes in the activity of the tibialis anterior ($Chi^2ANOVA = 106.10$, $P < 0.001$) and soleus muscles ($Chi^2ANOVA= 97.593$, $P < 0.001$) was documented in group C.

Conclusions. The application of the experimental stimulus in the form of sensorimotor training revealed that they soleus and tibialis anterior muscles possess the highest sensitivity to the type of the surface, thus confirming their significant role in maintaining stable posture.

Cel pracy. Ocena zmian aktywności bioelektrycznej mięśni u kobiet słabowidzących w wieku 50–65 lat po zastosowaniu jednorazowego treningu sensomotorycznego z wykorzystaniem trenażerów równowagi Thera-Band.

Materiał i metody. Grupę eksperymentalną tworzyło 30 kobiet z II i III kategorią zaburzeń widzenia w wieku 50–65 lat, a w skład 30-osobowej grupy porównawczej weszły kobiety w podobnym wieku, ale ze wzrokiem normalnym. Pomiary przeprowadzano przed i po treningu na trenażerach równowagi Thera-Band w pozycjach swobodnego stania, maksymalnego wychylenia do przodu i do tyłu, przy oczach otwartych i zamkniętych. Rejestrację sygnału EMG wykonywano metodą czterokanałową z zastosowaniem elektrod powierzchniowych. Badano cztery mięśnie: piszczelowy przedni, płaszczkowaty, brzuchaty łydki – głowa przyśrodkowa oraz brzuchaty łydki – głowa boczna.

Wyniki. Po zastosowaniu treningu sensomotorycznego stwierdzono istotne statystycznie obniżenie się aktywności bioelektrycznej mięśnia piszczelowego przedniego ($P \leq 0{,}05$) oraz płaszczkowatego ($P \leq 0{,}05$) w obu badanych grupach. Tymczasem w przypadku mięśnia brzuchatego łydki obserwowano jedynie pojedyncze statystycznie istotne zmiany ($P \leq 0{,}05$) w grupie porównawczej. Ponadto zaobserwowano istotne statystycznie różnice, korzystne dla grupy eksperymentalnej, dotyczące mięśni piszczelowego przedniego ($P \leq 0{,}05$) oraz płaszczkowatego ($P \leq 0{,}05$ lub $P < 0{,}01$) w odniesieniu do grupy porównawczej. Dalsza analiza statystyczna w grupie eksperymentalnej wykazała istotne zróżnicowanie modelu zmian aktywności mięśnia płaszczkowatego ($Chi^2ANOVA = 125{,}845$; $P < 0{,}001$) we wszystkich pomiarach. W grupie porównawczej obserwowano natomiast istotne zróżnicowanie modelu zmian aktywności mięśni piszczelowego przedniego ($Chi^2ANOVA = 106{,}10$; $P < 0{,}001$) oraz płaszczkowatego ($Chi^2ANOVA = 97{,}593$; $P < 0{,}001$).

Wnioski. Zastosowanie u kobiet słabowidzących treningu sensomotorycznego korzystnie wpłynęło na poprawę równowagi ciała przez obniżenie aktywności bioelektrycznej mięśni płaszczkowatego oraz piszczelowego przedniego, potwierdzając tym samym znaczenie tego treningu w postępowaniu rehabilitacyjnym.

Introduction

Numerous architectural and urban obstacles present in the environment make visually impaired or blind persons especially prone to falls. Moreover, falls are much more frequent in women than in men [1]. This is due to post-menopausal changes that intensify after the age of 50 years and that significantly reduce functional fitness and weaken mechanisms responsible for maintaining postural stability [2]. Even falls that do not result in a serious injury can lead to long-term anxiety states and a reduction in future physical activity [3]. Research on the ways of improving compensation mechanism in visually impaired women may play a major role in reducing the risk of falls and injuries.

Specific rehabilitation programs aimed at visually impaired persons include health services, providing information on visual impairment and its functional consequences, stimulating one's sight, teaching one to make better use of visual information about one's surrounding, and adjusting the environment to one's needs. To this end, exercises are used that develop visual skills without optical cues, exercises with visual and non-visual cues, and exercises with electronic devices. In terms of preventing falls, rehabilitation methods that involve activating non-visual systems of controlling body posture are considered to play an important role [4, 5, 6]. These systems include the somatosensory system and the vestibular system [7]. A previous study found that sensorimotor exercises can effectively improve body balance and motor abilities. Moreover, they benefit the development of spatial organization and movement and increase one's use of non-visual sensory information [8].

Kinesiological electromyography allows therapists to monitor changes that occur during rehabilitation, motor re-education, vocational re-education, and to assess a patient's functioning. Researchers indicate the increasing potential to enhance studies by using devices that register the bioelectrical activity of muscles [9]. Furthermore, many analyses of postural stability are supported by an EMG reading. Every movement taken while the body is in the vertical position engages not only the muscles that are directly responsible for the movement, but postural muscles of the torso and of the lower limbs as well. This is due to the displacement of the center of body mass. Even though the engagement of muscles in maintaining postural stability is a well-known phenomenon, studies are still conducted on the effect of various factors on muscle activity [10]. In particular, researchers give special attention to factors that disrupt body balance, the role of the proprioceptive system, and the way in which the central nervous system controls body balance [11, 12, 13, 14, 15]. Studies on visually impaired women in terms of postural stability and the bioelectrical activity of postural muscles are rare and do not lead to clear conclusions. Nakata and Yabe (2001) conducted a study on blind persons and found no statistically significant correlation between the electromyography (EMG) of postural muscles in lower limbs (tibialis anterior, gastrocnemius, rectus femoris, and biceps femoris muscles) and postural stability. On the other hand, Bugnariu et al. found no correlation between visual information and muscle activity [14].

This study assessed the effect of sensorimotor training using Thera-Band stability trainers on changes in the bioelectrical activity of selected muscles in visually impaired women aged over 50 years. The study involved women with a high risk of falling due to both visual impairment and postmenopausal changes occurring in the body. A hypothesis was put forward that sensorimotor training is an effective method of rehabilitation for visually impaired women and improves body balance by reducing the bioelectrical activity of postural muscles in lower limbs.

Material

The experimental group (group E) comprised 30 visually impaired women aged 50–65 years ($\bar{x}$ = 58.9 ± 5.6 years). According to the International Classification of Impairments, Disabilities, and Handicaps, the women in the experimental group belonged to categories II and III of visual impairment.[17] The group was recruited from members of the Polish Association of the Blind. The control group (group C) comprised 30 women of similar age, i.e., 50–65 years ($\bar{x}$ = 56.2 ± 4.9 years) with normal sight (greater than 0.3 diopters) [17].

Methods

This study was conducted with approval No. 305/11 of the Bioethics Committee at the Karol Marcinkowski University of Medical Sciences in Poznan of 16 June 2011 and with the written consent of each participant. Prior to the assessment, each participant was obliged to provide her current results of a visual examination that confirmed her level of visual impairment or, in the case of the control group, the lack thereof.

The EMG reading was taken using the Nicolet Viking Quest EMG machine, made in the United States (with software version as of 11 January 2008). The assessment was conducted using the four-channel method with superficially placed electrodes. Frequency length of the EMG amplifier ranged from 10 Hz to 500 Hz [18], with the majority of frequency power of the superficial EMG ranging between 10 Hz and 250 Hz. No other filters were used in the study. The RMS value of the EMG signal (the root mean square value of the electromyographic signal for a given time interval T) was assessed, which allowed us to estimate the number of active muscle fibers. The value of RMS EMG was calculated using software integrated with an analogue-digital transformer located in a computer that received signals from the EMG amplifier. Differences between the bioelectrical activity of muscles before (PRE) and after (POST) the sensorimotor exercises (performed with Thera-Band trainer) in the experimental and control groups were analyzed using the maximum voluntary contraction (MVC) method of normalization of the EMG signal (RMS EMG_{MVC}). Preparations for the assessment were conducted according to the guidelines [18, 19, 20]. The following muscles were assessed: **the tibialis anterior muscle** (TA), the soleus muscle (SOL), **the medial head of the gastrocnemius muscle** (GM), and the lateral head of the gastrocnemius muscle (GL).

Sensorimotor training was conducted on an unstable surface provided by using 2 black-colored Thera-Band Polska stability trainers (filled with air).

Procedure

1) Attaching the electrodes

- Channel 1: TA – electrodes were placed at one-third the distance between the head of the fibula and the medial malleolus,
- Channel 2: SOL – electrodes were placed at two-thirds the distance between the medial condyle of the femur and the medial malleolus,
- Channel 3: GM – electrodes were placed on the most protruding point of the muscle belly,
- Channel 4: GL – electrodes were placed at one-third the distance between the head of the fibula and the ankle.

2) Measuring the value of the RMS EMG_{MVS} (μV) in the sitting position:

- TA – knee joints bent at 80–90° and feet bent at 45° at the ankle. The participants were asked to perform a maximum voluntary dorsiflexion of the foot;
- SOL – knee joints bent at 80–90° and feet bent at 45° at the ankle. The participants were asked to perform a maximum voluntary plantarflexion of the foot;
- GM and GL – extension of the knee joints and feet bent at 45° at the ankle. The participants were asked to perform a maximum voluntary plantarflexion of the foot.

3) Measuring the value of RMS EMG μV) in an upright position on a flat surface:

- EMG reading taken while the patient was standing freely and remaining immobile, as far as possible,

for 20 seconds. The first reading was taken with eyes open and the second reading was taken with eyes closed.
- EMG reading taken while the patient was standing maximally leaned forward and backward for 10 seconds. The first reading was taken with eyes open and the second reading was taken with eyes closed.

4) Conducting a 15-minute-long set of 16 exercises on an unstable base.

- standing on toes (30 times),
- standing on heels (30 times),
- standing freely on both legs,
- performing a maximal voluntary leaning of the body in the sagittal and coronal plane while standing on both legs,
- standing freely on one leg,
- performing a maximal voluntary leaning of the body in the sagittal and coronal plane while standing on one leg.

Each exercise was performed with eyes open (EO) and closed (EC) (Brugioni & Falkel, 2004; Powers et al., 2004).

5) Repeated EMG reading immediately after all exercises have been performed according to the procedure described above.

Statistical analysis

Statistical analysis was performed using the StatSoft STATISTICA software (StatSoft Inc., OK, United States). Statistical significance of all measurements was accepted at $P \leq 0.05$ and $P < 0.01$. The Shapiro-Wilk test was used to assess the normality of the distribution. The following non-parametric tests were used to assess differences in mean values of EMG parameters: Wilcoxon, Friedman's ANOVA for repeated measurements, and the Mann-Whitney U test.

Results

Study participants underwent measurements of selected somatic characteristics, i.e., body height, body mass, and BMI. Table 1 shows the obtained results. No statistically significant difference in age, body height, or body mass was observed between the E and C groups. Small differences were found only in terms of BMI, which was slightly higher in the E group than in the C group ($P \leq 0.05$).

Analysis of the bioelectrical activity of muscles in the EMG reading using maximum voluntary isometric contraction

The first measurement involved obtaining the RMS value during the MVC of the above-mentioned muscles: TA, SOL, GM, and GL. Table 2 presents mean RMS EMG values for each muscle, which are the basis of normalization to MVC values. RMS values in the E group do not show normal distribution for the following muscles: SOL, GM, and GL ($P \leq 0.05$). Similarly, the C group did not show normal distribution in the case of GM and GL ($P \leq 0.05$). The Mann-Whitney U test found statistically significant ($P < 0.01$) differences in the mean MVC values for the SOL muscle between the E and C groups. The mean values were higher in the C group.

Bioelectrical activity of muscles after the sensorimotor training with eyes open and with eyes closed

Table 3 shows changes in the values of bioelectrical activity of the TA muscle observed after the sensorimotor training. A statistically significant ($P < 0.01$) reduction in the RMS value after the sensorimotor training was observed in both groups for measurements performed with EO for both the free-standing position and the maximal forward lean. The RMS value increased only in the E group for measurements during the maximal

Table 1. Mean values and standard deviations of morphological characteristics in the C group and E group and ANOVA effect for differences between the groups

$\bar{x} \pm SD$	Age [years]	Body height [m]	Body mass [kg]	BMI [kg/cm^2]
E	58.90 ± 5.60	1.63 ± 0.10	78.23 ± 18.63	29.39 ± 5.86
K	57.26 ± 4.94	1.62 ± 0.06	72.53 ± 15.07	27.35 ± 4.85
$F_{(1,58)}$ (p)	1.50 (0.225)	0.02 (0.886)	1.70 (0.197)	2.16 (0.035)*

* indicates significance level of $P \leq 0.05$

Table 2. Basic characteristics, values of the Shapiro-Wilk normality test for each muscle in the studied groups, and values of the Mann-Whitney U test for RMS EMG_{MVC} parameters in the E group and C group

RMS EMG_{MVC}	Group	$\bar{x} \pm SD$	Min. – Max.	W	Z
TA (μV)	E C	961.17 ± 403.84 896.33 ± 275.35	80–1784 210–1478	0.99 0.98	0.60
SOL (μV)	E C	242.63 ± 212.43 330.57 ± 143.60	41–679 109–666	0.81** 0.96	–2.63*
GM (μV)	E C	238.23 ± 105.83 208.27 ± 48.63	121–678 129–291	0.77** 0.92*	0.88
GL (μV)	E C	238.23 ± 105.83 208.27 ± 48.63	121–678 129–291	0.77** 0.92*	0.88

* indicates significance of $P \leq 0.05$; ** indicates a significance at level $P < 0.01$

W – values of the Shapiro-Wilk normality test; Z – Standardized value of the Mann-Whitney U test

backward lean. For PRE and POST measurements with EC, all differences found for both E and C group were statistically significant ($P < 0.01$ or $P \leq 0.05$) and due to a reduction in bioelectrical activity of analyzed muscles.

Table 4 presents changes in the bioelectrical activity of the SOL muscle. Group E showed a decrease in this parameter in all measurements during the POST test. Interestingly, the results in this group exceeded 100% of the MVC value for the SOL muscle. The measured parameters were statistically lower in the POST test than in the PRE test by 136.62 ± 3.55% ($P < 0.01$) during the maximal forward lean and by 5.42 ± 3.02% ($P \leq 0.05$) during the maximal backward lean with EO; and by 63.40 ± 1.58% ($P \leq 0.05$) during the maximal forward lean and by 41.37 ± 1.61% ($P < 0.01$) during the maximal backward lean with EC. Changes in the C group were analogous to changes in the E group:

Table 3. Mean, standard deviation, and the difference in the values of RMS EMG signal amplitude expressed as a percentage of MVC for the tibialis anterior muscle (TA) prior to ($\bar{x}_{PRE}$) and after ($\bar{x}_{POST}$) sensorimotor training in the E group and C group, together with the value of the Wilcoxon test for significance of differences between repeated measurements

Measurement postion TA	Group	$\bar{x}_{PRE} \pm SD$ %MVC	$\bar{x}_{POST} \pm SD$ %MVC	Difference $\bar{x}_{POST} - \bar{x}_{PRE} \pm SD$	Z
Eyes open					
Free standing	E C	22.44 ± 0.21 28.22 ± 0.36	19.79 ± 0.14 13.16 ± 0.18	–1.64 ± 0.25 –15.06 ± 0.23	3.40** 4.35**
Maximal forward lean	E C	27.44 ± 0.26 23.91 ± 0.21	19.14 ± 0.56 14.23 ± 0.18	–8.30 ± 0.61 –9.69 ± 0.20	3.36** 3.24**
Maximal backward lean	E C	27.16 ± 0.23 34.00 ± 0.23	27.70 ± 0.60 24.57 ± 0.16	0.55 ± 0.66 –9.44 ± 0.19	2.17* 2.48**
Eyes closed					
Free standing	E C	14.99 ± 0.15 28.33 ± 0.37	7.81 ± 0.07 15 ± 0.19	–7.18 ± 0.15 –13.37 ± 0.24	3.14** 3.61**
Maximal forward lean	E C	21.64 ± 0.23 26.15 ± 0.28	10.39 ± 0.10 13.56 ± 0.15	–11.25 ± 0.22 –12.59 ± 0.20	3.16** 3.34**
Maximal backward lean	E C	41.14 ± 1.09 35.10 ± 0.27	16.88 ± 0.17 23.17 ± 0.16	–24.26 ± 1.07 –11.93 ± 0.19	1.98* 3.16**

* indicates significance of $P \leq 0.05$ ** indicates significance of $P \leq 0.01$

Z – standardized value of the Wilcoxon test for the significance of differences

Table 4. Mean, standard deviation, and the difference in the values of RMS EMG signal amplitude expressed as a percentage of MVC for the soleus muscle (TA) prior to ($\bar{x}_{PRE}$) and after ($\bar{x}_{POST}$) sensorimotor training in the E group and C group, together with the value of the Wilcoxon test for significance of differences between repeated measurements

Measurement postion SOL	Group	$\bar{x}_{PRE} \pm SD$ %MVC	$\bar{x}_{POST} \pm SD$ %MVC	Difference $\bar{x}_{POST} - \bar{x}_{PRE} \pm SD$	Z
Eyes open					
Free standing	E	146.52 ± 1.92	120.59 ± 1.86	–26.01 ± 1.01	1.57
	C	48.67 ± 3.34	52.69 ± 7.04	4.02 ± 6.74	1.45
Maximal forward lean	E C	264.08 ± 4.39 64.42 ± 5.15	127.46 ± 2.03 47.30 ± 5.06	–136.62 ± 3.55 –17.12 ± 5.21	3.04** 2.95**
Maximal backward lean	E C	183.14 ± 2.86 54.46 ± 4.56	177.73 ± 4.57 36.23 ± 3.64	–5.42 ± 3.02 –18.73 ± 4.35	1.94* 2.38*
Eyes closed					
Free standing	E C	119.19 ± 1.46 52.22 ± 3.94	109.16 ± 1.73 45.34 ± 5.54	–8.92 ± 1.23 –6.98 ± 5.77	0.92 2.07*
Maximal forward lean	E C	173.17 ± 2.15 69.20 ± 4.91	109.77 ± 1.60 41.37 ± 2.74	–63.40 ± 1.58 –27.83 ± 4.13	2.21* 3.79**
Maximal backward lean	E	158.05 ± 2.20	110.94 ± 1.75	–47.11 ± 1.61	2.27*
	C	68.02 ± 5.9	34.32 ± 2.4	–33.70 ± 4.9	3.40**

* indicates significance of $P \leq 0.05$ ** indicates significance of $P \leq 0.051$

Z – standardized value of the Wilcoxon test for the significance of differences

Table 5. Mean, standard deviation, and the difference in the values of RMS EMG signal amplitude expressed as a percentage of MVC for the medial head of the gastrocnemius muscle (GM) prior to ($\bar{x}_{PRE}$) and after ($\bar{x}_{POST}$) sensorimotor training in the E group and C group, together with the value of the Wilcoxon test for significance of differences between repeated measurements

Measurement postion GM	Group	$\bar{x}_{PRE} \pm SD$ %MVC	$\bar{x}_{POST} \pm SD$ %MVC	Difference $\bar{x}_{POST} - \bar{x}_{PRE} \pm SD$	Z
Eyes open					
Free standing	E K	50.50 ± 3.75 62.81 ± 8.16	57.38 ± 7.94 30.64 ± 3.25	6.88 ± 5.94 –33.12 ± 8.71	0.69 2.35*
Maximal forward lean	E K	64.64 ± 5.10 66.09 ± 5.46	83.07 ± 1.24 52.65 ± 4.02	18.43 ± 8.83 –13.44 ± 3.71	0.92 2.23*
Maximal backward lean	E K	79.81 ± 0.11 50.69 ± 6.46	73.05 ± 9.95 34.44 ± 3.61	1.48 ± 5.90 –16.24 ± 6.06	1.35 1.22
Eyes closed					
Free standing	E K	57.63 ± 6.14 54.09 ± 6.24	66.73 ± 8.64 45.58 ± 5.84	9.09 ± 5.92 –8.41 ± 7.00	0.69 0.98
Maximal forward lean	E K	63.54 ± 5.05 64.78 ± 5.56	70.40 ± 7.56 56.83 ± 5.53	7.68 ± 5.91 –7.95 ± 4.32	1.22 1.41
Maximal backward lean	E K	51.71 ± 5.54 58.67 ± 8.93	72.71 ± 9.60 33.14 ± 2.80	20.99 ± 6.80 –25.53 ± 8.72	0.67 1.10

* indicates significance of $P \leq 0.05$ ** indicates significance of $P \leq 0.01$

Z – standardized value of the Wilcoxon test for the significance of differences

the measured parameters were statistically lower in the POST test than in the PRE test by 17.12 ± 5.21% ($P < 0.01$) during the maximal forward lean and by 18.73 ± 4.35% ($P \leq 0.05$) during the maximal backward lean with EO and by 6.98 ± 5.77% ($P \leq 0.05$) in the free-standing position, by 27.83 ± 4.13% ($P < 0.01$) during the maximal forward lean, and by 33.70 ± 4.9% ($P < 0.01$) during the maximal backward lean with EC.

The next part of the analysis concerned changes in the bioelectrical activity of the GM muscle (Table 5). EMG amplitude increased in the E group, but the difference between the PRE and POST test was not statistically significant for any measurement. At the same time, the C group showed a statistically significant reduction of the EMG amplitude, amounting to 33.12 ± 8.71% ($P \leq 0.05$) for the freestanding position with EO and to 13.44 ± 3.71% ($P \leq 0.05$) during the maximal forward lean after the sensorimotor training. Values of other parameters showed no statistical significance.

Table 6 presents changes observed in the bioelectrical activity of the lateral head of the gastrocnemius. The measured parameter decreased in both groups for measurements with EO, except for the maximal forward lean in the E group, where the value increased. For measurements with EC, the EMG amplitude increased in the E group. The C group showed opposite changes, but they were not statistically significant. The C group displayed a significant ($P \leq 0.05$) decrease in the EMP amplitude amounting to 15.41 ± 4.61% in the POST test for the maximal backward lean with EC.

The further part of the analysis involved performing the unpaired Mann-Whitney U test to determine differences in the bioelectrical activity of muscles in each measurement according to the "group" factor (Table 7). It was found that changes in the bioelectrical activity were statistically significant for 2 muscles. In the case of the TA muscle, differences between the E and C groups for measurements with EC were significant both in the PRE test ($Z = -2.15$, $P \leq 0.05$) and in the POST test ($Z = -2.14$, $P \leq 0.05$). In the case of the SOL muscle, differences between the groups for measurements were found for the free standing position both in the PRE test ($Z = 2.49$, $P < 0.01$) and the POST test ($Z = 2.15$, $P \leq 0.05$) with EO, for the maximal forward lean in the POST test ($Z = 2.27$, $P \leq 0.05$) with EC, and for the maximal backward lean in the POST test with EO ($Z = 2.21$, $P \leq 0.05$) and EC ($Z = 2.51$, $P \leq 0.05$).

Table 6. Mean, standard deviation, and the difference in the values of RMS EMG signal amplitude expressed as a percentage of MVC for the lateral head of the gastrocnemius muscle (GM) prior to ($\overline{x}_{PRE}$) and after ($\overline{x}_{POST}$) sensorimotor training in the E group and C group, together with the value of the Wilcoxon test for significance of differences between repeated measurements

Measurement postion GL	Group	$\overline{x}_{PRE} \pm SD$ %MVC	$\overline{x}_{POST} \pm SD$ %MVC	Difference $\overline{x}_{POST} - \overline{x}_{PRE} \pm SD$	Z
Eyes open					
Free standing	E C	64.49 ± 6.90 48.30 ± 3.40	55.55 ± 7.41 41.48 ± 3.90	–8.94 ± 7.40 –6.82 ± 4.14	1.08 1.14
Maximal forward lean	E C	80.71 ± 8.73 60.44 ± 4.00	97.09 ± 3.55 51.50 ± 3.32	16.39 ± 2.94 –8.93 ± 3.66	0.69 1.49
Maximal backward lean	E C	66.88 ± 1.20 50.47 ± 4.52	56.88 ± 8.34 37.68 ± 3.2	–10.00 ± 0.71 –12.79 ± 4.80	0.65 1.14
Eyes closed					
Free standing	E C	58.33 ± 6.34 48.89 ± 3.7	60.93 ± 9.04 42.58 ± 3.71	2.61 ± 8.16 –6.04 ± 4.48	0.69 0.75
Maximal forward lean	E C	62.46 ± 5.17 58.66 ± 3.83	71.92 ± 9.36 51.49 ± 3.61	9.46 ± 0.13 –7.17 ± 3.69	1.24 1.24
Maximal backward lean	E C	46.51 ± 4.8 51.45 ± 4.54	61.76 ± 9.92 36.03 ± 3.05	15.26 ± 9.44 –15.41 ± 4.61	0.17 1.98 *

* indicates significance of $P \leq 0.05$ ** indicates significance of $P \leq 0.01$

Z – standardized value of the Wilcoxon test for the significance of differences

Table 7. Coefficient of variability of the mean value of EMG amplitude relative to the E group and C group, determined with the Mann-Whitney U test

Measurement position	Conditions	Test	Z
TA			
Maximal backward lean	OC	PRE	–2.14*
Maximal backward lean	OC	POST	–2.15*
SOL			
Free standing	EO	PRE	2.49**
Free standing	EO	POST	2.15*
Maximal forward lean	OC	POST	2.27*
Maximal backward lean	EO	POST	2.21*
Maximal backward lean	OC	POST	2.51**

* indicates significance of P ≤ 0.05 ** indicates significance of P ≤ 0.01

Z – standardized value of the Mann-Whitney U test significance

Table 8. Detailed values of RMS EMG measurements and the significance of differences between the bioelectrical activity of the TA muscle determined with EMG prior to (PRE) and after (POST) sensorimotor training in the E group, verified using Friedman's ANOVA

PRE / POST	Free standing with EO	Maximal forward lean with EO
Free standing with EO	3.98**	–
Maximal forward lean with EO	–	4.45**

* indicates significance of P ≤ 0.01

EO – eyes open

Effect of sensorimotor training on changes in the bioelectrical activity of muscles

One of the aims of this study was to assess the effect of sensorimotor training on changes in the bioelectrical activity of muscles. This is why the next stage of the statistical analysis involved determining differences in assessed parameters between the PRE and POST tests by using Friedman's analysis of variance by ranks for repeated measurements. Within the E group, the analysis found significant differences only for changes of activity of the TA muscle in all measurements: Chi^2ANOVA = 125.845 (P < 0.001). The next stage of the post-hoc analysis concerned determining correlations between the values of RMS EMG according to the "PRE-POST" factor. Table 8 shows the results for the E groups. It was found that the value of RMS EMG for the TA muscle after the training was related to its low initial level. Kendall's coefficient of concordance for this muscle was 3.98 (P ≤ 0.05) for the freestanding position and 4.45 (P ≤ 0.05) for the maximal forward lean.

Friedman's ANOVA found significant differences in the C group for changes in the bioelectrical activity in all

Table 9. Detailed values of RMS EMG measurements and the significance of differences between the bioelectrical activity of the TA and SOL muscles determined with EMG prior to (PRE) and after (POST) sensorimotor training in the C group, verified using Friedman's ANOVA

PRE / POST	Free standing with EO	Free standing with EC	Maximal forward lean with EO	Maximal backward lean with EC
TA				
Free standing with EO	4.18**	–	–	–
Free standing with EC	–	3.72**	–	–
SOL				
Maximal forward lean with EO	–	–	3.80**	–
Maximal backward lean with EC	–	–	–	3.20*

** istotność statystyczna na poziomie P ≤ 0.01 ** indicates significance of P ≤ 0.01

EO – eyes open, EC – eyes closed

measurements for the TA muscle ($Chi^2ANOVA = 106.10$, $P < 0.001$) and the SOL muscle ($Chi^2ANOVA = 97.593$, $P < 0.001$).

A detailed post-hoc analysis found statistically significant correlations between the variables in the C group (Table 9). Correlations were also observed in terms of changes of the bioelectrical activity of 2 muscles. In the case of the TA muscle, Kendall's coefficient showed significant differences between the PRE and POST test for the freestanding position both with EO (4.18, $P \leq 0.05$) and with EC (3.72, $P \leq 0.05$). In the case of the SOL muscle, the coefficient showed significant differences between the PRE and POST test for the maximal forward lean with EO (3.80, $P \leq 0.05$) and for the maximal backward lean with EC (3.20, $P \leq 0.05$).

Discussion

The motor system is given special attention when considering the risk of falling in visually impaired persons. Electromyography enables us to register and analyze reactions and postural strategies that are the basis of body balance mechanisms [9]. The functioning of postural muscles is considered especially important in the diagnosis of balance disorders [23, 24].

The majority of studies to date attempted to explain the mechanisms of compensation processes by using tests that involved stimulating non-visual systems of body balance control [6, 25, 26]. These studies indicated that exercises on an unstable surface stimulate muscles to prevent the loss of balance more effectively [27]. Using stability training activated the somatosensory system, which is considered crucial in the process of compensating for visual impairment [6, 7, 26]. The main aim of this study was to assess changes in the bioelectrical activity of muscles as a result of a destabilizing factor, i.e., a short sensorimotor training performed with Thera-Band stability trainers. The aim was realized through registering the EMG signal of 4 muscles: tibialis anterior, soleus, the medial head of the gastrocnemius muscle, and the lateral head of the gastrocnemius muscle.

The study found a significant decrease of the EMG amplitude in the tibialis anterior and soleus muscles, which confirms that the experimental factor affects bioelectrical activity of these muscles. It is worth noting that visual conditions, i.e., eyes open or closed, and the position of the body during the measurement were not important in this case. The results of this study are supported by findings of Bugnariu et al. [14], who observed no correlation between visual information and muscle activity. Nakata and Yabe [16] obtained similar results when assessing postural muscles in lower limbs (tibialis anterior, gastrocnemius, rectus femoris, and biceps femoris) in blind persons with measurements taken on a posturographic platform. The researchers found that changing the position of the platform relative to the ground had no statistically significant effect on EMG activity. They also observed no significant differences in body sways compared to persons with normal sight. These result suggested that being blind from birth has no effect on postural control and maintaining balance, which indicated that the experimental group had highly developed compensation systems [27].

This study found no statistically significant differences in EMG amplitude between the PRE and POST tests for the medial and lateral head of the gastrocnemius in any of the groups; that is, neither in the experimental nor in the control group. The study only found that the direction of changes of analyzed parameters was different. This may lead us to suppose that stimuli affecting the receptors of the proprioceptive system do not cause changes in the differences of the bioelectrical activity of the gastrocnemius. On the other hand, Cordov et al. showed that displacement of the center of pressure, especially in the sagittal plane, causes an increase in the activity of the tibialis anterior muscle and of the medial head of the gastrocnemius that prevents loss of balance [28].

Normalization of the EMG RMS values using the MVC method for each measurement allowed for a reliable comparison of obtained results according to the groups. Analysis of the results consistently showed the dominant role of the tibialis anterior muscle in both the experimental and the control group. Values of the bioelectrical activity of this muscle indicated its special responsiveness to sensorimotor training. On the other hand, this muscle is composed in about 80% of fast-twitch fibers (type II), while fast-twitch fibers in other muscles amount to about 50% [29]. This explains why the soleus muscle showed the highest activity among the assessed muscles [30]. Studies by other authors did not support the results of this study. Bugnariu and Fung [14] showed that introducing an unstable platform primarily activated the tibialis anterior muscle and the medial head of the gastrocnemius, regardless of age.

In addition to assessing the effect of sensorimotor training on changes in the bioelectrical activity of muscles, this study aimed at establishing differences in muscle activity between the experimental and control group. Significant differences were found in the activity of 2 muscles, i.e., tibialis anterior and soleus. In the case of the tibialis anterior muscle, significant differences between the groups were found for the maximal backward lean with eyes closed. Both the experimental group and the control group showed a decrease in the EMG amplitude. However, these differences concerned the initial value of the EMG signal. In the case of the soleus muscle, differences between the groups were much more pronounced and concerned all measurement positions. All measurements in the experimental group found significantly higher bioelectrical activity of the soleus muscle. The observed difference in the activity of the soleus muscle for the PRE and POST test in the experimental group compared to the control group, calculated using the Mann-Whitney U test, can constitute a cause for concern. This is because the results could lead to the conclusion that visually impaired women suffer from pathological states of this muscle. EMG values were the highest in the maximal forward lean, which may suggest an correlation between the above-mentioned changes and postural anteversion, typical for visually impaired persons, which causes excessive strain on the soleus muscle [31].

Changes in the medial and lateral head of the gastrocnemius were not definite. However, it should be noted that for the vast majority of assessed parameters, their values were greater in the experimental group of visually impaired women, both prior to and after the sensorimotor training. Other studies indicated that an increase in muscle activity results from exhaustion [32]. The obtained results may stem indirectly from the backward displacement of the center of pressure of the body after the training, which could have caused a decrease in anteversion and an improvement in postural stability. According to Anderson and Behm (2005), the activity of the soleus and tibialis anterior are similar on a hard surface. However, on an unstable surface, the activity of the soleus increases together with the amplitude of movements in the ankle. Furthermore, Anderson and Behm observed that directional changes in torque in response to a displacement of the center of gravity constitute an important source of information on the mechanism of maintaining posture [12]. The most interesting part of the results of this study seems to be the indication of abnormalities in the activity of the soleus muscles, as well as the observed differences between the groups.

The introduction of an experimental factor (the sensorimotor training) improved the activity of the assessed muscles in visually impaired women over the age of 50 years, especially in the case of the soleus muscle. At the same time, the study confirmed the hypothesis that sensorimotor training is an effective method of rehabilitation in visually impaired persons and benefits postural stability by reducing the bioelectrical activity of postural muscles in lower limbs. The obtained results provide additional information on planning compensation strategies. However, it should be emphasized that these data were collected in a single, laboratory assessment. Therefore, further research should be conducted to verify the obtained results and to provide more detailed information on the potential of sensorimotor training in terms of preventing falls in persons with visual dysfunctions. As stated by Mętel, sensorimotor exercise programs can constitute an effective method of improving a person's body balance and functional fitness [33]. Nonetheless, physical activity programs aimed at persons with visual dysfunctions should be comprehensive and affect all components of physical fitness, i.e., the morphological, muscle-skeleton, motor, circulatory, respiratory, and metabolic components [34].

Conclusions

1. Soleus and tibialis anterior muscles were found to be the most responsive to the experimental stimulus, i.e., a short sensorimotor training on an unstable surface. The soleus muscle showed the highest activity in all measurement positions both with eyes open and with eyes closed, which indicated its important role in maintaining a stable posture.
2. The observed increase in bioelectrical activity of the soleus in visually impaired women was a cause for concern, as it indicated that the muscle underwent excessive strain. The highest values of RMS EMG_{MVC} were observed for the maximal forward lean and indicated a correlation between these changes and postural anteversion, typical for visually impaired persons.
3. A reduction in the bioelectrical activity of the soleus muscle after sensorimotor training on an unstable surface, combined with an increase in the activity of the lateral head of the gastrocnemius, indicated an improvement in postural stability. The study observed a correct response of systems of postural control to the sensorimotor training on an unstable surface.

4. The introduction of sensorimotor training benefited body stability by reducing the bioelectrical activity of postural muscles in lower limbs. Using such training may constitute an effective form of rehabilitation in blind and visually impaired women.

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THE ROLE AND USE OF FRENKEL'S EXERCISES IN REHABILITATION[1]

ROLA I ZASTOSOWANIE ĆWICZEŃ FRENKLA W REHABILITACJI RUCHOWEJ

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Key words: physical therapy, ataxia, Frenkel's compensatory movement treatment, ageing generation
Słowa kluczowe: terapia ruchem, ataksja, kompensacyjne ćwiczenia lecznicze Frenkla, pokolenie osób starszych

SUMMARY • STRESZCZENIE

Introduction. Searching for physical exercise forms attainable for people in the physical rehabilitation process that compensate for certain neurological deficits is very often seen as a challenge. Meanwhile, the ideas of H.S. Frenkel at the end of the 19th century concerning compensatory treatment movement in tabetic ataxia fulfil this condition.

Method. In order to expose the actuality and therapeutic significance of Frenkel's proposal concerning the treatment of tabetic ataxia by means of systematic exercise, an analysis of its basic premises has been provided in this article.

Results. Frenkel's movement treatment programme was based on theoretical and clinical premises, as well as on practical experience. It was not only a pioneering enterprise in neurological rehabilitation, but it also referred to the fundamental theses of physical ergonomics. The simplicity and usefulness in improving human coordination allows for using Frenkel's programme of systematic exercise with ageing people, too.

Conclusion. Frenkel's programme of the treatment movement, in spite of its 19th century origins, remains present in physical therapy and can be used in the recreational activities with ageing people.

Wstęp. Poszukiwanie form ćwiczeń fizycznych, które mogą z powodzeniem wykonywać osoby podlegające procesowi rehabilitacji ruchowej w celu kompensacji zaburzeń neurologicznych, bardzo często bywa postrzegane jako współczesne wyzwanie. Tymczasem warunek ten spełnia już zainicjowana przez H.S. Frenkla u schyłku XIX wieku idea kompensacyjnego leczenia ruchem w ataksji.

Metoda. Wyeksponowanie aktualności i znaczenia propozycji Frenkla dotyczącej systematycznej terapii ruchem w ataksji za pomocą analizy jej podstawowych założeń.

Rezultaty. Program kompensacyjnego leczenia ruchem Frenkla, wsparty nie tylko na teoretycznych i klinicznych przesłankach, lecz również na praktycznych doświadczeniach, to nie tylko pionierskie przedsięwzięcie w rehabilitacji neurologicznej, ale także nawiązanie do podstawowych założeń ergonomii fizycznej. Prostota i skuteczność systematycznie prowadzonych ćwiczeń Frenkla, jako narzędzia do redukcji zaburzeń koordynacyjnych, jest przesłanką dla ich stosowania u osób starszych.

Wniosek. Program ćwiczeń leczniczych Frenkla, pomimo dziewiętnastowiecznego rodowodu, jest wciąż obecny w postępowaniu terapeutycznym oraz może być stosowany w rekreacji ruchowej osób starszych.

[1] In the many years of my practical experience gained since 1989 in my work as a physical therapist with MS patients at the Clinic for Patients with MS in Kraków (operated at Kraków branch of Polish Society for Combatting Disabilities, where I am also a member of Presidium), as well as my scientific interests in the field of kinesiology, have led me to search for the original sources of Frenkel's method concerning the treatment by means of regular exercise. The presented article is one of the results of the research I have undertaken.

Introduction

Searching for forms of moderate intensity exercise appropriate for people in physical rehabilitation who require the treatment of neurological deficits, such as disturbances in coordination resulting in the loss of the proper movement, seems to be regarded often in recent years as a challenge of patterns [1–4]. Meanwhile, in looking back at the history of the development of rehabilitation one can surprisingly note that not just the idea, but the clinical foundations, principles and concrete proposals of exercising had already been formulated by the end of the 19th century [5]. In order to justify the argument that H.S. Frenkel [6] added significant contributions to the progress of rehabilitation, I would like to underline the basic theses of the work of this author, accenting those contributions that are focused on the problem of treating by movement. What specifically inclines me to evaluate Frenkel's work positively is the quantity and quality of the enumerated exercises that had been clearly described and analysed from the medical perspective of the late 19th century. In the last part of this article, I have cited the basic techniques of Frenkel's exercises, as many current publications only provide the general concepts of his exercises rather than providing detailed descriptions.

The concept of the treatment by movement

Some basic information about Frenkel's book can help in better understanding his ideas about the problems of tabetic ataxia and the ways of compensating for its results by means of systematic exercise. The book consists of 185 pages and is divided into two parts.

Part one, entitled *General part* [6, pp. 1–66], has an introductory character and covers areas relating to the types of tabetic ataxia, explaining coordination, defining ataxia, and indicating its aetiology. Moreover, one can find information in this part of the book on ways to examine cutaneous sensibility, a description of the sensation of passive movements at the joints, and the characteristics of voluntary muscle contraction. This set of practical clinical information provides for the understanding of the fundamentals of the diagnosis of ataxia, the symptoms of which should be tested in the standing position and during locomotion. Author's analysis of human locomotion, evaluated in the context of someone's walking skills (with or without support), which depend on motor abilities like power and balance (according to Frenkel, Rhomberg's phenomenon is a symptom of the loss of balance), leads to an explanation of hypotonia. Frenkel [6, p. 34] noted in the chapter: 'We therefore observe, besides motor ataxia in voluntary movements and static ataxia in trying to keep the balance when standing erect, a third change in the functions of the muscular system, an abnormally situated centre of gravity'. By using a concrete example, Frenkel characterizes hypotonia in tabetic patients:

> If the extended limb can be raised to an angle of 60 to 100 degrees and more, as is frequently the case in tabes, then the flexors of the thigh (semitendinosus, semimembranosus and biceps muscles) must have undergone as alteration of their function, and this alteration we call hypotonia. [6, p. 39–40]

The alterations of muscular functions described by him concern the flexors of lower leg, quadriceps, adductors, the muscles of pelvis and spinal column, as well as the muscles of the hands and fingers. Finally, the problems undertaken in the first part of the book, such as the influence of hypotonia on the attitudes of the body, the use of the different diagnostic procedures in the disease, and the dependency between the loss of sensibility and ataxia, significantly shape the theory of tabetic ataxia, which highlights the role of the treatment by movement:

> Every ataxic movement becomes still more ataxic as soon as its control by the eye ceases. This is an axiom to which there is no exception, and which is entirely due to loss of sensibility. The so-called Rhomberg's sign is only one instance of this general rule. Standing is complicated feat of coordination, which must become unsafe if the sensibility of the various parts of the body becomes impaired, and deficiency thus created is not made up by ocular control. When Rhomberg's sign is present, the sensibility of the motor apparatus or of the skin of the soles of the feet will always be found impaired. […] We shall see later that the good results obtained by the treatment of tabes by means of systematic exercises have given new support the theory, which holds that ataxia is caused by loss of sensation. These good results cannot be explained from any other point of view. [6, pp. 65–66]

Those opinions ending the first part of Frenkel's script clearly show that although the aetiology of discussed hypotonia has its roots in the dysfunction of the nervous system, the only effective way of treating the disability and improving the functions of the human body is undertaking the regular and appropriate treatment by movement. In the second part of his work, entitled *Special part*, Frenkel presents the set of physical exercises, accenting their specific role in the treatment of tabetic ataxia.

Part two, entitled *Special part* [6, pp. 67–182], explains the importance of movement in the clinical process of therapy in the light of the core problems concerning (1) the movement practice, (2) the mechanisms of human body movements at the joints of foot, knee and hip (including skills like standing on one leg, bending the knees, gait patterns in healthy and tabetic subjects, walking sideways, getting up and sitting down, as well as walking up and down the stairs), (3) the conditions of the treatment, (4) the therapeutic exercises of lower and upper extremities in different body postures (also with the use of supporting apparatus) classified on the basis of compensating for the loss of coordination, (5) ataxia of the body in its pre-stage, (6) the therapy of hypotonia, (7) the treatment of the muscles of the eyeball, (8) the paresis of the muscle of the larynx and (9) the paralysis of the bladder. According to Frenkel, the therapeutic exercises suitable to each of the situations enumerated above should be applied.

Exercising

The pillars of the therapeutic system

The accurate analysis of therapy by movement professionally described in Frenkel's book seems to be based to a great degree on his own clinical experience gained from the time when he worked as a medical superintendent at the 'Freihof' sanatorium in Heiden, Switzerland. The following important basic pillars of Frenkel's therapeutic system, which refer to his practical clinical experience, can be found in the work of this author.

1) The first argument concerns understanding the conception of the practice of the treatment movement. In answering this question, Frenkel explains the mechanisms of physiological processes referring to both the economic way of learning movement and the effects obtained in each of the distinguished phases of the whole learning process:

> We have seen that in order to "learn" a movement it is required that the motor stimulus be repeated, and that the attention of the mind be directed to it. At first the movement is accompanied by a more or less prominent sensation of muscular fatigue, which decreases as the movement becomes more familiar. Further, one notices at the beginning of the practice movements, which are absolutely useless, because they are quite outside the purpose for which the movements are intended; these useless movements disappear after a time. This sensation of fatigue and those useless movements show that at the beginning of the practice of new movements the work of the muscles is exaggerated, that they contract with unnecessary force, and call into play muscles which not only have nothing to do with intended movement, but even impede and distort it. Hence we must conclude that under the influence of that complicated function which we call muscular practice a selection takes place of the muscles and amplitudes of contraction that are most suited for the purpose. [6, pp. 67–68]

Regardless of the issues stated by him in the text on how fascinating and perfectly organized the process of learning movement is, Frenkel stresses in the cited fragment the need for undertaking regular movement therapy.

2) The second argument emphasizes the role of knowledge in human muscle cooperation with the sensory system while performing human movement. According to Frenkel [6, p. 68] one of the fundamental '[…] results of the practice of movements, therefore, is that various component parts of the group of the muscles, which form an anatomical and physiological entity become so emancipated from each other that each individual muscle becomes perfectly independent'. In the description of the movement practice and its results, the author [6, p. 68] highlights the issue of coordinating the work of muscles by an intervention of a central nervous system: 'When a new combination of muscular contractions is being acquired the sensory impressions which are received from the joints and muscles of our extremities, and from the objects with which they come into contact are rearranged and eliminated, as the case can be'. The idea presented by him in the quoted paragraph above can be treated nowadays as a basic concept of sensorimotor training intended for both impaired people in order to make the movement therapy and for healthy people to enable them to participate in forms of mass sport.

3) The third argument shows how to realize in an effective way the purpose of physical therapy, when the mechanism of movements is generally known. Using the example concerning exercise in the case of blind people, Frenkel indicates the necessary repetition of each exercise while learning therapeutic techniques. As he writes [6, p. 69] '[…] in reality the precision with which they perform the required movements is the result of long-continued practice by which the central nervous system has learnt to be satisfied with an oft-repeated of tactile impressions'. Furthermore, he reports that while treating people with tabetic ataxia: 'Repetition enables the central nervous system to differentiate stimuli of minute intensity; its sensibility becomes so great that often repeated slight stimuli act on it with the same force as rarer but much stronger impressions'. Finally, the author argues that besides the differences occurring between tabetic and healthy persons, the scheme of motor learning runs in both cases according to the same rules:

> Theoretically, the transformation of an ataxic movement into a normal movement takes place in tabetic subjects according to the same laws as the acquisition in healthy persons of a complicated movement, which acquires the differentiation of tactile impressions of minute strength. [6, p. 69]

In the quoted opinion, Frenkel clearly states that the rules of the mechanism of acquiring new movements by people are always the same; therefore, in such a case, it does not matter whether those movements are designed more for physical rehabilitation or for sports training. The differences then relate only to the actual level of functions of the human body depending on the state of its health status. Hence, Frenkel compared the effectiveness of the movement therapy in ataxia to the effectiveness of acquisition of the difficult motoric tasks by healthy people.

The process of motor learning, which is realized particularly as a part of the therapeutic programmes, always requires the choice of the essential conditions for its implementation. The crucial remarks stated by Frenkel relating to this problem will be analysed in the following subsection.

Conditions of the movement treatment

Frenkel enumerates and describes the conditions influencing the treatment of ataxia (points 1–5) and gives practical instructions (points 6–7) referring to the procedure of the movement therapy:

1) spinal irritation, which may ‘appear at any stage of the disease’ and ‘shows itself in constant and dull pain and paraesthesia of varying intensity, which attacks the muscles of the back, and in some cases of the extremities also’ [6, p. 94];
2) blindness – in the opinion of the author ‘The optic sense is the greatest supporting factor in the movement treatment’ [6, p. 94];
3) in a case of hypotonia of moderate degree, the additional resources of the movement treatment are not required, whereas hypotonia of severe degree ‘especially of the knee joints may necessitate the correction of the faulty position of the joints by means of orthopaedic appliances, previous to the commencement of the exercises’ [6, p. 94]
4) heart disease does not exclude the use of therapeutic movement; however, it requires ‘great care with regard to the selection and duration of the exercises’;
5) patient control during the treatment process, described accurately by Frenkel, should first of all be treated as a safety condition: fulfilling this will enable patients to be protected against accidents while exercising. Thus, ‘The attendants must be the intelligent persons, who without touching the patient must raise in him the confident belief that the accident is absolutely impossible’ and be aware that ‘A very frequent accident during the exercise is the turning over of the foot which causes the patient to fall and often produces even the severe distortion of the ligaments’ [6, p. 96]. In order to highlight the risk of accidents during the therapeutic process, Frenkel gives examples of selected clinical cases[2];
6) appropriate attire both for the women and men: ‘The exercise treatment is tiring the most patients; it raises the pulse-rate and makes the patients perspire. For this reason the patients should wear light garments, which do not interfere with or obscure the movements of their limbs’ [6, p. 99];
7) the practise rooms and apparatus:

> The most suitable practise room and apparatus is that which allows of the simultaneous treatment of several patients. While one party exercises, the other has an opportunity to rest and watch them; thus fatigue is prevented, the heart has time to slow down, and perspiration becomes normal again. Moreover, the didactic value of seeing the various exercises being gone through by fellow-patients […] is very great indeed [6, p. 99].

Nevertheless, Frenkel explains that the values of practising exercise in groups cannot be applied equally to the patients immobilized in bed who receive rehabilitation. Because of their diverse needs during this process, particularly in the cases of severe ataxia, the character of movement of those patients has a ‘relatively exhaustive nature’, while the lying position enables each patient ‘to follow the instructions of the doctor with ease and attention’ [6, p. 99]. According to Frenkel, in order to carry out physical therapy in the so-called practise rooms (the rooms should be the appropriate length and width and shape that allows a patient to walk freely) with the use of apparatus, the requirement primarily concerned equipping these rooms with chairs along the walls in order to allow the patients to rest. The set of apparatus consisting of a portable floor cross with handrails, floor marks like straight black stripes according to the patterns (for example, the ‘zigzak’ pattern), foot prints (shaded), and other elements should be available in public movement treatment practice; however, it is not necessary in private practice at home. Frenkel argues

[2] Those clinical cases described by Frenkel concerned a transverse fracture of the thigh close above the knee in a man aged 40 years, an enormous haematoma in tabetic subject aged 45 years, or troubles with walking in a woman aged 48 years.

In private practice single patients should be exercised in long and well-lighted corridors. These corridors should not be so narrow that the patient with outstretched arms could touch the walls because if such were the case the patient as well as the doctor would get a wrong idea of the patient's ability to maintain his balance, which would be roughly dispelled as soon as the patient tried to repeat his exercise in a larger room. [6, p. 99]

Apart from the apparatus described above, Frenkel suggested using a set of apparatus for the re-education of the upper extremities 'designed for the purpose of practising the more delicate coordination of the arms and hands' [6, p. 105]. The apparatus consists of a triangular block, a perforated board, a peg board, a board with loose pegs, coloured balls suspended from a bar, round discs, and diagrams for copying.

Moving in different positions practised in groups and alone

According to Frenkel [6, p. 105], therapeutic exercises can be classified dependently based on the various functions of the affected limbs and a state of ataxia. These exercises should be considered separately for the lower limbs, the trunk and the upper limbs because of the diverse functions those parts serve for the human body. The lower extremities work chiefly during locomotion, while the upper limbs are responsible for performing 'an enormous number of complicated movements of relatively small amplitudes'. The exercises for lower extremities had been systemized into movements practiced in the recumbent, sitting and standing positions, and while walking, too. Yet most of the exercises proposed by Frenkel for the lower limbs concerned the exercises in the recumbent position, mainly because of the possibility of eliminating the influence of gravitation and the necessity of keeping equilibrium in that position.

All 86 exercises in the lying position had been classified into 6 groups. Frenkel treats the first group of 16 therapeutic exercises in the recumbent position as the basic group. The leading movements while practising these exercises are flexion, extension, abduction, and adduction of lower extremities in knee and hip joints with the dorsiflexion of the foot accented. Although the other exercises in the recumbent position, which are grouped in the sets of exercises 17–44, 45–50, 51–54, 55–75 and 76–86, are more difficult than those from the first group, they have been designed based on the rules typical for the first group of exercises. Below are some of these rules [6, pp. 105–106]: (1) 'the movements are to be continued until the maximum excursions are reached'; (2) 'the heal has throughout the exercise to rest on the couch or bed, and slides over it backwards or forwards'; (3) 'the eyes are to be kept open and should follow the movements with great attention'. Characterizing the tempo of the performed movements, Frenkel [6, p. 107] aptly notices that the tendency 'which all patients have of making the movements rapidly must be overcome by energy and patience; the movements should be made as slowly as possible; the greater the progress made by the patient, the slower the movement will become'. He advises that none of the exercises should be repeated more than four times in order to fix the attention of the patient on the performed movement. When moving the legs, it is important that the patient to try to keep them in the vertical plane due to the tendency for lateral oscillations to often appear. In addition, it can be observed that many severe patients keep a plantar flexion in the ankle joint. Therefore, in Frenkel's opinion, a patient should be asked at the beginning of exercises to keep the foot in dorsiflexion when moving the limb. Moreover, he [6, pp. 107–108] gives attention to the issue of keeping angles while exercising lower extremities: between the thigh and the lower leg, the thigh and the pelvis, and the thigh and the level. As opposed to healthy people where these angles are limited by 'the residence of the ligaments capsules of the joints and the muscle tone', in patients with locomotor ataxia the muscle tone is lost and the capsules are flaccid. Consequently, the possible range of motion in joints is much greater than normal; however, while exercising with the tabes 'the movements must take place within the normal limits'. Another very important feature of these exercises in the recumbent position is the practice of static coordination linked with 'the more or less prolonged fixation of the leg in the certain indicated position' [6, p. 111]. For this reason, Frenkel suggests performing repetitions of some movements in each of the groups of lower limbs exercises with an additional pause that can be managed by either a patient or a doctor in order to obtain static coordination.

While describing the procedures of movement treatment with the tabes with extreme ataxia, Frenkel ensures that such cases require special care and attention on the part of a supervisor and a patient [6, pp. 120–121]. He explains: 'For this purpose we employ simple contractions in single muscles of groups of muscles, which have the same functions limiting the movements as much as possible to one joint'. Those movements had been divided into the groups of exercises referring to:

(1) the toes – systematic isolated movements 'are nevertheless very important, because in the course of tabes one often sees an develop anomalous position of the toes which consists of hyperextention of the first phalanx and hyperflexion of the second, respectively the second and third phalanges';
(2) the foot – 'Tabetic pseudo-paresis of the peronei muscles […] emphasizes the necessity for carefully exercising the muscles, which produce the movements of the foot';
(3) the leg – 'For these exercises […] it is important to eliminate movements in the hip joint';
(4) the thigh – 'In practising rotation […] the medical man should be careful *to avoid excessive outward rotation*, on account of the pronounced hypotonic condition of the muscles which normally produce inward rotation'.

At the end of the description of lower extremity exercises in the recumbent position, Frenkel draws attention to exercises in bed with the use of special apparatus (the numbers of exercises: 89–94) and those practised with closed eyes ('sensory exercises') which enable the patient to imitate from memory with 'his other limb the position which the first limb has occupied or is still occupying' [6, p. 129]. All exercises in the lying position are fundamental in movement treatment in view of their relative ease of use by the tabes, which results in the improvement of ataxic dysfunction in this group of patients and allows them to maintain functional independence as far as possible. Hence, the next and/or parallel step in the treatment process covers exercises in the sitting posture preceding walking exercises. In the first case, Frenkel analyses the sequence of a patient movements of particular body parts and in joints when sitting down and getting up. In the second case, he recommends for his patients various forms of walking (forward, sideways, and backwards) in slow tempo with differing lengths of steps, maintaining the position of the upper extremities, controlling eye movement, and changing direction while walking, standing and walking with bent knees, and walking on the narrow boarder. Apart from the advice presented above, Frenkel instructed on how to use the apparatus (footprints, the stairs) while walking and how to practise this form of locomotion in groups. He also undertakes the problem of practising the gait in cases of severe – and severest – ataxia and explains how to use the special belts in order to help the patient to hold the upright position during the gait. At last, he proposes ways to examine for upper extremity ataxia concerning the shoulder, elbow, and wrist joints, and he indicates the treatment of those limbs, mainly with the use of the appropriate apparatus. Frenkel [6, pp. 181–182] also proposes ways of treating hypotonia of the whole body affected by ataxia connected with the treatment of the muscles of the eyeball ('paralysis of the muscles of the eyeball must be considered to be analogous to the tabetic paralysis of the other muscles of the body'), the muscles of the larynx ('the practice of breathing speaking and singing exercises, based upon the same principle as the exercises of the other muscles'), and treatment in case of paralysis of the bladder ('The treatment consists in instructing the patient to empty his bladder in regular intervals, a plan which invariably succeeds during the early stages of the disease').

The set of Frenkel's fundamental exercises in the lying position

In the conclusion of that subsection, it seems to be interesting to show some examples of the exercises in order to imagine how original and innovative the conception of Frenkel's therapy is in compensating for the deficits of ataxia. While performing the basic recommended exercises, a patient should assume the recumbent posture on the back on a low wedge-shaped bolster and with the head raised in such a position that the patient can watch every movement and his/her body rests at the same time. Each exercise begins with the initial and fundamental position in which 'Both lower limbs are stretched out in apposition to one another' [6, p. 106] and ends up in the starting position after the performance of the movement by a patient. The initial movement in case of each of the first eight exercises enumerated by Frenkel is flexion of one lower extremity in knee and hip joints followed by extension of that extremity in those joints leading back to the starting position of exercise. Between the first and last movements of the performed exercises the following modifications can take place: abduction and adduction of the flexed extremity (2, 4), the same movements as in the exercises 1–4 while flexing or extending the lower extremity (5–8) with a voluntary halt signalled by the doctor or patient. Similar rules relate to exercises 9–16. However,

Table 1. Frenkel's fundamental exercises in the recumbent position

The number of Frenkel's exercise	Description of the treatment movement
1	'Flexion of one lower extremity (hereinafter called 'leg') in the knee and hip joints – extension'.
2	'Flexion of one leg in knee and hip joints, abduction of flexed leg, adduction of flexed leg – extension'.
3	'Flexion of one leg in knee and hip joints, but only to one-health the angle – extension'.
4	'Flexion of one leg in knee and hip joints, up to one-halth of angle (as in 3), abduction, then the adduction – extension'.
5	'Flexion of one leg in knee and hip joints, a voluntary halt to be made during flexion by the patient – extension'.
6	'As in 5, with this modification that the halt is called by the doctor'.
7	'Flexion of one leg in knee and hip joints – extension, a voluntary halt being made by the patient during extension'.
8	'As in 7, but the halt is called by the doctor.'
9	'Both legs are simultaneously flexed in knee and hip joints – extension.'
10	'Flexion of both legs in knee and hip joints, abduction, adduction in flexed position – extension'.
11	'Half-flexion of both legs in knee and hip joints – extension'.
12	'Half-flexion of both legs; abduction and adduction in this position – extension'.
13	'Flexion of both legs; a voluntary halt made by the patient during flexion – extension'.
14	'Flexion of both legs; halt called by the doctor during flexion – extension'.
15	'Flexion of both legs in knee and hip joints – extension; voluntary halt made by the patient during extension'.
16	'Flexion of both legs in knee and hip joints – extension; halt called by the doctor during extension'.

in these exercises both lower limbs should perform the single movement act simultaneously.

The basic exercises in the lying position in Frenkel's original citation have been revealed in Table 1 [6, pp. 106–107].

Conclusions

The advantages of the therapeutic concept proposed by Frenkel can be evaluated at least in several aspects. Apart from the essential medical results obtained by the use of this therapy, one can note that the methodological solutions realized in practice refer to the basic assumptions of physical ergonomics[3].

First of all, this idea seems to be pioneering in the aspect of using physical exercises in the treatment process in cases of the neurological disturbances. This idea is justified by the example in which patients with MS (multiple sclerosis) are still cured by Frenkel's exercises in the contemporary process of rehabilitation [10–12]. Secondly, the regularity, principles and ways of practising these exercises were based on theoretical premises as well as clinical experiences. Thirdly, the description of therapeutic exercises is based strictly

[3] The term ergonomics, having its ancient Greek etymology, was used for the first time in the contemporary lexicon by Polish scientist of the 19th century Wojciech Jastrzębowski in his article from the year 1857 entitled *The Outline of Ergonomics, i.e. Science of Work, Based on the Truths Taken from the Natural Science*, as a science about using given a man by the Creator forces and abilities, [7, 8]. The Council of IEA approved in 2000 the definition of ergonomics according to which that scientific discipline is 'concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system' [9]. In the practical way of ergonomics, organizing environments and systems to make them compatible with the needs, abilities, and limitations of people is of big importance. One of the fundamental ergonomic branches, being under this condition stated above, is physical ergonomics: accenting human characteristics (anatomical and physiological) in their relation to physical activity.

on Frenkel's diagnosis of people with ataxia at different stages of their impairment, the documentation concerning their therapeutic needs, and his clinical observations of the effects of undertaking his exercise. Even now, as neurological patients who are involved in the process of physical therapy are revealing their own diverse movement needs and capacities, the procedure for measuring individual characteristics and designing a set of exercises suitable for an individual requires both medical knowledge and the experience of medical attendants in the field. Fourthly, the range of treatment encompasses not only physical exercises, but also the use of particular apparatus necessary for compensating for the lost functions of the disabled limbs and the whole body in ataxia. Contemporary technical branches working for medicine have been constantly developing the offer of orthopaedic and other type apparatus used in the treatment process addressed to the particular groups of patients. Fifthly, some exercises suitable for the disabled patients may also be used by healthy people in the form of light exercises aimed at improving good coordination and a proper range of motion in joints. The growing popularity of an aging generation doing exercise requires a search for the forms of physical activity tailored to the diverse needs of seniors. Frenkel's exercises fulfil this condition due to simplicity and usefulness in practice.

The arguments stated above are those that prove the value and ergonomic benefits of motion exercises offered by H.S. Frenkel. However, the strongest advantage of this treatment offer originating from the 19th century is its actuality.

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PHYSICAL ACTIVITY AND MOBILITY OF PRESCHOOL CHILDREN LIVING IN URBAN SETTINGS IN THE OPINION OF THEIR PARENTS

AKTYWNOŚĆ FIZYCZNA A RUCHLIWOŚĆ DZIECI PRZEDSZKOLNYCH ZE ŚRODOWISKA WIELKOMIEJSKIEGO W OPINII RODZICÓW

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Key words: physical activity, motor skills, preschool children
Słowa kluczowe: aktywność fizyczna, umiejętności ruchowe, dzieci przedszkolne

SUMMARY • STRESZCZENIE

Aim of the study. The aim of this study was to assess the level of physical activity in a group of preschool children, including the preferred leisure activities, the scale of participation in physical activities, and the level of motor skills. An important research objective was to evaluate the relationship between mobility and chosen aspects of lifestyle and motor skills of children based on their parents' subjective assessments.

Material and methods. A questionnaire survey was conducted with 227 parents of preschool children, including 112 girls and 115 boys, from several districts of Kraków. Statistical comparison of the selected aspects of physical activity, depending on gender and level of children's mobility, was carried out by means of the chi-squared test for independence with the Statistica 8.0.PL software package. The confidence level was set at 95% ($P < .05$).

Results. The study revealed that boys were characterized by a higher level of mobility, more frequent participation in extracurricular forms of physical activity, and a higher level of selected motor skills in regard to skiing, cycling, and playing football. According to their parents, girls were better at other forms of physical activities, including skipping rope, ice skating, and roller skating. Moreover, significant correlations were observed between higher mobility and preferences for movement activities and games, participation in extracurricular forms of physical activity and a smaller amount of passive leisure time in summer that was spent watching television, and between lower mobility and more frequent participation in corrective gymnastics. Furthermore, statistically significant relationships were also found between the degree of mobility and the level of certain motor skills, especially in regard to swimming, cycling, running, skiing and playing football.

Conclusion. The study demonstrated that the levels of physical activity and of certain motor skills differed depending on gender and level of preschool children's mobility as declared by their parents.

Cel pracy. Ocena poziomu aktywności fizycznej grupy dzieci przedszkolnych z uwzględnieniem preferowanych form spędzania czasu, skali uczestnictwa w zajęciach ruchowych i poziomu umiejętności ruchowych. Istotnym celem pracy była ocena zależności między ruchliwością a wybranymi wskaźnikami trybu życia i umiejętnościami ruchowymi dzieci na podstawie subiektywnej opinii rodziców.

Materiał i metody. Badaniami, prowadzonymi z wykorzystaniem przygotowanego kwestionariusza, objęto grupę rodziców 227 dzieci w wieku przedszkolnym, w tym 112 dziewcząt i 115 chłopców, w kilku dzielnicach

Krakowa. Statystyczne porównanie wybranych aspektów aktywności fizycznej, w zależności od płci oraz poziomu ruchliwości dzieci, wykonano za pomocą testu niezależności chi^2 z programu Statistica 8.0.PL, na poziomie ufności 95% ($P < 0,05$).

Wyniki. Badania wykazały, że chłopcy cechowali się wyższą ruchliwością, częściej podejmowali dodatkowe pozaprzedszkolne zajęcia ruchowe, a także wykazywali wyższy poziom niektórych umiejętności ruchowych, w tym jazdy na nartach i na rowerze oraz gry w piłkę nożną. W ocenie rodziców dziewczęta lepiej radziły sobie z innymi formami ruchu, w tym ze skakanką oraz jazdą na łyżwach i rolkach. Wykazano także zależności między wyższą ruchliwością a preferowaniem ruchowych gier i zabaw, uczestnictwem w dodatkowych pozaprzedszkolnych zajęciach ruchowych i mniejszą objętością biernego spędzania czasu wolnego przed telewizorem w miesiącach letnich, a także między mniejszą ruchliwością a częstszym uczestnictwem w gimnastyce korekcyjnej. Istotne statystycznie zależności stwierdzono również między stopniem ruchliwości a poziomem niektórych umiejętności ruchowych, w szczególności pływania, jazdy na rowerze, gry w piłkę nożną i biegania oraz jazdy na nartach.

Wnioski. Wykazano zróżnicowanie poziomu aktywności fizycznej i niektórych umiejętności ruchowych w zależności od płci oraz poziomu deklarowanej przez rodziców ruchliwości dzieci przedszkolnych.

Introduction

One of the operational objectives of the National Health Programme for 2007–2015 was to increase the physical activity levels of different population groups, including children and adolescents. Studies have corroborated the crucial importance of physical activity in increasing health potential and the role of hypokinesia in the etiology of certain degenerative diseases, such as obesity and type 2 diabetes [1, 2, 3]. These disorders are significant epidemiologically in children and adolescents in Poland and in the world [4, 5]. Numerous studies have confirmed the beneficial effects of physical activity on children's metabolic and hemodynamic parameters that are essential in preventing chronic diseases. These effects include optimizing body composition and lipid profile as well as decreasing insulin resistance and exercise heart rate [3, 6, 7]. An active lifestyle should be promoted from an early age in order to early prevent metabolic diseases and to develop motor skills, both of which determine physical activity at later stages of ontogeny [1, 8]. At the same time, many studies have substantiated the observation that there is a decline in the levels of physical activity in preschool children in different countries, including Poland [9, 10, 11, 12, 13, 14, 15, 16, 17]. The rationale for undertaking the present research was the lack of a reported relationship between mobility, which is associated with very large natural need of preschool children to move [18, 19], and motor skills.

The purpose of the study was to assess the level of physical activity in a group of preschool children including the preferred leisure activities, the scale of participation in physical activities, and the level of motor skills. An important research objective was to evaluate the relationship between mobility and chosen aspects of lifestyle and mobility skills in children based on their parents' subjective assessments.

Material and methods

The voluntary and anonymous surveys were carried out among 227 parents of preschool children aged 4–6 years (χ = 5.5 years), including 112 girls and 115 boys, in several districts of Kraków (Nowa Huta, Śródmieście, and Krowodrza). Preschools were selected in a random manner. The number of respondents from the districts was similar (72, 76, and 79, respectively). The largest proportion was 6-year-olds (47.1%) and 5-year-olds (42.3%), while four-year-olds made up 10.6% of the respondents. The financial situations of families were described by the parents mainly as good (49.3%), less often as satisfactory (39.7%) and very good (11.0%). Families with one child accounted for 42.7%, with two children for 44.1% and three children for 13.2% of the group. Most parents had higher education (44.0%) or secondary (44.0%); the fewest – vocational (12.0%). The research tool was a questionnaire, prepared on the basis of a study by Chalcarz and Merkiel [15], and carried out among parents with the consent of preschool directors. The questionnaire mostly consisted of closed questions and concerned the level of mobility; preferred games, activities, and other forms of movement; participation in additional sports activities and corrective gymnastics. The levels of mobility and motor skills of children were only subject to the subjective assessment of their parents. It was not reported that a parent refused to participate in the research. Statistical comparison of the selected aspects of physical activity, depending on gender and declared level of children's mobility, was carried out by means of the chi-squared test for independence in the Statistica 8.0.PL software package, with the confidence level set at 95% ($P < .05$).

Results

In the opinions of their parents, children were characterized mostly by high mobility (48%) and very high mobility (26.4%), varied depending on gender, with its higher level among boys ($P < .05$). A larger proportion of children preferred movement activities and games (67%) rather than static games (26.9%). Consequently, a higher percentage of total number of children spent time in an active way (79.7%) rather than passively (18.1%). Active leisure activities were significantly more frequently chosen by boys than girls ($P < .05$). Children spent mostly 1–2 hours a day passively watching television; however, in the winter months, the number of children watching television at least three hours per day increased (0.9% and 21.6%, respectively). In the summertime, 86.4% of children took walks at least once a day, while in the wintertime, 33.1% of the children took walks at least once a day. Frequency of walks and time spent watching television did not depend on gender (Table 1).

Gymnastics classes in preschool were attended by 83.3% of the children; corrective gymnastics, by

Table 1. Mobility, movement preferences, and forms of leisure time activities of preschool children in their parents' opinions (%)

Assessed aspects		Total	Boys	Girls	P
Mobility	Very high	26.5	33.0	19.6	Chi^2: 10.81 **< 0.05**
	High	48.0	48.7	47.3	
	Average	22.0	17.4	26.8	
	Law	3.5	0.9	6.3	
Preferred games and activities	Movement	67.0	71.3	62.5	NS
	Static	26.9	21.7	32.1	
	Both types	6.1	7.0	5.4	
Leisure time activities	Active	79.7	84.3	75.0	Chi^2:6.82 **< 0.05**
	Passive	18.1	12.2	24.1	
	Both types	2.2	3.5	0.9	
Watching TV in summer	≥3h a day	0.9	0.0	1.8	NS
	1–2h a day	76.2	76.5	75.9	
	Once a week	22.9	23.5	22.3	
Watching TV in winter	≥3h a day	21.7	20.5	22.6	NS
	1–2h a day	70.4	70.6	70.4	
	Once a week	7.9	8.9	7.0	
Strolls in summer	Twice a day	40.1	43.5	36.6	NS
	Once a day	46.3	41.7	50.9	
	Less	13.6	14.8	12.5	
Strolls in winter	Twice a day	3.1	1.7	4.5	NS
	Once a day	30.0	30.4	29.5	
	Less	66.9	67.9	66.0	
Average duration of strolls [min/day]		31.0	31.0	31.0	NS

* Statistically significant differences at the defined level ($P < 0.05$)

44.9% of the children; organized extracurricular sports activities, by 35.5% of the children. Statistical analysis found differences between girls and boys with regard to frequency and willingness to participate in additional physical activities; this indicated a greater involvement of boys in this area (P < .05). According to the parents, only 18.1% of the children presented a sufficient level of physical activity and fitness (Table 2). According to the parents, almost all children acquired a skill, to a very good or good extent, in running (99.9%), cycling (95.2%) and playing with a ball (91.65%); about half the children could play football (52%) and swim (43.6%); and a number of children could ski (26.9%), roller skate (23.8%), and ice skate (16.3%). Statistical analysis showed that the ability to play with a ball, play football, cycle, and ski was acquired by a higher percentage of boys than girls, while the ability to skip rope, roller skate and ice skate was developed by a greater proportion of girls than boys (Table 3).

Table 2. Participation of preschool children in movement activities in their parents' opinions (%)

Assessed aspects		Total	Boys	Girls	P
Gymnastics class in preschool		83.3	82.6	83.9	NS
Organized extracurricular sports activities		35.7	40.9	30.4	NS
Corrective gymnastics in postural distortions		44.9	38.3	51.8	NS
Frequency of participation in additional activities	> Twice a week	2.2	0.0	4.5	Chi²: 9.55 **< 0.05**
	Twice a day	14.5	16.5	12.5	
	Once a day	18.9	23.5	14.2	
	Less	64.4	60.0	68.8	
Willingness to participate in physical activities	Very eager	59.9	66.1	53.6	Chi²: 6.14 **< 0.05**
	Eager	29.5	27.8	31.2	
	Reluctant	10.6	6.1	15.2	
Sufficient level of children's physical activity and fitness in their parents' opinions		18.1	18.3	17.9	NS

* Statistically significant differences at the defined level (P < 0.05)

Table 3. The proportion of preschool children with specific motor skills acquired to a very good or good extent in their parents' opinions (%)

Forms of movement	Total	Boys	Girls	P
Running	99.9	99.1	99.1	NS
Cycling	95.2	97.4	92.9	Chi²: 9.08 **< 0.05**
Playing with a ball	91.6	93.9	89.3	Chi²: 26.44 **< 0.05**
Playing football	52.0	85.1	17.9	Chi²: 113.30 **< 0.05**
Swimming	43.6	46.1	41.1	NS
Skipping rope	39.2	17.4	61.6	Chi²: 49.34 **< 0.05**
Skiing	26.9	32.2	21.4	Chi²: 17.14 **< 0.05**
Roller skating	23.8	12.2	35.7	Chi²:17.40 **< 0.05**
Ice skating	16.3	8.7	24.1	Chi²:11.08 **< 0.05**

* Statistically significant differences at the defined level (P < 0.05)

Table 4. Declared level of mobility and selected aspects of physical activity among preschool children (%)

Assessed aspects		Children's mobility in parents' opinion		p
		Very high and high	Average and low	
Preferred activities and games	Movement	86.4	13.8	Chi²: 105.90 **<0.05**
	Static	11.2	72.4	
	Both	3.6	13.8	
Participation in additional physical activities		40.4	19.0	Chi²: 12.88 **<0.05**
Watching television in summer	≥ 3h a day	1.1	0.0	Chi²: 23.80 **<0.05**
	1–2h a day	72.9	86.2	
	Less	26.0	13.8	
Participation in corrective gymnastics classes		33.7	75.9	Chi²: 32.35 **<0.05**
Undertaking physical activity	Very eager	63.9	13.8	Chi²: 55.64 **<0.05**
	Eager	15.4	32.8	
	Reluctant	20.7	53.4	

* statistically significant differences at the defined level ($p<0.05$)

The research demonstrated a correlation between the level of children's mobility declared by the parents and some physical activity parameters of preschool children (Table 4). Children with very high and high mobility undertook physical activity and preferred movement activities and games more often than children with average and low mobility ($P < .05$). They also participated more frequently in additional physical activities and spent less time watching television in the summer months ($P < .05$). Moreover, corrective gymnastics classes were attended by a higher percentage of less active children (75.9%) than by more active ones (33.7%). The observed differences were statistically significant ($P < 0.05$).

The study also found a statistically significant relationship between the level of children's mobility declared by the parents and some of the motor skills of preschool children (Table 5). The abilities to swim, ride a bike, play with a ball, play football, run and ski were acquired by a higher percentage of children with very high and high mobility than by children with average and low mobility ($P<.05$).

Discussion

The present study found differences of some physical activity parameters of preschool children depending on gender. Parents pointed to a higher level of mobility among boys than girls, which translates into making more frequent extracurricular forms of physical activity, a greater desire to participate in various physical activities, and more advanced skills in certain forms of movement activities. Relatively high mobility of children, declared by three-quarters of the surveyed parents, is inherent in this preschool age as a period of ontogeny characterized by a strong natural need to move, which implies the need to create conditions for children to develop their spontaneous physical activity that significantly affects the growth of their motor skills [18]. As with the present research, previous studies have described a children's tendency to favor movement activities and games and children's high mobility declared by their parents [19]. However, at the same time, numerous studies have shown a reduced level of physical activity and a trend towards a rather passive lifestyle in this population group [18, 20]. The latest British and Canadian guidelines for physical activity of preschool children recommend 180 minutes of activity per day [21, 22]. Physical activity guidelines were met by only 9% of the boys and 4% of the girls at preschool age in the Canadian population [20]. Generally unsatisfactory physical activity, higher for boys than girls, was confirmed by the study among preschool children from Nowy Sącz and the surrounding area [15]. Different results, indicating a higher physical activity among girls than boys, were obtained in a group of preschool children in Poznań [16]. Furthermore, research performed by Łoś-Rycharska and co-authors [17] showed the lack

Table 5. Declared level of mobility and selected motor skills of preschool children (%)

Assessed aspects	Skill level	Children's mobility in parents' opinion		P
		Very high and high	Average and low	
Skipping rope	Very high	5.9	3.5	NS
	High	33.1	36.2	
	Average or none	61.0	60.3	
Swimming	Very high	17.8	0.0	Chi²: 31.19 **<0.05**
	High	35.5	15.5	
	Average or none	46.7	84.5	
Cycling	Very high	49.7	13.8	Chi²: 29.14 **<0.05**
	High	47.9	74.1	
	Average or none	2.4	12.1	
Playing football	Very high	28.4	6.9	Chi²: 36.99 **<0.05**
	High	33.1	17.2	
	Average or none	38.5	75.9	
Playing with a ball	Very high	35.5	10.3	Chi²: 25.56 **<0.05**
	High	58.0	75.9	
	Average or none	6.5	13.8	
Running	Very high	75.7	32.8	Chi²: 37.92 **<0.05**
	High	23.1	67.2	
	Average or none	1.2	0.0	
Roller skating	Very high	8.3	5.2	NS
	High	16.6	15.5	
	Average or none	75.1	79.3	
Skiing	Very high	14.8	1.7	Chi²: 16.49 **<0.05**
	High	17.8	8.6	
	Average or none	67.4	89.7	
Ice skating	Very high	4.7	1.7	NS
	High	14.8	5.2	
	Average or none	80.5	93.1	

* Statistically significant differences at the defined level ($P<0.05$)

of correlation between gender and physical activity. The frequently described lower natural need for physical activity in girls can be reflected in decreased intensity, not in a decreased frequency of physical activity [17]. Studies indicating sufficient physical activity of preschool children were less abundant [23, 24]. Children's physical activity was diminished by time spent watching television. The present research, though, has not revealed significant differences between genders with regard to time spent watching television, in contrast to the results of the research by Łoś-Rycharska and co-authors [17], which found that a greater amount of time was spent in this manner by boys than girls. It should be emphasized that not more than two hours a day should be spent in front of a television. This especially concerns the studied group of children in Kraków, where the percentage of children watching television at least three hours per day in the winter has increased. Canadian preschool children were found to spend approximately six hours per day in front of a television [20]. The preschool children in the rural community of American Indians watched television on average for two hours per day [18]. Reduced physical activity and passive leisure time activities promote the development of postural distortions, which are common among preschool children. Corrective gymnastics classes were attended by almost half of the children, more girls than boys (51.8% and 38.3%, respectively), which corresponded to their lower physical activity. The tendency to choose passive recreational activities, which increases with age, is a reason why the period until four years of age should be maximally used to develop children's motor skills. However, this does not exclude the possibility of acquiring certain motor skills later in life.

The most popular form of physical activity among the studied children was walking that lasted on average 30 minutes, which should be used for movement activities. Frequency of strolls among the individuals varied depending on the time of year, indicating a greater frequency in summer than winter. Differences in frequency and duration of strolls depending on gender were observed by Chalcarz and Merkiel [15], whose studies showed that boys went for long walks and did gymnastics at home more often than girls. Development of interest in physical activities among children was affected by cultural and environmental factors. Girls usually preferred games with reduced expression of movement, while boys preferred games requiring more physical effort, done in a larger space, and with elements of competition. These differences in movement preferences had an impact on the level of fitness and physical performance, which was generally higher among boys [25]. The present study also found differences in the level of motor skills in the selected preferred forms of physical activity, depending on gender. A larger proportion of boys could ski, cycle, and play football; girls could skip rope, roller skate, and ice skate. These characteristics were also confirmed in the research of preschool children from Poznań and Mazowieckie Voivodeship [16, 26]. Studies have substantiated the significant role of family background in establishing healthy habits among children, especially regarding the correlation between physical activity of parents and children [15, 27, 28, 29]. These relationships can be explained by the importance of the mechanisms of identification and **interiorization** in a process of socialization. Family sports and recreational events could help to form pro-health attitudes, including these favoring physical activity. Statistical analysis of the results demonstrated the correlation between the level of mobility and some physical activity parameters of preschool children: the relationship between greater mobility and preference for movement activities and games, participation in extracurricular forms of physical activity, a smaller amount of passive leisure time spent watching television in summer and eagerness to participate in various physical activities. Furthermore, children described by their parents as less active more often attended corrective gymnastics classes, which may indirectly indicate that lower physical activity contributes to development of postural distortions in children.

Statistically significant dependencies were also found between the level of mobility and the levels of some children's motor skills declared by the parents, especially these regarding swimming, cycling, playing football, running and skiing. According to other studies, children who were less physically active had poorer motor skills [30].

Basic skills (running, jumping, etc.) are essential for development of other, more advanced motor skills used in various forms of physical recreation and sports. Therefore, practicing motor skills among preschool children may determine the level of active participation in physical culture at the later stages of ontogeny, which brings health benefits in somatic, emotional, and social dimensions. Thus, the preschool period is crucial for adopting an active lifestyle, which is conducive to achieving long-term health effects [1].

Conclusion

1. The studied group of preschool children consisted mainly of children described by their parents as active and very active, willing to participate in various forms of physical activities, mostly walks, and being capable of running, cycling, and playing with a ball.
2. Active participation of children in physical activities primarily concerned activities organized in preschools, and their participation was lower in the case of extracurricular activities. Gymnastics and gymnastics correction classes were commonly attended during children's stay in preschools.
3. Differentiation of certain aspects of physical activity among children, depending on gender, was demonstrated, in particular a higher level of mobility, which determines eager and more frequent participation in various forms of physical activity, including additional activities, and higher levels of certain motor skills among boys.
4. A correlation between the level of mobility and some physical activity parameters of children was found, which may indicate a relationship between larger mobility and preference for movement activities and games, willing participation in additional activities, and higher levels of certain motor skills.
5. When planning physical activity of children in the family and preschool settings, the presented differences in motor skills and the level of mobility among girls and boys should be taken into consideration.

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ASSESSMENT OF ENERGY EXPENDITURE OF SECONDARY SCHOOL STUDENTS DURING PHYSICAL EDUCATION CLASSES INCLUDING SELECTED ACTIVITY TYPES

OCENA WYDATKU ENERGETYCZNEGO LICEALISTÓW W CZASIE LEKCJI WYCHOWANIA FIZYCZNEGO NA PRZYKŁADZIE WYBRANYCH RODZAJÓW ZAJĘĆ

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Key words: physical education, physical activity, energy expenditure, accelerometer, youth, early disease prevention
Słowa kluczowe: wychowanie fizyczne, aktywność fizyczna, wydatek energetyczny, akcelerometr, młodzież, wczesne wykrywanie i zapobieganie chorobom

SUMMARY • STRESZCZENIE

Aim of the study. The aim of the study was to monitor 45-minute physical education classes in order to assess energy expenditure as well as intensity of physical effort.

Material and methods. The research was carried out in April 2012 with a group of 32 students at one of the secondary schools in Biała Podlaska, Poland. Four types of classes were monitored: football, basketball, athletics, and gymnastics classes. Energy expenditure and physical effort intensity were measured with the GT3X+ accelerometer. Electronic medical scales and stadiometer were used to evaluate anthropometric parameters. Data was analyzed with the use of the ActiLife5 computer program and the Statistica 7.1 statistical program.

Results. Average energy expenditure measured during the monitored classes turned out to be very low: boys' expenditure was calculated at 176 kcal and girls' as 157 kcal. Nearly half of the time was spent with physical effort intensity which did not exceed 3METs. Classes involving team sports were the most beneficial in terms of physical effort intensity and energy expenditure.

Conclusions. The research results show that the effectiveness of physical education (PE) classes is very low as far as energy expenditure is concerned. Systematic monitoring of PE classes can help to plan intervention studies aimed at increasing the effectiveness of the classes.

Cel pracy. Celem prezentowanego badania był monitoring 45-minutowych lekcji WF, realizowany pod kątem wydatku energetycznego oraz struktury w zakresie intensywności wysiłku fizycznego.

Materiał i metody. Badanie przeprowadzono w kwietniu 2012 roku na 32-osobowej grupie uczennic i uczniów jednego z liceów ogólnokształcących w Białej Podlaskiej. Monitorowano cztery rodzaje lekcji: lekcję piłki nożnej, piłki koszykowej, lekkiej atletyki i gimnastyki. Pomiary wydatku energetycznego oraz natężenia wysiłku prowadzono za pomocą akcelerometru GT3X+. Do oceny parametrów antropometrycznych wykorzystano elektroniczną wagę lekarską oraz stadiometr. Analizę danych przeprowadzono wykorzystując program komputerowy ActiLife 5 oraz program statystyczny Statistica 7.1.

Wyniki. Wydatek energetyczny uzyskany z pomiarów prowadzonych w czasie monitorowanych lekcji okazał się bardzo niski i wyniósł u chłopców 176 kcal, a u dziewcząt 157 kcal. Niemal połowa czasu lekcji realizowana była z intensywnością wysiłków, która nie przekraczała 3 MET. Najkorzystniejsze z punktu widzenia intensywności wysiłku oraz wydatku energetycznego były lekcje gier zespołowych.

Wnioski. Uzyskane wyniki wykazały, że efektywność lekcji WF pod względem wydatku energetycznego jest bardzo niska. Prowadzenie systematycznego monitoringu tych zajęć może pomóc w projektowaniu badań interwencyjnych zmierzających do zwiększenia ich efektywności.

Introduction

Physical activity is essential for appropriate development and early prevention of non-communicable diseases. Evaluating the impact of physical activity on the incidence of chronic diseases in adults has been one of the main tasks of epidemiology, especially in recent years [1]. The World Health Organization (WHO) experts recommend that young people should perform at least 60 minutes of physical activity at moderate to vigorous intensity every day [2]. Increasing the level of physical activity undertaken at such intensity is at present the core strategy of health promotion and early prevention of non-communicable diseases. It should be implemented in a person's early years.

For more than 10 years, intensive scientific research has been conducted all over the world with the aim of finding the factors conditioning the epidemic growth of excess weight and obesity, especially among young people. These results convince us that one of the priorities in fighting this phenomenon should be to strive to implement recommendations for an appropriate level of physical activity [3].

In accordance with the current core curriculum [4], the weekly number of physical education classes (PE) in the secondary school is three (135 minutes). Physical activities carried out in this time could complete a minimum of weekly physical activity in about 30% of the time, provided that their implementation is appropriately effective. The aforementioned aspect has been discussed in Polish studies [5, 6, 7, 8, 9] as well as international studies [10, 11]. Their results show that the effectiveness of PE classes is unsatisfactory; however, it could be changed with an appropriate choice of the learning content.

We currently lack data (nationwide or regional) on the fulfillment of the WHO recommendations regarding the minimum level of physical activity undertaken by schoolchildren. Such data would allow us to assess to what extent physical education classes contribute to the minimum of the recommended weekly physical activity. The fragmentary study conducted among high school students in Biała Podlaska indicates that the proportion of physical effort performed by teenagers at school is the lowest in relation to the three remaining spheres of life (commuting, home, and free time) with regards to weekly energy expenditure [12, 13, 14].

These results, although derived from fragmentary studies conducted with population samples which do not meet the requirements of the representativeness of the general population, encourage reflection and urge further studies in this area to be undertaken. Such studies are not easy, as they require the use of proven tools that ensure obtaining highly accurate, reliable data on the intensity and duration of physical effort [15]. These parameters constitute a basis for calculating energy expenditure, which is the most important part of the detailed analysis of physical activity.

The accelerometer is currently one of the best tools to objectively measure the level of physical activity undertaken in various areas of everyday life. Positive results of stringent validation tests of physical effort intensity measurement with the use of these tools has led accelerometers to be considered the gold standard in the study of physical activity [16, 17, 18]. These tools are commonly used in studies that require a precise measurement of physical effort intensity and duration as well as energy expenditure without the need to use expensive and complicated laboratory methods [19, 20].

The aim of the study was to monitor 45-minute PE classes in order to assess students' energy expenditure, and after analyzing the data, to answer the following questions:

1. What is the energy expenditure of pupils actively involved in the monitored classes?
2. What is the average intensity of the physical effort expended during the monitored classes?
3. What is the effectiveness of the lesson in terms of the physical effort intensity?
4. How much lesson time is used for the implementation of moderate to intense physical effort, which should prevail in physical activities conducted in this age group?

5. What is the structure of the lesson in terms of the physical effort intensity for boys and girls?
6. What kinds of lessons are the most effective in achieving the recommended effort intensity, ranging from moderate to intensive?

Material and methods

The research was conducted in April and May 2012 in one of the secondary schools in Biała Podlaska, Poland. The research material consisted of 32 randomly selected students (16 girls and 16 boys) in classes representing all levels of education (grades 1 to 3) and different profiles of education (humanities, natural sciences, mathematics, and physics). To evaluate the effectiveness of physical activities, four types of PE classes were selected: football classes (FB), basketball classes (BB), athletics classes (AT), and gymnastics classes (GM). Eight lessons (two of each type) were monitored with the purpose of evaluating energy expenditure of students selected for the study who were prepared to actively participate in the class. The main aim of all monitored classes was to perfect acquired technical elements.

In order to obtain data on the basic parameters of the body, which is necessary to calculate energy expenditure, each student was weighed with RADWAG WPT 200 electronic medical scales and measured with an SECA 213 stadiometer (Table 1).

Table 1. Anthropometric characteristics of the study group

	girls	boys
	n $\bar{x} \pm SD$	n $\bar{x} \pm SD$
weight	16 55±4.37	16 74,0±4.62
height	16 165.6±4.35	16 183.3±5.00

Monitoring physical effort was performed with the use of a GT3X+ ActiGraf accelerometer. The accelerometers were attached to the right hip by means of rubber-coated tape, in such a way as to fit closely to the body. The students had their accelerometers attached a few minutes before the lesson, and removed after the lesson.

Data was analyzed using Actilife 5, a computer program used for reading and analyzing measurements recorded by accelerometers. Freedson's equations were used to calculate MET coefficient and energy expenditure [21]. The Statistica 7.1 software was used for statistical calculations.

Neither the teachers conducting the lessons nor the students in the lessons were informed about the objectives and purpose of the study.

Results

A detailed analysis of data obtained from the recording of the body movements showed that students' average energy expenditure was 166 kcal. In the group of boys, the index was higher by 19 kcal, mainly because of their greater body weight (Figure 1). The reverse results concerning physical effort intensity factor characteristic for boys and girls confirmed the calculations. For girls, the average value of MET was 4.0, while it was only 3.4 for boys (Figure 2). The latest models of accelerometers used in the study, working in three axes, made it possible to estimate the intensity of physical effort and its duration with very high accuracy. The results were used to devise the structure of the monitored lessons in terms of the total duration of physical effort, in different ranges of intensity, as well as in terms of their percentage distribution in a 45-minute lesson.

Analysis shows that students were engaged in sedentary activities (intensity not exceeding 2 METs) during every lesson for an average of 9 minutes (that is, 20% of the lesson length) [22]. In total, 27% of the lesson (12 minutes) was devoted to activities of very low intensity, lower than required for regular walking (less than 3.0 METs). The longest period, 40% of the lesson (18 minutes), involved moderate effort implemented in the intensity of <3.0–6.0> METs. It should be noted that the mean metabolic rate fluctuated for a long time around the lower range limit designated for moderate effort. Only 13% of the lesson (6 minutes) was filled with the physical effort of high intensity (over 6.0 METs), which is the most desirable for this age group (Figures 3 and 4). Thus, in assessing the percentage distribution of the time that was used effectively – from the perspective of implementing the WHO recommendations – it was concluded that nearly half of the time (46.7%) of the monitored classes was "wasted" on sedentary activities.

Another problem analyzed on the basis of the obtained data concerned the physical effort of various intensity as performed by the respondents of the different genders. The results in this regard are consistent with the overall regularity described earlier. During their classes, girls spent less time on sedentary activities,

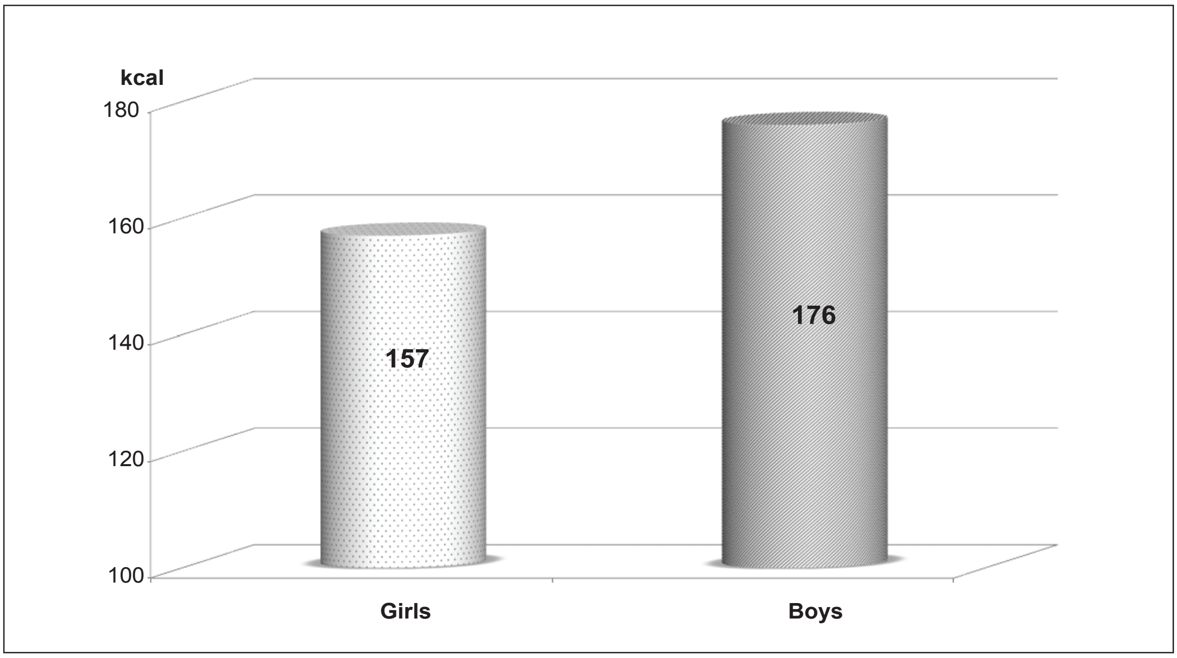

Figure 1. Average energy expenditure obtained during the monitored classes in each group

and expended much more effort on activities of moderate and high intensity (Figure 5).

Discussion

One of the most important issues that has been addressed in this study was to evaluate which lesson type (of the four monitored) provides the most efficient use of time in terms of physical effort expended by young people that helps them implement the recommended physical activity levels. Results showed that the team sports classes are more effective than track and field or gymnastics classes. The latter proved to be the least favorable from the standpoint of energy

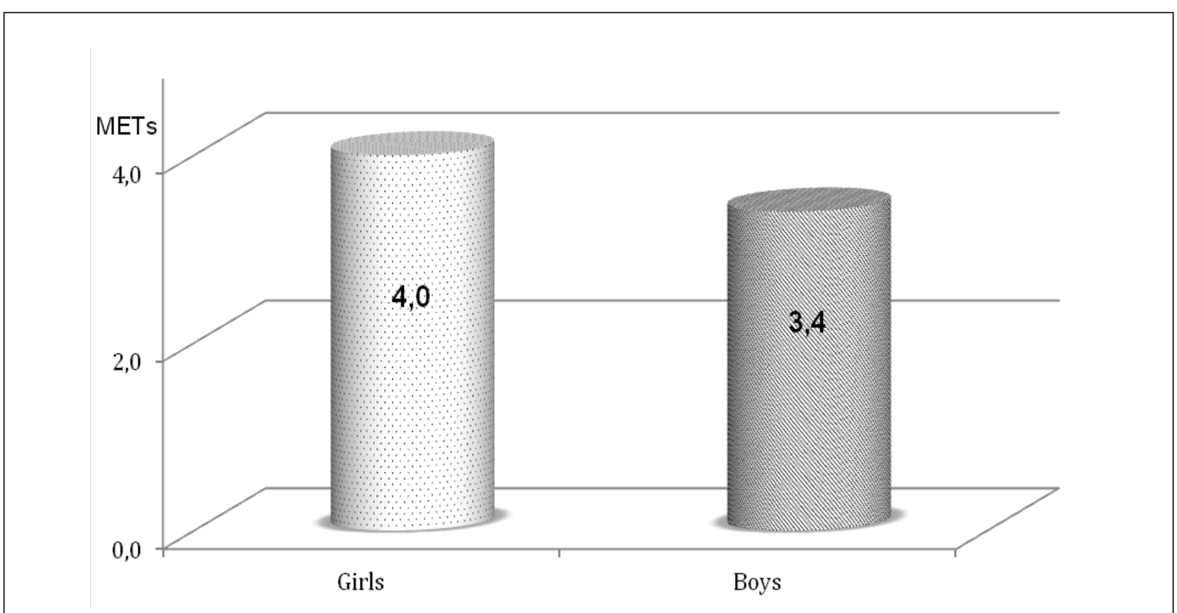

Figure 2. The average physical effort intensity obtained during the monitored classes in each group

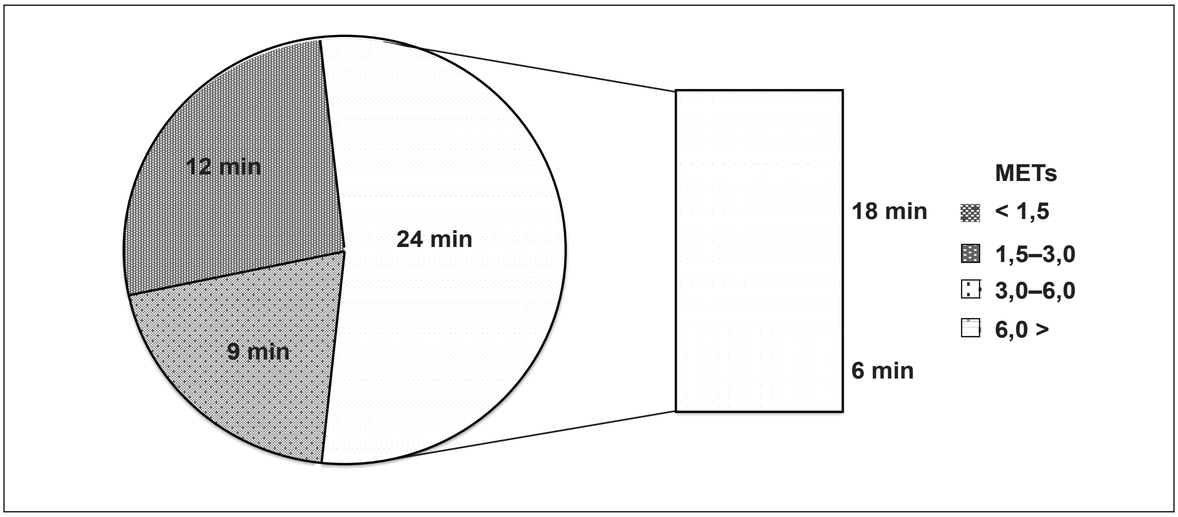

Figure 3. The time structure of the monitored lessons with regards to intensity of physical effort

expenditure. Such consistency was observed in both groups (Figure 6).

The results indicate that the effectiveness of physical education as regards energy expenditure of students attending the classes is small, in particular for boys. For most of the monitored classes, the physical effort in both groups was expended at moderate to low intensity levels (less than 5 METs), while intensive to moderate levels of physical effort should dominate this age group [2]. Taking the structure of the whole lesson into consideration, almost half of the lesson time was inefficient in terms of energy expenditure, as there were too many fragments of low effort intensity. Mainly, these included activities such as checking attendance, as well as the teacher's instruction, description, and demonstration involved with a particular exercise. At these moments, intensity of physical activity fluctuated between 1 to 3 METs. Researchers studying this issue agree that the activity in which the intensity of effort does not exceed the value of 3 METs should be classified as sedentary (up to 1.5 METs) or light (1.5–3.0 METs) [2, 23].

It should be noted that the classes conducted with girls have a more favorable energy expenditure struc-

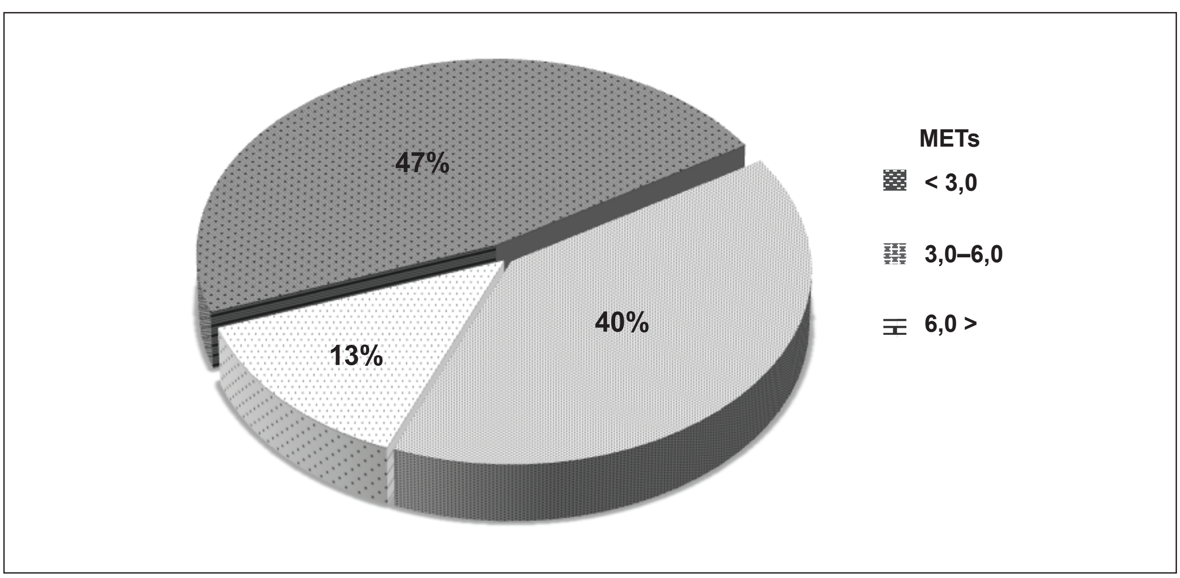

Figure 4. The percentage structure of the monitored lessons with regards to intensity of physical effort

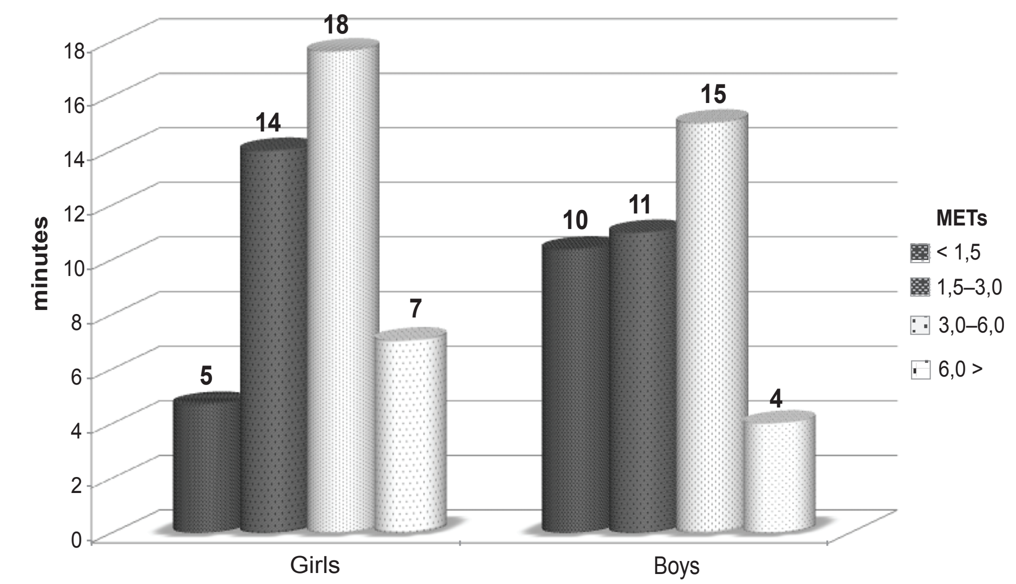

Figure 5. The structure of the physical effort intensity during the monitored lessons for boys and girls

ture, and the physical effort is more often of moderate and high intensity. Of the four types of classes, those including team sports had a better structure of energy expenditure, while gymnastics classes were the least favorable in this respect. This result may indicate that both in the selection of learning content for each lesson as well as during its implementation too little attention is paid to the intensity curve. It is especially important in gymnastics and athletics classes, which incorporate interval training. This aspect of PE lessons has been emphasized by Bronikowski [5, 6, 7] and Pańczyk [8], who pointed to the different physiological effects of var-

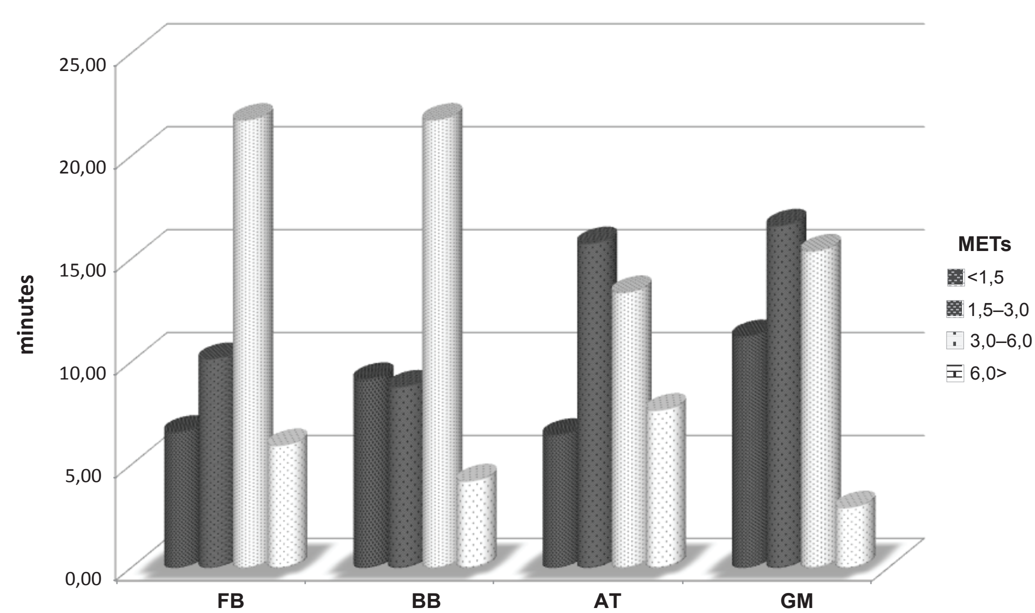

Figure 6. The distribution of particular categories of physical effort intensity depending on type of classes

ious types of physical education lessons. The results obtained in their studies showed that field athletics and team sports lessons stimulate the cardio-respiratory system the most, while table tennis and gymnastics lessons have the most limited physiological impact. The aforementioned regularity is also confirmed in this study. This is therefore further proof that should be taken into account when planning the learning content and types of PE lessons, as well as ways of conducting them.

Another important issue, often overlooked, or not at all taken into consideration in the process of programming PE lessons, is striving to increase energy expenditure during students' active participation in the classes. To give priority to this issue in physical education curricula can significantly affect the fulfillment of expert recommendations for weekly physical activity level of students.

Conclusions

Based on these results, we can conclude that:

1. Opportunities offered by physical education classes for implementing expert recommendations on the minimum of weekly physical activity are not fully utilized.
2. Choosing classes based on team sports can improve the organizational structure of the lesson and its effectiveness in energy expenditure.
3. Systematic monitoring of physical education classes in every school with the use of objective tools can provide a basis for planning intervention studies and taking action to improve their effectiveness.
4. The study confirms that there is a need for the detailed monitoring of physical education classes, especially among secondary school students who are on the threshold of adult life, when the threat of sedentary lifestyle increases rapidly.

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INFLUENCE OF PHYSICAL ACTIVITY ON BODY COMPOSITION AND PODOMETRIC FEATURES OF YOUNG MEN

WPŁYW AKTYWNOŚCI FIZYCZNEJ MŁODYCH MĘŻCZYZN NA SKŁAD CIAŁA I UKSZTAŁTOWANIE STÓP

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Keywords: physical activity, body composition, angles and arches of foot
Słowa kluczowe: aktywność fizyczna, skład ciała, kąty i łuki stóp

SUMMARY • STRESZCZENIE

Introduction. The article introduces the somatic analysis (weight and height of body, BMI index) of the examination results of males in terms of different levels of physical activity. The podometric features connected with the functional capabilities of the feet were used in the analysis. The analysis also includes features of body composition from the tissue perspective.

Aim of the study. The aim of the study is to assess the impact of the level of physical activity on body composition and foot arch in male students at the University School of Physical Education in Wroclaw.

Material and methods. The examined men were students of University School of Physical Education in Wroclaw, divided into two groups characterized by high (n = 148) and low (n = 53) levels of physical activity. Students declared the level of physical activity on the basis of the proposed criteria. The height and weight of the examined males were measured, and their Body Mass Index was calculated. Body tissue composition was examined by the use of the analyzer that measured the body resistance on the electrical current. An analysis of the feet was conducted using the podoscope: angles and curves showing the correct foot arch were measured.

Results. Students declaring higher levels of physical activity have significantly higher fat-free mass and lower fat mass compared with less active students. The state of foot arch is a little better in students declaring high levels of physical activity, which may indicate that sport selects and eliminates those with foot disorders.

Wstęp. W pracy dokonano charakterystyki somatycznej (masy i wysokości ciała oraz wskaźnika BMI) mężczyzn w aspekcie zróżnicowanego poziomu aktywności fizycznej. Do oceny wykorzystano cechy podometryczne świadczące o możliwościach funkcjonalnych stóp. W analizie uwzględniono również cechy składu ciała w ujęciu tkankowym.

Cel pracy. Ocena związków pomiędzy poziomem aktywności fizycznej a składem ciała oraz cechami świadczącymi o wysklepieniu stóp u mężczyzn studiujących w AWF we Wrocławiu.

Materiał i metody. Badanych mężczyzn, studentów AWF we Wrocławiu, podzielono na dwie grupy, przyjmując za kryterium deklarowany wysoki (n = 148) oraz niski (n = 53) poziom ich aktywności fizycznej. Poziom aktywności fizycznej studenci określali stosując się do zaproponowanych kryteriów. Badanym zmierzono wysokość i masę ciała, na podstawie których obliczono wskaźnik BMI. Skład tkankowy ciała zbadano przy użyciu analizatora oceniającego oporność ciała na przepływający prąd. Analizę stóp przeprowadzono za pomocą podoskopu – zmierzono kąty oraz łuki świadczące o prawidłowym ukształtowaniu stóp.

Wyniki. Studenci deklarujący wyższy poziom aktywności fizycznej wykazują istotnie wyższą masę ciała szczupłego oraz niższy poziom otłuszczenia w porównaniu do mężczyzn słabo aktywnych. Wysklepienie stóp jest nieco lepsze u studentów o wysokim poziomie aktywności fizycznej, co może świadczyć o pozytywnym wpływie ruchu na stopy, gdyż sport selekcjonuje i eliminuje osoby z dysfunkcjami w obrębie stóp.

Introduction

During the process of evolution, human beings acquired the characteristic ability of bipedal upright movement [1]. Gradual changes in the morphology of the body in combination with brain volume growth, curiosity, and the desire to expand made it easier to settle in areas beyond Africa, the cradle of humankind [2, 3]. The emergence of human specific characteristics, such as spinal curvature, lower limb elongation and arches of the foot, are the result of gradual changes. However, despite the fact that these changes facilitated the evolutionary success of Homo sapiens as a species, they also tend to be a burden for the body [4]. Bipedal movement allowed for efficient motion and living space penetration, but the complicated structure and functions of feet subject to excessive burden can cause permanent, pathological changes. The size of the longitudinal arch determines ability of the feet to stabilize the body and support the entire body's mass [5]. The practice of competitive sports, which is associated with increased shock absorption, requires constant control of the state of the feet and all their defining parameters. Thanks to consistent diagnosis and prevention, it is possible to sustain the proper condition of feet in order for the feet to perform their functions despite being overburdened with physical exertion.

The human body tissue composition is vulnerable to the influence of exogenous factors, which is why the tissue shows significant change under the influence of diet and physical activity. The athlete's body contains more tissue associated with physical activity: muscles and bones, and less fat tissue [6, 7]. Analysis of the size of tissue components is helpful in creating an optimal structural model of the body that will be able to meet the demands of a given sports discipline.

The aim of this work is to assess the links between the level of physical activity and body composition, and characteristic features indicating the type of the foot arch in men studying at the University School of Physical Education in Wroclaw. The work tries to provide answers for the following research questions:

1. Is there a connection between the level of physical activity and the amount of tissue components among surveyed men?
2. Does the shape the foot depend on the level of physical activity?

Material and methods

Data comprised of measurements of the students of the University School of Physical Education in Wroclaw were used in research. The analysis used data compiled from 2004 to 2012 by the staff of Physical Anthropology Department. Somatic measurements are always made among first-year students. This can mean that the subjects are not always the same age, particularly among part-time students. The test subjects were divided into two groups, taking into account the level of physical activity declared by the respondents: a group with a higher level of physical activity n = 148, age = 20.3 years, a group of lower activity n = 53, age = 21.9 years.

The group with a higher physical activity level consisted of subjects who declared systematic participation in physical exercise 3–4 times a week at leas 60 minutes a day. The analysis included players of different sports disciplines with at least a five-year training period. The second group consisted of students who declared lower amount or a complete lack of physical activity. Such levels of physical activity could be found among students of the faculties of Tourism and Recreation as well as Physiotherapy, especially if they were part-time students.

Anthropometric measurements were done with a measurement technique proposed by Martin [8]. Somatic characteristics were measured using standard anthropometric equipment. Body height was measured with an anthropometer to an accuracy of 1 mm. An electronic scale (standardized regularly) was used to determine body weight to an accuracy of 0.1 kg. On the basis of the aforementioned data, body mass index (BMI) was calculated. The width (mtt-mtf) and the length (ap-pte) of the foot were measured using a small bow caliper to an accuracy of 1 mm [9].

The work includes an assessment of body composition using the bioelectrical impedance method.

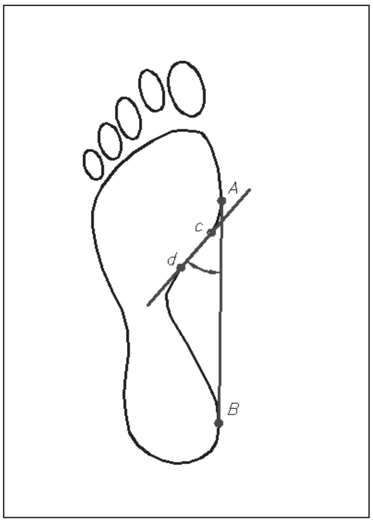

Figure 1. Clarke's angle

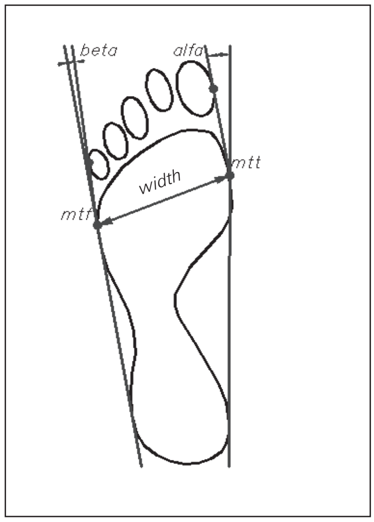

Figure 2. Alfa and Beta angles

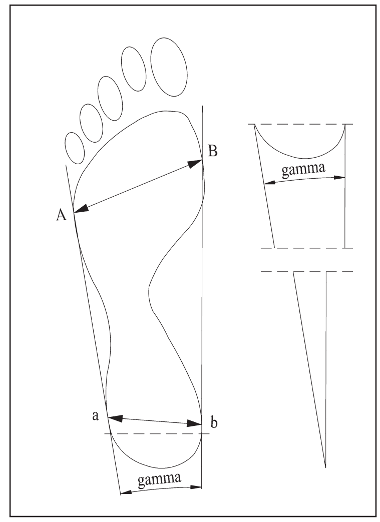

Figure 3. Gamma angle

Drawings made by the author

The Akern 2000 bioelectrical impedance analyzer was used. The method involves measuring electrical resistance using the impedance analyzer. It is one of the most modern body composition analysis methods. It is non-invasive, relatively easy to apply, and the individual examination is very brief. For the result obtained by this method to be reliable, the subject should not eat prior to the test, should not have just completed intensive physical exercise, and not consume alcohol. The test subject is lying down, four electrodes are fastened to the subject's hand and foot in order to allow the flow of low intensity, high frequency alternating current. After a while, the values of two impedance components, resistance (active resistance) and reactance (passive resistance), are taken from the analyzer. On the basis of the values of the components, a number of factors can be determined: TBW – total body water, FFM – fat-free mass, MM – muscle mass, FM – fat mass [10].

Parametric assessment of the feet was made using the Podoscope [11]. The device allows for taking a photo of the plantar part of a foot using a digital camera. The image is transferred to a computer, where, using the appropriate software, an analysis of the foot is made (the arch, position of toes). The work analyzed the Clarke's angle (Figure 1) indicating the longitudinal arch of the foot, Alpha angle describing the position of the big toe (Figure 2), Beta angle evaluating the position of the fifth toe (Figure 2), and the Gamma angle, also called the "heel angle" (Figure 3).

The longitudinal arch was rated on the basis of the value of the Clarke's angle [12]. The aforementioned author gave a threshold of 42º as the appropriate value [13, 14, 15]. The work uses a classification based on the value of the angle given the by the Podoscope software, where the range below 28º corresponds to a flat foot; 28–39.5º – a lowered foot; 40–51º – an appropriate foot; values above 51º indicate an overly arched foot. Bieniek [16] and Ignasiak [17] have applied a similar division. The alpha angle, describing the difference between the big toe and the foot axis is also referred to as the big toe valgus angle. According to Wejsflog [18], the range of the big toe valgus angle is 0–9º; increasing the angle causes the pathological offset of the first metatarsal bone, along with the first toe of the foot. This dysfunction causes pain that may impede an individual from playing sports or even exclude a player from professional sport. The gamma angle, defined as the heel angle, describes the height of the transverse arch. According to Wejsflog's classification, the standard is 15–18º. Using this classification, the following foot types can be distinguished: transverse – hollowed with the value of less than 15º; correct; transverse – flattened, with values exceeding 18º [5].

All measurement data were developed using basic statistical methods. Differences between the average values were assessed using a Student's t-test for independent samples. The relationship between selected parameters was examined using Pearson linear correlation coefficient [19].

Material analysis

The material analysis (Table 1) showed that subjects declaring high levels of physical activity significantly exceed the inactive ones statistically in terms of body height development. The considered feature shows a relatively small variability [20]; hence, the active and inactive students are groups with small internal diversity in terms of body height development. Neither of the studied groups showed a significant difference in terms of body weight (with substantial variation of the characteristic between both research groups), which is also reflected in the values of the body mass index (BMI). This index reaches slightly higher values among students characterized by low physical activity, but the observed difference does not show signs of any statistical importance. The sampled students fit within the normal range of BMI values. The relation of body weight to the square of body height varies slightly among students with higher levels of physical activity, but there is a large variety among less active students.

The research analyzed body tissue composition, thus enabling a much more detailed assessment of the human body, which is particularly important for people engaged in competitive sports. The analysis of tissue components clearly enhances the knowledge given by the relation of body weight to body weight in height-growth indices (e.g., BMI).

Students declaring greater physical activity have a significant advantage in terms of fat-free mass development, as the amount of fat mass is lower. Fatness in both research groups is characterized by high variability, which in the case of active men may arise from the specifics of the practiced sport discipline. In the case of inactive people, the greater amount of fatty tissue is probably the result of low physical activity. What is noteworthy is that muscle mass is only slightly higher in highly active men. This is interesting due to the significantly higher amount of fat-free mass among active students that consists of muscle mass. This raises the suspicion that the advantage of fat-free mass is the result of greater skeleton participation. As a confirmation of the aforementioned inference, there is a statistically notable difference in the body height in the group of active men, as the weight of the skeleton is largely connected to the aforementioned somatic feature.

The correlation between body composition characteristics indicates a close link between body weight and

Table 1. The statistical characteristics of somatic features and body composition

Feature	Body Height	Body Mass	BMI	Fat mass (%)	Fat free mass (%)	Muscle mass (%)
Active						
average	186.0	76.7	23.26	19.21	80.79	58.30
standard deviation	9.90	9.75	2.23	3.98	3.98	4.40
minimum	179.0	63.0	19.30	10.50	68.90	43.80
maximum	193.0	127.3	34.20	31.10	89.50	70.20
variation coefficient	5.32	12.72	9.60	20.72	4.95	7.55
Inactive						
average	179.1	76.6	23.90	20.90	79.10	56.70
standard deviation	6.70	10.30	2.80	5.60	5.60	68.90
minimum	164.4	61.7	19.00	5.90	65.60	5.80
maximum	193.0	109.0	31.80	34.40	94.10	41.30
variation coefficient	3.70	13.04	11.80	26.70	7.10	10.20
Student's t-test	4.68*	0.05	–1.66	–2.35*	2.35*	0.28

*$P < 0.05$

Table 2. Pearson's correlation coefficient between body mass and features of body composition

Feature	Body mass	FFM	FM
	Active		
TBW – Total body water (kg)	0.83	0.94	0.14
FFM – Fat free mass (kg)	0.85	–	0.16
FM – Fat mass (kg)	0.65	0.16	–
MM – Muscle mass (kg)	0.77	0.93	0.10
	Inactive		
TBW – Total body water (kg)	0.87	0.99	0.60
FFM – Fat free mass (kg)	0.87	–	0.60
FM – Fat mass (kg)	0.92	0.60*	–
MM – Muscle mass (kg)	0.27	0.28	0.20

* $P < 0.05$

active components, and the levels of fat in a group of subjects characterized by high levels of physical activity. Similar, positive correlations have been observed between muscle mass and the amount of water, which is the basic element of muscle cells. In the case of men characterized by low levels of physical activity, body

Table 3. The statistical characteristic of podometric features

Feature	Left foot angles				Right foot angles			
	Alpha	Beta	Gamma	Clarke	Alpha	Beta	Gamma	Clarke
Active								
average	8.4	19.8	20.1	41.5	7.4	21.7	20.9	42.8
standard deviation	4.14	5.17	2.48	5.55	3.92	5.17	2.53	6.29
minimum	0.5	7.3	13.8	14.1	0.4	8.3	15.2	6.0
maximum	20.2	37.7	25.7	56.2	19.0	34.3	27.0	56.9
variation coefficient	49.48	26.13	12.32	13.37	53.10	23.87	12.07	14.68
Inactive								
average	9.5	19.7	21.0	43.9	7.7	22.0	21.6	45.6
standard deviation	5.10	5.47	2.40	6.02	4.71	4.93	2.42	7.05
minimum	0.3	5.8	14.5	22.5	0.3	10.3	14.8	29.3
maximum	22.2	31.9	26.2	53.8	16.2	35.1	26.1	59.1
variation coefficient	53.50	27.82	11.47	13.72	60.71	22.41	11.21	15.47
Student's t-test	–1.58	0.14	–2.20*	–2.59*	–0.52	–0.40	–1.71	–2.61*

$^*P < 0.05$

Table 4. Pearson's correlation coefficient between angles of feet and features of body composition

Alpha angle			Clarke's angle						Gamma angle
Beta angle	**Clarke's angle**	**Gamma angle**	**Gamma angle**	**Foot length**	**FFM**	**FM**	**MM**	**mass**	**Foot width**
Active									
Left foot									
–0.14	0.01	0.05	0.08	–0.05	0.25	0.07	0.15	0.03	0.45
Right foot									
–0.03	0.11	0.28	0.15	0.18	0.28	0.07	0.20	0.12	0.52
Inactive									
Left foot									
0.16	0.07	0.06	0.01	–0.22	–0.05	0.04	0.04	0.00	0.48
Right foot									
0.26	0.14	0.49	–0.24	–0.39	–0.33	–0.15	–0.01	–0.24	0.65*

*$P < 0.05$

weight highly correlates with water content, fat-free mass, and fat mass. Strong relations have been found between fat-free mass, water, and fat mass. The fat mass, in turn shows a high correlation with the water level and fat-free mass.

The podometric evaluation of the shape of the feet (Table 3) allowed the researchers to notice a slight predominance of the alpha angle in inactive students. This angle, which allows the valgus or varus position of the big toe to be assessed, in both research groups is higher in the case of the left foot. Additionally, in the group of less active students, the mean values do not fit in the correct range, which means that there is a tendency towards a valgus alignment of the left foot's big toe. The alpha an-

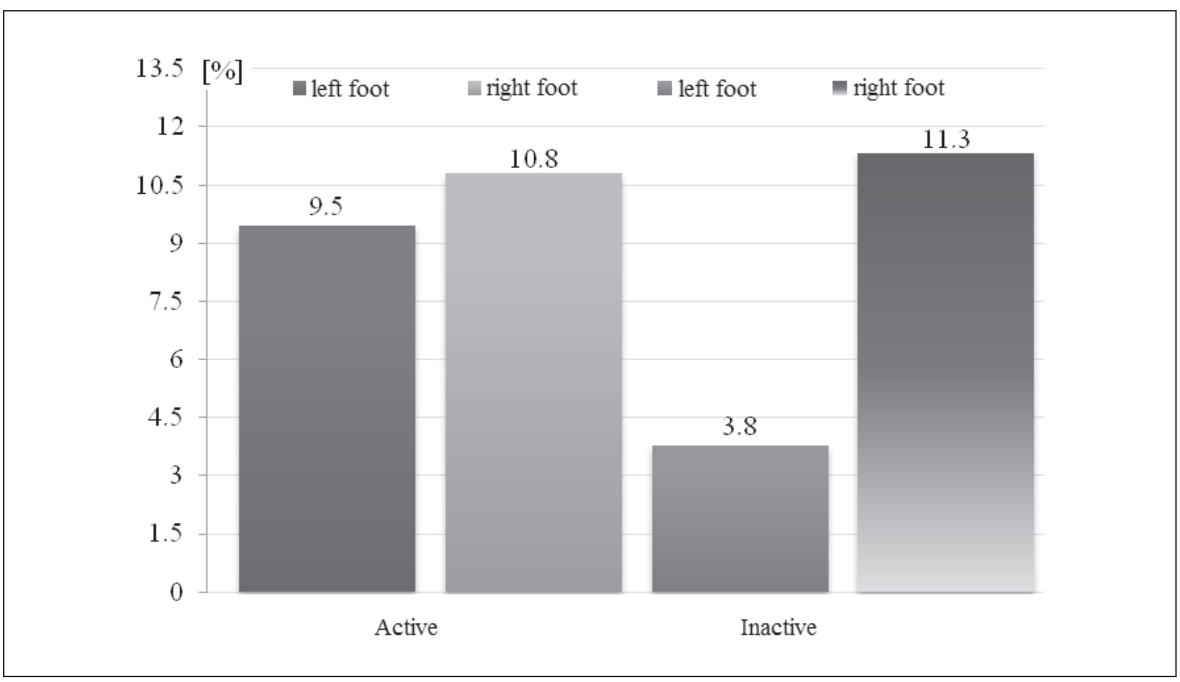

Figure 4. The frequency of varus position of big toe

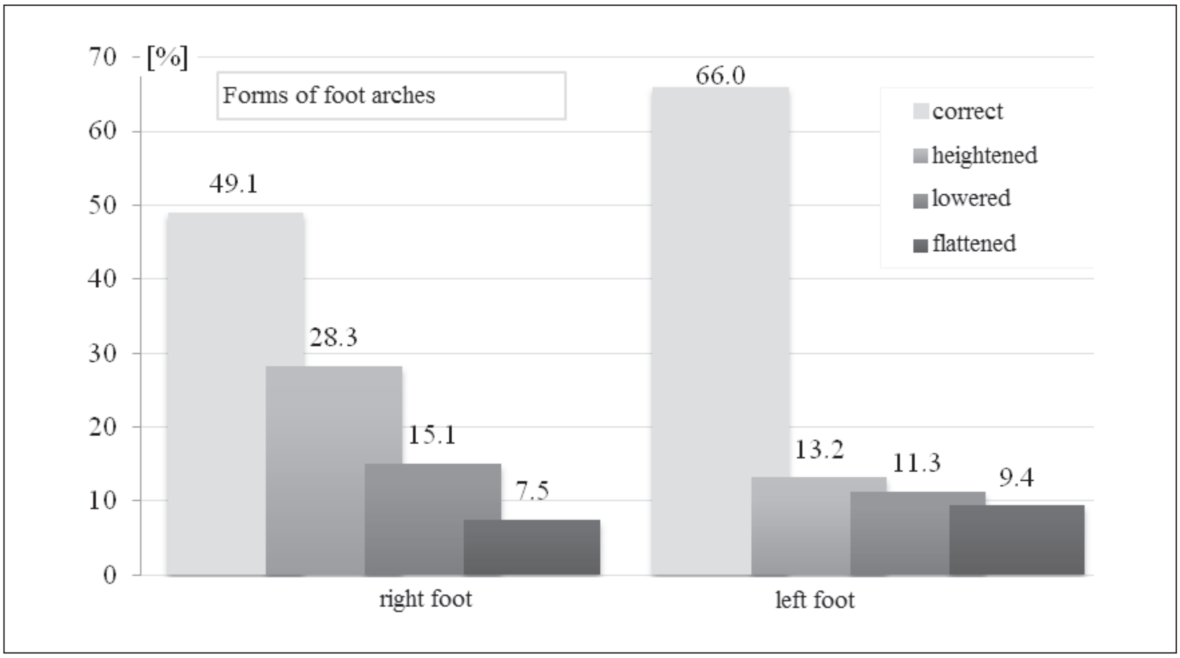

Figure 5. The percentage participation of longitudinal arch type of men with low physical activity

gle of the right foot reached similar values in both groups, without exceeding the correct values. In both active and inactive students (Figure 4), the value of the alpha angle indicates a varus position. This setting of the big toe is the most common on the right foot. This characteristic is a little more clearly marked among less physically active men. The active students, in turn, show a higher percentage of varus position on the left foot.

The beta angle, characterizing the fifth toe alignment, reaches similar values in both research groups.

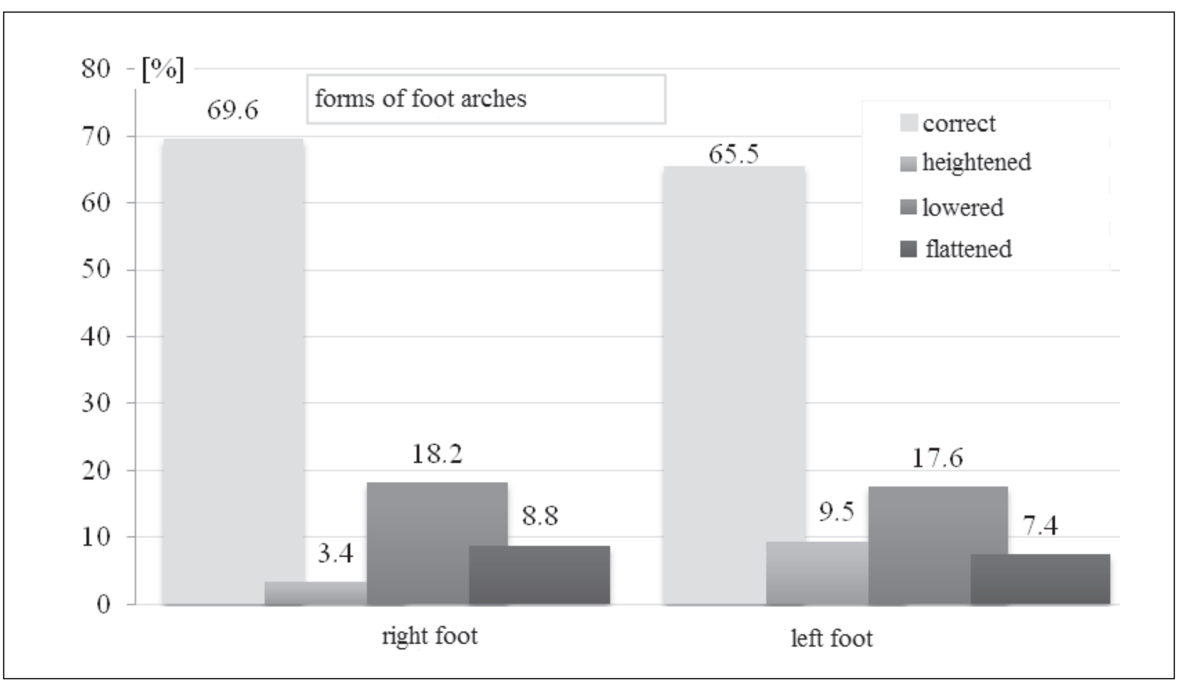

Figure 6. The percentage participation of longitudinal arch type of men with high physical activity

However, it may be important to point to the higher values of the discussed angle on the right foot, in the absence of a statistically significant dominance of representatives of particular levels of physical activity.

The correct range of the values of the gamma angle, which allows the degree of the transverse arch to be assessed, are between 15 and 18 degrees. In the case of men tested in this study, the angle shows elevated values regardless of the level of physical activity. This indicates the presence of transverse flat feet. This is the feature that shows significant variability in both research groups, thus indicating a large diversity of inter-individual gamma angle values among the students. Among the inactive students, this feature demonstrates significantly higher values on the left foot; on the right foot the difference is statistically irrelevant with respect to men with increased physical activity.

Clarke's angle, which characterizes the value of the longitudinal arch, reaches the values set in the confines of a correct arch, regardless of the level of physical activity of men. In both research groups, a slightly higher arch of the right foot was noticed, which is a commonly occurring tendency. The larger and statistically significant values for the Clarke's angle were found in low physical activity students.

The analysis of the participation of various forms of feet arches (Figures 5 and 6) demonstrates the greater longitudinal arch shape correctness of the feet of men characterized by higher physical activity. This group is characterized by a high percentage of properly arched right feet; in addition, there was observed a small percentage of excessively arched feet. Among active men, there were a higher percentage of feet with a lowered longitudinal arch. The number of flattened feet, in turn, is equal in both research groups, despite the difference in physical activity level.

The observed configuration of longitudinal arch on feet of highly active men indicates a preference towards correct feet. In addition, these are the feet with a tendency towards a slight lowering of the arch. Flattened feet and ones with the tendency towards a raised arch comprised a small part of the group.

The Pearson's linear correlation coefficient (Table 4) shows the rather weak interdependencies of the obtained angle values. Similarly, small correlations have been observed in the case of Clarke's angle and tissue components as well as foot length. Only the gamma angle is highly correlated with the foot width. This is the effect of determining the angle on the basis of, inter alia, foot width (and heel width).

Discussion

The human body acquired features in the course of evolutionary development that help perform motor activities that require high amounts of active tissues and fat mass reduction, which, in the case of athletes, is regarded as unnecessary weight. Men are characterized by a high level of muscle mass [21], and this feature increases its contribution to body composition with age [22]. In this study, subject men have similar muscle mass. This is a tissue component that builds a slim body, and this element substantially prevails among men with a high level of physical activity. Hence, it can be concluded that the high amount of fat-free mass in athletes is the result of high amounts of bone mass, which, as was demonstrated by Zanchetta et al. [23], increases with higher levels of physical activity. In turn, intensive exercise greatly reduces the amount of fat mass, which can be seen in skinfold thickness [24, 7]. A similar relationship was observed in the analyzed material: highly active students displayed lesser amounts of the inactive component, which is the fatty tissue.

This work includes an analysis of the selected features of feet, which indicate the correctness of their shape. Numerous authors have pointed to the importance of such systematic monitoring, as the foot is both an element of the motor system and an absorber of the shock generated during the act of walking [25, 26]. This means that properly developed feet both eliminate micro-vibrations and prevent them from causing negative changes in joints, internal organs, the spine, and the nervous system. Feet change dynamically with age [27, 28]; therefore, the observation of feet in the early stages of development may result in functionally fitter adult men.

Athletes with extensive training experience are subject to a strong selection, which eliminates people prone to injuries from competition. According to selected authors [29, 30], sport may be eliminating in character: it is probable that only individuals who represent a fitter and more resistant phenotype remain in competitive sports. This statement is reflected in the work of Canseco et al. [31], who claimed that the deepened valgus angle of the great toe changes the quality of gait, provoking the appearance of pain. Firak et al. [32] claim, in turn, that certain sports disciplines (acrobatics) may have a positive influence on the morphology of feet and even improve their functionality.

Galiński et al. [33] discovered the prevalence of higher longitudinal arches of the left foot in comparison the right foot in adult judokas, which was explained by the characteristic position taken by the fighter during a fight. Also, Demczuk-Włodarczyk and Bieć [34], in examining the practitioners of combat sports, concluded that morphological construction disorders appear in the front segments of the foot, the transverse arch.

The findings of this work do not allow such conclusions to be drawn, as there was no sports disciplines division. However, it can be generally concluded that men characterized by high physical activity have better shaped feet than their not-active peers. This can be caused by strengthening the muscles and ligaments responsible for feet arches in people performing regular physical activity of adequate intensity.

Sporadic occurrence of flat and flattened feet found during the research of men actively involved in sports activities may be the result of specific burdens to which feet are subjected during training. The marginal presence of overarched feet can be determined by functional considerations. Feet with too high longitudinal arch do not fully meet its supporting function due to the limited plantar area of the foot in contact with the ground. That is why these areas are vulnerable to incorrect weight distribution, which puts the overburdened front or rear part of the foot at risk of injury. Susceptibility to injuries, in turn, may lead to the elimination of such persons from physical recreation or competitive sports.

Conclusions

1. Men characterized by high levels of physical activity have significantly higher amounts of fat-free mass and a lower level of fat mass in relation to less active men.
2. The shape of the foot is slightly better in highly active students, which may attest to the positive impact of movement on feet. On the other hand, it cannot be excluded that sport selects and eliminates people with foot dysfunction.

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THE EFFECTIVE USE OF INTELLECTUALIZATION IN TEACHING SELECTED DISPOSITIONS TO PLAY AND ITS INFLUENCE ON REDUCING INJURY RATES OF LOWER LIMBS IN ADEPT FOOTBALL PLAYERS

WPŁYW SKUTECZNEGO WYKORZYSTANIA INTELEKTUALIZACJI W NAUCZANIU WYBRANYCH DYSPOZYCJI DO GRY NA OGRANICZANIE URAZOWOŚCI KOŃCZYN DOLNYCH U ADEPTÓW GRY W PIŁKĘ NOŻNĄ

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Key words: effectiveness of training, intellectualization, sports injuries, teaching
Słowa kluczowe: Intelektualizacja nauczanie, efektywność szkolenia, urazy sportowe

SUMMARY • STRESZCZENIE

Introduction. Success in sports requires strenuous physical effort, thus causing serious risk to an athlete's health. This is why investigation into effective and health-promoting methods of training is gaining special recognition. With the above in mind, this study proposes a method of intellectual teaching that involves mastering movements (techniques of playing) with decreased strain during training for young football players. Effective training methods are therefore needed to reduce injury rates in sports.

Aim of the study. This study proposes a method of intellectual training for young football players that involves mastering movements (techniques of playing).

Material and methods. The didactic and health-promoting effects of intellectual teaching were presented during experimental training at the Athletic Championship School in Krakow. The average age of study participants was 16 years old. Continuous research based on intellectual teaching was conducted between 1996 and 2002. Study participants comprised 108 players divided into 2 groups, the experimental group and the control group, each comprising 54 players.

Results. The study showed that intellectualization of teaching reduces strain during training (by 14%), thus benefiting the health of participants (by reducing the injury rates of lower limbs).

Conclusions. Intellectual teaching considerably increases the technical effectiveness of young football players. The method can also reduce the injury rates of lower limbs in football players through the reduction in physical strain and a conscious analysis of one's movements during the game.

Wstęp. Sukces sportowy stawia przed zawodnikiem wysokie wymagania, do których zalicza się duże obciążenie wysiłkiem fizycznym, stwarzającym często poważne zagrożenie dla zdrowia sportowca. W przeciwdziałaniu negatywnym skutkom tego zjawiska szczególnego znaczenia nabiera poszukiwanie rozwiązań z dziedziny skutecznego i prozdrowotnego treningu sportowców.

Cel pracy. W artykule proponuje się metodę intelektualnego treningu młodych piłkarzy nożnych, ukierunkowaną na opanowanie przez nich działań ruchowych (techniki gry) z równoczesnym zmniejszeniem obciążeń treningowych.

Materiał i metody. Efekty intelektualnego szkolenia w aspektach dydaktycznym i prozdrowotnym analizowano podczas eksperymentalnego programu zajęć, którymi objęto 16-letnich uczniów Szkoły Mistrzostwa Sportowego w Krakowie. Badania ciągłe oparte na nauczaniu intelektualnym prowadzono w latach 1996–2002. Zbadano 108 graczy w dwóch grupach – eksperymentalnej i kontrolnej, z których każda liczyła po 54 osoby.

Wyniki i wnioski. W trakcie badań wykazano, że intelektualizacja szkolenia, redukując obciążenie treningowe o14%, oddziałuje korzystnie na stan zdrowia, przyczyniając się do zmniejszenia urazowości kończyn dolnych, a także wpływa pozytywnie na efekty szkolenia. Analizując wyniki badań można wnioskować, że intelektualizacja znacznie poprawia efektywność szkolenia. Przez zmniejszenie obciążeń treningowych oraz świadomą analizę działań ruchowych w grze piłkarzy nożnych może także przyczynić się do zmniejszenia urazowości kończyn dolnych.

Introduction

Competitive sports training requires good physical fitness, which is why mastery in sports is reached only after a dozen or more years of strenuous physical effort. Systematic engagement in high-volume, high-intensity specialist exercises is needed starting at a very young age. During the period of dynamic growth during adolescence, the body is especially sensitive to unilateral physical strain.

The development and shaping of lower limbs (including bones, muscles, tendons, and joints) is governed by biological laws; pressing and stretching forces affecting the skeleton during its intense growth are considered especially important in this regard. The long and unilateral strain put on the skeleton of young players intensifies adapting changes that can become pathological changes in different parts of the skeleton. These changes include bone spurs, heel spurs, development of Osgood-Schlatter disease, and avascular necrosis of secondary ossification centers in the long and small bones of the upper and lower limbs [1].

The above considerations are important in practice because, as mentioned above, disregarding these biological laws can lead to acute injuries of the lower limbs with harmful effects even amounting to permanent disability.

All this aims at making trainers at sports clubs aware of potential dangers to a young, developing body that are the result of enforcing unilateral, excessively strenuous training.

The role of a trainer of adolescent athletes involves special responsibility, as training that is properly organized and conducted can determine the future career of a young player. When training is understood and realized in this manner, it also becomes the most effective method of preventing sports injuries.

Severe sports injuries during adolescence should not constitute a serious issue, as rational training, which is required at this age, should reduce risks. However, the strain and injury rates of lower limbs are increasing in competitive sports, mainly among players of team sports.

These injuries become increasingly more difficult to treat as a result of the increased demands placed on an athlete's body; these demands exceed the body's capability for adaptation. At the same time, trainers and athletes expect physicians to help them quickly eliminate numerous conditions that either hamper intense physical effort or make it impossible. Moreover, conditions in sport are constantly changing. External conditions demand increasingly strenuous adaptation on the part of the athlete, for which there is not enough time. The aforementioned injuries occur as a result of excessive strain during sports training. Injuries of lower limbs due to overtraining are in most cases viewed as whole-body strain.

This leads to the conclusion that high-volume, high-intensity sports training that exploits the body from a very young age can pose a serious threat to an athlete's heath, especially when conducted irrationally. Available literature [2, 3, 4] suggests that success in sports, which unfortunately is considered the main goal already at the beginning stages of sports training, causes severe strain of the lower limbs. Trainers demand heavy effort on the part of a young player's motor system in order to achieve higher effectiveness on the field. A football player's training focuses on physical preparation. The resultant excessive strain of the motor system leads to injuries, especially of the lower limbs [1]. It seems, therefore, that such a method of training not only limits rational teaching, but also constitutes a considerable threat to a young player's health. This thesis is supported by many studies within the fields of sports medicine and theory of sport [2, 5, 6, 7]. Furthermore, research on the subject has proved that developing new solutions for the football training process (reducing motor strain in favor of technical preparation) decreases the injury rate of lower limbs [8]. Thus, training should take into account the player's health and focus more on the specificity of football, which is based more on purposeful actions and accurate decision-making than on thoughtless physical engagement [9]. In view of the above observations, a question arises about traditional football training: how does one increase the effectiveness of football training by reducing strain, which considerably affects the injury rate of lower limbs? It seems that a promising method for achieving this aim is looking for solutions based on the intellectualization of teaching of motor actions.

The Dictionary of Polish Language defines intellectualization as "the ability to understand situations around oneself and to find appropriate, purposeful reactions: the ability to understand in general, cleverness, comprehension" [10]. As far as intellectualization in the teaching of sports games is concerned, a few selected definitions can be used; according to Naglak, "the intellectualization of the teaching process is nothing else but becoming a conscious participant in the process by imbuing one's actions with an intellectual quality" [2].

Panfil defines intellectualization of teaching of motor actions as "replacing uncontrolled behavior with intellectual, in other words, conscious, control on the part of the athlete" [11]. Therefore, the issue here is the conscious reception of motor stimuli, i.e., perception of movement, based on thinking, with mental actions related to understanding, apprehension, assessment, and inference [2, 4, 11].

In teaching sports games, intellectualization aimed at raising the effectiveness of a sportsperson's actions involves two main directions of influence: developing the efficacy of mental processes (perception, intelligence, and decision-making) and the process of sharing specialist knowledge [12, 13]. In the practical teaching of sports games, this means providing the player with knowledge about actions in an effective way and using this knowledge to teach actions through activating that player's mental processes [4, 14, 15, 16].

To realize the aims of motor actions in sports games, intellectualization of teaching should involve learning the theoretical rules of effective motor actions while taking into account biomechanical laws that accompany motor actions [17]. This is because research has proved that the more aware an athlete is of actions and their use (conscious participation in an action), the better they are at perceiving different situations in a game and effectively realizing the aims of the game [7, 8, 16, 17] .

Assuming that effective development of motor habits in sports games takes place on the level of meaning and motion [18] , it is speculated that intellectual teaching compensates for an excessive amount of time devoted to practical training, while prolonged effort (strain) severely exploits the body, especially that of a young athlete.

Therefore, it may be assumed that a player's conscious participation in the process of training will lead towards effective teaching of sports that does not endanger health.

Aim of the study, research questions, and research hypotheses

Assessments conducted in this study are utilitarian in nature. This is because the main aim of the study was to modify the current notion of teaching methodology in sports games by emphasizing the role of the knowledge of motor actions being learned and actions within the game, based on football. Therefore, based on the assumption that taking conscious actions can significantly increase a player's effectiveness [2, 3], the study looked for confirmation of this thesis in terms of physical health, that is, whether conscious actions affect the safety of the game by reducing the risk of injury of lower limbs in football players. Thus (not to interfere with the main aim), the effect of intellectualization on effectiveness of teaching sports games was assessed first, followed by the assessment of the effect of intellectual training (conscious actions in football) on the injury rates of lower limbs.

The study was conducted in institutions that train young, talented players (adepts of football).

Taking into account that young, talented players in Athletic Championship schools undergo high-volume, high-intensity training (a total of 20 sessions within the microcycle, as required by the curriculum), the study looked for didactic measures that would display a rational impact (intellectualization of the teaching process). These measures were the object of research and were used to determine:

1. whether mental teaching (intellectualization) will benefit the efficiency of motor (technical) actions,
2. whether intellectualization of teaching that reduces physical strain put on the athlete and emphasizes conscious actions will reduce the injury rate of lower limbs in young players.

If the answer to these questions is found to be positive, it will allow one to look for reserves in other areas of influence in a young player's training. By solving this problem, we can expect significant benefits related to didactics and health, as the effectiveness of such teaching will increase the effectiveness of actions and decrease strain during sports training, which in turn will decrease the risk of exploiting the body of an athlete.

With the above considerations in mind, we proposed the following research hypothesis:

Intellectual elements during training compensate for physical and motor impact, thus increasing the effectiveness of technical actions and decreasing injury rate of lower limbs in young football players.

Material and methods

The method of pedagogical experiment was used to assess effectiveness (of learning and teaching) of special motor skills. The technique of parallel groups was used [19]: the experimental group (E) and the control group (C).

The independent variable in this study was the method of presenting and distributing information based on the intellectualization of teaching of motor actions (special techniques) performed by the player.

The dependent variables were quantifiable results pertaining to:

1. specialist knowledge on motor actions of players;
2. ability of the players to perform technical actions in isolated conditions and during games;
3. the assessment of injury rates of muscles and joints of lower limbs in study participants.

Study participants comprised students of the Athletic Championship School of Football (ACSF) in Krakow aged 16 years (i.e., the younger junior category) who underwent football training in which their physical strain (physical activity according to the curriculum and regulations of the ACSF) was rigorously controlled. Continuous research was conducted in annual cycles from 1996 to 2002. The annual cycles were as follows:

I – 1996/1997, 10 participants each in the experimental (E) and control (C) group, for a total of 20 participants

II – 1997/1998, 10 participants each in the experimental (E) and control (C) group, for a total of 20 participants

III – 1998/1999, 10 participants each in the experimental (E) and control (C) group, for a total of 20 participants

IV – 1999/2000, 8 participants each in the experimental (E) and control (C) group, for a total of 16 participants

V – 2000/2001, 8 participants each in the experimental (E) and control (C) group, for a total of 16 participants

VI – 2001/2002, 8 participants each in the experimental (E) and control (C) group, for a total of 16 participants

A total of 108 young players participated in the continuous research. They were divided into 2 groups of 54 players each as part of an organized selection: the experimental (E) and the control (C) group.

Throughout the research, experimental groups underwent experimental training sessions (theoretical and practical classes) of 45 minutes once per week. These sessions were based on intellectual training and in general involved a smaller volume of practical classes. Overall, each experimental group underwent 92 sessions of intellectual training. This constituted about 14% of global annual volume of training (658 sessions).

In the control group, training was conducted using traditional methods. Knowledge of techniques of playing football was taught during practical exercises as part of instruction.

The research was divided into 2 stages. In the first stage, an introductory assessment (a pre-test) was conducted to determine base values and to select uniform (as far as it was possible) research subgroups (with no statistical differences) in terms of specialist knowledge and motor fitness. The groups were chosen based on an organized selection [4], wherein players were classified according to ranking charts. In the second stage, a second assessment (a post-test) of specialist knowledge and motor fitness was conducted.

Training in experimental and control groups took place under the following rules:

1. Didactic aims realized during the training sessions were the same.
2. The number of sessions was the same in E and C groups.
3. The sessions lasted 45 minutes in E and C groups.
4. The method of teaching motor actions constituted the difference in didactics of the sessions between the E and C group.
5. The control groups underwent 92 practical sessions more than the experimental groups within the annual cycle.

6. The experimental groups underwent 92 theoretical sessions (intellectualization of the process of teaching) more than the control groups within the annual cycle.

The following assumptions were made for both E and C groups during the research:

1. The curriculum would be realized according to the prepared program.
2. Training sessions would be conducted by the same trainers.
3. The same students (football players) would participate in the training sessions. Results for the E and C groups were calculated based on research participants with the same attendance (overall attendance in the E and C groups was 91%).
4. The intensity of the training sessions was the same for the E and C groups: individual and group exercises (the area of aerobic and mixed metabolism) and teaching through play (the area of mixed and anaerobic metabolism). The participants were monitored using sports testers.

The experimental training involved intellectual teaching of motor actions, i.e., technical skills during play, aimed to develop motor imagery related to a given motor technique. Verbal and visual methods were used in intellectual teaching and were treated as didactic enhancement. The experimental method took into account the following stages of technical teaching of football [4]:

Stage I: Introductory knowledge on the motor structure of a given action and on biomechanical rules pertaining to a given motor task (presentation of figures and schemas).

Stage II: Presentation of educational video footage showing an isolated motor action in real time, followed by the same footage shown in slow motion to enable a more detailed analysis and better internalization.

Stage III: A practical presentation of a model motor action, followed by the players attempting to perform the action themselves.

Stage IV: Analytical teaching of practical skills (methodology of teaching motor actions), supported by visual material (such as programmed learning or a series of pictures showing a sequence of motions performed during a technical action).

Stage V: Presentation of a video recording (obtained during a training session with a camera) of the player performing a motor action being learned (the player watches their own recorded movements).

Stage VI: A correct description of a given motor action (motor imagery, i.e., ideomotion) – intellectual training.

Stage VII: Teaching with the use of creative methods:

Task-based methods in which the trainer postulates a problem and the players try to solve it by using various movements (techniques), such as performing a motor action by oneself as part of a game.

Stage VIII: The trainer and the student jointly assess the performed motor action (self-assessment).

A standardized test (t = 0.85, r = 0.87) of knowledge on a motor (technical) action was used to assess the level of knowledge of the participants [8]. The test included problem-based open-ended questions, close-ended questions, and questions about the participant's opinion that concerned an alternative choice for solving a given motor action. The problems were related to motor actions during a real football match. The questions concerned the correctness of motor (technical) actions and took into account the analysis of movement, biomechanical rules, and rules of the effective performance of an action during the game.

A standardized test (t = 0.88, r = 0.87) of effectiveness of motor actions was used to assess motor actions of young football players [8]. The test involved the following measurements of motor actions: sense of the ball (juggling with legs and the head), speed of slalom dribbling, sending the ball as far as possible by kicking it or hitting it with one's head, accuracy of passing the ball at a distance, accuracy of kicking (kicking the ball into selected sectors of the goal). Objectified observation sheets (t = 0.93, r = 0.86) were used to assess motor actions of participants during 4 × 4 simulation matches [4]. Players were selected for the teams in an organized way (according to ranking grades for special fitness) and were assessed at 4 matches in which participants from the experimental groups played against participants from the control groups. Selected individual defensive actions (use of one's body and passing and receiving the ball by running ahead) and offensive actions (leading the ball, fakes, dribbling, and kicking) were analyzed. Successful and unsuccessful actions were taken into account that allowed for calculating reliability indicators [11]. The results of tests of physical fitness in isolated conditions and during simulated play were converted onto a standardized 10-point scale (point tables). The experimental training took place with participation and supervision on the part of the faculty of the Section of Theory and Methodology of Football at the University School of Physical Education in Krakow.

Each participant's knowledge of motor actions and their motor fitness were measured as part of the assessment of the studied groups. Analysis of medical documentation (information sheets on lower limb injuries) in terms of strain during training was employed to assess a participant's health. In particular, we conducted a detailed analysis of injuries of muscles and joints of lower limbs in participants during their annual cycle of training (the duration of the experiment for a given group). We took into account injuries of lower limb muscles and joints in participants whose state qualified them to be excused from attending physical training for more than 3 days [20].

Basic mathematical operations were used to calculate the research results: arithmetical mean, standard deviation, and Student's t-test. The Student's t-test was used to determine the statistical significance of observed differences. The Pearson product-moment correlation coefficient was used to determine correlations between assessed values [21].

Results

It was assumed that study participants who underwent the experimental training (intellectual teaching of motor actions) will perform better in terms of specialist knowledge and efficiency of motor actions in isolated conditions and during the game. The study also attempted to establish whether intellectual teaching reduces the injury rate of lower limbs. With this in mind, a research aim was realized. First, we looked for an answer to the question: Will the experimental teaching lead to measurable benefits in terms of a participant's efficiency of motor actions? Next, we attempted to establish whether the experimental training based on intellectual teaching of football, which compensated for the volume of physical strain, will reduce the exploitation of the muscle-tendon system of lower limbs in young football players.

No statistical differences were found for the measured parameters of motor skills and efficiency of motor actions as a result of an organized selection in the control and experimental groups prior to the experiment (first assessment). Furthermore, players selected for the experimental and control groups were physically healthy prior to the experiment (there were no contraindications to performing physical exercises). Therefore, the groups can be considered uniform (Tables 1–3).

The research results also indicated that the measured parameters improved considerably over the 10-month training in both the experimental group and the control group. However, in terms of practical and research-related purposes, the dynamics of improvement of the results in the experimental and control groups were important for the applied method. That is why the research sought to establish the differences between the experimental and control groups in the second assessment conducted after the experiment (that is, after the annual research cycle).

When analyzing the specifics of football, specialist knowledge can be considered the basis for motor actions of the players [2, 3]. Such knowledge determines the efficiency of actions in the changing conditions of the match, wherein a player anticipates, perceives, and decides on the best way to perform a motor action based on their own experience [15]. That is why the first stage of the research process was related to this disposition. The experimental groups showed statistically higher values ($P < 0.01$) of the progress in learning (Table 1) compared to the control groups.

Table 1. Mean values of indicator of knowledge on motor actions in studied groups

Studied groups / Order of assessments	Experimental groups (E – points)	Control groups (C – points)	Significance of differences Student's t
First assessment	38.33 ± 4.83	38.55 ± 4.66	0.84
Second assessment	48.53 ± 7.65	41.98 ± 5.75	4.65***

*** Significant ($P < 0.001$) difference compared to the control group

The analysis of progress in learning motor actions in isolated conditions found interesting results. Table 2 shows that motor skills were more advanced in the experimental groups than in the control groups, with statistical significance of $P < 0.05$. This means that participants undergoing the experimental training progressed faster during the process of teaching.

The best way to verify progress in sports training is to play a match. It is the match that, in the circumstances of direct competition, determines the level of parameters of effective actions. Even though the analysis of calculated reliability parameters that

Table 2. Assessment of motor actions in isolated conditions (a technical test) in studied groups

Order of assessments \ Studied groups	Experimental groups (E – points)	Control groups (C – points)	Significance of differences Student's t
First assessment	57.20 ± 4.19	58.28 ± 4.55	1.53
Second assessment	62.80 ± 5.1	60.96 ± 4.25	2.21*

* Significant (P < 0.05) difference compared to the control group

Table 3. Assessment of motor actions in simulation games in studied groups

Order of assessments \ Studied groups	Experimental groups (E – points)	Control groups (C – points)	Significance of differences for E and C groups
First assessment	56.12 ± 3.5	57.41 ± 4.19	1.99
Second assessment	60.71 ± 3.95	59.52 ± 4.03	1.68
Significance of differences for the first and second assessments	6.49***	2.81*	

Significant difference: * (P < 0.05), *** (P < 0.001) compared to the first and second assessment

reflected the efficiency of a player's actions (Table 3) did not find significant differences between the groups during the second assessment, reliability increased considerably more dynamically in the experimental group.

Differences between the first and second assessments showed statistical significance of α = 0.001 in the experimental group and α = 0.05 in the control group. These values may lead to the conclusion that the experimental training based on intellectualization was better at developing dispositions for effective play during a match. This thesis is confirmed by a high correlation between the main factor of intellectual teaching, i.e., the level of specialist knowledge, and the effectiveness of actions in isolated conditions and during a match (Table 4).

The obtained results confirmed the benefits of intellectual training and provided grounds for further research aimed at establishing whether intellectual training (characterized by a reduced strain during training) would also benefit health of young players (that is, whether it would reduce the injury rate of lower limbs).

In terms of health of players, it was found that the number of training sessions involving physical effort caused very significant (α = 0.001) differences between the experimental and control groups (Table 5).

This means that participants in the control groups underwent more practical sessions and, therefore,

Table 5. Differences in strain during training within the annual training cycle of the studied groups

Parameter \ Group	Experimental group (n – number of training sessions)	Control group (n – number of training sessions)
Arithmetical mean	565.52	657.77
Standard deviation	16.62	17.21
Significance of differences	8.49***	

*** Significant (P < 0.001) difference compared to the control group

Table 4. Correlation between selected motor actions and the level of specialist knowledge in studied groups

Type of measurement \ Value in a group	Value in a given group		Level of specialist knowledge in a given group		Correlation	
	Group (points)		Group (points)		Group (points)	
	E (δ)	C (δ)	E (δ)	C (δ)	E (δ)	C (δ)
Test: technical efficiency	62.80 ± 5.1	60.96 ± 4.25	48.53 ± 7.65	41.98 ± 5.75	0.58***	0.56***
Game: technical efficiency	60.71 ± 3.95	59.52 ± 4.03	48.53 ± 7.65	41.98 ± 5.75	0.337*	0.441**

Correlation (statistical significance): *α = 0.05, **α = 0.01, *α = 0.001

Table 6. Mean number of injuries of muscles and joints in studied groups

Group / Parameter	Experimental group (number of injuries)		Control group (number of injuries)	
	Muscles	Joints	Muscles	Joints
Arithmetical mean	0.77	0.53	1.09	0.70
Standard deviation	0.61	0.62	0.83	0.77
Significance of differences	→	→	2.54**	2.11*

Significant difference: * ($P < 0.05$), ** ($P < 0.01$) compared to the control group

Table 7. Number of injuries of lower limbs in players from the ACSF within the annual training cycle

Location of injury	Experimental group (n – number of injuries)	Control group (n – number of injuries)
Muscles	42	59
Joints	29	38
Total	71	97

Table 8. Number of injuries according to location

No.	Location of injury	Experimental group (n – number of injuries)	Control group (n – number of injuries)
1	knee joint	16	21
2	ankle	13	17
3	quadriceps femoris muscle	18	26
4	biceps femoris muscle	14	20
65	triceps surae muscle	10	13

underwent greater physical exploitation during the process of training. Next, the study provided data on how intense practical training affects the injury rate of joints and muscles of lower limbs. Table 6 shows that participants in the experimental groups, who underwent mainly intellectual training, suffered considerably fewer injuries than participants in the control groups. The difference was statistically significant for injuries of both muscles ($P < 0.01$) and joints ($P < 0.05$) of the lower limbs.

Tables 7 and 8 provide data on the injury rates of lower limbs within the annual cycles.

As mentioned above, an essential part of intellectualization of teaching is the effectiveness of sharing specialist knowledge. Publications on the subject state that specialist knowledge determines what action a player is to take next and how to perform it [2, 3, 4, 16, 22]. In practical terms, this means that the player realizes a given aim in a conscious way [23] by following tactical and motor rules based on biomechanical characteristics of a given action [17]. With the above considerations in mind, an attempt was made in the further part of the study to assess the effect of specialist knowledge on the injury rates of muscles and joints of lower limbs. Statistical analysis of obtained results found a strong relationship between the level of specialist knowledge

Table 9. Effect of level of specialist knowledge on injury rate of lower limbs in studied groups

Group / Parameter	Experimental group			Control group		
	Knowledge (points)	Muscles (n)	Joints (n)	Knowledge (points)	Muscles (n)	Joints (n)
Arithmetical mean	48.53	0.77	0.53	41.98	1.09	0.70
Standard deviation	7.65	0.61	0.62	5.75	0.83	0.77
Correlation	→	0.458**	0.321*	→	0.399**	0.304*

Significant difference: * ($P < 0.05$), ** ($P < 0.01$) compared to the control group in both E and C groups and the injury rate of muscles ($P < 0.01$) and joints ($P < 0.05$) of lower limbs (Table 9).

The analysis of the concept of intellectual training of young players shown above shows the great didactic value of this method despite its unpopularity in the everyday teaching of sports games [4]. It can therefore be concluded that intellectual teaching increases the effectiveness of training of young athletes. The obtained results are also important for the health of young players, as they indicate a reduction of physical and motor impact during their training. This has been confirmed by this research, during which the experimental group spent 14% less time on practical training (3600 minutes throughout the annual cycle). This value constitutes a significant part of the total strain of the motor-tendon system in training of football players [9]. Intellectual teaching optimized the training process and had a twofold effect. Firstly, it reduced the volume of strain; secondly, it increased time of restitution within the microcycle. These factors may have considerably benefited the effectiveness of the motor system in study participants [20, 24]. The study also indicated the major influence of intellectual teaching on the effectiveness of technical actions performed in isolated conditions and during a match (Table 4). This means that methods that reduce physical strain can be used in intense sports training (in optimal proportions). The confirmation of the influence of specialist knowledge on a player's effectiveness during a game can also mean that physical impact during sports training will not endanger a player's health. For example, knowing biomechanical rules in motor structure (optimal posture during actions, optimal dynamics of movement) can significantly decrease the number of sports injuries [17]. Taking into account that the problem of volume of strain sustained by an athlete's body, especially in young players, has a major influence on their health, intellectual teaching gains a humanitarian aspect [6]. Furthermore, intellectual training affects a sportsperson's mind, which benefits their health by being consistent with the notion of holistic training. Intellectual training in general means searching for reserves in all aspects of training of athletes that could compensate for the excessive amount on time spent on physical effort, a factor which is especially important for young players.

Conclusions

1. Intellectual training increases the effectiveness of motor actions of young football players;
2. Incorporating intellectual teaching, which is based on conscious actions, into the curriculum benefits the health of players.

Postulates

1. There is a need for a more comprehensive teaching of knowledge on motor actions in sports games due to the long-term process of acquiring specialist skills;
2. Intensive training of talented players should include methods of high didactic and health-related values.

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CHANGES IN TACTILE INFORMATION DURING SPORT TRAINING IN BASKETBALL PLAYERS AND SWIMMERS

ZMIANY INFORMACJI DOTYKOWEJ PODCZAS TRENINGU SPORTOWEGO NA PRZYKŁADZIE ZAWODNIKÓW UPRAWIAJĄCYCH KOSZYKÓWKĘ I PŁYWANIE

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Key words: tactile sensitivity, perception, aesthesiometer, basketball, swimming
Słowa kluczowe: wrażliwość dotykowa, percepcja, estezjometr, koszykówka, pływanie

SUMMARY • STRESZCZENIE

Aim of the study. The aim of the study was to determine the changes in tactile information in two sport disciplines that train in different environments and in which different external stimuli affect the surface of the skin.

Material and methods. Aesthesiometric measurements were carried out with 36 male basketball players, 32 female swimmers, and 32 women representing a control group, aged 19 to 20 years. In order to establish changes in tactile information taking place during sport training, measurements were taken 3 times (the first measurement was taken before the start of the training, the second measurement after 10 minutes, and the third measurement after 30 minutes of sport training) and on 3 measurement points of the dominant hand: on the pulp of the little finger, on the pulp of the index finger, and on the metacarpus on the inside of the hand between the thenar and hypothenar. A Touch-Test™ Sensory Evaluator (Semmes-Weinstein Monofilaments) aesthesiometer was used for the measurement. Nonparametric tests were used for the analysis of the results.

Results. A gradual lowering of tactile sensitivity was noted in basketball players during training, and a gradual increase in tactile sensitivity was noted in swimmers during training.

Conclusions. It was noted that during specialist sport training, changes in tactile threshold occur in athletes depending on external stimuli characteristic for individual sport disciplines.

Cel pracy. Określenie zmian informacji dotykowej w dwóch dyscyplinach sportowych, których treningi odbywają się w różnych środowiskach, a na powierzchnię skóry oddziałują odmienne bodźce zewnętrzne.

Materiał i metody. Pomiarom estezjometrycznym poddano 36 zawodników uprawiających koszykówkę, 32 zawodniczki uprawiające pływanie i 32 kobiety reprezentujące grupę kontrolną, w wieku od 19–20 lat. W celu ustalenia zmian informacji dotykowej zachodzących w czasie treningu sportowego pomiary wykonano w 3 terminach pomiarowych (pomiar 1 wykonano przed rozpoczęciem treningu, pomiar 2 – po 10 minutach a pomiar 3 – po 30 minutach treningu sportowego) i w 3 punktach pomiarowych ręki dominującej: na opuszce palca małego, na opuszce palca wskazującego, na śródręczu po stronie dłoniowej ręki, między kłębem a kłębikiem. W badaniach wykorzystano estezjometr: Touch-Test™ Sensory Evaluator (Semmes-Weinstein Monofilaments). Do opracowania wyników zastosowano testy nieparametryczne.

Wyniki. Stwierdzono stopniowe obniżanie się wrażliwości dotykowej podczas treningu u zawodników uprawiających koszykówkę w wybranych punktach pomiarowych i stopniowy wzrost wrażliwości dotykowej podczas treningu u zawodniczek uprawiających pływanie.

Wnioski. Podczas specjalistycznego treningu sportowego zachodzą zmiany w wysokości progu dotykowego u zawodników. Zmiany te zależne są od charakterystycznych dla poszczególnych dyscyplin sportowych bodźców zewnętrznych.

Introduction

Thanks to signals coming from joint afferents, muscle afferents, and cutaneous afferents after the process of analyzing them at various levels of the nervous system, proprioception allows for planning, executing, and controlling movement, regulation of muscle tone, and coordination of muscle work. The receptors of this sense (proprioceptors) receive stimuli related to pressure on the skin and skin stretching, as well as position and movement of body parts in relation to each other. Each population of afferent neurons contributes to proprioception in different ways. Muscle afferents appear to mediate position sense; joint afferents play a role in sensations associated with moving the joint to a limit of its motion. Cutaneous afferents may have a "facilitatory" role on afferents from other structures. The role of cutaneous afferents in proprioception comes mainly from the fact that cutaneous afferent neurons, particularly the slowly adapting afferents, in fact encode joint movements and joint position [1]. Cutaneous afferents provide not only certain proprioceptive information, but also exteroreceptive information relating to direct surroundings of the body, receiving stimuli directed to individual parts of the skin during its contact with the ground, clothing, and, in sports, equipment and apparatuses. The tactile afferents that innervate the inside of the hand signal the transformation of soft tissues that occurs when the hand interacts with objects and thus provide information about the physical properties of the object and the contact between the object and the hand [2]. When an object contacts the skin, the fingertip is at first compliant, conforming to the shape of the object and changing the geometry of the distal segment. Information about curvature of objects contacted by the human fingertip and the direction of the contact force can be conveyed both by firing rates assessed by spike counts [3, 4] and by precise timing of spikes in populations of tactile afferents [5]. The brain uses tactile afferent information related to the time course, magnitude, direction and spatial distribution of contact forces, the shapes of contacted surfaces, and the friction between contacted surfaces and the digits [2]. Thanks to these roles played by cutaneous afferents, one cannot disregard the significance of tactile sensitivity in sports, and since it is an ecosensitive property, the uniqueness of individual sport disciplines in which intensive and highly directed means are used may cause changes in tactile sensitivity. These changes may affect not only the encoding of fingertip events by tactile afferents, but also affect the motor commands. The CNS needs information about the current mechanical state of the soft tissues both for accurate motor commands and for predicting and evaluating their sensory consequences [2]. The aim of the study was to establish the changes in tactile sensitivity in two sport disciplines that train in different environments and in which different external stimuli affect the surface of the skin.

Material and methods

The study participants were 36 basketball players (having regular sport training supervised by coaches for at least 5 years), 32 female swimmers (having regular training supervised by coaches for at least 7 years), and 32 women representing a control group for swimmers (consisting of students of the University School of Physical Education in Poznań who did not participate in competitive sports) in a narrow age range from 19 to 20 years. The fact that mechanical properties of skin change with age may contribute to changes in tactile sensitivity [6]. None of the participants had any conditions that could interfere with the experiments such as having neurological or dermatological problems. Tactile sensitivity is measured using calibrated filaments, such as Semmes-Weinstein monofilaments [7] or von Frey hair [8]. The filaments of the aesthesiometer used in the current study are characterized by an appropriate strength of pressure expressed in grams. In order to facilitate statistical calculations and normalize the distribution of the dependent variable, the creator of the aesthesiometer, Sidney Weinstein, found the logarithm of the numerical value of the pressure force expressed in grams according to the formula $\log_{10F(mg)}$, and he obtained measurement units, so-called Semmes-Weinstein monofilaments (SWM). The complete set of 20 monofilaments ranges from 1.65 to 6.65 SWM (0.008–300 g target force). In this study, as recommended by the creator of the aesthesiometer, numerical values corresponding to markings of filaments were selected as measurement units for the statistical analysis: SWM ($\log_{10F(mg)}$).

Before the beginning of the study, the method was explained to each participant. Next, the participant undertook a pre-test to experience a supraliminal stimulus with a thick, perceptible filament and subliminal stimulus with a thin, imperceptible filament. Then, the participant was asked to close his or her eyes, and the filaments of the aesthesiometer, starting from the filament with the smallest pressure strength, were applied on selected measurement points of the dominant hand (glabrous skin): the pulp of the little finger, the pulp of the index finger, and the metacarpus (on the palm side of the hand, between the thenar and hypothenar) until the participant indicated a threshold filament. Aesthesiometric measurements were taken 3 times. In the groups of athletes, the first measurement was taken before the start of sport training specific for each group, the second measurement was taken after 10 minutes, and the third measurement, after 30 minutes of sport training. In the control group, in which the participants soaked their hands in a specially prepared container with swimming pool water, the tactile threshold was also measured 3 times: the first measurement was taken before putting hands in the water ("dry" measurement); the second measurement, after 10 minutes of soaking hands; the third measurement, after 30 minutes of soaking hands. With swimmers, the second measurement happened after the end of the warm-up. The third measurement followed after passing 800 m of strength and technical exercises for arms and legs. With basketball players, the second measurement followed by half-time warm-ups, and the third measurement at the beginning of the major part of the training, after a series of dynamic exercises in pairs with balls. Nonparametric tests were used for the statistical analysis (the results of the Shapiro-Wilk test showed that distribution of the dependent variable significantly varies from the normal distribution).

Results

In the analysis of the effect of sport training on the tactile threshold in basketball players, Friedman's ANOVA test was used. The result of this test on metacarpus ($F = 26.42$, $p = 0.01$) justified performing a detailed comparative analysis of tactile sensitivity of the measurement point on other measurement times, for which a post-hoc analysis for Friedman's test was used. A gradual lowering of tactile sensitivity (an increase in tactile threshold) was noted in individual measurements, whereas statistically significant differences were noted between the first and second measurements and the first and third measurements (Table 1). The result of Friedman's ANOVA test on the pulp of the index finger ($F = 5.26$, $p = 0.07$) indicated the tendency to significant variation between measurements on subsequent measurements, but the post-hoc analysis for Friedman's test did not show statistically significant differences. The result of Friedman's ANOVA test on the pulp of the little finger was statistically insignificant. The changes in the tactile threshold at measurement points upon subsequent measurements in basketball players are presented in Figure 1.

In the group of swimmers and in the control group, the results of Friedman's ANOVA test (on the pulp of the index finger: swimmers $F = 11.46$, $p = 0.01$, control group $F = 30.72$, $p = 0.01$; on the pulp of the little finger: swimmers $F = 14.72$, $p = 0.01$, control group $F = 19$, $p = 0.01$; on metacarpus: swimmers $F = 18.92$, $p = 0.01$, control group $F = 13.93$, $p = 0.01$) justified performing a detailed comparative analysis, which was carried out using the post-hoc test for Friedman. Both in the group of swimmers and in the control group, the lowering of the tactile threshold in all measurement points was noted (an increase in tactile sensitivity) on subsequent measurements (Figure 2). Statistically significant differences were noted: on the pulp of the index finger (in swimmers, between the first and third measurements; in the control group, between the first and second measurements and between the first and third measurements), on the pulp of the little finger (in swimmers, between the first and third measurements; in the control group, between the first and second measurements and the first and third measurements), on the metacarpus (in swimmers, between the first and second and the first and third measurements; in the control group, between the first and third measurements) (Table 1).

Using the U Mann-Whitney test mean values of the tactile threshold of the pulp of the index finger, the pulp of

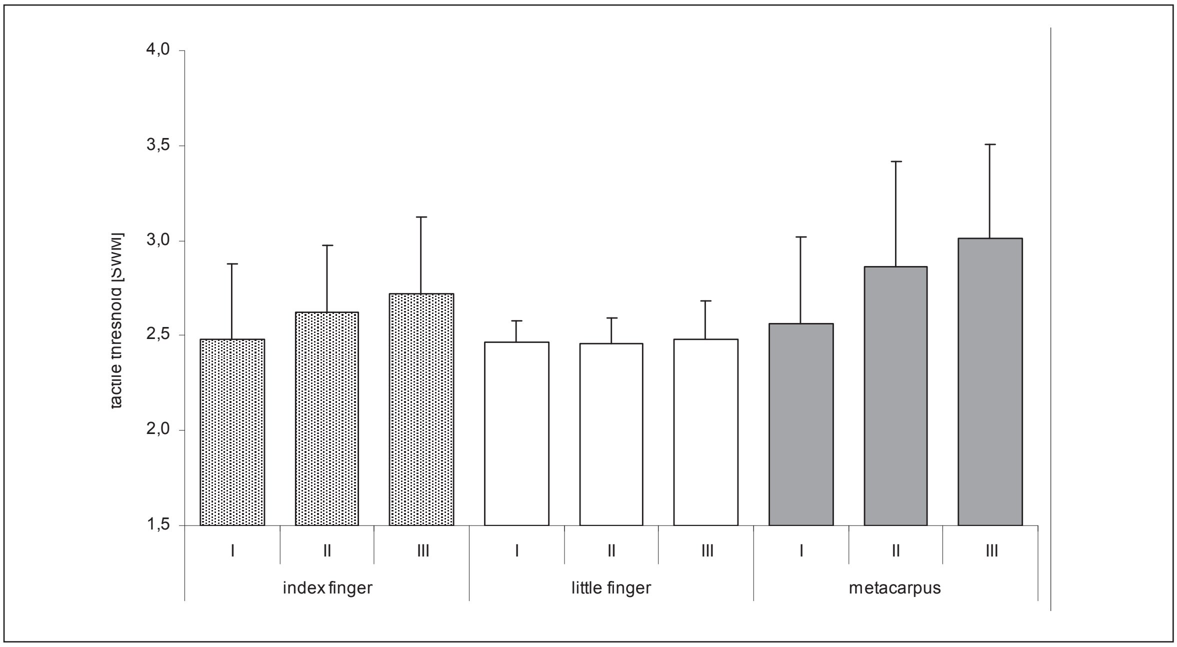

Figure. 1. Changes in the level of tactile threshold of measurement points on three measurements (1 – measurement before the start of the sport training, 2 – measurement after 10 minutes of sport training, 3 – measurement after 30 minutes of sport training) in basketball players

the little finger and metacarpus were compared between swimmers and the control group. The swimmers showed a higher tactile sensitivity in all measurement points compared to women in the control group; moreover, the statistically significant difference was noted on the index finger ($p = 0.01$) and on the little finger ($p = 0.05$).

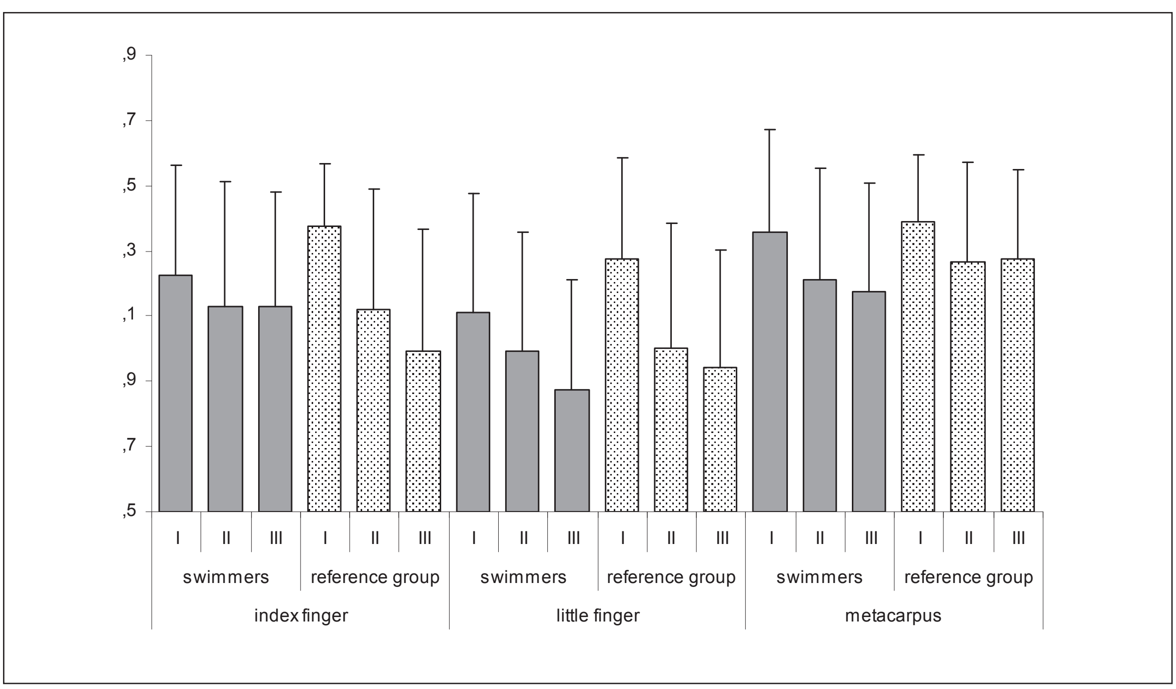

Fig. 2. Changes in the level of tactile threshold of measurement points on three measurements (the first (I) – "dry" measurement, the second (II) – measurement after 10 minutes of swimming or immersing hand in water, the third (III) – measurement after 30 minutes of swimming or immersing hand in water) in the swimmers and in the reference group

Table 1. Significant differences in terms of changes in the level of tactile threshold of measurement points between subsequent measurements (the first (I) – measurement before the start of the sports training unique for each of the groups, the second (II) – measurement after 10 minutes of sports training, the third (III) – measurement after 30 minutes of sports training) in basketball players, swimmers and in the control group

	index finger			little finger			metacarpus		
	I–II	II–III	I–III	I–II	II–III	I–III	I–II	II–III	I–III
basketball players	ns	ns	ns	ns	ns	ns	$p \leq 0.01$	ns	$p \leq 0.001$
swimmers	ns	ns	$p \leq 0.05$	ns	ns	$p \leq 0.05$	$p \leq 0.05$	ns	$p \leq 0.01$
reference group	$p \leq 0.01$	ns	$p \leq 0.01$	$p \leq 0.05$	ns	$p \leq 0.01$	ns	ns	$p \leq 0.01$

ns – non significant difference

In all studied groups, the lowest tactile threshold was noted on the pulp of the little finger, followed by the pulp of the index finger, and the highest tactile threshold on the metacarpus. The statistically significant difference occurred only between the pulp of the little finger and metacarpus ($p = 0.05$) both in basketball players and in swimmers.

Discussion

Skin receptors, located on the boundary of the epidermis and dermis, are Meissner's corpuscles (tactile corpuscles, FA I) and Merkel's disks (tactile meniscuses, SA I). They are related to perception of shape and type of surface. Deep in the skin, there are Ruffini corpuscles (SA II) and Pacinian corpuscles (FA II), which are mainly sensitive to skin stretching. During the everyday grasping and manipulating that constitute normal hand function, there is a complex sequence of events. Information about complex mechanical fingertip events are conveyed by the relative timing of impulses in individual members of ensembles of afferents, and this code can operate fast enough to account for the use of tactile signals in natural manipulation tasks [5].

The choice of measurement points for this study was a result of the choice of specific sport disciplines in which the hand is subject to various environmental influences during sport training as well as from the distribution of tactile receptors. Digital pulps are characterized by a high density of tactile receptors. For example, the density of nerve fibers associated with Meissner corpuscles is 1.4 fibers/mm^2 at the fingertip [9]. Their number decreases toward the wrist. An appropriately higher density of receptors is related to a higher tactile sensitivity, which is in line with our results (Figure 1 and 2). In basketball players, manipulation of the ball (bouncing, passing) causes mechanical pressures, numerous frictions, and blows to the fingers and wrists. They can modify the epidermis, and this may cause changes in tactile sensitivity (Figure 1, Table 1). An increase in tactile sensitivity in swimmers and in the control group (Figure 2, Table 1) was caused by soaking the body in water, which led to changes in mechanical properties of the skin as a result of hydration of its corneal layer [10, 11, 12, 13] and may result in a change in its tactile sensitivity [13, 14]. A higher tactile sensitivity of swimmers compared to women in the control group in the first measurement may be explained by a lot of training and competitions in the water environment; this is related to the sensitizing of skin receptors to stimuli, which may lead to better efficiency of tactile analyzer [15].

Skin receptors provide information about the body's direct surroundings receiving stimuli affecting individual parts of the skin—for example, during its contact with the ground, clothing, apparatuses, equipment, or in the case of swimmers, subtle physical stimuli coming from the water environment.

The SA I and FA I populations, which have a high innervation density on the finger pad, convey information about the temporal and spatial parameters of surfaces scanned over the skin, with the SA I population appearing to play the major role in signaling spatial information [16]. Information about characteristics of the object, such as its local shape, orientation, or position on the skin, are signaled primarily by the SA I receptors [17, 18, 19, 20, 21]. The contact force between the finger and the object is also signaled by the SA I population in the region of contact, but this signal starts to saturate at higher forces [22]. In another experiment, the stimuli consisted of spheres of different curvature contacting the finger-pad skin at different forces. The SA I receptors innervating the sides and end of the distal segment responded. It is unlikely that the afferents on the sides and end of the finger make a major contribution to encoding the local shape of objects contacting the finger pad [22], but these afferents may play a role in determining load forces on the digits during manipulations [23] and provide the CNS with considerable information about contact force on the finger pad [22].

Slowly adapting type 2 (SA II) cutaneous afferents respond to lateral stretching of the skin that occurs in finger movements [24], and they discharge steadily during certain maintained finger positions [25, 26]. SA II afferents are the best candidates for providing proprioceptive information about joint position [1]. SA IIs produce sensations of skin stretching, fluttering, or unnatural sensations [27]. In another study, in the analysis of how tactile afferents of the distal phalanges encode fingertip forces, it was noted that the responses in most SA I, SA II, and FA I afferents of the distal phalanges are influenced by the direction of fingertip forces that occur in manipulative tasks. The directional preference of the afferent was in some instances related to the location of its receptive field on the phalanx [28]. The role of skin receptors in individual sport disciplines cannot be underestimated. There are few studies on tactile sensation formation due to physical activity [15, 29, 30, 31]. The athletes must be characterized by a high sensitivity, perception of the surrounding environment, and have the properties generally called "equipment feeling," "apparatus feeling," or "water feeling." An increase in tactile sensitivity noted in swimmers during sport training is a favorable property. In studies of the effect of skin hydration on tactile sensations, it was noted that total hydration of skin within 7 to 8 minutes from the moment of immersion [32] and immersing hands in water for 30 minutes improves tactile sensitivity [33]. Thanks to skin receptors, a swimmer receives stimuli from the water environment, which affects his or her driving movements. This requires a high tactile sensitivity as well as experience that creates and develops such skills. A sudden change in stimuli requires fully developed sensory abilities for a fast and creative motor reaction not only in swimmers, but also in athletes representing other sports. In basketball, "ball feeling" is quite important for the competitor, as it allows the player to manipulate the ball very precisely. Many factors result from feeling the ball, but certainly one factor is tactile sensitivity of the skin. Findings indicate that during practice, their metacarpi become less sensitive; moreover, ball feeling after 10 minutes of classes is already decreasing. This test result is a clear indication for a coach: if intending to work on the nuances of training techniques with the ball, a coach must do so in the early part of training and avoid the high dynamics exercises that reduce the hand's tactile sensitivity. However, in swimmers, the hydration of the skin helps to improve tactile sensitivity. And so, in swimmers, the work on details of the technique should come after about 30 minutes of classes. While this advice is dictated only an aspect of changes of the tactile sensitivity, it is proper to take it under advisement.

Conclusions

It was noted that during specialist sport training, changes in athletes' tactile threshold occur depending on external stimuli characteristic for individual sport disciplines. In basketball players, an increase in tactile threshold was noted (a lowering of tactile sensitivity) with statistically significant changes occurring on metacarpus, whereas in swimmers, during sport training in water, a lowering of the tactile threshold (an increase in tactile sensitivity) was noted in all tested points.

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INTERGENERATIONAL VARIABILITY OF STRENGTH ABILITIES IN CHILDREN FROM THREE MALOPOLSKA AGGLOMERATIONS IN THE CONTEXT OF THEIR SOMATIC AND MENTAL DEVELOPMENT

ZMIENNOŚĆ MIĘDZYPOKOLENIOWA ZDOLNOŚCI SIŁOWYCH DZIECI Z TRZECH AGLOMERACJI MAŁOPOLSKI W KONTEKŚCIE ICH ROZWOJU SOMATYCZNEGO I PSYCHICZNEGO

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Key words: secular trend, children between 4 and 14 years of age, biological and mental development, Malopolska region
Słowa kluczowe: trend sekularny, dzieci w wieku 4–14 lat rozwój biologiczny i psychiczny, region Małopolska

SUMMARY • STRESZCZENIE

Introduction. The Authors used some of the materials from their own research and some gathered by a research team from Jagiellonian University 30 years earlier in order to define long-term change tendencies at the turn of the twentieth and twenty-first centuries in terms of the biological and mental development of children between 4 and 14 years of age living in three different agglomerations of the Malopolska region. The reason for conducting this research was a well-documented phenomenon of temporal variability of the physical and mental development in subsequent generations of people living in a specific ecological niche under the influence of changing environmental conditions.

Aim of the study. The main aim was to discover the range and direction of the long-term generational changes in children between 4 and 14 years of age living in three different agglomerations in the Malopolska region during the system transformation in Poland. Another aim was to assess the influence of intergenerational variability of the children during their progressive ontogenetic development on the range and direction of environmental differences (social gradients) resulting from the sociocultural status of their place of residence.

Materials and methods. The research was conducted between 2005 and 2010 using the observation method. The following characteristics of 1429 boys and girls between 4 and 14 years of age were measured: body height, strength abilities, and nonverbal intelligence. The same observations of somatic, motoric, and mental development conducted between 1975 and 1980 by researchers of Jagiellonian University were used as a point of reference in the assessment of intergenerational changes.

Results. The detected range and direction of long-term change tendencies in somatic, motoric, and mental development in children were relative to: the stage of the biological and mental development, the place of residence, and the level of development of the biological and mental characteristics in the given calendar age.

Conclusions. The research did not confirm the existence of the “scissors effect” and the possibility of changing the environmental differences existing in previous generations in the somatic, motoric, and mental development of children living in the specific environmental niches.

Wstęp. Autorzy – częściowo na podstawie materiałów pochodzących z badań własnych, a po części wykorzystując dane sprzed 30 lat, które zostały zebrane przez zespół badawczy z Uniwersytetu Jagiellońskiego – podjęli się opracowania długookresowych tendencji zmian w zakresie rozwoju biologicznego i psychicznego u dzieci w wieku 4–14 lat, mieszkających w trzech różnych aglomeracjach regionu Małopolski na przełomie XX i XXI wieku. Przesłanką dla podjęcia tych badań było dobrze udokumentowane zjawisko zmienności w czasie poziomu rozwoju fizycznego i psychicznego kolejnych pokoleń mieszkańców określonej niszy ekologicznej pod wpływem zmieniających się warunków środowiskowych.

Cel badań. Poznanie zakresu i kierunku długookresowych zmian pokoleniowych u dzieci w wieku 4–14 lat mieszkających w trzech różnych aglomeracjach Małopolski w epoce transformacji ustrojowej naszego kraju. Zamiarem badaczy była również ocena wpływu zmienności międzypokoleniowej dzieci znajdujących się na etapie progresywnego rozwoju ontogenetycznego na zakres i kierunek różnic środowiskowych (gradientów społecznych) wynikających ze statusu społeczno-kulturowego ich miejsca zamieszkania.

Materiał i metody. W badaniach, które realizowano w latach 2005–2010, zastosowano metodę obserwacji. U 1429 dziewcząt i chłopców w wieku 4–14 lat przeprowadzono pomiar wysokości ciała, zdolności siłowych oraz inteligencji niewerbalnej. Punktem odniesienia do oceny zmian międzypokoleniowych były identyczne obserwacje rozwoju somatycznego, motorycznego i psychicznego wykonane w latach 1975–1980 przez pracowników Uniwersytetu Jagiellońskiego.

Wyniki. Stwierdzony zakres i kierunek długookresowych tendencji zmian w rozwoju somatycznym, motorycznym i psychicznym u badanych dzieci był relatywny do etapu rozwoju biologicznego i psychicznego, miejsca zamieszkania oraz poziomu rozwoju cechy biologicznej i psychicznej w danym wieku kalendarzowym.

Wnioski. Badania nie potwierdziły wystąpienia u dzieci mieszkających w określonych niszach ekologicznych zjawiska „rozwartych nożyc” i możliwości zmiany istniejących w poprzednich pokoleniach dystansów środowiskowych w rozwoju somatycznym, psychicznym i motorycznym.

Introduction

Long-term change tendencies, also called secular trends or intergenerational variability [1], are well known and described based on the observation of the basic factor of human physical development, which is considered to be body height. The directional changes phenomenon of the discussed characteristic has been a research subject of anthropologists from many countries since the beginning of the last century. There are periodically published reports that summarize the effects of its observed variability in people living in a specific environmental niche over a long period of time. Based on this observation, a macro-scale picture (continent, region) is usually created of the long-term variability trends in its kinetics and dynamics of development in different ontogenesis stages. The publication Changements séculaires de la croissance et du développement en Europe, published in the early twenty-first century by the international team of Susanne et al. [2] is definitely one of such elaborations.

The publication presents a summary of research conducted in the twentieth century on mainly the secular trend of body height, but it also presents a description and discussion of such issues as: the regional character of the trend; biological development acceleration; the environmental basis of secular trends and social gradients; the relation with nourishment, especially protein consumption in given populations; and the shaping of both aforementioned variables.

Based on the research results provided by the work, it has to be assumed that in most European countries the positive trend of intergenerational changes in body height still occurs. Furthermore, it is regionally variable [3] and the biggest in the poorest regions of Europe. This has been confirmed by Polish [4, 5, 6, 7, 8], Italian [9], French [10], and Belgian [11] studies.

Moreover there is a confirmed relation between the intensification of the secular trend and subsequent stages of the progressive development of a child [1]. In longer periods of time the intergenerational changes usually remained at the level of: 1.5 cm/decade (before puberty), 2.5 cm/decade (during puberty), and 1 cm/decade (after puberty). The population of most countries shows a strong relation between the pace of intergenerational changes, biological development acceleration, and socioeconomical conditions. This has been confirmed by, inter alia, Polish studies [8, 12, 13, 14] and the results of other observations made in European countries [3, 15].

Attention has also been drawn to the lowered development rate of girls since the 1980s (which correlates with the beginning of the economic crisis in Poland). This could mean that the causes of intergenerational changes are environmental, not genetic. Yet the topic of whether the observed phenomenon of biological development deceleration of girls in several countries [2, 9, 11, 15, 16, 17, 18, 19] is a result of a genetically-determined barrier of reaching subsequent stages of development in a given population, or a result of the deterioration of children's development conditions, is still under discussion.

Tanner, in his works [20, 21, 22, 23, 24, 25], points out the strong connection between the secular trends of body height and the improvement in society life conditions, health, and nourishment. Such connections are called an "auxology epidemic" [20, 21], or a "litmus paper of social changes in time" [1, 25].

For a number of years Polish scientists have been the leading group in the field of secular trends and their social conditions. This field takes a very important place in scientific projects conducted at the regional scale by most Polish academic institutions with the subject of physical anthropology [26]. Their number has been pointed out by reviews and by the most recent monographic studies of the issue of secular trends of biological development in children [26, 27, 28].

What is interesting is the fact that, despite a slight tendency to decrease the social difference (by a faster rate of intergenerational changes) in acquiring subsequent body height development stages, especially in social groups located lower in the social hierarchy, social contrasts are still present in many studies [4, 5, 6, 8, 25, 28, 29, 42]. A similar phenomenon, as well as the earlier maturity of children from richer families and whose parents had higher education, took place in less industrialized countries [17, 19, 31, 32, 34, 35, 36, 37, 38, 39, 41]. This is considered a borderline of human biological adaptation.

Studies of the variability of intergenerational motoric ability are conducted very rarely, both in regional and international scale. Without looking into the reasons of such an order of things it should be said that in Poland there is only one full elaboration by Przewęda and Dobosz [42] that raises the problem of long-term changes of somatic and motoric development, including the environmental modifiers. The comparative analysis included there was conducted on materials gathered in 1979, when over 233,000 students undertook an auxological evaluation [43]; in 1989, when over 219,000 students were evaluated [44]; and in 1999, when materials regarding over 73,000 children were gathered [42]. An effect of these studies was the conclusion that there is a positive trend in the somatic development and the phenomenon of biological development acceleration. The detailed analysis of the material included in the work allowed for the confirmation of the phenomenon of a distinct dynamic of the long-term changes in different stages of ontogenetic development, signalized in the research of Evelet and Tanner [34]. It could be seen, both in girls and in boys, most clearly during the biological development stage and, less clearly, right before and right after that stage. The range of the changes then was, in terms of numbers, a lot bigger than in the aforementioned English work. This may indicate that there are still considerable reserves of body height increase located in a Polish child's genotype.

The optimistic conclusion that there is a positive trend in somatic development is not reflected by the motoric one. All of the motoric abilities measurements, especially those focusing on strength abilities, indicate a level regress. Such a differentiated tendency in intergenerational variability is sometimes called the "scissors effect," because the growing morphological development is accompanied by falling levels of physical ability and efficiency. Such developmental asymmetry between somatics and motorics has been deepening with each decade. It can be assumed that decreasing physical fitness can be dangerous for young Poles' positive health in the future. The more detailed analysis did not reveal any other tendency within our country – only regional variation in the acceleration [34].

The literature review indicates that little research has been made in Poland on the intergenerational variability of mental abilities. It should be mentioned that attention toward this fact has only been made after the famous Flynn discovery.[1]

[1] Such an effect is presently called the Flynn effect, though the term was first used not by James R. Flynn but by Richard Hermstein and Charles Murray, authors of *The Bell Curve* (Flynn 2008). According to J. Philippe Rushton (1999), the term Flynn effect should be accompanied by the name of R. Lynn, who was the first to identify the phenomenon described earlier by Flynn and published the then identified trend (inter alia Japanese) in *Nature* magazine (Lynne 1982). That is why J. Philippe Rushton proposed an extended name of the effect: the Lynn-Flynn effect.

As it is known, the researcher James R. Flynn from the University of Otago in New Zealand made an interesting discovery. Within the intergenerational variability of the aforementioned psychosomatic development determinant he noticed a characteristic long-term change tendency. This phenomenon is described by him in the late twentieth-century work *The Mean IQ of Americans: Massive Gains 1932 to 1978*, [45]. After analyzing the results of 13,000 tests from 24 countries, conducted since the beginning of the twentieth century all over the world, he discovered that it is possible to determine a monotonic, almost linear increase in the intelligence quotient since the beginning of the twentieth century. The regression equation allows it to be determined at the level of 0.3 point per year or three points per decade.

At the end of the twentieth century, within a framework of applied psychology, a very interesting stage of time and space variability of nonverbal intelligence, tested by the Raven test, began [45, 46]. Dozens of studies from the turn of the twentieth and twenty-first centuries, conducted in different countries throughout the world, have proven Flynn's theory right. Within several dozen years the results of children, adolescents, and even adults have systematically grown. It seems that the phenomenon of surpassing the effects of intelligence testing in younger generations can be connected with the phenomenon of the secular trends mentioned before, or the intergenerational variability of the biological characteristics. What has also seemed interesting is the examining of intergenerational changes in strength abilities in the context of long-term change tendencies of the aforementioned body height and Raven test nonverbal intelligence results.

Not much research has been conducted in Poland that raises the problem of temporal variability of social gradients manifested in somatic, mental, and motoric development. Undoubtedly the research conducted by anthropologists from the University School of Physical Education in Cracow can be seen as an effort to solve this problem [26]. They refer to observations conducted for 40 years by the School of Anthropology at the University School of Physical Education in Cracow [47, 48, 49].

The aim of the aforementioned research was to examine the size of long-term change tendencies in the fields of maturity acceleration, body size, slimming of children, and motoric efficiency. Furthermore, the interdisciplinary research attempted to determine the sociocultural modifiers, including educational ones, and mental determinants conditioning the secular changes. Somewhat on the outer edge of this Cracovian field of research on the symptoms and conditions of long-term tendencies, parallel interdisciplinary observations of the changes in somatic, motoric, and mental development took place in three agglomerations of the former Cracow region (Cracow, Bracice, Slawkow). They were initiated by a research team consisting of Cracovian anthropomotorists and psychologists of the present Institute of Sport and Institute of Social Sciences of the University School of Physical Education in Cracow. Their aim was to repeat the study program analyzed between 1975 and 1980 by workers of Jagiellonian University under the guidance of Prof. M. Przetacznik-Gierowska [50].

Using part of the results of that research [50] and the research repeated 30 years later, it has been decided that this work will draw attention to some characteristic aspects of long-term change tendencies of the selected physical fitness component during the system transformation in Poland, in the context of body height development and nonverbal intelligence indicators in children between 4 and 14 years of age in three agglomerations that differ in size.

Research aim

1. Discover the range and direction of long-term generational changes at the turn of the twentieth and twenty-first centuries in the significantly important muscle component of physical fitness understood within the framework of health, meaning the strength abilities (Bouchard and Shepard [51]) of children at the preschool and school age who lived in three different agglomerations in the Malopolska region during the system transformation in Poland.
2. Determine the influence of intergenerational variability during the 30-year period in selected components of the somatic, motoric, and mental development structure of children during their progressive ontogenetic development on the range and direction of environmental differences (social gradients) resulting from the sociocultural status of the place of residence: a village, a small town, or a large city.

Research material and methods

1. Number of people studied

The studies were conducted between 2005 and 2010 in three agglomerations in the Malopolska region that differ in size: a city – Cracow, a village – Barcice, and a small town – Slawkow. The studies used the same methodology as the one used during the observations in 1975–1980 [50]. The overall number of people studied was 1429 boys and girls between 4 and 14 years of age, including: 202 girls and 217 boys from Barcice (the village); 221 girls and 199 boys from Slawkow (small town); and 274 girls and 316 boys from Cracow.

2. Research methods and tools

During the observations of somatic, mental, and motoric development the following characteristics were measured:

1. Body height within the Frankfurt plane,
2. Strength abilities, using two tests:
   a) the overhead medicine ball throw forward [52],
   b) the standing long jump [52],
3. Nonverbal intelligence using two versions of Raven's Progressive Matrices Test:
   a) the Colored Progressive Matrices Test (CPM) for younger children (4–7 years) [53],
   b) the black-and-white Progressive Matrices Test [54] for children ages 8–14.

3. Statistical study methods

1. After checking the normality of the characteristics and indicators measurement distribution, the Kolmogorov-Smirnov test was used to calculate the arithmetic average ($\bar{x}$) and standard deviation (SD), including: age, sex, and place of residence of the subjects: Barcice, Cracow, and Slawkow.
2. The range of intergenerational changes (long-term change tendencies) was calculated using:
   a) differences in arithmetic averages,
   b) standardized difference indicators (SDI), with the point of reference being the arithmetic average of the results from 1975–1980 [50].

Results

1. Long-term change tendencies in the somatic, motoric, and mental development of children aged 4–14 years in three localities of the former Cracow region

a) Strength abilities

The same two tests as the ones used 30 years earlier by the research team from Jagiellonian University were conducted for this research: the long jump test and the 2 kg medicine ball overhead throw forward [52]. Abbreviated names of such motoric abilities tests, taken from sports practice, are often used: explosive and dynamic strength. It should be noticed that these tests measure only the ability to do something, to manage a task, not the physical cause of the change of movement or rest conditions of the body or its deformation. Each of the names only determines in an associative way the potential abilities of managing the motoric task of overcoming external resistance with the subject's own muscle strength. With these conclusions having been made, it can be concluded, based on the analysis of the collected data (presented in Figures 1 and 2), that the intergenerational variability revealed small, irrelevant changes in the development level of the aforementioned motoric abilities.

Such a range of long-term change tendencies of motoric abilities allows us to see both the improvement and the decline of the motorics development level in children from different agglomerations. More cases of the decline were noticed in girls and boys at the school age living in the village and the small town. However, it is hard to formulate any far-reaching conclusions, based on the results of this research, regarding the range and direction of intergenerational changes that took place in the measurements of the leg strength abilities of children living in the three different Malopolska agglomerations. In this situation it should rather be said that there is a halt in the dynamics of intergenerational changes of a specific ability to overcome external resistance with a tendency to a slight regress at the school level, especially in children living in the village and the small town. A clearer situation can be observed by analyzing the results of the medicine ball throw test, which is considered a very valuable strength abilities trial for large muscle groups [50].

The data presented in Figures 3 and 4 indicate that, excluding the measurements of a few cases, in comparing the differences in strength ability level found in the years 2005–2010 and 1975–1980 in children from three

Figure 1. The range and direction of the long-term change tendencies of girls to develop explosive strength, based on standardized difference indicators in three localities from the former Cracow region

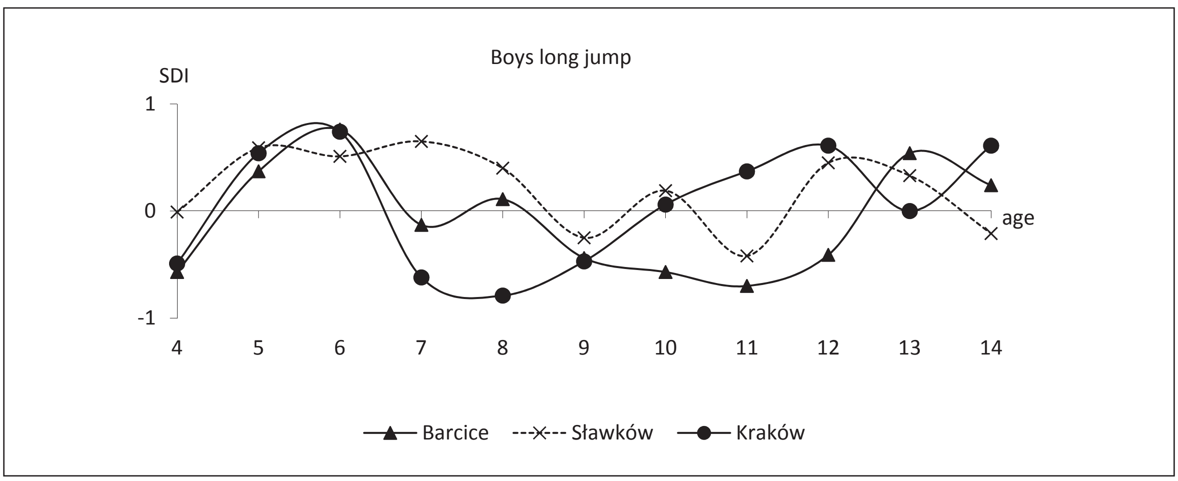

Figure 2. The range and direction of the long-term change tendencies of boys to develop explosive strength, based on standardized difference indicators in three localities from the former Cracow region

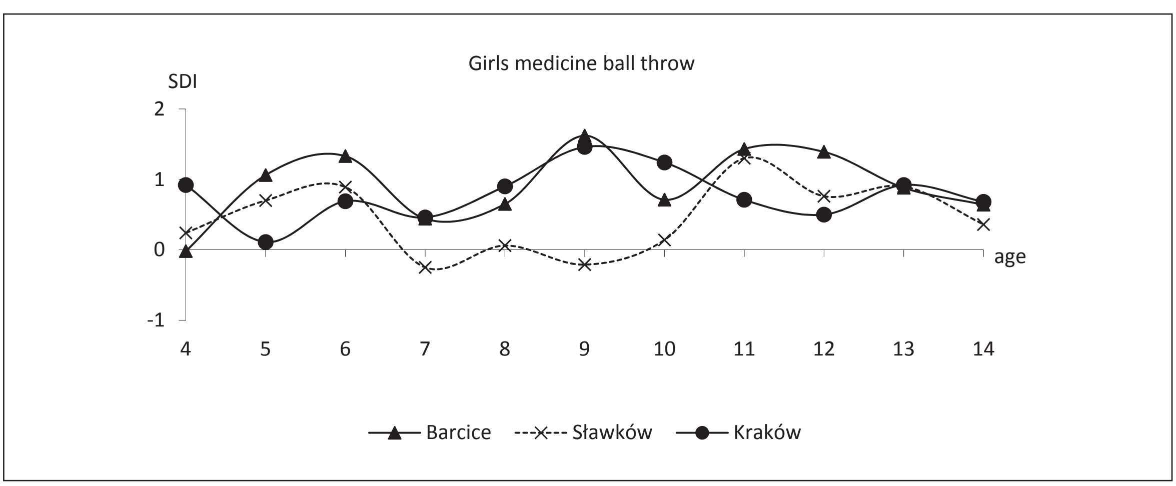

Figure 3. The range and direction of the long-term change tendencies of girls to develop dynamic strength, based on standardized difference indicators in three localities from the former Cracow region

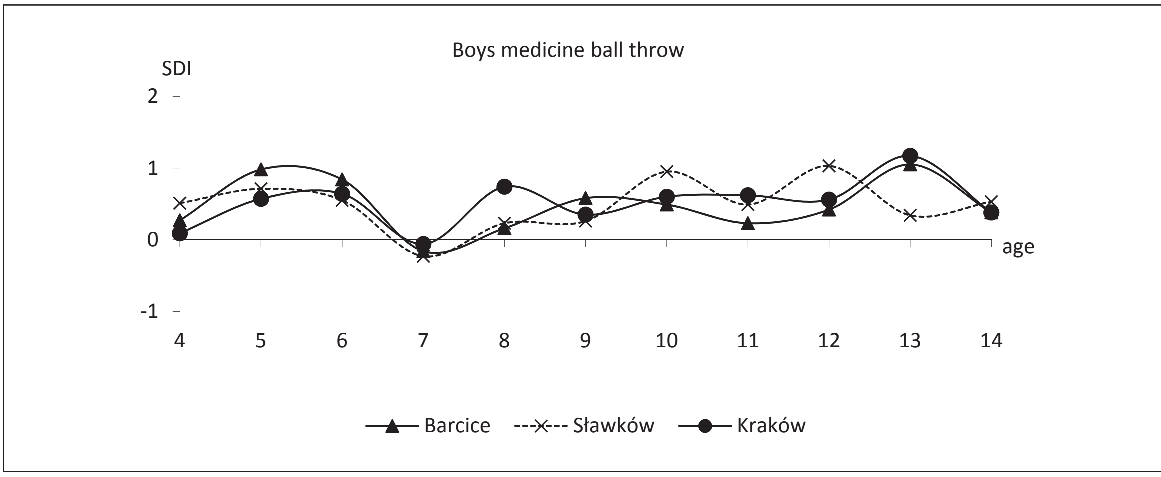

Figure 4. The range and direction of the long-term change tendencies of boys to develop dynamic strength, based on standardized difference indicators in three localities from the former Cracow region

different Malopolska agglomerations, there is a tendency toward visibly directional, positive intergenerational changes of the ability to overcome resistance using large muscle groups within the next 30 years. What is interesting is that these changes were bigger in the younger age groups and in boys and girls living in the village and the large city. Most differences in the girls' case were statistically important. The statistical test results in the boys groups allow for some conclusions to be drawn regarding tendencies toward the visible and directional intergenerational changes of the discussed motoric abilities.

b) Body height

According to the accepted research assumption, the intergenerational variability of strength abilities in girls and boys has to be shown on the background of the long-term change tendencies of their basic somatic characteristic, meaning body height. At a certain stage of ontogenesis, its level can be considered according to the opinion of physical anthropology, a biological development indicator [50].

Figures 5 and 6 present the arithmetic averages and the diffusion rate of the body height measurement of boys and girls conducted in three agglomerations in Malopolska in 1975–1980 and 2005–2010. The analysis of the difference level between the studies indicates that the range and direction of the intergenerational changes varied within the given ontogenesis stage. What is particularly interesting is the characteristic slowdown in the body height change rate in boys and girls at the preschool age (4–6 years), who lived in the village and the small town. Most astonishing is the vis-

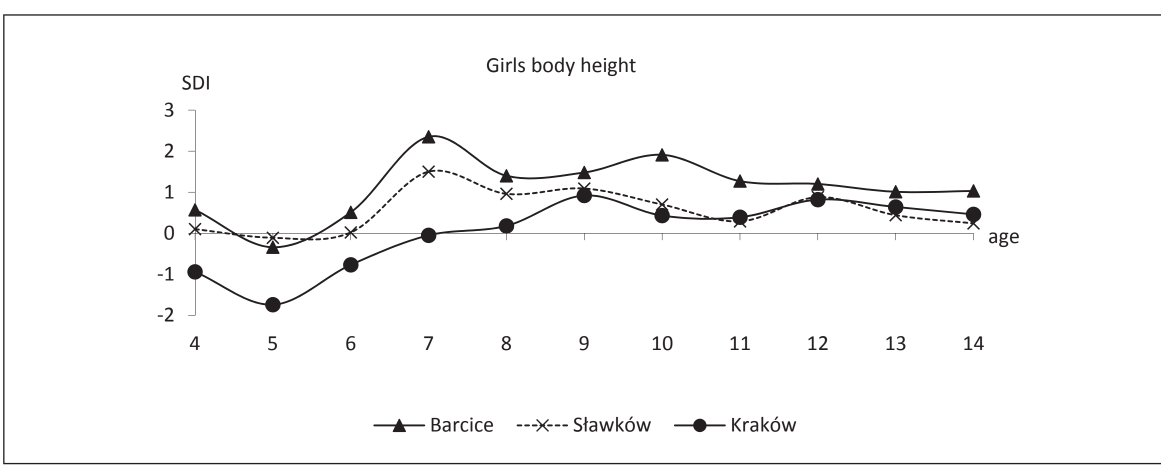

Figure 5. Long-term change tendencies based on standardized difference indicators of the body height of girls from three localities of the former Cracow region

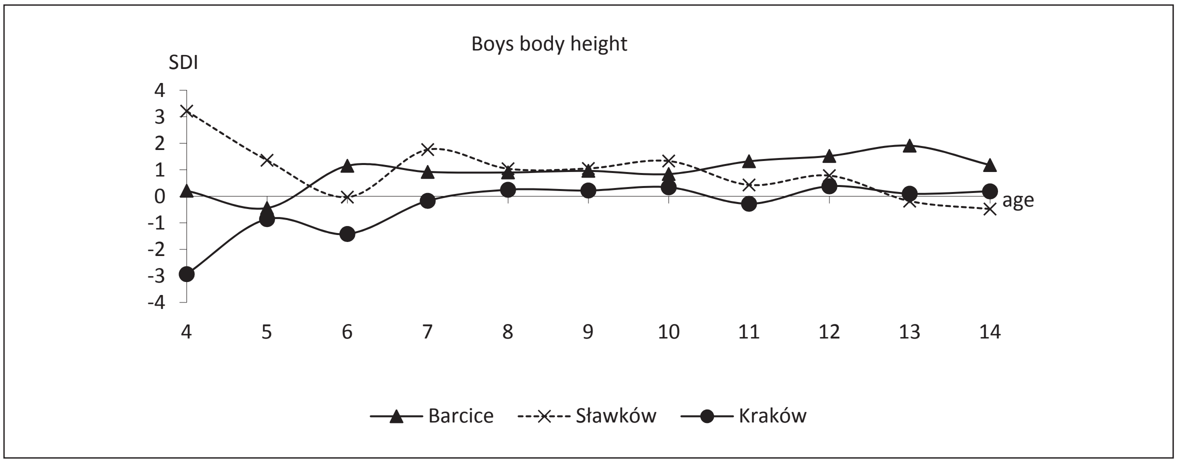

Figure 6. Range and direction of long-term change tendencies based on standardized difference indicators of the body height of boys from three localities of the former Cracow region

ible lowering of this basic characteristic development level in their peers living in the big city. Such a tendency was not found in children at the school age. As anticipated, all studied localities revealed the tendency for the children in the second measurement to outgrow their peers from the first measurement 30 years earlier. It should be noted that the intergenerational variability range was biggest in the groups of children living in the village and the small town. Not all of these differences are statistically relevant, though.

The scale and direction of the intergenerational changes may be indicated by comparison of the average differences in body height measurements in three studied age groups: preschool age (4–6 years), prepuberty age (8–10 years), and puberty age (11–14 years). The results of the analysis of intergenerational changes during the decade (Figures 7 and 8) do not provide enough evidence to confirm in other populations the tendency to increase dynamics of long-term change tendencies during the biological development of children.

Apart from the phenomenon of the visible slowdown in the rate of intergenerational changes at the preschool age, the range of intergenerational differences and their diffusion throughout the subsequent development stages of the children were not similar to tendencies in other studies, nor to the intergenerational variability of strength abilities (Figures 3 and 4). This may be proven by, e.g., the highest increase in body height taking place at the age of 7–10 years in girls living in the village (2.17 cm per decade) and in boys living in the small town (2.76 cm per decade). What is most unusual is the regress level in the body height of preschool chil-

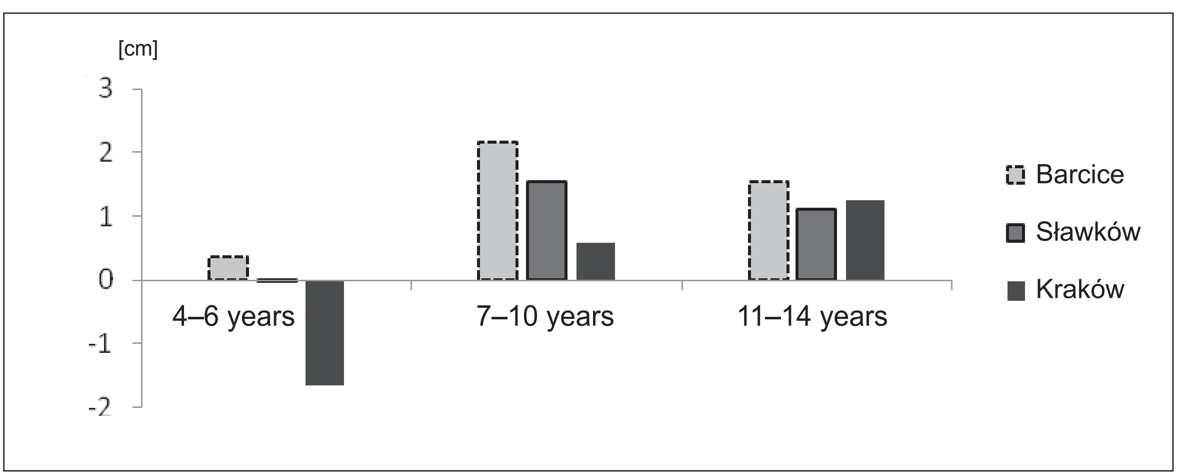

Figure 7. Intergenerational variability of the body height of girls from three localities of the former Cracow region calculated per decade, divided into three ontogenetic development stages: 4–6, 7–10, and 11–14 years

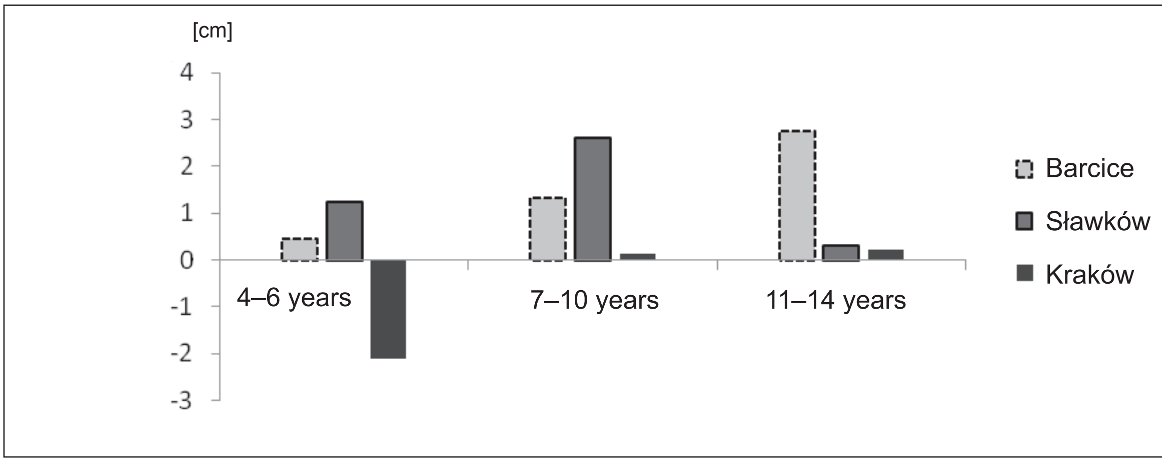

Figure 8. Intergenerational variability of the body height of boys from three localities of the former Cracow region calculated per decade, divided into three ontogenetic development stages: 4–6, 7–10, and 11–14 years

dren, especially those living in the big city. In terms of centimeters per decade, it was high: 2.11 cm/decade in boys and 1.66 cm/decade in girls. In other age groups there was a slight tendency toward the directional intergenerational changes in children from Cracow, but this tendency does not give rise to the claim that there are directional, long-term intergenerational changes. The greater range, in turn, of these changes in the case of children from the village may be considered an attempt to "make up for" biological development delays, which were the effect of unfavorable socioeconomical conditions of the lives of the families, previously existing in this place of residence, which was mentioned earlier in the literature review. The lower rate of intergenerational changes in the urban environment may be connected to the ability to reach the borders of human's biological adaptation in a specific ecological niche. In light of the research results, the phenomenon existing in the preschool group should be excluded from such interpretation, especially in the case of the children living in the big city. It seems that in that case only the worsening of life conditions of families at the beginning of the twenty-first century may be considered the cause of that phenomenon.

c) Nonverbal intelligence indicator

The 2005–2010 research used the same measurement tool to assess the nonverbal intelligence development level (Raven's test) as was used in the research conducted 30 years earlier by researchers from Jagiellonian University. Material analysis for the reasons of comparison was also conducted using the

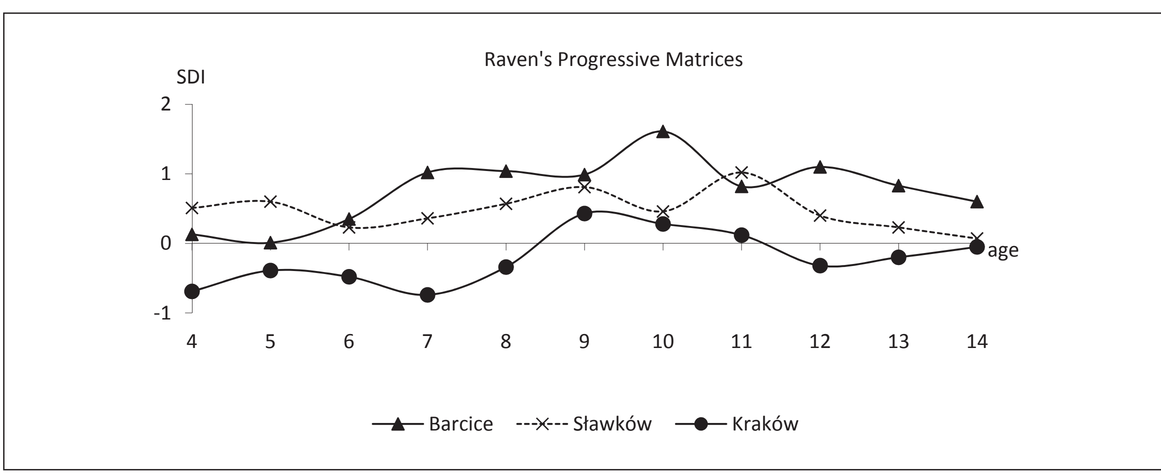

Figure 9. Range and direction of long-term change tendencies based on standardized difference indicators of nonverbal intelligence measured with the Raven's test in three localities in the former Cracow region

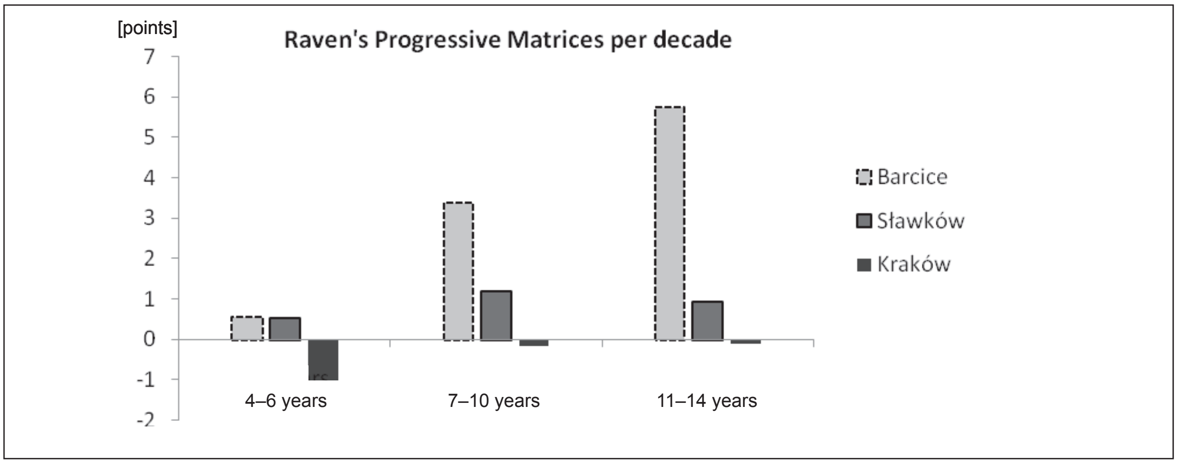

Figure 10. Intergenerational variability of nonverbal intelligence of children from three localities of the former Cracow region calculated per decade, divided into three ontogenetic development stages: 4–6, 7–10, and 11–14 years

same method of average results presentation, without taking into consideration the age of the child (Figure 9).

As can be seen in the analysis of the size and direction of the intergenerational changes of the results from 1975–1980 and 2005–2010, their standardized difference profile is very similar to the one previously presented with body height. The characteristic rank order occurred. The studied children's development stage showed a clear tendency toward an intelligence level regress, with a particular intensification (statistically significant differences) at the preschool age (Figure 10). A lesser degree of positive intergenerational changes could be noticed in children from the small town. Most of the differences were not statistically relevant, though there was a clear improvement in the Raven's test results of children living in the village. Only children from the preschool age showed no statistically relevant changes. Without going into detail about the causes of such a phenomenon, they could be both of environmental and developmental origin. There is much evidence confirming the correlation between mental and physical development, and similarities of the somatic and mental development change tendencies found in children living in the big city seem to confirm it. The genetic study shows, in turn, the vulnerability of nonverbal intelligence to both environmental factors and medium-to-strong genetic conditioning. Therefore it can be thought that there could have been an accumulation of influences, both developmental and environmental factors, on the shaping of the differences shown in the Raven's test of three child groups divided according to the agglomeration type in the former Cracow region.

It should also be pointed out that the temporal variability of the intergenerational differences in this research does not in any way confirm the Flynn effect found in other populations.

2. Intergenerational variability of the social gradients

– Motoric development

As is noted in the Introduction to this work, it is common for people to think that there are efficiency models for children from urban and rural environments. According to these models children from rural environments should be characterized by a higher level of strength abilities than the ones from urban environment. In light of the analysis of the materials collected during this study's research and the research conducted 30 years earlier, this notion is highly debatable. Most of the analyzed relations show the level and direction of the intergroup variability as statistically irrelevant, with a slight tendency to achieve better results by children living in cities. In the case of strength abilities the results were better in residents of the cities for the medicine ball throw and in residents of the village for the long jump. The intergenerational changes of the strength abilities described above changed little in the subject relations. Only some of the variability ranges changed in favor of the residents of the village for the long jump; the intergroup distances in the medicine ball throw decreased.

– Somatic development

The detailed analysis of the collected materials makes it hard not to notice that despite the fact that intergenerational differences in body height were negative for the residents of the large city, they still held the lead in somatic development ahead of their peers from the small town and the village. In most cases the aforementioned tendencies to weaken the secular trend in children from the urban environment caused the intergroup differences in body height to be smaller than those from 30 years earlier. There is an interesting phenomenon of children from the village outgrowing their peers from the small town, which is the effect of their faster somatic development. It can be said that the direction of the intergenerational variability of the discussed somatic characteristic led to the preservation of the clear difference between children from the small town and the big city.

– **Mental development**

The analysis of the presented data indicates that, similar to the somatic development, there was a slight clearing in environmental distance in the intergenerational variability of the Raven's test results in the children studied. The statistically relevant intergroup differences in the research conducted 30 years earlier have diminished to a level that shows no important differences in the statistical analysis. Therefore it is difficult to draw any far-reaching conclusions regarding the higher-potential intellectual abilities level of urban children than, e.g., rural ones, based only on the tendency toward a slight advantage of the nonverbal intelligence indicators of the studied children living in three different agglomerations in the twenty-first century.

Discussion summary

The comparative analysis results presented in this work allowed for the determining of the variable range and direction of long-term intergenerational changes at the turn of the twentieth and twenty-first centuries. Up until now Polish and foreign research, conducted in countries with low industrial development levels, pointed at the positive trends in basic somatic characteristics, above all in body height, where the highest trend was visible in the poorer countries in Europe [2]. This phenomenon was confirmed by the results of Polish [4, 5, 6, 7, 8] and foreign observations [9, 10, 11].

This study's research can only partially lead to such conclusions. The results of the comparative analysis allowed the researchers to notice the phenomenon of body height development retardation and a relative stabilization of the intergenerational changes in studied children at the school age.

During the search for the reason for this situation, attention was drawn to a relatively similar development level of Cracovian children studied in 2005–2010 [26] and very varied body height measurement results from the earlier studies [50].

Little difference between these research results and the ones conducted in Cracow 30 years earlier may result from grouping the studied children according to age. Both this study's research and the research conducted 30 years earlier included full years. As a result, the group of, e.g., 7-year-olds included both children aged 6 years and 6 months and ones aged 7 years and 5 months. This allowed for the subsequent years to be calculated from the averaged numbers. Other studies [see 12, 26] use the birth year of the studied person as a basic calendar age indicator. In that case the subsequent years are given a "middle age," meaning 4.5, 13.5, 14.5 years, etc. As a result, children in the observation may have been biologically younger by about six months than children studied at the same time by the University School of Physical Education team. Undoubtedly this could have an influence on the level of body height of the studied children during their progressive development. It is hard to determine why the body height of children in the preschool age studied by the Jagiellonian University team 30 years earlier [50] was significantly higher than the one found by the more recent studies conducted in Cracow. Perhaps the number of observations or the randomness of the sample influenced this?

Based on the results of this study's research and avoiding the hard-to-explain reasons of the observed phenomenon, it needs to be concluded that similar tendencies for the stabilization of body height level or even its retardation were noticed in works mentioned in the Introduction [2, 9, 11, 15, 16, 17, 18, 19]. It has to be noticed, though, that in this study's research such phenomenon occurred only in the group of children living in the big city. In the case of children living in the small town or in the village there was a tendency to outgrow their peers from the research conducted 30 years earlier. It should also be noted that a different intergenerational variability rhythm occurred in body height between 4 and 14 years of age than was found in highly developed countries [20–23]. As was noted in the Introduction, the intergenerational variability during the 10-year period varied during the progressive development stage and reached: 1.5 cm before puberty, 2.5 cm during puberty, and 1 cm after puberty [2, 20, 21].

What seems interesting is the strongest intergenerational variability dynamics in the group of children living in the village, which is an environment so far considered as standing lower in the economic-cultural hierarchy of Polish society. It can be concluded that in this case a phenomenon, also noticed in other studies, of the long-term changes is happening faster in populations that had worse development conditions in the past [17, 19, 31, 32, 34, 35, 36, 37, 38, 39, 41].

When looking for the causes of body height retardation or relevant stabilization in children living in cities, especially boys, it is hard not to notice the possible influence of still-decreasing living conditions of families at a rate inversely proportional to the system transformation development in Poland. Many works mentioned in the Introduction discuss the relation between socioeconomic conditions and the tempo of intergenerational changes in somatic development [3, 8, 12, 13,14, 15]. It seems that when interpreting this study's research, one should also take into consideration the influence mentioned by Susanne et al. [2] between the tempo of interpopulation changes and reaching the borders of biological adaptation by the given population. The analysis results of the intergroup somatic development (social gradients) level variability of the studied children between 4 and 14 years of age can prove this suggestion. This research analysis has proven that there still is a characteristic tendency to outgrow children from the village by their peers from the city, despite the faster intergenerational body height changes tempo characterized before. It can therefore be thought that in small town and big city populations there are still large reserves in reaching the adaptation border observed for some time in the biological development of children from the big city in Poland.

The fact that the research results do not give any basis to confirm the occurrence of the Flynn effect (presented in more detail in the Introduction of the work [45, 46]) in groups of children living in localities differing in size in the former Cracow region is not the only interesting thing. Also interesting, resulting from this research, may be the large similarities in the range and direction of the intergenerational changes of body height (in a certain range of the biological development indicator) and nonverbal intelligence, measured with the Raven's test, of boys and girls living in three different agglomerations in Malopolska. This indicates in some way the strong relation between somatic and mental development (the development of upper levels of the central nervous system). This suggestion may find its confirmation in the characteristic direction of the nonverbal intelligence intergroup variability, with the faster intergenerational changes tempo in groups of children living in the village and the small town.

The occurrence of such direction and range of long-term change tendencies was not confirmed by the strength abilities tests of the studied children who lived in three different agglomerations in Malopolska. Undoubtedly this may indicate a different human motorics vulnerability to environmental factors than previously thought [55]. Judging by the rate of the interpopulation changes it should be thought that its level was higher in groups of children living in the village. It would also be hard not to notice the relatively visible, positive long-term change tendencies in the studies' physical fitness components, studied within the concept of health, in all environmental groups: village, small town, and big city. Their range, similar to the physical and mental development, was higher than in groups that had a lower development level of the discussed motoric ability. Evidence for this may be found in the greater intergenerational change dynamics seen in the explosive strength tests of the lower limbs of children from the small town and big city (the social gradients direction was in favor of the children from the village). A reverse situation was observed in the measurements of the dynamic strength of the upper limbs, in which the social gradients direction was in favor of children from the urban environment.

All of the examples above may indicate that both our own research and the research conducted 30 years earlier showed no basis for establishing the typical stronger rural child model. The tempo of the long-term change tendencies in motoric development did not influence in a significant way the direction of the intergroup variability present in the previous century, which was observed during our own research.

It should also be added that such a tendency was also noticed in the previously characterized physical and mental development indicators. Furthermore, the most interesting thing in this research is the lack of confirmation of the scissors effect suggested by the Polish national research, meaning the faster long-term change tendencies in the somatic development together with significantly slower intergenerational changes in the motoric development. This may indicate the better motoric development stimulation in the field of strength abilities of children living in different agglomerations in the Malopolska region than in other regions of Poland.

Conclusions

The research results regarding the direction and range of long-term changes at the turn of the twentieth and twenty-first centuries in the very important components (musculoskeletal and morphologic) of physical fitness within the concept of health [51], and in nonverbal intelligence, found in children at the preschool and primary school age in three agglomerations in the Malopolska region (village, small town, and big city), provide the basis for the following general conclusions:

1. Both the range and the direction of the long-term change tendencies in somatic, motoric, and mental development may be relative to the age of the subjects, their place of residence, and the development level of the somatic and mental characteristics in children.
2. The interpretation of the range and direction of the intergenerational changes should consider not only the possibility of the environmental factor influence, but also the possibility of reaching the limit of human adaptation in biological and mental development in certain human populations.
3. The lack of evidence regarding the faster intergenerational changes of the somatic development and slower changes of the motoric development ("the scissors effect") in the comparative analysis results of this research may be considered a desirable and expected effect from the point of view of the directional and instrumental goals realization by teachers of children attending kindergartens and primary schools in different agglomerations in the Malopolska region.

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DISCUSSIONS
POLEMIKI I DYSKUSJE

THE RESPONSE OF THE HUMAN IMMUNE SYSTEM TO PHYSICAL EXERTION

ODPOWIEDŹ UKŁADU IMMUNOLOGICZNEGO CZŁOWIEKA NA WYSIŁEK FIZYCZNY

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Key words: exercise, leukocytes, lymphocytes, natural killer cells, neutrophils, monocytes, dendritic cells, immunoglobulins, cytokines
Słowa kluczowe: wysiłek fizyczny, leukocyty, limfocyty, komórki NK, neutrofile, monocyty, komórki dendrytyczne, immunoglobuliny (Ig), cytokiny.

SUMMARY • STRESZCZENIE

The human immune system is quite complex with respect to its structure and function. A functional immune system is absolutely necessary to maintain the integrity of the human organism. Athletes are a very particular group of people: they are expected to be psychologically and physically prepared for challenges. Even slight immune disorders, e.g., during upper respiratory tract inflammation (URTI), can negatively affect their workouts and their performance during sports events. Unfortunately, authors of scientific reports present no uniform consensus regarding the impact of exercise on the immune system. It is widely accepted that a single exercise session modulates the immune system, whereas heavy exercise to the point of exhaustion suppresses the response of the immune system and moderate physical exercise stimulates immune functions. Following heavy and acute exercise, the most commonly described changes in the indexes of the immune system are: increased numbers of leukocytes (WBC), lymphocytosis with subsequent lymphocytopenia, neutrophilia, monocytosis, decreased IgA concentration in saliva, increased levels of certain cytokines in serum, and reduced phagocytic activity of neutrophils. Moreover, the enhanced activity of NK cells directly following exercise and a decrease in the NK number below normal levels while recovering from exercise have been reported. It has been suggested that physical training affects the immune system through several mechanisms: increased concentrations of steroid hormones (adrenaline, noradrenaline, cortisol, and growth hormone), muscle damage, reduced levels of glutamine in blood, and psychological stress.

Układ odpornościowy człowieka pod względem swojej struktury i funkcji jest niezwykle skomplikowany. Sprawne działanie tego układu jest warunkiem koniecznym do utrzymania integralności ustroju.

Sportowcy to szczególna grupa osób, od których wymaga się pełnej sprawności psychofizycznej, dlatego nawet niewielkie zaburzenia odporności, np. podczas infekcji górnych dróg oddechowych (URTI – ang. upper respiratory tract infection), mogą negatywnie wpłynąć na trening, skutkując poniesieniem strat w zawodach sportowych.

Niestety wśród autorów publikacji nie ma pełnej zgody w kwestii wpływu wysiłku na system immunologiczny. Dominuje opinia, że jednorazowy wysiłek fizyczny wpływa modulująco na układ immunologiczny, przy czym ciężki wysiłek do wyczerpania osłabia odporność, a tymczasem umiarkowany wysiłek stymuluje funkcje odpornościowe. Najczęściej opisywane zmiany we wskaźnikach układu immunologicznego po ciężkich, intensywnych wysiłkach fizycznych dotyczą: wzrostu całkowitej liczby leukocytów (WBC), limfocytozy z późniejszą limfocytopenią, neutrofilii, monocytozy, zmniejszenia stężenia immunoglobuliny A (IgA) w ślinie, zwiększenia stężenia w surowicy niektórych cytokin, zmniejszenia aktywności fagocytarnej neutrofilów. Poza wyżej wymienionymi zmianami obserwuje się zwiększoną aktywność komórek NK (ang. *natural killer*) zaraz po wysiłku oraz spadek ich ilości poniżej wartości spoczynkowych w czasie restytucji. Przypuszcza się, że wysiłek fizyczny wpływa na układ immunologiczny poprzez kilka mechanizmów. Do najczęściej wymienianych zalicza się: zwiększenie stężenia hormonów sterydowych (adrenaliny, noradrenaliny, kortyzolu, hormonu wzrostu), uszkodzenie mięśni, obniżenie poziomu glutaminy we krwi oraz stres psychologiczny.

Introduction

The immune system is structurally and functionally one of the most complex systems in the human body. It is comprised of central and peripheral lymphatic organs, cells, and molecules that make up a network of mutually interacting elements. The main function of the immune system is to maintain the balance of an organism's internal environment by eliminating potential pathogens (bacteria and viruses) and cancer cells. An efficient immune system is a necessary condition for maintaining the integrity of the human organism. We learn about the role of a well-functioning immune system usually in times of its disturbed function. Both immune deficiency and excessive immune reactivity can lead to the development of various diseases, and in some cases, death [1, 2].

Athletes are a special group of people who require complete psychophysical efficiency. Therefore, even small immunity disorders such an upper respiratory tract infection (URTI) may negatively affect training and participation in sports competitions [3]. Both virus- and bacteria-caused infections can lead to acute inflammatory response, fever, loss of appetite, and increased muscle protein catabolism. It was found that following such infections, there is a decrease in aerobic capacity and isometric strength associated with the negative balance of nitrogen [4].

Several authors have reported that increased risk of upper respiratory tract infection is related to exhausting physical exercise of long duration or high intensity [5, 6]. The aforementioned study uses a "J" curve (Figure 1) in order to show the relationship between physical exercise and susceptibility to infections [7]. According to the proposed model, there is less likelihood of URTI in people who undertake exercise of moderate intensity compared to sedentary people. However, in people who undertake high intensity exercise, the probability of infection is greater than in the case of persons not physically active [8, 9]. For example, Matthews et al. [10] observed that performing regular moderate exercise for two hours a day is associated with a 29% reduction in the risk of URTI compared to sedentary people. A study by Peters et al. [11, 12] demonstrated that in the first several weeks after heavy competition, the risk of URTI in players engaged in endurance sports increases by 100%–500%, while a study with a large group of marathoners [13] did not confirm the growth of morbidity rate after intense, long-term exercise. No relation has been found between training intensity within 6 months before a marathon and reports of URTI after the race. Similarly, there was no difference in the incidence of infections within 3 weeks after the race compared to the time before this period.

Intense exercise is associated with increased production of reactive oxygen and nitrogen during intracellular respiration, which in turn can also weaken the function of certain immune system cells. In addition, the risk of inhaling dust and pollutants in the air that later become pathogens rises with the increase in the frequency and depth of breathing. Prolonged intense exercise in different environmental conditions, for example in the heat, can lead to increased permeability of the intestinal wall, which increases the flow of bacterial endotoxins into the blood stream. Increased exposure to pathogens, along with various physical, psychological and environmental factors, contributes to the fact that athletes, especially those who compete in endurance disciplines, have a more weakened immune system and are more susceptible to infections than people performing regular moderate physical exercise [14, 15].

Unfortunately, the authors of this publication could not reach an agreement as to the influence of the exercise on the immune system. There is the dominant opinion that heavy, intense exercise induces transient changes in the indexes of the immune system, while moderate exercise stimulates immune functions [7, 16, 17, 18].

Physical exercise forces immune system cells to circulate; the number of cells depends on the intensity and duration of the exercise. Exercise that is intense and lasts a long time resulted in a decreased quantity of lymphocytes [19], a decline in the activity of NK cells [20], reduced secretion of IgA in saliva [21], and elevated levels of cytokines in the circulatory system [22].

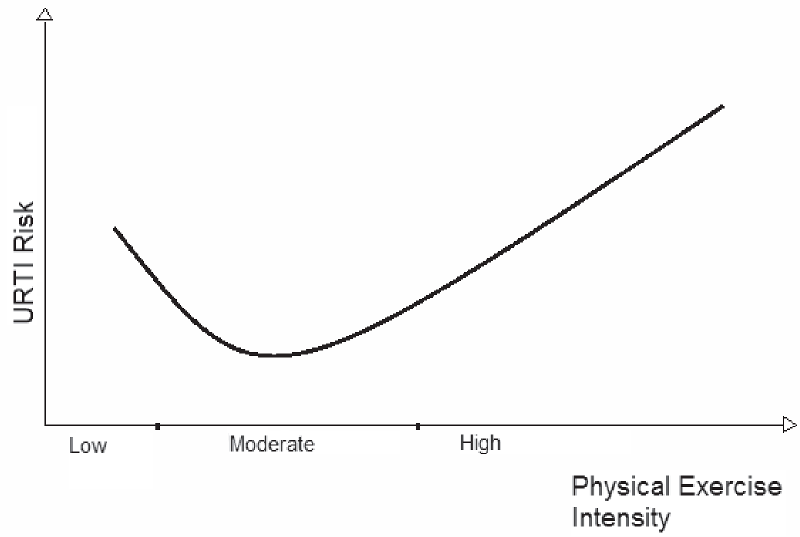

Figure 1. "J" curve [according to 9]

Such changes in the immune system are immunosuppressive and may cause increased susceptibility to infections. This phenomenon has been called "the open window" [23]. Many researchers believe that 2 mechanisms play the main role in the immune response: neuroendocrine factors and muscle damage [9, 24].

Elements of cellular immunity and humoral immunity

Post-workout Leukocytosis

Endurance training lasting a minimum of 1 hour at an intensity level of ≥ 60% VO_2max causes a biphasic change in the number of circulating leukocytes [9, 25]. In the first place, immediately after the exercise ends, the total number of leukocytes (WBC) rises by 50%–100% of the resting value. Post-workout leukocytosis is represented mainly by neutrophils and lymphocytes, with little contribution from monocytes. In the 30th minute of restitution, the number of lymphocytes drops by 30%–50% below the resting value and stays at this level for 2–6 hours. The level of eosinophils also decreases, while the number of basophils does not change. The neutrophil count rises again a few hours after the exercise and remains elevated for an extended period of time. After exercise of constant intensity that lasts 2–3 hours, the increased number of leukocytes can remain at that level for up to 24 hours [26]. Moderate intensity exercise (< 60% VO_2max) causes lower leukocytosis, lymphocytosis, neutrophilia, and even lymphocytopenia in the period of restitution.

The initial increase in the number of leukocytes is probably caused by their demargination from the vascular endothelium and mobilization for the circulation of liver, lungs, and spleen cells. Available data indicate the important role of the sympathetic nervous system [27], catecholamines [28], and cortisol [29] in the described phenomenon. During physical exercise, levels of cortisol and catecholamines in the blood grow from the point at which the exercise's intensity level exceeds 60% of VO_2max. Epinephrine causes an increase of leukocytosis with a shorter exercise (< 1 hour), while the effects of cortisol prevail after 3–4 hours of exercise [30].

Lymphocytes

Lymphocytosis proportional to the intensity and duration of exercise usually occurs during and immediately after exercise. During the early stages of restitution, there is an observable drop in the number of lymphocytes below the level measured prior to the exercise. A return to the resting values usually occurs within 24 hours following the end of exercise [3].

Due to physical exercise, mostly B-lymphocytes (CD19 +), NK cells (CD16 + CD56 +) and, to a lesser extent, T-lymphocytes (CD4 +, and CD8 +) reach the circulatory system. Due to the fact that the number of helper lymphocytes (CD8 +) increases faster than the number of suppressor cells (CD4 +), there is a change in the CD4/CD8 ratio. Most of the aforementioned changes are temporary, and training probably has no significant effect on the number of lymphocytes subpopulations [26, 31].

In order to assess the functional capacity of T- and B-lymphocytes, an in vitro test of a proliferative response (blastic transformation) of lymphocytes to mitogens was carried out. Intense and prolonged endurance exercise reduces the lymphocyte proliferation stimulated by mitogens, while moderate-intensity exercise of short duration has little or no effect at all [32, 33]. It is believed that the reduction of the mitogen response after exercise is caused by the relatively smaller number of T-lymphocytes compared to the NK cells [34]. Recent studies have reported that physical exercise inhibits the activity of lymphocytes after the completion of training through short-term apoptosis stimulation. Additionally, it is believed that the post-workout lymphocytes apoptosis level depends on the exercise [35, 36].

NK cells

NK cells are 10%–15% of all lymphocytes in the circulation system. They are large, granular lymphocytes that function as cytotoxins and immunoregulators [37]. They have the ability to spontaneously kill tumors and virus-infected cells, which is why they play an important role in the response to tumors and infections [38].

The total activity of NK cells usually increases during and immediately after brief and moderate exercise, but after long and exhausting exercise as well [39]. During the exercise, NK cells are mobilized to circulate faster than any other lymphocyte sub-population [21, 40, 41].

It was found that in the case of extended (> 1 hour) heavy exercise with an intensity of > 60% VO_2max, NK cell activity increases immediately after exercise; during the period of restitution, however, it falls below the resting value [42]. It is believed that the increase in activity of NK cells after exercise and the regenerative decrease is caused by the redistribution of NK cells from the circulatory system to other tissue [9].

There was no reduction in the activity of NK cells in the case of exercise that was limited to a small muscle mass and motion that involved a single joint [43].

Neutrophils

Neutrophils are the basic cells of the early inflammation phase. They cover about 60% of all leukocytes present in the circulatory system. They migrate to the place of infection, where they bind, absorb, and kill pathogens through phagocytosis. High-intensity physical exercise causes rapid and deep neutrophilia, followed by a delayed increase in the number of neutrophils in the circulatory system several hours later. The size of the observed change is dependent on the duration of the exercise and its intensity [44, 45]. The first increase in the number of neutrophils in the blood that occurs immediately after exercise is probably caused by their movement to the circulating cell pool from the marginal pool, which includes neutrophils fixed to the endothelium [46]. The increase of neutrophil granulocytes may be in turn caused by cortisol, which stimulates the release of neutrophils from bone marrow [47].

Physical exercise also affects the individual functions of neutrophils. In order to assess the functional capacity of the neutrophil granulocytes, it is necessary to assess the level of phagocytosis (the ability to absorb pathogens) and the measurement of respiratory burst (the ability to destroy the absorbed pathogens) [42]. It was found that after intense exercise, the phagocytic activity of the neutrophil granulocytes increases, but the respiratory burst effect decreases [45]. According to Eberhardt [48], physical exercise of moderate intensity increases phagocytic activity of neutrophils as well.

Monocytes

Monocytes are the largest cells among leukocytes (20–40 μm). They constitute 4%–6% of all leukocytes in the blood. Migrating to the place of ongoing inflammation, they are the second-largest population of wandering cells, after neutrophils, capable of phagocytosis and killing microorganisms. Mature monocytes enter the damaged tissue from the blood and transform into macrophages [9].

Heavy physical exercise causes temporary monocytosis, which is most likely the result of cortisol or the transfer of the marginal monocytes pool into the blood stream [49]. According to some researchers, physical exercise may also have an impact on the phenotype of monocytes. For example, in response to heavy exercise there is a preferential mobilization of monocytes with an proinflammatory phenotype CD14 +/CD16 + with regard to classic monocytes with the phenotype CD14 +/CD16- [50, 51]. It is interesting that the proportion of monocytes with a pro-inflammatory phenotype is reduced during restitution, which may indicate a remarginalization of those cells or recruiting them by tissue [52].

Due to the fact that monocytes are immature cells, exercise-triggered changes in their function may not reflect the actual role of tissue macrophages. For this reason, experiments with animals [53] were carried out to examine the impact of exercise on macrophage function. The experiments were conducted in order to study the impact of exercise on the function of pulmonary alveolar macrophages, which play a vital role in the defense against viral infections of the upper respiratory tract. These tests showed that mice undergoing exercise to the point of exhaustion decreased antiviral macrophage function, which resulted in increased susceptibility to herpes simplex virus (HSV-1) infection.

Macrophages, apart from phagocytosis, participate in antigen presentation to lymphocytes. T. Ceddia et al. [54] reported that prolonged exercise caused a decrease in the expression of class II major histocompatibility complex (MHC). In a study conducted with mice, there was a case of a 22%–40% decrease in the expression of antigens on macrophages influenced by exercise.

Dendritic cells

Dendritic cells play an important role as initiators and modulators of immune response. They constitute a main population of antigen presenting cells (APCs). There is little information regarding the impact of exercise on the number and functions of dendritic cells. Available data show that exercise could increase the number of circulating dendritic cells, but the impact of exercise on their functions is not known [55].

Immunoglobulins

Immunoglobulins (Ig- antibodies) are a group of serum proteins and body fluids produced by activated B-lymphocytes, and more specifically, by plasma cells. Their main task is binding to antigens (e.g., viruses, bacteria, and toxins) and neutralizing them. Based on the basic construction of the molecule, immunoglobulins are divided into 5 classes (IgG, IgA, IgM, IgD, and IgE). Among them, the IgG and IgA are best described in conjunction with physical exercise. IgG are a basic class of immunoglobulins having the largest concentration in the serum. IgA is the main protein of the immune system present in human mucous excretions: saliva, colostrum, tears, and nasopharyngeal secretions. Reduced levels of immunoglobulins can cause increased susceptibility to infections.

After physical exercise, minor changes of the level of antibodies in serum, or even a lack of them, were observed [56]. According to Nieman et al. [57], the decrease in the level of antibodies in the blood after a run of less than 40 km is small; however, after a run of more than 40 km, immunoglobulins concentration changes can last up to 2 days.

Intense, long-lasting exercise can cause a decrease in IgA levels in saliva, while moderate exercise might even raise the level of immunoglobulins [56, 57]. It is thought that the post-workout drop in IgA concentration in saliva is a result of changes in the transport of IgA in mucinous epithelium or narrowing of blood vessels in the sub-mucosa tissue of the mouth, which leads to a reduction in migration of cells which synthesize and secrete IgA [58]. A study by Gleeson et al. [59] showed that the low level of post-workout IgA in saliva was associated with an increase in the incidence of URTI.

Cytokines

Cytokines are small, soluble protein molecules (often glycoproteins) released by activated cells of various tissues. They have a significant influence on the reactions of the immune response, inflammatory reactions, and tissue repair processes. Cytokines are secreted by leukocytes, muscle cells, endothelial cells, fat cells, skin cells, and others. Thus far, more than 100 cytokines with pro-and anti-inflammatory effects have been described, of which at least 12 are released in response to physical exercise. Cytokines, which originate from muscle fibers, are called myokines [60].

Studies have shown that the amount of released cytokines based on one period of exercise depends on exercise intensity, duration, active muscle area, and type of muscle contractions [61]. The greatest changes in cytokine concentrations can be observed after exercise in which there are eccentric contractions that cause damage to muscle fibers. Particular attention should be paid to IL-6, a myokine that is released during exercise and appears in much higher concentrations in comparison with other cytokines [62, 63]. After a long-lasting endurance exercise (a marathon), the concentration of IL-6 in blood rose 128-fold. These studies have also shown a 27-fold increase of IL-10 in competitors' bodies, together with more than a twofold increase of TNFα and IL-1β immediately following the race. The relation between the duration of the exercise and the size of the IL-8 level increase in the blood was observed, just as in the case of IL-6. Suzuki et al.

[65] noted an up to 10-fold increase in IL-8 following 60%–65% VO_2max exercise. Exercise lasting up to 30 minutes triggered small changes: a twofold increase in IL-6 was observed; IL-8 increased by 35%; there was a minimum increase of IL-1β; a decrease of IL-10; and no change or a decrease in TNFα [60]. According to Haahr et al. [66], exercise with a 70% VO_2max intensity caused no changes in the IFNγ concentration in blood.

The rising levels of pro-inflammatory cytokines are responsible for the development of acute inflammatory response that leads to activation of granulocytes, and subsequently, macrophages. It is also believed that cytokines stimulate monocytes to produce prostaglandins, which cause muscular pain at the time of restitution after hard and intense physical exercise [23].

Work mechanisms

According to researchers, several mechanisms lie at the heart of physical exercise-induced immunomodulation: hormonal and metabolic changes, muscle damage, and psychological stress.

Hormonal changes

Muscular work causes an elevation in the levels of a number of steroid hormones in the blood, including epinephrine, norepinephrine (catecholamine), cortisol, and growth hormone [24]. Long-lasting exercise during which muscles use oxygen to create energy results in an increase in catecholamine concentration in the serum. It has been shown that epinephrine and, to a lesser extent, norepinephrine cause an increase in the number of lymphocytes and Il-6 in the blood and also cause an increase in the activity of NK cells [67]. The effect of catecholamines becomes weaker after exercise lasting more than 1.5 hours [42]. After physical exercise lasting from 2.5 to 3 hours, the number of lymphocytes is practically the same as the resting value [68], which clearly contrasts with the increase in the number of these cells after exercise lasting less than 1.5 hours [16, 23]. It is believed that after exercise lasting more than 1.5 hours, cortisol starts to play an important role in hormonal environment [42]. The concentration of cortisol in the blood increases only after prolonged exercise; slight changes of the hormone were observed with exercise lasting up to 1 hour [70]. It is believed that the increase in cortisol concentration in the blood after long, hard exercise is one of the factors responsible for the post-workout weakening of immune response [71]. It has been shown that intravenous corticosteroids administration (e.g., cortisol) causes an increase in the number of neutrophils, a decrease in the number of lymphocytes, and a reduction in the functioning of T-lymphocytes and NK cells [69].

An increase in the growth hormone levels in the blood caused by prolonged physical exercise (> 1 hour) causes an increase in the number of neutrophils [69]. Intravenous administration of growth hormone at a dose that would cause a concentration comparable to the concentrations observed during physical exercise does not affect lymphocyte sub-populations, NK cells activity, or the production of cytokines [72].

Metabolic changes

A deficiency of the glutamine amino acid in the human organism can cause immune function impairment, especially after intense, prolonged exercise. This amino acid is the energy source for the immune system cells. Reducing the level of glutamine after a marathon may persist for 6–9 hours after the end of a run [73]. In addition, glutamine is a nitrogen source for purine and pyrimidine nucleotides synthesis, which facilitates proper proliferation of lymphocytes. It was found that the reduction of the glutamine concentration in an in vitro culture resulted in a decline in the pace of mononuclear blood cells division and reduced phagocytosis and cytokine production by macrophages [74]. On the basis of these reports, it can be assumed that the changes in the levels of glutamine could contribute to the weakening of the immune system observed after exercise [73].

Muscle damage

Intensive physical exercise with a predominance of eccentric muscle contractions can cause microtrauma to muscle fibers, particularly to people not in training. As a result of myocytes damage, intramuscular enzymes, e.g., creatine kinase (CK), begin to appear in blood. As a result, the immune system activates. Stimulated immune cells, mainly neutrophils and monocytes, enter the damaged tissue from the circulatory system. The functioning of these cells is heavily regulated by cytokines [75].

According to Smith et al. [76], cytokines are important effectors of physiological overtraining syndrome symptoms. In accordance with the aforementioned theory, overtraining is a phenomenon when local inflammation that occurs in places of myocytes damage after heavy physical exercise is not fought before the next series of exercise. In this case, local inflammation may transform into chronic, and subsequently systemic, inflammation. A large number of proinflammatory cytokines are released: IL-1β, TNFα, and IL-6 [77]. Long-lasting persistence of elevated levels of these cytokines may cause symptoms typical of medical condition, e.g., loss of appetite, weight loss, and depression by stimulating the central nervous system [78].

Studies have shown that exercise involving eccentric contractions causes a greater increase in the levels of IL-6 in blood than exercise with a predominance of concentric contractions. Furthermore, the increase in IL-6 after exercise was associated with an increase in creatine kinase [79]. Muscle cell damage activates monocytes, which produce and release prostaglandine E_2 (PGE_2). The effect of PGE_2 is a powerful endogenous inhibition of the immune system. It has been proven that a 2-hour, 65% VO_2max exercise caused the decrease of NK cells activity by 28%, while PGE_2 level in the blood increased by 36% and correlated negatively with NK cell activity [80].

Psychological stress

Another factor that has a negative impact on the immune system of sportspeople is psychological stress, such as during major sports competitions. The weakening of the immune system caused by stress can lead to infection and intensification of autoimmune diseases symptoms [81].

Conclusion

On the basis of the information presented above, we can conclude that physical exercise significantly affects the functioning of the human immune system. Changes in the immune system can be both positive and negative. Parts of the indexes of the immune system remain unchanged. The size and direction of changes may depend on the intensity of exercise, the duration and the type of exercise, individual predisposition, and the human body's adaptation to physical exercise.

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