Description and profile of the journal

Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES) is the official, reviewed, quarterly academic publication of the International Association of Sport Kinesiology (IASK), issued by the University of Physical Education in Krakow since 1989, and from 2010, in cooperation with the University School of Physical Education in Wroclaw. The journal has received academic patronage from the Rehabilitation, Physical Education and Social Integration Committee of the Polish Academy of Sciences and can be found in the IC Journal Master List international indexing database. Since 2014, the journal is published in the original electronic version in English. On subscribers’ request, the journal may be issued in English and Polish in book format.

Aim

In Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES) the results of innovative experiments and observations on human locomotive activities conducted under natural and laboratory conditions by researchers of human motor skills (anthropomotoryka) or related fields and disciplines, such as: physiology, psychology, physical anthropology, biomechanics, medicine, computer sciences, economics, genetics, pedagogy, sports education are presented. This allows to acquaint oneself with the essence of human physical activities, their structure, skills, motor functions and aptitudes, learning of these motor functions, their monitoring and control, and the health and sports effects of the broadly understood human notion of physical activity.

In accordance with the aim of the journal, the subject of the article should fall under one of the four thematic categories:

I. Theoretical and applied aspects of kinesiology (Fundamental and Applied Kinesiology).
II. Scientific basis of motor function training in sports and recreation (Sport Sciences).
III. Teaching, controlling and monitoring motor functions. Scientific basis, formation and evaluation of activity and physical fitness (Exercise Sciences).
IV. Reviews, debates and discussions, historical elaborations, conference announcements, reports from conferences and congresses of the IASK and brief summaries of papers printed in foreign journals, book reviews on the theory of human motor skills and also, assessment of the current state and prospects for the development in anthropomotoric research achievements (Varia).

Requirements for submission

Submitting the paper should be done via the Index Copernicus Publishers Panel – the electronic system for management of the editing process. For this purpose, it is necessary to register on the following website: http://970.indexcopernicus.com/.

Manuscript registration takes place in accordance with the instructions for authors: http://970.index-copernicus.com/ic_publishers_panel_instrukcja_obslugi_dlaAutorow.pdf

• Once registered on the IC Publishers Panel platform, authors should contact the editorial office via the IC Publishers Panel e-mail or the editorial office directly via e-mail: antropomotoryka@awf.krakow.pl.
• The author responsible for correspondence with the publisher concerning the article receives notification confirming submission of the article, and information about stages of its publication.
• Editors will not accept an article in which the phenomena of “ghostwriting” and “guest authorship” is present or showing signs of any aberrancies.
• All publications are copyrighted on the basis of the Berne Convention and the Universal Copyright Convention, exceptions being only cases allowed by national law.
• The author submits a statement (in the case of collaborative papers, the lead author submits the statement on behalf of all co-authors) asserting that materials submitted for publication become the sole property of the publisher and cannot be published in whole or in part by other journals or digital media without the permission of the publisher.
• Submission for publication is tantamount to the author(s) relinquishing ownership rights to the publisher, which is claimed by the lead author in a statement posted on the website: http://970.indexcopernicus.com/
• The lead author is required to determine the contribution of the co-authors in creation of the article in accordance with the requirements of the IC Publishers Panel – electronic system for managing the editorial process.

Texts submitted for publication should be written in English or Polish in accordance with the following editorial requirements:

• The volume of empirical work including the summary, figures and tables should not exceed 22 pages, and the reviews – 30 pages standard A4 size (up to 1,800 characters including spaces per page);
• Texts should be prepared using only Microsoft Office Word text editor, pages should be numbered, font: Times New Roman; size: 12 points; spacing: 1.5; justified text; title written in bold typeface; centred.
• Tables and figures labelled using Arabic numerals and headers, explanations and descriptions of illustrations below the figures and the results above the tables should be placed on separate pages in the English and Polish versions. Headers, explanations and descriptions below the figures and above the tables should be in English and Polish.

Example:
Tabela 1., Ryc. 1., Objaśnienia, Chłopcy
Table 1., Fig. 1., Commentary, Boys
• Figures and tables should be placed on separate pages (See: Illustrative material);

Title page (English and Polish versions on separate pages – if article is meant for publication in both English and Polish) containing the full title of the paper and its short title (up to 40 characters including spaces) to be placed in the running head, names of author(s), affiliation of the author(s) presented according to the following scheme: faculty, university, country, contribution of the co-authors in the creation of the article using symbols in the case of collective works (pattern of symbols according to the instructions in IC Publishers Panel); mailing address of the lead author (author’s full name, address, e-mail address and phone number).

Abstract and key words (English and Polish versions on separate pages – if article is meant for publication in both English and Polish), taking the following structure into account:
Full title of the work, summary about 250 words with division into parts; (in English) Purpose, Basic procedures, Main findings, Conclusions (in Polish: Cel pracy, Materiały i metody, Wyniki, Wnioski), keywords containing from 3 to 15 words (preferably using the MeSH dictionary);

The main body of the text (in English and Polish)
The main body of the text should include the following parts:
Introduction. Introduction acquaints the reader with the subject of the article and places it against the background of existing research (literature review).
At the end of the introduction, the aim, research problems and hypotheses should be clearly stated.
Material and methods. An accurate description of the research subject (material) should be presented in the methodological part. The number of subjects, their age, sex and other characteristics of the participants should be indicated. Additionally, information regarding the conditions of testing, time and methods, techniques and research instruments, with particular emphasis on the description of the used apparatus should be given. The name and address of its producer should be given. If an original method or technique of research was used, it should be described precisely by presenting its validity and reliability (reproducibility). In the case of modifying already recognized methods, the applied changes must be described and the need for these changes must be justified. Statistical methods should be explained so that it can be easily determined whether they are properly suited for the purpose of research. The author of the review or meta-analysis should provide methods of searching for materials, methods of selection, etc.

Results. Presentation of the results should be logical and cohesive, and closely linked to the data in the tables and figures. Referencing results presented in the tables or figures, the abbreviated name of the table and figures (Table 1, Fig. 2) should be placed in parentheses and on the margins of the work, suggesting their location in the comments. In the main body of the paper, the same results in tables and figures cannot be repeated.

Discussion. The author should relate the results to data from literature (other than described in the introduction), highlighting the innovative and significant aspects of his/her work. The adopted hypotheses should be verified or falsified.

Conclusions. Presenting cognitive and applicative findings, the posed hypotheses should be considered and vague statements not supported by the results of the research should be avoided.

Acknowledgements. A list of persons or institution(s) contributing to the preparation of the article, financially or technically supporting the research process or article publication may be given. It is particularly desirable to provide the study grant number.

References. The bibliographic list contains only items which are referenced in the body of the text. Bibliographic descriptions, enumerated using Arabic numerals and listed in the order of citation (not in alphabetical order) should be printed on a separate page. Each referenced item should start with a new line. The sequenced number of the bibliographical item, given in square brackets, must correspond to the order of reference to the publication in the body of the text.

Bibliographic description of the article should include:
the name of the author(s), initial(s), surname(s), title of the article, name of the journal in functioning abbreviated form, year of publication, issue, volume number, pages, DOI number (if the publication has one). Bibliographic description should end with a full stop.

The Vancouver Referencing Style, also known as the author-number system of citation, recommended for medical sciences should be used in the publication (https://www.library.uq.edu.au/training/citation/vancouver.pdf). Enumeration of the referenced texts and principles of citation are defined by the so called Vancouver Convention drawn up by the ICMJE (International Committee of Medical Journal Editors). According to it, referencing material from the source in the body of the text should end in the bibliographic item number in square brackets, e.g. [1]. In the case that reference is made to the authors, the reference is placed immediately after the author’s surname (without first name initial) (e.g.: “According to Aronson et al. [23] this study is ...”).

Repetition of the reference to the same publication is done by its earlier established number. References of attachments are organized according to the order of their citation in the body of the text. Citing two or more publications should be included in square brackets in chronological order of their publication.
Explanatory notes or supplementary text should be numbered using the Oxford Referencing System, maintaining consistency throughout the article.
Examples

Monograph by no more than six authors:


Monograph by more than six authors After the sixth author, the following abbreviation is placed: et al.


Subsequent editions of the monograph (Edition number is placed after the title)

Monograph publisher (collaborative work)

Chapter in the monograph (collaborative work)

Conference reports (papers)

Conference reports (papers) in electronic version

Articles in journals. Standard, list only six authors, above six – abbreviated: et al.

Articles in journals published in journal supplements

Articles in journals published in electronic version without DOI (digital object identifier). Enter the URL (Uniform Resource Locator) – journal website

Articles in journals published in electronic version, with digital DOI


Articles in journals published in electronic version, found in the PubMed database.

Important information for authors of articles submitted for publication
In view of the fact that since 2014 onwards, the quarterly journal will be published in the original electronic version in English, please translate into English: titles of articles in the bibliographic listing published in a language other than English, providing the language of the original in square brackets after the English title. The title of the journal must remain in full version or in functioning abbreviated form. Example:


The National Library of Medicine recommends placing the English translation of the title in square brackets, and information regarding the language of the article after the page
Regulations for article publication

Illustrative material

- **Technical requirements**
  - **Figures** – should follow a consistent background colour scheme; do not use grid lines or shading.
  - **Tables** – standardized format, reducing grid lines to a minimum.

Example:

<table>
<thead>
<tr>
<th>Group Variable</th>
<th>A</th>
<th>B</th>
<th>d</th>
<th>Significance level p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>21.5</td>
<td>2.2</td>
<td>22.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Body height [cm]</td>
<td>176.2</td>
<td>3.3</td>
<td>178.0</td>
<td>4.1</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>68.3</td>
<td>2.7</td>
<td>79.4</td>
<td>3.5</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>22.3</td>
<td>2.2</td>
<td>25.7</td>
<td>2.8</td>
</tr>
</tbody>
</table>

NS – statistically non-significant difference
* – p<0.05; ** p<0.01; ***p<0.001

**Scanning.** The resolution of scanned illustrations must be at least 300 dpi. Black and white illustrations (lines of the art.) should be in TIFF format, or colour and images (grey) in TIFF or JPEG format (low degree of compression, up to 10%). All files can be compressed using RAR or ZIP; **Symbols,** for example: arrows, asterisks or the abbreviations used in tables or figures should be clearly explained in the legend. **Equations** must be written legibly, especially indices and exponents in powers.

Regulations for reviewing:

- Articles submitted for publication by the IC Publishers Panel are reviewed by at least two independent reviewers. The names of the reviewers are not revealed. Authors and reviewers do not know each other’s identity (double-blind review process).
- The publisher reveals a list of reviewers to the public once a year, in the last issue of the quarterly journal.
- Reviews are performed using the IC Publisher Panel review worksheet. **Reviewers are required to formulate a clear conclusion regarding approval or rejection of an article for publication.**
- Reviewing procedures should be in accordance with the guidelines of the Ministry of Science and Higher Education of Poland, which may be found on the following websites:
  - http://www.antropomotoryka.pl
  - http://bbn.uj.edu.pl/node/76

Concluding remarks

- **Publication of articles in Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES) is free of charge.**
- The author responsible for correspondence concerning the article receives a free PDF file with the issue of the quarterly journal, in which his/her paper is published.
- **Abstracts and full texts in English and Polish are posted on the following websites:** http://www.antropomotoryka.pl/ and http://970.indexcopernicus.com/.
- **Subscription to issues of the journal published in book format can be ordered for a fee at:** joanna.stepien@awf.krakow.pl.
- **Distribution and sales of current and archival issues of “Antropomotoryka. Journal of Kinesiology and Exercise Science” can be found at:**
  - Department of Academic Research and International Relations at the University School of Physical Education in Cracow. Address: al. Jana Pawła II 78, 31-571 Kraków, Tel./Fax: 48 12 683 1224; Tel.: +48 12 683 1278.
  - Krakow Physical Culture Bookshop. Address: al. Jana Pawła II 78, 31-571 Kraków, Tel./Fax: 48 12 681 36 22.


Veracity in Scientific Research and Respect for Intellectual Property:
http://bbn.uj.edu.pl/node/76


Example:

CONTENTS

EDITOR-IN-CHIEF’S FOREWORD
This issue of Krakow–Wroclaw Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES) with Professor Robert Malina from the United States ................................................................. 9

SECTION – VARIA
Robert M. Malina
Movement proficiency and talent development in sport ............................................................... 15

SECTION – SPORT SCIENCES
Beata Florkiewicz, Sławomir Fogtman, Piotr Lesiakowski, Teresa Zwierko
The effect of visual perception training on sensorimotor function in handball players ......................... 25
Michał Boraczyński, Tomasz Boraczyński, Robert Podstawski, Zbigniew Wójcik
Relationships between anthropometric traits, body composition and aerobic capacity in male soccer players aged 13–15 years ........................................................................................................ 33
Wacław Mirek, Gradek Joanna, Mleczko Edward
Using lactate threshold to determine the intensity of marathon running in women practicing sports unprofessionally ...... 41

SECTION – EXERCISE SCIENCES
Adam Haleczko
New procedure for equalization of powerlifting results .................................................................... 55
Daniel Puciato, Michał Rozpara, Władysław Mynarski, Bożena Królikowska
The caloric expenditure of selected tourist activity of students from Opole University of Technology ................. 65
Krystyna Sawicka, Beata Sikorska-Krzyżosiak
The attitude of Bavarian youth towards school physical activity .............................................................. 75
This next, already 69th issue of our Krakow–Wroclaw journal opens with an article by the world-famous kinesiologist and anthropologist, a kinanthropometry precursor, who is closely acquainted with the research interests of the representatives of the anthropomotorics discipline created in Poland. Evidence of this may be the earlier and current close-ties of the Antropomotoryka Office with the world-famous scholar. For several years he was a member of its Editorial Board. In the past, also well-known was the fruitful collaboration with the first chief-editor of our journal, Professor Jan Szopa. Unfortunately, it was interrupted by the unexpected, untimely death of the Polish scientist. The Polish-American exchange of experiences was initiated over a quarter of a century ago thanks to the well-known creator of the Cracow Anthropomotorics school, and still goes on. The initiative to maintain collaboration came from the Poznan and above all Wroclaw researchers of human motor skills. It was not only due to our thread of sympathy towards the American scientist of Polish descent, which is documented by the name Malina passed on to next generations of European immigrants settled in the United States, but above all, due to the hope for benefits that may result from collaboration with a world-renown scientist. It is difficult not to point to the merits of our journal’s editor, Prof. Zofia Ignasiak, in maintaining the Wroclaw-American contact, and also the laudator of the honoris causa doctorate awarded to Prof. Robert Malina by AWF Wroclaw.

Prof. Robert Malina is a remarkable scientific figure. He is the author of over 1,000 scientific publications: monographic, didactic, hundreds of congress and conference speeches, chapters in textbooks and academic monographs, published and developed mainly in English but also in several other national languages, including mostly Polish. He is also a man with a great personality: loving father to his three children, educator of a multitude of students from various American universities (University of Texas in Austin, Tarleton State University and Michigan State University), as well as the trustworthy supervisor of M.A. (he promoted 27 M.A. graduates) and Ph.D. students (he has promoted 44 doctors) and foreign scholars doing their internships (the latter were under the now-retired Professor of the Department of Kinesiology and Health Education, University of Texas at Austin: Takashi Satake Department of Anatomy, Nihon University School of Dentistry in Matsudo, Chiba, Japan and Jan Konarski, Department of Theory of Sport, Eugene Piasecki Academy of Physical Education, Poznan; Poland).

It is worth adding that currently, Professor Robert Malina, despite his mature age, is as scientifically and physically active as earlier. Perhaps such a passion for exercise and an attitude of lifelong concern for his own body and health have been instilled in him from youth, when he practiced American football? With even just a cursory review of his scientific or other works, there is no doubt that the amount of success Prof. Malina has achieved in the scientific field is incomparable to that achieved as an active athlete.

Among some of his main areas of scientific interests, one may find a small but very important field of exploration, which is sport, mainly in children and adolescents. For those with a good knowledge of Professor Robert Malina’s biography, it may seem surprising

1 The specificity of American university studies should be taken into account. Undergraduate studies last 4 years and are the equivalent of B.A. studies in Poland. Graduate studies in the U.S.A. are the equivalent of Ph.D. studies. The M.A. level is only a certain path to Ph.D. studies. In the U.S.A., there are not many programs ending in achieving an M.A. title: either higher education ends in graduating with a Ph.D. or at the B.A. level.

2 Research Interests: 1. Growth, maturation and physical performance; 2. Physical activity as a factor in child/adolescent health, growth and maturation; 3. Motor development, with emphasis on cross-cultural comparisons; 4. Nutritional aspects of growth and performance, with emphasis on under-nutrition, overweight, obesity; 5. Youth sports, growth and maturation of young athletes, talent development, coach education; 6. Women in sport, with emphasis on physique, body composition, menarche, family background; 7. Latin America, with emphasis on Mexico.
that in his scientific considerations, a lot of valuable time and energy was and still is devoted to sports issues. To them, just how tragically his active football practice ended is no secret. He was accidentally hit in the eye with a baseball and almost lost his sight in his youth. The remaining scars, forming a lasting impression of this sports adventure, made it greatly difficult to carry out the cataract operation which Professor recently underwent. Thanks to his extraordinary vitality and the efficient hands of surgeons (hard not to emphasize), who drew a particle of knowledge from Professor’s achievements, he succeeded in a speedy comeback to his research workshop and publishing plans. Among them was the earlier announced article prepared for the 1st International Scientific Conference: Motor Ability in Sports – Theoretical Assumptions and Practical Implications, Bronisław Czech University of Physical Education, Krakow, Poland, September 23, 2015. Its Polish version will be published in the post-conference materials.

After studying the content of only selected works and above all, after further even short conversations with Prof. Robert Malina, it may be concluded that the amazing personality of the American Professor is little known in Poland, as well as his rich publishing work, as also ... the source of information for scientists around the world, including the Polish. In the Polish language, there are no complete sources of information on this truly Renaissance man or his works. And this such short biographical review given in laudations delivered on the occasion of Professor’s honoris causa doctorate granted by the Krakow or Wroclaw University of Physical Education, or notes announcing his stay in our country at conferences or lectures given mainly at the University of Physical Education in Wroclaw, hardly constitutes as such a source. Such information extracted by the protocol of a ceremony or a form of journalistic communication does not reflect Professor’s position in the global scientific world or his rank of impressive scientific achievements. To make up for the undeniable gap in knowledge on the biography of this scientist and athlete, the initiative to develop bibliographic descriptions of all his publications has been undertaken. Conversations on obtaining a permit for the dissemination of such a particle of Professor Robert Malina’s curriculum vitae are currently being carried out. Of their effects, we will inform readers in the next issues of our Krakow-Wroclaw Antropomotoryka.

And now, let us move on to the content of our next issue. At the beginning, a little more than usual on the topic: what may surprise Antropomotoryka readers about the review article on the characteristics of the meta-analysis: Movement Proficiency and Talent Development in Sport? This is a review article containing characteristics of meta-analysis summarizing the research achievements included in 76 bibliographical items. The following program of research penetration was outlined in it: “This paper reviews general concepts related to the development of movement proficiency in childhood and adolescence and several societal trends that may influence demands placed upon movement development and proficiency. It then focuses on movement proficiency in the context of sport talent development programs.”

It was carried out at several stages. In the first chapters, bluntly titled: Movement Proficiency: Process and Product and Movement Proficiency: Maturation Effects, you can find a factual summary of the most important studies in the field of motor and somatic development carried out around the world, which may be useful in the organization and implementation of a system of training at a high level of competitive sports. Particular attention was paid to the issue of acquisition of ontogeny of motor skill resources in early stages up to a championship level (Movement Proficiency); its name can be referred to the term “motor competences” (Competence in Movement), as it is recognized in the most recent Polish Antropomotoryka. An outline of motor skills.

In turn, we proceed to a review of research (mostly American) related to exploring the developmental and environmental determinants of human motor skills. Attention was paid to the changes in the methodology currently used in considering the signaled issues. Multi-variable statistical models replace the simple statistical methods. Their use has contributed to indication of the multi-directional pace of development of motor and somatic potential in children and adolescents. Lack of close links between them demonstrated in a number of works was also an impulse for researchers to focus attention on the significance of the primary source of motor skill component development, which is undoubtedly physical activity.

In the following sub-chapters: Societal Conditions and Activities of Youth, Sport Talent Development Models, General, Scheme of Talent Programs The Long Term Athlete Development Model – you can find a comprehensive overview and synthesis of literature concerning the issue of sports training in talented children and youth. Following theoretical assumptions and practical implications, in our country, it is difficult not to see the blurred traces of European methodological solutions created in the former Soviet Union and East Germany, and which are now being creatively developed on the American continent.
In very detailed discussions, as is custom for American professors, on the topic of the carried out experimental studies, the only thing lacking are the projected costs of the functioning of the organizational model of training children and youth. However, you can find an estimate of the work needed, for example to train a football player at a championship level. Evidence of this can be found in the following statement: “Scientific research has concluded that it takes eight to twelve years of training for a talented player/athlete to reach elite levels. This is called the ten-year rule or 10,000 hour rule, which translates to slightly more than three hours of practice daily for ten years”.

In the final chapters we feel slightly disappointed (which proves the honesty in the way of passing on study results) because of the difficulty to use relative recognition of physical fitness due to the age of morphological development of young athletes. Much evidence of the need for distance in speaking up about the prognostic value of mathematical models is given honestly, which allows determination of the period of the fastest growing prevalence of body height in one year, called Peak height velocity (PHV). Pointed to are controversial issues in identifying sports talent in various disciplines. Attention was also paid to the issue of environmental considerations in the organization of sports training of children and adolescents in the United States, with particular emphasis on the implementation of The Long Term Athlete Development Model (LTAD). Also given were examples of the existence of good practices and establishing the sports training system in the United States on a scientific basis. These included, among others: “IMG Academy was formerly the International Management Group that operated a boarding school for tennis players. The IMG Academy is a school that now offers academics as well as programs in baseball, basketball, American football, golf, lacrosse, soccer, tennis, track and field, and general athletic development”.

The results of source material analysis included in 76 bibliographical items led to some very interesting conclusions:

1. The development of proficiency in movement skills is a major development task from childhood through adolescence.
2. The development of overall movement and sport-specific skills is the primary priority of sport talent programs.
3. Programs aimed at developing talented young athletes need to recognize several important features:
   - First, talent development is a highly individualized and dynamic process.
   - Second, the process is superimposed upon a constantly changing base, specifically the demands of physical growth, biological maturation and behavioral development, and their interactions as children pass from childhood into and through puberty and adolescence, and into adulthood.

   - Third, the process is exclusive; focus is often on the "most talented" individuals in a given sport or sport discipline/position, whereas many others are systematically excluded and/or voluntarily withdraw from the sport.
   - Fourth, although some talent models view the developmental process as long-term, paths to elite status are highly variable among individuals.

As it may be deduced from the above conclusions, surely no one will be disappointed with taking the time to study the article, which introduces the reader to innovative, important issues in applied anthropometrics. It is also possible to believe that empirical studies published in the quarterly can also provide us with much satisfaction from exploring both motor capacity, and the possibility of its usage and improvement.

An example of this may be the publication New procedure for equalization of powerlifting results, which is continuation of the work of our faithful collaborator since the beginning of issuing Antropomotoryka. The author is the creator of the currently used result conversion tables for the supine position bench-press in the Olympic biathlon in disabled athletes, which have been created thanks to his initiative and are currently used worldwide in International Paralympic Committee (IPC) competitions. It is worth noting that our journal was present at the beginning of the road to the internationalization of the currently used method for relative result evaluation according to the “Haleczko Formula”. Although, it is a shame that the Editorial Office did not participate in the IPC discussions (concluded without a happy ending), regarding the unlawful usage of the developed proprietary version of the tables at sporting events without giving the name of its Polish author ... and which it is not without significance coming from someone Polish, and AWF Wroclaw! Let us hope that this time, the efforts of the still physically and scientifically active doyen of Polish anthropometrics are rewarded, proving to the world that the level of science that we create in Polish academies of physical education shows that we are not its byways and have the right to claim a patent for intellectual creation even appearing in a journal which is not yet present on the Master Journal List. With great satisfaction, we are the first to publish the new procedure of result equalization in powerlifting, developed using a method currently called the “Haleczko Formula”. We hope that, like the previous one, it finds application in weightlifting sports competitions in handicapped athletes, subordinate to the International Paralympic Committee IPC, but with a full bibliographic
description of publications containing the name of its creator – Adam Haleczko, along with his address.

In the next article, Using lactate threshold to determine the intensity of marathon running in women practicing sports unprofessionally, the authors undertook verification of the method to determine the optimum speed and heart rate during a constant run, continued at the level of maximal acidosis balance (Maximal Lactate Steady State – MLSS), using the quite popular lactate threshold test. 10 women involved in amateur marathon running for 3–8 years (R = 5 years) participated in the study. During this period, they reached a varied sports levels in marathon running.

In the week before the marathon, a test on an athletic track was used to determine lactate threshold and running speed and heart rate at its level. It was assumed that indicators set at the level of maximal lactate threshold balance (Maximal Lactate Steady State - MLSS) would be an objective indication for the realization of tactical tasks in a proper manner while running a marathon. The results confirmed the relationship, but only for the more experienced female runners who had higher levels of running pace and intensity of exercise sensation. Ipso facto, the interaction (not always obvious) of coordination (feeling the running pace) and physical condition (endurance abilities) abilities in a long-term physical effort.

The paper entitled The effect of visual perception training on sensorimotor function in handball players should be regarded as belonging to a similar trend to adapt theoretical assumptions of human motor function research for sport purposes. The authors undertook the task of proving in an experiment that six weeks’ usage of methods typical for orthoptics and sports training can improve sensorimotor performance in athletes, practising handball as well as in people not practising sports. The assumption was also made that adaptive changes of longer-lasting effects than those achieved in other training experiments could be achieved. As follows from the well-documented research results, the objective was achieved in the group of people training to a satisfactory degree, but the effect of post-training changes (adaptive in character) was short-lived. Consequently, this led to the conclusion that in order to maintain a stable level of visual sensorimotor function in athletes, there is the need to implement a systematic programme of perception training into the exercise programme.

After reading the article, one can be impressed by the scope of research and methodology used. Apparently, the scientific nature of the paper limited the possibility for a detailed description of the techniques and tools used in the training experiment. A careful reader will also spot the lack of justification for using Orthoptic Vision Therapy methodology, the scientific value of which is not without reservations. One can hope that the cooperation between the scientists from Szczecin and Antropomotoryka Journal of Kinesiology and Exercise Sciences will continue and that in future publications, even small deficiencies (found after close analysis) will be compensated for; the dissertation at hand is, after all, a very interesting, valuable, recommended paper.

Undoubtedly, similar reflection must arise after the analysis of some aspects of the paper entitled Relationships between anthropometric traits, body composition and aerobic capacity in male soccer players aged 13–15 years. Its authors, after two years of continuous observation of 27 boys training football, assessed the implementation of the training programme negatively, due to its adverse effects on the level of development of body composition components and the correlation between the development and aerobic efficiency. Not only do the presented results encourage further observations, but must also lead to reflection on the difficulty of applying statistics to explain developmental processes and the phenomena in children (both practising and not practising sports) during adolescence. The authors, through honest acknowledgment of the difficulty in explaining some of the results of statistical analyses, drew attention to the unresolved problem of relative assessment of maximal oxygen uptake. So far, intense discussions centred around the problem of relativisation of strength abilities, which consequently led to the results in weightlifting presented earlier in accordance with the very interesting Haleczko formula. Therefore, it might be worthwhile to once again, by analogy, attempt an interpretation of the data from relative strength research, presented in several works by human motor function researchers from Krakow and Wroclaw. Perhaps the attentive reader will see the need for referencing the still relevant views of Prof. Napoleon Wolański (on the role of statistics in the interpretation of biological phenomena), and more recent suggestions of statisticians from Wroclaw (about the need to revise the simplistic approach to the matter of relevance of Pearson correlation coefficient considering the size of the sample) in the interpretation of the results presented in this undoubtedly interesting article.

And would it not be possible to engage in an interesting and much needed scientific discussion in Antropomotoryka. Journal of Kinesiology and Exercise Sciences itself, as in previous years? I think that is not a rhetorical question!

Two other articles also encourage exchanging experience: The caloric expenditure of selected tourist activity of students from Opole University of Technology and The attitude of Bavarian youth towards school physical activity. In the first one, an interesting attempt was made to assess the effectiveness of tourist activity, over the course of 2 years, in 217 students aged from 18 to 35 years (109 men and 108 women), from one of the Polish
colleges. Two methods of observation were used: personal record-keeping and measuring calorie expenditure with the help of uniaxial accelerometer (Caltrac Monitor). The results presented clearly indicate that both methods are relevant and can complement each other.

On the other hand, in the other work you can get to know the effectiveness of implementation of directional and instrumental objectives of physical education in a region of Germany, in Bavaria. The study participants comprised of young men and women from two different cities. It was shown that regardless of place of residence, both girls and boys positively assessed physical education classes, but pointed to differences in the preferences of various forms of activity and its intensity. This is an interesting report summing up the clearly positive impact of the action in shaping pro-somatic attitudes in German children. The study results can be regarded as a valuable reference point for comparative studies. In addition, the value of the work is increased by usage of a modified research tool called Attitude Questionnaire – Semantic Differential.

Concluding the more lengthy than usual foreword to the subsequent issue of the Krakow–Wroclaw journal, I want to make a promise, the next foreword will be shorter. I must ensure you the materials in the next quarterly journals will be as interesting as in this one.

Editor-in-Chief

Edward Mleczko
MOVEMENT PROFICIENCY AND TALENT DEVELOPMENT IN SPORT*

Robert M. Malina ABCDEFG

Professor Emeritus, Department of Kinesiology and Health Education, University of Texas at Austin

Key words: fundamental motor skills, performance, growth, maturation, play, childhood, adolescence, youth sports

Abstract

The development of proficiency in movement skills is a major development task from childhood through adolescence. Proficiency in movement skills is also central to play behavior, to informal and formal games, and to sport-specific skills and functional capacities (power, speed, agility, strength, aerobic capacity, etc.). The teaching and refinement of sport-related skills is an objective of youth sport programs in general and of talent programs for specific sports. The development of movement proficiency is discussed in general and then in the context of talent development models and specifically the Long Term Athlete Development model. Four features of the talent development need to be recognized: (1) it is a dynamic and highly individualized process; (2) the process is superimposed upon a constantly changing base – the demands of physical growth, biological maturation and behavioral development, and their interactions; (3) the process is selective and exclusionary; and (4) fourth, although talent models view the process as long term, paths to elite status are highly variable among individuals.

Introduction

Movement proficiency – competence in movement or motor skills, is a primary developmental task during infancy and childhood, although the process continues through adolescence into adulthood. Movement proficiency is central to learning, to play behaviors, to informal and formal activities, games and sports, to sport-specific skills and functional capacities, and to sport talent development programs. Movement is also the basis of physical activity, “…any bodily movement produced by skeletal muscles that results in energy expenditure” [1, p. 126].

The development of movement proficiency from infancy through adolescence is a long term process that is superimposed on the demands of physical growth, biological maturation and behavioral development, and of the interactions among these processes which are often overlooked. Although the development of movement proficiency is largely dependent upon neuromuscular maturation and associated changes, movements are behaviors which occur in specific cultural contexts and as such are influenced by cultural demands and pressures.

This paper reviews general concepts related to the development of movement proficiency in childhood and adolescence and several societal trends that may influence demands placed upon movement development and proficiency. It then focuses on movement proficiency in the context of sport talent development programs.

Movement Proficiency: Process and Product

The development of movement proficiency involves two general aspects: first, the development and refinement of basic movement patterns (often labeled fundamental motor skills), and second, the integration of these

*This paper is based on the lecture, Movement proficiency and talent development in sport, presented at the 1st International Scientific Conference: Motor Ability in Sports – Theoretical Assumptions and Practical Implications, Akademia Wychowania Fizycznego im. Bronisława Czecha, Kraków, Poland, September 23, 2015.
patterns into more complex and specialized movement patterns and skills. The former is more general concept that focuses on the general features of a specific movement and on the process through which children progress from initial efforts in a specific movement task to the mature pattern (mastery). The latter, in contrast, focuses on the product (outcome) of specific movements more so than on the process. Improvement in the product of performance implies greater efficiency of movement (skill).

The movement patterns comprising nine fundamental movement skills have been described in a developmental context for children the mixed-longitudinal Motor Performance Study at Michigan State University [2, 3]. The approach was largely qualitative and focused on the ages at which the criteria for specific developmental stages for each movement pattern were attained by boys and girls. Boys tended to attain each stage of overhand throwing and kicking earlier than girls, whereas girls tended to attain each stage of hopping and skipping earlier than boys, which may be related to perceptions of the cultural appropriateness of activities that involve these movement patterns. The attainment of early stages for running, jumping, catching and striking showed considerable similarity between boys and girls, but there was more variation between boys and girls in ages at which the final or mature stages were attained. Mature patterns of most fundamental movements were attained by 6 or 7 years in 60% of the children in the Motor Performance Study, although some were not attained until later, e.g., standing long jump in both sexes, overhand throw in girls. Note, however, 40% of the children had not attained the mature levels by these ages, i.e., many 6 to 9 year old boys and girls had not developed sufficient movement control to successfully accomplish the mature patterns of the fundamental skills. Given the observed variability, there is a need to address the influence of outdoor play, parent-child and sibling interactions and modeling, specific instruction and practice, and/or early entry into a sport on progress through specific movement patterns and their integration into more complex movement sequences?

Currently used tests of fundamental motor skills [4–6] in surveys of children and adolescents are largely qualitative. Emphasis is on the specific components which define mature movement patterns (mastery) for several locomotor (run, jump, gallop, skip, etc.) and object-control (throw, catch, kick, etc.) skills. A variable number of criteria describe the mature pattern (mastery) for each skill. Performances are rated in terms of the presence or absence of the specific criteria. The tests have a major subjective component. Performances of children are evaluated and rated by trained observers, though inter- and intra-observer variability is not ordinarily reported.

The tests are used primarily to evaluate status and also to screen for movement problems. Status reflects level of proficiency at the time of observation, and as such reflects the outcome of the interactions among neuromuscular maturation, growth, and the environments of children. Percentages of Australian children attaining mastery or near mastery of fundamental movement skills (described as possessing advanced skills) tended to increase with age from 6 through 15 years of age [5, 7], although there was considerable variation by skill. Nevertheless, many youth, girls more so than boys, 9 through 15 years of age, did not show near mastery or mastery of six fundamental movement skills — run, vertical jump, throw, catch, strike, kick [7].

The results beg several important questions: What are the characteristics (growth, maturation, physical activity and other behaviors) of those who have and have not reached mastery in fundamental movement skills? What type(s) of intervention can enhance the fundamental movement skills of youth at these ages? What is the relationship between level of mastery subjectively assessed and performances (outcomes) in corresponding motor tests?

Motor performances on standardized tests of running (dashes, shuttle runs), jumping (standing long and vertical jumps), and throwing (ball throw for distance or velocity) improve, on average, through childhood into adolescence. Sex differences are minor in childhood except for the ball throw, but are magnified during adolescence. Performances of boys continue to improve, on average, through adolescence while those of girls tend to reach a plateau [8]. Performance data for standardized tests of striking, catching, skipping, etc. for the general population of youth are limited.

Movement Proficiency: Maturation Effects

Relationships among body size and maturity status (skeletal age) on one hand and movement proficiency on the other hand have received attention. Earlier studies were limited to correlational analyses, whereas more recent approaches attempted to control for interactions among age, maturation and body size. For example, skeletal age per se and in combination with chronological age, stature or body mass were not significant predictors of the standing long jump, vertical jump and shuttle run among girls among girls 6–16 years [9], but accounted for 6% to 13% of the variance in the vertical jump in boys 13–17 years and for only 1% to 3% of the variance in a shuttle run in boys 12–16 years [10]. Standardized residuals of skeletal age (note, skeletal age and chronological age are correlated) independently or interacting with stature and mass explained limited amounts of the variance in three motor performances (dash, standing
long jump, distance throw) of children 7–12 years, 4% to 30% in boys and 7% to 27% in girls [11]. On the other hand, standardized residuals of the regression of skeletal age on chronological age alone or interacting with body size were not strongly related to six locomotor and six object-control skills [4] and the four tests comprising of a motor coordination battery [12] in boys and girls 7–10 years; total variances explained ranged from 0 to 9% [13]. The available evidence, though limited, suggests that skeletal maturation as reflected in skeletal age, alone or interacting with stature and mass had a relatively limited influence on fundamental movement skills, motor coordination and motor performances of children and adolescents.

At the extremes of biological maturation among adolescent boys of the same chronological age, however, early maturers show better motor performances than late maturers; corresponding maturity-related trends are not clearly apparent in adolescent girls of the same age [8]. Variation in the timing and tempo of the adolescent growth spurt as a factor affecting motor performance has received limited attention. In a longitudinal sample of Belgian boys 12–18 years, running speed and speed of upper limb movement had adolescent spurs which occurred prior to peak height velocity (maximum rate of growth in height during the adolescent spurt), while the vertical jump had a spurt that occurred after peak height velocity [14, 15]. Results of a short term longitudinal study of Spanish boys and girls were consistent for the standing long jump, but not for running speed [16]. Static strength also had an adolescent spurt that occurred, on average, after peak height velocity in both sexes [15].

There is a need to identify and study other factors which influence the development of movement proficiency, motor skills and motor performances during childhood and adolescence. Several early reviews noted associations among parental attitudes, parent-child interactions and specific fundamental motor skills (standing long jump, overhand throw), and sibling interactions in eliciting selected object-oriented and locomotor activities [17–19]. Low motor proficiency was associated with low socioeconomic status (girls) and non-English speaking cultural backgrounds (boys) in Australian elementary and high school youth [20]. Low proficiency was also associated with reduced levels of physical activity and cardiorespiratory fitness. Overweight/obesity (BMI) was associated with low proficiency in locomotor skills, but was not consistently associated with proficiency in object control skills. Other factors, cultural, behavioral, familial and social, and their interactions with growth and maturity status which may influence the development of fundamental movement skills and motor performances need study.

**Societal Conditions and Activities of Youth**

Although limited to the United States, observations on changes in the daily activities of children and adolescents provide insights into societal factors which may have influenced physical activity and participation in sport, and by inference movement proficiency [21–24]. Across surveys in 1981, 1997 and 2003, time in school increased to 1997 but was then stable, while time in physical play (including sport) was replaced by organized sport, other organized activities (arts, academic, social) and non-physical play/leisure time (computer games, media in general). Time in sport declined from 1997 to 2003 among children 6–12 years (30–32). More recently, statistics from the Sports and Fitness Industry Association indicated 2.6 million fewer participants 6–12 years of age in several sports (basketball, soccer, football, baseball, softball, track and field) between 2008 and 2013 [25].

The time use surveys of children and adolescents between 1981 and 2003 were motivated by interest in the influence of family circumstances per se, of changes in family characteristics over time, and subsequently of several political and societal changes on the daily activities of children and adolescents. Persistence of the trends has been emphasized more recently [25]: continued increase in the number of single parent and dual-working parent families; cultural pressures to raise high achieving children - the “professionalization of parenthood”; persistence of state mandates for standardized testing which has contributed to an increase in after school classes/tutoring sessions and reductions in school recess and free play; and a parental focus on resume building for their child/children.

The trends suggest an “over-organization of childhood” which has implications for the development of motor proficiency. This is especially apparent in the increased prevalence of organized after-school activities among children and adolescents [26–28]. Emphasis on organized activities impacts discretionary time and specifically opportunities for free play, and may also contribute to early specialization in arts, sport and other activities. Superimposed upon the preceding is the ever-increasing presence of the media in the daily lives of youth and by inference increased opportunities for physical inactivity [29].

One consequence of increased time in organized activities is a reduction in time for free play, specifically outdoor play. Free play is unstructured; children created their own structure or structures while they play – real or imagine. Free play is also free of adult involvement and organization. In contrast, organized activities are likely to involve structured play which is structured by adults and directed towards specific activities and goals.
Free play of course can include a variety of activities. Of relevance to the present discussion are “street games” based on sports, so-called informal sports – stickball and punchball (variants of baseball which include throwing, catching, striking), inner city basketball, street soccer, ice hockey played on a frozen pond or roller hockey on the street – played under conditions free of adult supervision. Such informal activities represent what is now labeled deliberate play [30]. These and related activities/games have major implications for movement proficiency. They involve frequent repetitions (not under the eye of a coach), trial and error, experimentation and repetition, variable settings, and exposure to different conditions, skills and rules. Movement skills in general and sport-related skills are learned without awareness or explicit knowledge of the skills. Acquisition of skills under such circumstances represents informal or implicit learning [31]. Skills learned informally may be adaptable to variety of circumstances. It is also postulated that skills learned under informal are influenced less by stress and fatigue [32]. Research on implicit learning in sport is in its infancy but is expanding. Nevertheless, it is reasonable to assume that youth with a variety of experiences in informal, free play and street game activities are exposed to different situations and skill demands in which they attempt, practice and learn a variety of movement skills. It is also likely that such informally learned movement skills (and probably social skills) transfer relatively easily to other play, game and sport situations.

Sport Talent Development Models

The identification of potentially talented youth athletes is central to sport programs. Given the money involved in sport nationally and internationally, the search for and the development of sport talent are perhaps more structured at present than in the past. The process takes a variety of forms, including formal talent identification programs, sport-specific schools, clubs and academies, select teams in youth leagues, the quest for sport scholarship support, commercial enterprises such as the IMG academies [see Note 1], and probably others.

Although the approach varies by sport, the general pattern of talent development includes initial evaluation of physical characteristics (anthropometric), movement skills and perhaps behavioral characteristics beginning at relatively young ages. Each sport, of course, has its own template, timetable and approach. Protocols were rather systematic in the sport systems of the former Soviet Union and several Eastern European countries [33–38], which were extended and modified to Western countries, including the United States, Canada and Australia [39, 40]. The programs generally focused on individual sports or sport disciplines in contrast to team sports, perhaps because of the greater number of Olympic medals in the former. The structured approaches of the former Eastern European countries are to some extent still visible in artistic gymnastics, tennis, figure skating, swimming and perhaps other sports. Presently, these sports are largely operated by private clubs or organizations which are fee based.

Protocols for talent development in team sports are seemingly less structured on the surface. The general template includes physical, skill (general and sport-specific), physiological (functional), perceptual and cognitive, and psychological (behavioral) characteristics [41]. Application of the template in the development of talent is quite variable.

Most youth sports programs emphasize mass participation at relatively young ages and are largely community based. Programs become more specialized and competitive with increasing age during childhood and into adolescence. Focus on talented youngsters also increases at these ages. The search for talent occurs both informally, e.g., observing youth in game situations, noting those who are more skilled and inviting them for a specific team, and formally, e.g., regular tryouts for select or advanced teams, scholarships for elite school programs and perhaps others.

Special programs for talented young athletes in the United States are often labeled select or travel teams. Such programs emerge at about 10–12 years of age or so in basketball, baseball (boys), softball (girls), soccer, ice hockey and perhaps others. Talented youth are recruited from a local area and sometimes from adjacent areas for the purpose of participating at a higher competitive level. The programs operate independently of highly organized interscholastic sport programs (see below) and often encourage youth to participate in a single sport year round. In some sports where qualified coaches in schools may be limited (e.g., soccer), select or travel teams are often preferred by parents and sport organizations. Select programs vary in cost, most of which is borne by parents.

The focus on talented youth athletes in the United States is nationally apparent in many interscholastic sport programs in public and private schools [see Note 2]. High school sport programs are, in many ways, a feeder system for intercollegiate sport programs. There is also an increase of elite foreign athletes in high school programs, particularly basketball, and an increase in recruiting players from other school districts and states, and from public to private schools [42–44]. However, the number of high school players who make it to the collegiate level is quite small [45] and the number receiving a scholarship support is markedly smaller [46, 47]. Approaches to identifying skilled or talented youth in team sports are especially apparent for European football or soccer where many professional clubs have developmental and academy programs. Soccer is largely a sport
of the lower socioeconomic strata throughout most of the world. Competitions among youth at this level are routinely monitored by clubs looking for talented players. Once identified, talented youngsters are enrolled in the developmental program of a club at a relatively young age. Enrollment in a developmental club program is also aimed at retaining the talented youngster in the sport and also at keeping him away from other sports. Similar to soccer, youth baseball in the Caribbean region is also largely a sport of the lower social strata. It is characterized by many informal games and local programs, and by more formal programs run by professional baseball clubs locally and internationally. The primary purpose of the formal programs in both sports is to develop talented players for the professional market.

**General Scheme of Talent Programs**

Allowing for variation within specific models to identifying talented youth athletes, several generalizations are apparent: early emphasis on general movement skills in early and middle childhood; a shift to sport-specific skills and functional capacities (power, speed, aerobic, anaerobic, etc.) often during the transition into puberty and adolescence; and eventual specialization which occurred relatively late. Exceptions were the so-called "early entry sports", specifically artistic gymnastics, figure skating, diving, and more recently table tennis.

Two "windows of opportunity" during which responsiveness to training is presumably enhanced are implicit in the various talent development models. The first is responsiveness to motor skill instruction and practice during childhood and especially in "early entry sports", and the second is responsiveness to more intensive sport-specific training demands during adolescence. Although documentation of the influence of early instruction and practice in sport-specific movement skills has not been systematically reported, successful instructional programs for motor skills among children 4-5 years and older include guided instruction by specialists and/or qualified coaches, appropriate motor sequences, adequate time for practice, and constructive guidance and feedback [48, 49]. Adolescence is perceived as an interval of enhanced responsiveness to sport training and has received more attention. Adolescence is often viewed as a period of increased sensitivity of the muscular and cardiovascular systems to training, specifically in association with the hormonal changes of puberty [50].

**The Long Term Athlete Development Model**

The Long Term Athlete Development (LTAD) model [51, 52] is perhaps the most recent reiteration or modification of the formal East European models noted above. The LTAD model is really two models, an early specialization model and a late specialization model. The former includes artistic and rhythmic gymnastics, figure skating, diving and table tennis, and the authors propose that each sport develop a model suited to the specific demands unique to each. Proficiency in a diverse array of gross and fine motor and perceptual-motor skills is central to the early entry sports which often begin at 4–5 years of age. Except for table tennis which has its own unique perceptual-motor demands [53], the demands of gymnastics, figure skating and diving highlight unique movement skills and bodily control which highlight orientation in space, optical and acoustic reactions, balance, rhythmic sensitivity, among other factors. An adaptation of the model to diving has been developed [54, 55].

The late specialization model emphasizes four "stages" or "windows" in childhood through adolescence [51]:

1. **FUNdamental stage** – 6–8 years in girls and 6–9 years in boys, emphasizes the development of fundamental movement skills;  2. **Learning to Train stage** – 8–11 years in girls and 9–12 years in boys, emphasizes the development of fundamental movement skills;  3. **Training to Compete stage** – 11–15 years in girls and 12–16 years in boys, emphasizes the development of aerobic and strength capacities and of sport specific skills, described as "build the 'engine' and consolidate sport-specific skills" [51, p. 4]. Biological maturation is central to the third phase; the protocol calls for emphasis on the age at peak height velocity and identifying youth of contrasting maturity status (early, average, late).  4. **Training to Compete phase** – 15–17 years in girls and 15–18 years in boys, is focused largely on preparation for competition.

The late specialization model includes two further stages that extend from late adolescence through adulthood and that are beyond the scope of this discussion. It should be noted that an earlier iteration of the model combined the first two phases into a Fundamental Stage (6–10 years in both sexes), and had different age ranges for the Training to Train stage, 10–13 years in girls and 10–14 years in boys, and Training to Compete stage, 13–17 years in girls and 14–18 years in boys [56].

Two concepts are central to the late specialization model: the "10 year" rule derived from the expertise model in sport psychology and age at peak height velocity. Accordingly, "Scientific research has concluded that it takes eight-to-twelve years of training for a talented player/athlete to reach
elite levels. This is called the ten-year rule or 10,000 hour rule, which translates to slightly more than three hours of practice daily for ten years [51, p. 1],

and,

“One practical solution is to use the onset of Peak Height Velocity (PHV) as a reference point for the design of optimal individual programs with relation to ‘critical’ or ‘sensitive’ periods of trainability during the maturation process” [51, p. 1].

The theoretical framework of expert performance [57, 58], with a focus on deliberate practice over an extended period, emphasizes quality of instruction and practice and as well as ability of the individual to organize the specific knowledge. The accumulation of experience is ultimately represented in the motor and cognitive neural substrates. In contrast, evidence from elite athletes in a variety of sports indicates participation in several sports prior to specializing, variable trajectories to elite levels, and attainment of sport success at national and international levels without 10 years or 10,000 hours of deliberate training [59–61].

Use of PHV as a reference to individualize and optimize training programs is beset with problems. Age at PHV is an estimate of the chronological age (i.e., timing) at which the maximal rate of growth in height occurs during the adolescent spurt. The spurt begins when the rate of growth in height reaches its minimum in late childhood (age at take-off), followed by acceleration (increased rate) to a maximum rate (PHV), and then decelerates until growth in height terminates in the late teens or early twenties. Estimates of age at PHV require longitudinal data for individuals that span the adolescent teens or early twenties. Estimates of age at PHV are considered as highlighted in longitudinal data from the Wroclaw Growth Study [63,64]:

Girls (n = 198)
Age at PHV 8.9 ± 1.1 years, range 6.3 to 12.0 years
Age at PHV 11.9 ± 1.0 years, range 9.0 to 14.8 years

Boys (n = 193)
Age at PHV 10.5 ± 1.1 years, range 7.0 to 14.1 years
Age at PHV 14.1 ± 1.1 years, range 11.5 to 17.3 years

Quarterly measurements of height and calculating and plotting of velocities to monitor the shape of the velocity curve for height are recommended in the LTAD: “By plotting the velocity curves it will be possible to clearly distinguish the rate of growth from one point in time to another. The velocity curve will immediately show distinctive growth points (… the onset of the acceleration in the curve, the peak in the curve and the deceleration in the curve)” [65, p. 15].

Increments calculated over short intervals are influenced by technical errors of measurement, seasonal variation, and time of measurement (diurnal variation). Also, height measurements taken after a period of physical activity (running, jumping, etc.) are likely less than those taken after a period of rest. Measurements are not always taken at the prescribed intervals or dates; as such, derivation of increments needs to be adjusted for the interval between measurements and the prescribed interval, i.e., quarterly as suggested [65]. Given the preceding, short term increments have major limitations. Similar adjustments are also necessary if measurements are taken semi-annually or annually.

Although principles of the late specialization LTAD model are being used in a variety of sports and sport programs, several concerns should be noted. The underlying tenets of the model have been questioned due lack of data and questionable assumptions [66], while evidence addressing the responses of adolescent youth to aerobic-, strength-, and speed-specific training is not consistent with a “maturation threshold” [67]. Limitations of maturity classifications with established methods of assessment – skeletal age and pubertal stages [8, 62, 68], as well as maturity-related gradients among youth athletes in many sports sports [62, 69] have implications for tailoring sport-specific training programs to individuals.

The LTAD indicates differential timing of windows of responsiveness to training of different functional capacities during the interval of PHV [51, 52, 65]. However, the fact that body weight, lean tissue mass, bone mineral content, sitting height and estimated leg length (both sexes), static strength, power, speed and flexibility (limited to boys) and aerobic capacity (both sexes) have their own adolescent growth spurts that vary, on average, relative to the timing of PHV is seemingly overlooked [8, 14, 15, 70].

The preceding observations are based on means derived from longitudinal studies. Intra-individual variation in functional performances during the adolescent spurt needs more attention. For example, in the longitudinal study of Belgian boys, performances of some boys declined during the interval of PHV (vertical jump, bent arm hang, leg lifts, plate tapping-speed of arm movement, shuttle run). Interestingly, boys whose performances declined during the spurt had better performances in respective functional tests at the beginning of the interval of PHV than boys whose performances improved during the spurt [15].

Behavioral changes during childhood and adolescence are mentioned in discussions of the LTAD as well as other talent development models, but are not considered in depth. Sport does not occur in a social vacuum. There is a need to consider how youngsters adapt to sport-specific instructional and training programs, to the
associated social and emotional demands, to the adults who direct the programs, and of course to the competitive arena. The skills and bodies of young athletes hold important social stimulus value which impacts self-perceptions and self-evaluations, especially during adolescence, and also influence the nature and quality of interactions with peers, parents and adults involved with sport. Interactions among athletic peers, between coaches and athletes, as well as sport administrators, parents and athletes likely influence progress or lack thereof in talent development programs and obviously need systematic study. In contrast to athletes in talent development programs, relatively little is known about the physical, behavioral and performance characteristics of youth who voluntarily withdraw or who are systematically excluded from a sport. Detailed study of youth who discontinue participation in a sport may serve to inform the process of athlete development and retention, progression in a sport, and the re-orientation of excluded skilled athletes to other sports where they may attain success.

**Predicted Age at PHV**

Although not incorporated into the LTAD, sex-specific equations for predicting time before PHV (called maturity offset) from chronological age and anthropometric dimensions (height, weight, sitting height, estimated leg length) have been developed [71]. Predicted age at PHV (years) is calculated as the difference between chronological age and predicted maturity offset. The equations are often discussed in the context of talent development models [72, 73] and are increasingly used in studies of youth athletes, often classifying them as pre- or post-PHV, or in terms of time before or after PHV [63, 64].

Validation studies applying the maturity offset equations to longitudinal samples of Polish – Wrocław Growth Study [63, 64] and American – Fels Longitudinal Study [74] youth followed from 8 to 18 years indicated several limitations. First, predicted maturity offset and age at PHV were dependent upon chronological age at prediction, including age per sex and associated variation in body size. Second, predicted ages at PHV had reduced ranges of variation (SDs ≤ 0.5 year). Third, predictions were affected by individual differences in actual ages at PHV (also age at menarche); among early maturing boys and girls, predicted ages at PHV were consistently later than actual ages at PHV, while among late maturing youth of both sexes, predicted ages at PHV were earlier than actual ages at PHV. And fourth, intra-individual variation in predicted ages at PHV associated with chronological age at prediction was considerable. The original maturity offset prediction equations have been simplified and calibrated with external samples [75], but the new equations await validation in independent longitudinal samples.

The LTAD calls for identifying youth of contrasting maturity status, i.e., early, average or late maturing, though does not specify the method for doing so. The maturity offset prediction equation has been used by several English professional sport clubs to categorize players as early, on time or late maturing. Several club representatives noted that >90% of players were classified as average using a plus/minus one year criterion to define early, average and late maturing youth, (Sean P. Cumming, University of Bath, personal communication). This reflected the reduced range of variation in predicted ages at PHV. The observation was also consistent with data for Portuguese youth soccer players. Using a predicted age at PHV within plus/minus one standard deviation of the mean age at PHV for the three samples upon which the prediction equations were developed (13.8 ± 0.9, 12.9–14.7 years) as the indicator of average maturity status among 180 soccer players 11–14 years, 89% were classified as average [76].

**Summary**

The development of overall movement skills and sport-specific skills is the primary priority of sport talent programs. The development of functional capacities (power, speed, aerobic, and so on), which are largely based on motor performances, occurs largely during adolescence. Inter-individual variation is characteristic of the age at onset of the adolescent spurt and also of age at peak height velocity. Similar variation is also characteristic of the adolescent spurt in body mass and composition, and in functional capacities which vary relative to the timing of the spurt in height.

Programs aimed at developing talented young athletes need to recognize several important features. First, talent development is a highly individualized and dynamic process. Second, the process is superimposed upon a constantly changing base, specifically the demands of physical growth, biological maturation and behavioral development, and their interactions, as children pass from childhood into and through puberty and adolescence, and into adulthood. Third, the process is exclusive; focus is often on the “most talented” individuals for a given sport or sport discipline/position, whereas many others are systematically excluded and/or voluntarily withdraw from the sport. And fourth, although some talent models view the developmental process as long term, paths to elite status are highly variable among individuals.

**Notes**

1. IMG Academy was formerly the International Management Group that operated a boarding school for tennis players. The IMG Academy is a school that
now offers academics as well as programs in baseball, basketball, American football, golf, lacrosse, soccer, tennis, track and field, and general athletic development (https://www.imgacademy.com/about-img-academy).

2. In the 2014-2015 school year, the ten most popular sports (participants) among boys were American football, outdoor track and field, basketball, baseball, soccer, wrestling, cross-country, tennis, golf and swimming and diving; the corresponding sports among girls were outdoor track and field, volleyball, basketball, soccer, softball (fast pitch), cross-country, tennis, swimming and diving, competitive spirit squads, and lacrosse (National Federation of State High School Associations, http://www.nfhs.org/ParticipationStatistics/ParticipationStatistics.aspx/).

References


Address for correspondence:
Prof. Robert M. Malina
10735 FM 2668
Bay City, TX 77414 USA
e-mail: rmalina@1skyconnect.net
979 240-3446
THE EFFECT OF VISUAL PERCEPTION TRAINING ON SENSORIMOTOR FUNCTION IN HANDBALL PLAYERS

Beata FlorkiewiczABDE, Sławomir FogtmanABD, Piotr LesiakowskiF, Teresa ZwierkoACDEG

Faculty of Physical Culture and Health Promotion, University of Szczecin, Poland

Key words: visual perception, reaction time, handball

Abstract

Aim. The present study is aimed at investigating the efficiency of a specific perceptual training program used to enhance visuomotor processing in athletes.

Material and methods. The experimental group involved 15 university handball players. The control group included 13 non-athletic students. Both groups were homogeneous in terms of age and gender. The simple and differential reaction time included in the Vienna Test System (Schuhfried, Austria), eye-hand coordination test and visuospatial specific run test (Fitlight Sports Corp., Canada) were performed three times: before the experiment, after six weeks of perceptual training, and a retention test at intervals of four weeks. The perceptual exercise methodology was based on vision enhancement and specific visual-motor reaction training.

Results. Following the training period, the majority of visuomotor parameters improved. The greatest effect was observed in the differential reaction time test ($p<0.01$), eye-hand coordination test ($p<0.001$) and visuospatial specific run test ($p<0.001$). Perceptual training does not affect the results of the simple reaction task ($p>0.05$). The results of the retention test confirmed the visual training effects.

Conclusion. The six-week training period suggests that perceptual skills are trainable and can be improved by means of appropriate training. The positive effects obtained after a period of six weeks of training are limited. Proper implementation of the perceptual training program into sports practice in handball is recommended.

Introduction

Sensorimotor mechanisms of visual efficiency are determined by the speed of visual spatial location, discrimination of moving objects in central and peripheral vision, hand-eye coordination, and by the ability to maintain visual attention stability[1]. In sports demanding visual sensorimotor functions, such as handball, speed detection of proper stimulus is a factor conditioning the efficiency of motor response.

Research conducted to evaluate visual function and motor skills in athletes showed that advanced professionals, in comparison to beginners and persons who do not train at all, are characterised by: (1) more efficient coding and collecting of relevant information, (2) faster, more accurate detection and location of objects and patterns of motor behaviour, (3) more efficient use of available information, i.e. making optimal decisions during motor activities, and (4) faster processing of information [2–9]. From the viewpoint of cognition, as well as direct relevance to sports training, it seems important to recognise the adaptability range of sensorimotor functions as far as demands of sports training are concerned.

Thus far, the results of experimental studies conducted mainly using laboratory methods pointed to the possibility of improving certain sensorimotor functions. For example, Maman et al. [10] conducted an 8-week
training program (3 times a week, sessions of 45 minutes) among table tennis players, which perfected the visuomotor functions (visual fixation, the speed of eye movement), accommodation, peripheral vision, the time of reaction to visual stimuli, the speed of target movement and hand-eye coordination. The results of the experiment indicated a significant improvement (p < 0.05) in levels of both sensory and motor variables studied, with a lack of significant variability of the parameters (p > 0.05) in the control group and the placebo group. Similarly, Wimshurst et al. [11] observed significant improvement in visual function (static and dynamic visual acuity, saccade, peripheral vision, the speed of discrimination of moving stimuli) among hockey players, as a result of a 10-week visual stimulation through exercises based on a computer program. The mean improvement of the studied sensory and motor function was over 30%. On the other hand, Schwab and Memmert [12] found a positive effect of a 6-week training perfecting visual function in young field hockey players (improved reaction time to visual stimuli, better peripheral vision).

One of the key issues associated with the effects of interventions for the improvement of visual-motor function is the possibility of utilising them in conditions of a particular sports discipline. Some studies confirm the possibility of transferring the effect of visual perception training conducted in the laboratory directly into the improvement of athletic performance [10, 13, 14]. Other reports, however, indicate little to no effect of the training programmes applied in relation to sports results [12, 15]. The ambiguity in the results of research suggests a need to seek new directions of methodological solutions.

In our opinion, studies on identifying determinants of sensorimotor processes in athletes are essential for understanding the mechanisms of adaptation of visual function to the conditions determined by the demands of sports training. It is interesting as well to evaluate the sustain ability of the potential effects of the training. It seems that from the methodological point of view, the most accurate way of increasing the efficiency of exercises improving visual sensorimotor functions is to create a programme based on the methods that can be used in the conditions of specific sports discipline and its appropriate motor activities. The aim of this study was to evaluate the effectiveness of an exercise program for sensory and motor functions, implemented in handball sports training. Perceptual training methodology was based on vision enhancement exercises and specialised handball training. The study sought to verify the hypothesis that a 6-week training intervention is sufficient to achieve positive results in terms of improving the timing of the sensorimotor functions studied.

Material and methods

The study was conducted among a group of 28 students of the Faculty of Physical Education and Health Promotion at the University of Szczecin. The average age of subjects was 20.32 ± 1.39 years. Experimental research was attended by male (n = 10) and female athletes (n = 5) from the academic handball section AZS Uniwersytet Szczeciński. The average sports seniority was 6.2 ± 3.1 years. The control group consisted of students (5 women and 8 men) not participating in regular physical activity outside of the curriculum. The experimental group took part in perceptual training programme – 1 hour three times a week over a period of 6 weeks. The study involved individuals characterized by proper assessment of the basic functions of the eye. All candidates were subject to routine sight examination.

Before the experiment – 6 weeks after the period of stimulation with training and 4 weeks after the end of the study – both groups were rated for the following parameters:

(1) Time of a simple and complex motor reaction to visual stimuli, measured using the Vienna Test System v. 29.01 (Schuhfried, Austria). To evaluate the reaction time, the S1 version of the test was used – measurement of the reaction time to simple visual stimuli (yellow light). The reaction cycle consisted of 28 light stimuli generated in randomly selected time intervals (2.5 sec. – 6 sec.) The exposition time was 1 second. The reaction time test was performed with the index finger of the dominant hand. To assess the time of a complex reaction, the S4 version of the test was used – measurement of the reaction time to complex visual stimuli. A total of 48 stimuli were presented on the computer screen, displayed in the form of different combinations of yellow and/or red light combined with a sound signal. Of all the combinations of stimuli, only 16 required a reaction from the subject. The exposition time was 1.2 s. The intervals between successive stimuli varied from 1.5 to 4.0 s.

(2) Target movement speed, measured in eye-hand coordination test, performed using a FitLight Trainer device (Fitlight Sports Corp., Canada) in accordance with the procedure described by Zwierko et al. [16]. The subject was positioned in front of the measurement position with one leg forward, with their dominant hand placed on the starting point (Fig. 1.). At the time of the appearance of stimulus, by moving the dominant hand, the subject was trying to deactivate light discs as soon as possible (touch function). Two series of tests were carried out, each consisting of 22 reactions. The intervals between successive stimuli ranged from 0.3 s to 3.0 s.

(3) Movement speed in a specific test for visual-spatial perception (Fitlight Sports Corp., Canada.) Eight light discs were programmed and placed 50 cm above...
The effect of visual perception training on sensorimotor function in handball players the effect...

The test used blue light blue, appearing on the whole surface of the disc. The subject was set on the starting position. The task was to reach the lit disc as fast as possible, deactivate it (touch function) and return to the starting position. The average time of deactivation of the discs (s) in 30 seconds was measured. The maximum duration of the activation of a single disk was 5 seconds. The reliability of the test as measured in a pilot study was $r = 0.72$ ($p < 0.05$).

The methodology of the training programme was based on vision enhancement exercises (10 min.) and specialized handball training with elements of reaction speed forming, visual searching and visual-motor coordination. The methods of orthoptic exercise had been prepared by a specialist in vision training. Examples of exercise profiles include:

1. Exercising extraocular muscles: smooth eye movements in different directions, with closed and open eyelids (central fixation, lateral moves to the right/left, up/down; up right/left, down right/left, circular eyeball motion), rest.
2. Tracking movements of the eye (e.g. following the movements of partner’s finger, “drawing” shapes/figures at different speed; tracking moving objects, for example a Marsden’s ball with specific optotypes, marked handball balls, tennis balls).
3. Horizontal and vertical saccades (e.g. searching for numbers/letters on boards with eye tracking, searching for selective light signals, searching for particular optotypes on boards, balls or the court).
4. Exercise in increased focusing of visual attention (e.g. searching for optotypes placed on boards within time limit; visual control over objects held (balls placed on gymnastic canes held in both hands); visual control, in an out-of-balance position, over moving objects).

---

Figure 1. Station for data measurement of the eye-hand coordination test

The ground within a handball court, as shown (Fig. 2.)

Figure 2. Scheme of the visuospatial perception test course
(5) Specialized training program based on exercises that require focusing visual attention, fast visual searching, reaction time, spatial orientation, agility, movement speed (with and without the ball). Profile of the training, both individual and group training, contained a diverse set of exercises to enhance visual attention and improve eye-hand coordination. Among the devices used were indoor trainers (in the form of programmed versions of the light discs), optotypes, marked balls, balls of different sizes, balls of reduced pressure, tennis balls etc.

The scope and methodology of the experimental work received a positive opinion from Bioethical Committee at the Regional Medical Chamber in Szczecin (decision No. 11/KB/V/2013).

Statistical methods

In order to determine the significance of differences between dependent variables, a double classification analysis of variance was performed for repeated measurements (ANOVA). Analysis of variance included the inter-group factor “Group” (experimental group vs. control group) and the intra-group factor “Training” (effects of training: T1 – the measurement before the experiment; T2 – the measurement after the 6-week training period; T3 – the measurement 4 weeks after the end of the study). In the case of a significant effect of the variance analysis the Bonferroni correction (p<0.05) was used to estimate the differences between chosen variables.

Results

The effect of perceptual training on reaction time

The results of variance analysis for repeated measurements indicate no significant impact of either “Training” (F(2,52) = 2.48, p = 0.315; Ƞ² = 0.08) or “Group” factors (F(1,26) = 1.04, p = 0.093; Ƞ² = 0.03) on variability of the results of simple reaction time. In contrast, a statistically significant effect of both factors was found in the case of complex reaction time – the results of the variance test for the “Training” factor were F(2,52) = 9.32; p = 0.0003; Ƞ² = 0.26, and for the factor “Group” F(1,26) = 4.46; p = 0.044; Ƞ² = 0.14. Moreover, important interaction between the two factors (Training × Group) (F(2,52) = 3.22, p = 0.048; Ƞ²=0.11) confirms the different course of results’ variation for the test that evaluated complex reaction time in the experimental group compared to the control group. Analysis of post-hoc tests shows significant changes (p = 0.001) in complex reaction test results (changes that stem from the perceptual training programme (T1 vs. T2), and a significant drop (p = 0.045) in control measurement results (T2 vs. T3) (Figure 3).

![Figure 3. Significant interaction of Training x Group factors (F(2,52) = 3.22; p = 0.048; Ƞ² = 0.11) in the complex reaction time test measurements. Significant intra-group differences were observed (**p = 0.001; *p = 0.045), T1 vs. T2, and T2 vs. T3 in the experimental group), as well as significant differences (p = 0.031) between athletes and non-athletes in post-test differential reaction time, which is marked with †.](image-url)
The effects of perceptual training on eye-hand coordination

Analysis of variance of the eye-hand coordination test results indicates a highly significant impact of “Training” factor on the variability of the results of three consecutive measurements ($F_{(2.52)} = 23.21, p = 0.000; \eta^2 = 0.47$). The “Group” factor also showed a significant impact on result variability ($F_{(1.26)} = 5.98, p = 0.021; \eta^2 = 0.19$). The interaction of factors Training × Group has been confirmed ($F_{(2.52)} = 39.49, p = 0.000; \eta^2 = 0.60$). Examining the differences in detail, it can be noted that significant changes in the results of research are related to the experimental group, in which there was observed a highly significant decrease in time of test completion after a 6-week training simulation (T1 vs. T2, $p = 0.000E$), then a significant deterioration (T2 vs. T3, $p = 0.026$), with a simultaneous lack of significant variability in the control group ($p > 0.05$). Significant inter-group differences were confirmed in the results of the T2 ($p = 0.0001$) and T3 ($p = 0.049$) tests (Fig. 4).

The effects of perceptual training on the speed of visuospatial perception

Analysis of variance shows that both the factor “Training” ($F_{(2.52)} = 21.63$ and $p = 0.000; \eta^2 = 0.45$) and the factor “Group” ($F_{(1.26)} = 15.35, p = 0.0002; \eta^2 = 0.377$) had significant impact on the variability of visuospatial perception speed test results. The interaction of both factors in this case equals ($F_{(2.52)} = 3.30, p = 0.044; \eta^2 = 0.11$). Analysis of the post-hoc tests indicates presence of inter-group differences in T1 ($p = 0.028$) and T2 ($p = 0.0007$) measurements. The effects of perception training was seen in the group of handball players as a significant difference ($p = 0.002$) in the results of the average time of deactivation of the light disks. In control measurement (T3) the test results did not differ with respect to the measurement from before the training intervention (T3) (Fig. 5, next page).

Discussion

The aim of the research was to evaluate the effectiveness of the exercise programme meant to improve visual sensorimotor functions. The initial assumption that a 6-week training intervention programme is sufficient to achieve improved times of the studied functions has been confirmed. In the vast majority of the variables tested, significant improvements in the times of the analysed tests were reported as a result of systematic stimulation with training.
The only instance of no post-training change (p > 0.05) in the experimental group are the results of the laboratory test evaluating the simple reaction time. In this case, the results of the study may suggest lesser sensibility to perceptual training for simple sensorimotor tasks. Nevertheless, previous observations conducted by Ando et al. [17, 18] show that a 3-week training for better simple reaction time to visual stimuli (appearing in the central and peripheral vision) caused a significant decrease in the EMG-RT time measurement. What is more, there appeared transfer of the effects of the training – of the better reaction time to stimuli appearing in the central field of view to the results of a simple reaction time to peripheral stimuli (and vice versa). Perhaps an explanation of the results of the present study is the usual lesser stimulation of the body (and thus lesser focus), which is observed while performing simple tasks as compared to complex perceptual tasks [19].

In the other analysed tests, i.e. the laboratory measurement of complex reaction time, eye-hand coordination, the speed of visuospatial perception in specific conditions, positive effects of the implemented training were observed. From a methodological point of view, results of the study confirmed that the 6-week training intervention is sufficient to achieve the positive effects of exercises improving visual sensorimotor functions. The results of other experiments conducted to improve cognitive function while implementing 6-week, 8-week and longer periods of training stimulation proved the positive effects of training, similarly to the present study [10, 12, 13, 20–23]. In the case of perceptual stimulation, shorter periods seem to be less effective. For example, Abernethy and Wood [15] found no significant changes in either sensory parameters or the analysed motor parameters in the case of implementing a 4-week programme of visual functions training.

It seems that the mechanisms of sensorimotor processes are conditioned by many factors, and the possibility of their formation depends on individual adaptability of oculomotor function, as well as the ability to shape cognitive functions. Attention processes can be identified as crucial for effective processing of visual stimuli. The results of experimental studies indicate that attention affects the perceptual sensitivity during discrimination of stimuli [24], increases contrast sensitivity [25], improves visual acuity [26], affects the conductivity of visual signals [27]. In sports, very important roles can be ascribed to: information selection (which selects stimuli from a particular field of perception), the ability to flip visual attention and divisible attention (the ability...
to monitor concurrent activities [28, 29]). Experimental studies pointed to the differences of attention mechanisms of athletes in team and individual sports [30]. It should be remembered, however, that despite the variety in the field of perception and the number of stimuli at work, attention functions as an integrated cognitive system. Earlier research shows that sports training can model certain attention features [6, 8]. It seems, therefore, that creation of training programs shaping attention for the specific conditions of motor performance is fully justified. The proposed perceptual training used in the present study stressed the ability to maintain attention in wide range, as a state of readiness for a motor response to unforeseen visual signals (in longer and shorter periods of time); it also included a diverse range perception. In can be said that the effectiveness of the programme used largely was to a large extent a result of exercise demanding readiness for motor reaction.

The important value of the applied sensorimotor exercise programme is definitely its application function. The proposed exercises, those of orthoptic character and those characteristic for a handball game, can certainly complement the process of sports training. The present study shows that the 4-week period of no stimulation of visual perception implemented in the research lowers the level of the effects of training. On the one hand, the results of the control test confirm the efficacy of the 6-week exercise period. On the other hand, lack of maintaining of the effects of the intervention indicates the need to implement a systematic programme to support the level of visual sensorimotor functions. However, the question of optimising the intensity of perceptual exercise during the macrocycle still requires further study. There are relatively few theoretical concepts describing the methodology of visual training [31]. We believe that the practical implication of current as well as future studies will act as a guideline for training process improvement.

**Conclusions**

1. Six weeks of the visual perception training program is sufficient enough to induce positive changes in the investigated aspects of visual sensorimotor processes in a group of handball players.
2. The significant effects of the visual perception exercise program carried out under conditions of specific handball activities occurred in the case of complex perceptual tasks, while no effects of the perceptual training were noticed on changes in test results evaluating simple reaction time.
3. The period of maintaining the positive effects of perception training is limited. After a one month break in the use of intervention with the exercise program improving visual sensorimotor functions, a gradual reduction in the level of the post-training positive effects obtained during the study could be observed.
4. In order to maintain a stable level of visual sensorimotor functions in athletes, there is a need to implement a systematic perception exercise program into the process of sports training.

**Acknowledgments**

This scientific work is funded from the 2013–2016 science budget as a research project within the program entitled “Development of Academic Sport”, grant number RSA201852.

**References**


Address for correspondence:
PhD Beata Florkiewicz
Faculty of Physical Culture and Health Promotion,
University of Szczecin, Poland
Al. Piastów 40 b blok 6
71-065 Szczecin
E-mail: b-t@g02.pl
Tel. 91 4442787
RELATIONSHIPS BETWEEN ANTHROPOMETRIC TRAITS, BODY COMPOSITION AND AEROBIC CAPACITY IN MALE SOCCER PLAYERS AGED 13–15 YEARS

Michał Boraczyński¹ ABDEF, Tomasz Boraczyński¹ ACDE, Robert Podstawski² BFG, Zbigniew Wójcik³ BG

¹ Faculty of Physical Education, Józef Rusiecki Olsztyn University College, Olsztyn, Poland
² Physical Education and Sport Center, University of Warmia and Mazury in Olsztyn, Poland
³ Department of Tourism, Recreation and Ecology, University of Warmia and Mazury in Olsztyn, Poland

Key words: physical development, aerobic capacity, soccer training

Abstract

Purpose. This study describes the relationships between body dimensions, body composition and aerobic capacity in young soccer players at a targeted stage of their sports training.

Basic procedures. A group of 27 soccer players (13.6–15.6 years of age) was examined during a 2-year training period. Anthropometry, body composition and aerobic capacity were assessed.

Main findings. Positive correlations were found between body mass (BM), fat free mass (FFM), skeletal muscle mass (SMM), and absolute maximal oxygen uptake (VO₂max) and physical working capacity (PWC₁⁷₀) values (p < 0.05). By contrast, there were unexpected negative correlations between BM, FFM, SMM, and relative VO₂max values (p < 0.01). Additionally, negative correlations between BMI and relative VO₂max values (p < 0.05) were noted.

Conclusions. The negative relationships between BM, FFM, SMM and relative VO₂max demonstrated the ineffectiveness of the soccer training process in terms of players’ aerobic capacity development. At the same time, decreasing relative aerobic capacity indices in consecutive years clearly point to the inadequate implementation of the training program or misconceptions in shaping aerobic capacity. Therefore, it is necessary to verify the implementation of this program in order to improve players’ aerobic capacity.

Introduction

Successful soccer performance is the result of multiple, complex and interdependent factors, which include, inter alia, players’ body build (anthropometric traits and body tissue components) and aerobic and anaerobic capacity [1, 2, 3, 4].

Studies show that significant differences in body height, body mass and body mass index (BMI) [5, 6] exist between professional soccer players playing different positions. Such variability was also noted in body build [7, 8] and body fat [9] for elite soccer players from different age categories.

Modern soccer requires from players not only top physical condition, but also adequate motor preparation, including high levels of aerobic capacity. This has been confirmed by descriptive studies [10], cross-sectional studies [11] and training-based studies [2]. With regard to matches, the energy demand in soccer players is mainly associated with the oxidative (aerobic) metabolic pathway [4]. Available data, however, point to different percentage contributions of the aerobic pathway during...
a match: Bangsbo [1] – 70%, Ekblom [12] – 80% and Helgerud et al. [2] even over 90%. At the same time, the mean intensity of the match effort remains around the anaerobic threshold (80–90% of maximal heart rate) [1, 2]. Moreover, researchers also revealed that a high level of aerobic capacity is a prerequisite to improved efficiency of anaerobic capacity during performing high-intensity intermittent exercise [13]. Better aerobic capacity also improves the course of post-exercise recovery of the organism [14]. The most important index of aerobic capacity and a crucial determinant of exercise intensity is maximal oxygen uptake (VO_{max}). Two other variables of exercise intensity: lactate threshold and running economy, were also shown to rise with increasing VO_{max}, which points to the need to indirectly examine this index outdoors (by way of coaching tests) as well as directly, in laboratory conditions [15].

Authors dealing with soccer as a subject of research, generally agree that anthropometric traits and high levels of motor preparation do affect the selection of young athletes. In consequence, talented individuals who mature late are eliminated at a very early stage of selection, and the long-term negative impact on sport talent identification procedures can be observed [7].

Research studies on young soccer players are often limited to assessment anthropometric traits and biological maturity in separation from players’ functional abilities and soccer-specific skills [16]. A review of literature shows that relationships between anthropometric traits, body composition and aerobic capacity in adolescent soccer players have rarely been studied.

Therefore, the aim of the present study was to examine the relationships between anthropometric traits, body composition and aerobic capacity in young male soccer players at a targeted stage of soccer training. The following research questions were formulated:

- What is the course of physical development of the selected young soccer players during a two-year study?
- How does the young players’ physical development course compare with the age population norms?
- What are the relationships between body anthropometric traits, body composition and aerobic capacity in the studied soccer players?
- What are the players’ levels of aerobic capacity indices?
- Do the players’ physical development and training affect the strength of relationships between the examined variables?

**Material and methods**

The study was conducted in the Central Research Laboratory at Józef Rusiecki Olsztyn University College in Olsztyn. A two-year observation was carried out on a group of selected 27 circumpubertal soccer players aged 13.59–15.57 years, constituting a homogenous training group from the Provincial Center of Youth Sports Training in Olsztyn (WOSSM). The selection of the boys from the Provincial Center was based on the results of a battery of motor tests. The training length of the selected players before the commencement of a cycle of three testing sessions (1st session – initial tests; 2nd session – after 12 months of training; 3rd session - after 24 months of training) was 4.6 years. Until completion of the study, the players underwent a uniform training program in accordance with the guidelines developed by the Polish Soccer Association for youth soccer (PZPN, 2010). The frequency of the training protocol was 5 training sessions per week (from Monday to Friday, plus playing regional league matches). The duration of the standard training session was 90 minutes. The protocol was mainly based on both continuous and intermittent exercises at intensities lower than those associated with maximal oxygen uptake – VO_{max}. To improve aerobic capacity, soccer players had one continuous session during a single microcycle (15–20 minutes, 1500–4500 m at 90% maximal heart rate – HR_{max}) and one session (from 60 to 90 minutes) dedicated to aerobic activities (soccer, running) and intermittent exercises (10 × 10 m, 6 × 200 m, 4 × 600 m at 80% HR_{max}). The aim and the protocol of the study were described to the coaching staff, the players and their parents, and their written consent was obtained.

Before the exercise test measurements of players’ basic anthropometric traits and selected body components were carried out. Body height (BH) [kg] was measured to the nearest 0.1 mm with a stadiometer of calibrated medical scales (WB-150, Tryb-Wag ZPU, Poland). Body mass (BM) [kg], body mass index (BMI) [kg/m²], body fat (BF) [kg and %] and fat-free mass (FFM) [kg] were measured with a Tanita BC 418 MA body composition analyzer (Tanita Corporation, Japan) using bioelectric impedance analysis (BIA). Skeletal muscle mass (SMM) was calculated according to the formula by Lee et al. [17]:

\[
\text{SMM} = (0.226 \times \text{BM}) + (13 \times \text{BH}) - (0.089 \times \text{age}) + 6.3 \times \text{sex} + \text{race} - 11
\]

where:

- sex = 1 – men, 0 – women; race = 1.4 – African-American, 0 = Caucasian or Hispanic, 1.2 – Asian

The variables were compared against standard Polish national growth charts and scoring boards for body height, body mass and BMI [18]. All the measurements were carried out in accordance with the standards of the International Society for the Advancement of Kinanthropometry (ISAK).
The players’ HR_{max} was calculated using the following formula: 205 – 0.5 x age [19]. Aerobic capacity was assessed indirectly on the basis of PWC_{170} test (Physical Working Capacity) results [19]. PWC_{170} index is an estimated power of effort with heart rate at 170 beats per minute (bpm). After a 5-minute warm-up, the players performed three standard submaximal 4-min cycloergometer tests (Monark Exercise AB, Sweden). The intensity of these tests was adjusted for individual players so that their HR during physiological steady state ranged between 120 and 150 bpm.

During the exercise test, the players’ HR was measured with a Polar heart rate monitor (Polar Electro OY, Finland). The mean HR values taken at the end of each 4-min test were used to calculate the PWC_{170} index in Watts and Watts/kg and then VO_{2max} in L/min and in mL/kg/min, using the Karpman’s formula [20]:

\[ \text{VO}_{2\text{max}} = 10.2 \times \text{PWC}_{170} + 1240 \]

where:

- 10.2: dimensionless constant.
- 1240: dimensionless constant.

### Statistical analysis

The descriptive statistics included arithmetic mean (M), standard deviation (SD), Pearson (R) correlation coefficient (r), coefficient of determination (R^2), and linear regression equation (y). The significance of differences was checked with a t-test. The level of statistical significance was set at α = 0.05. All statistical calculations were made using the STATISTICA v. 7.1 software package (StatSoft Inc., USA).

### Results

During the two-year study, dynamic physical development of young soccer players was observed, as illustrated by the results in table 1. All the measured indices increased significantly (p < 0.01), with the exception of body fat percentage (p < 0.01).

Table 2 demonstrates the assessment of physical development of young soccer players. Their body height (BH), body mass (BM) and body mass index (BMI) were evaluated in centiles and points in T scale according to population standards (Dobosz, 2012).

### Table 1. The anthropometric, body composition and aerobic capacity values of soccer players aged 13–15 years (N = 27)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Age</th>
<th>BH [cm]</th>
<th>BM [kg]</th>
<th>BF [%]</th>
<th>FFM [kg]</th>
<th>SMM [kg]</th>
<th>BMI [kg/m²]</th>
<th>VO_{2\text{max}} [L/min]</th>
<th>VO_{2\text{max}} [mL/kg/min]</th>
<th>PWC_{170} [W]</th>
<th>PWC_{170} [W/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>13.59</td>
<td>166.44</td>
<td>53.33</td>
<td>16.59</td>
<td>44.45</td>
<td>27.78</td>
<td>18.42</td>
<td>2.686</td>
<td>50.94</td>
<td>141.72</td>
<td>2.67</td>
</tr>
<tr>
<td>SD</td>
<td>0.25</td>
<td>5.92</td>
<td>7.39</td>
<td>1.89</td>
<td>6.05</td>
<td>2.31</td>
<td>4.11</td>
<td>0.277</td>
<td>6.22</td>
<td>27.18</td>
<td>0.44</td>
</tr>
<tr>
<td>M</td>
<td>14.51</td>
<td>172.11</td>
<td>59.95</td>
<td>16.40</td>
<td>50.02</td>
<td>29.93</td>
<td>20.19</td>
<td>2.831</td>
<td>47.80</td>
<td>155.98</td>
<td>2.63</td>
</tr>
<tr>
<td>SD</td>
<td>0.23</td>
<td>5.44</td>
<td>7.50</td>
<td>2.27</td>
<td>5.63</td>
<td>2.23</td>
<td>1.94</td>
<td>0.285</td>
<td>6.58</td>
<td>25.98</td>
<td>0.47</td>
</tr>
<tr>
<td>M</td>
<td>15.57</td>
<td>177.11</td>
<td>65.43</td>
<td>15.80</td>
<td>55.04</td>
<td>31.73</td>
<td>20.85</td>
<td>3.019</td>
<td>46.44</td>
<td>174.40</td>
<td>2.68</td>
</tr>
<tr>
<td>SD</td>
<td>0.22</td>
<td>5.51</td>
<td>6.54</td>
<td>2.16</td>
<td>5.05</td>
<td>1.96</td>
<td>1.75</td>
<td>0.265</td>
<td>4.88</td>
<td>25.43</td>
<td>0.38</td>
</tr>
</tbody>
</table>

#### Difference (%)

<table>
<thead>
<tr>
<th>Age</th>
<th>13 vs. 14</th>
<th>14 vs. 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>3.40</td>
<td>2.91</td>
</tr>
<tr>
<td>SD</td>
<td>1.14</td>
<td>9.14</td>
</tr>
</tbody>
</table>

#### p

<table>
<thead>
<tr>
<th>Age</th>
<th>13 vs. 14</th>
<th>14 vs. 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>SD</td>
<td>0.5813</td>
<td>0.0098</td>
</tr>
</tbody>
</table>

#### Comments:

- BH – body height, BM – body mass, BF – body fat, FFM – fat free mass, SMM – skeletal muscle mass, BMI – body mass index, VO_{2\text{max}} – maximal oxygen uptake, PWC_{170} – estimated power of effort with heart rate at 170 bpm, M – mean, SD – standard deviation, Difference (%) – percentage difference between the results in consecutive years, p – probability.

### Table 2. The evaluation of physical development in centiles and points in T scale according to population standards (Dobosz, 2012)

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Evaluation</th>
<th>BH [cm]</th>
<th>BM [kg]</th>
<th>BMI [kg/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.59</td>
<td>Centiles</td>
<td>61.6</td>
<td>50.9</td>
<td>45.2</td>
</tr>
<tr>
<td></td>
<td>Points</td>
<td>53</td>
<td>50</td>
<td>49</td>
</tr>
<tr>
<td>14.51</td>
<td>Centiles</td>
<td>60.7</td>
<td>53.6</td>
<td>49.6</td>
</tr>
<tr>
<td></td>
<td>Points</td>
<td>53</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>15.57</td>
<td>Centiles</td>
<td>60.2</td>
<td>52.4</td>
<td>48.9</td>
</tr>
<tr>
<td></td>
<td>Points</td>
<td>53</td>
<td>51</td>
<td>50</td>
</tr>
</tbody>
</table>
calculated against Polish national growth norms for boys [18] on a T scale from 1 to 100 points, where the arithmetic mean (M) of a given variable was 50 points, and the standard deviation (SD) – 10. Thus, each result at M + 1SD corresponded to “60 points” points on the T scale, and at M – 1SD to “40 points”. The norms above population standards were based on the results of a study carried out in the 2009/2010 school year on a representative sample of boys aged 7–19 years (N = 25,908) from selected schools from every province in Poland.

Particular indices of aerobic capacity displayed different directions of change. The absolute maximal oxygen uptake VO\textsubscript{2max} (L/min) and PWC\textsubscript{170} (W) increased in consecutive testing sessions, and the differences between consecutive sessions were statistically significant (p < 0.01). The relative PWC\textsubscript{170} (W/kg) did not change significantly. Unexpectedly, relative VO\textsubscript{2max} (mL/kg/min) decreased significantly (p < 0.01), despite a dynamic increase in fat free mass (FFM) and skeletal muscle mass (SMM) (Fig. 1).

According to the accepted norms, the players’ physical development during the two-year study was correct and above the mean (points) and median (centiles) body height (BH). The players’ body mass (BM) was close to the mean and median values, whereas the BMI was below the means and medians. The dynamics of changes decreased for BH and increased for BM and BMI. It must be noted that body fat percentage (BF%) decreased as BM increased, and these changes were statistically significant (p < 0.01).

To examine the relationships between physical development (anthropometric traits and composition) and aerobic capacity for particular variables during each testing session, the Pearson’s (R) correlation coefficients were calculated and presented in the form of correlation matrices (Tables 3, 4, 5).

As expected, positive correlations were found between BM, FFM and SMM, and absolute VO\textsubscript{2max} and PWC\textsubscript{170} (p < 0.05). The negative correlations between BM, FFM, SMM, and relative VO\textsubscript{2max} were quite

![Fig. 1. The relationships between skeletal muscle mass (SMM) and maximal oxygen uptake (VO\textsubscript{2max}) in soccer players aged 13–15 years (N = 81). SMM (kg): VO\textsubscript{2max} (mL/kg/min); R\textsuperscript{2} = 0.5330; R = -0.7300; p = 0.0000; y = 98.3 – 1.674 · x.](image-url)
### Table 3. Values of Pearson’s ($R$) correlation coefficients of physical development and aerobic capacity indices in soccer players aged 13.6 years (N = 27)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BH [cm]</td>
<td>1.000</td>
<td>0.762</td>
<td>0.005</td>
<td>0.779</td>
<td>0.884</td>
<td>0.252</td>
<td>0.242</td>
<td>−0.683</td>
<td>0.242</td>
<td>−0.356</td>
</tr>
<tr>
<td>BM [kg]</td>
<td>0.762</td>
<td>1.000</td>
<td>0.206</td>
<td>0.987</td>
<td>0.976</td>
<td>0.348</td>
<td>0.525</td>
<td>−0.701</td>
<td>0.525</td>
<td>−0.228</td>
</tr>
<tr>
<td>BF [%]</td>
<td>0.005</td>
<td>0.206</td>
<td>1.000</td>
<td>0.048</td>
<td>0.148</td>
<td>0.095</td>
<td>0.243</td>
<td>−0.056</td>
<td>0.243</td>
<td>0.086</td>
</tr>
<tr>
<td>FFM [kg]</td>
<td>0.779</td>
<td>0.987</td>
<td>0.048</td>
<td>1.000</td>
<td>0.973</td>
<td>0.338</td>
<td>0.494</td>
<td>−0.709</td>
<td>0.494</td>
<td>−0.250</td>
</tr>
<tr>
<td>SMM [kg]</td>
<td>0.884</td>
<td>0.976</td>
<td>0.148</td>
<td>0.973</td>
<td>1.000</td>
<td>0.337</td>
<td>0.459</td>
<td>−0.735</td>
<td>0.459</td>
<td>−0.284</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>0.252</td>
<td>0.348</td>
<td>0.095</td>
<td>0.338</td>
<td>0.337</td>
<td>1.000</td>
<td>−0.118</td>
<td>−0.467</td>
<td>−0.118</td>
<td>−0.408</td>
</tr>
<tr>
<td>VO₂max [L/min]</td>
<td>0.242</td>
<td>0.525</td>
<td>0.243</td>
<td>0.494</td>
<td>0.459</td>
<td>−0.118</td>
<td>1.000</td>
<td>0.026</td>
<td>1.000</td>
<td>0.704</td>
</tr>
</tbody>
</table>

### Table 4. Values of Pearson’s ($R$) correlation coefficients of physical development and aerobic capacity indices in soccer players aged 14.5 years (N = 27)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BH [cm]</td>
<td>1.000</td>
<td>0.661</td>
<td>0.033</td>
<td>0.733</td>
<td>0.821</td>
<td>0.227</td>
<td>−0.040</td>
<td>−0.687</td>
<td>−0.040</td>
<td>−0.552</td>
</tr>
<tr>
<td>BM [kg]</td>
<td>0.661</td>
<td>1.000</td>
<td>0.565</td>
<td>0.980</td>
<td>0.971</td>
<td>0.880</td>
<td>0.331</td>
<td>−0.731</td>
<td>0.331</td>
<td>−0.441</td>
</tr>
<tr>
<td>BF [%]</td>
<td>0.033</td>
<td>0.565</td>
<td>1.000</td>
<td>0.391</td>
<td>0.441</td>
<td>0.724</td>
<td>0.305</td>
<td>−0.345</td>
<td>0.305</td>
<td>−0.151</td>
</tr>
<tr>
<td>FFM [kg]</td>
<td>0.733</td>
<td>0.980</td>
<td>0.391</td>
<td>1.000</td>
<td>0.979</td>
<td>0.806</td>
<td>0.289</td>
<td>−0.740</td>
<td>0.289</td>
<td>−0.464</td>
</tr>
<tr>
<td>SMM [kg]</td>
<td>0.821</td>
<td>0.971</td>
<td>0.441</td>
<td>0.979</td>
<td>1.000</td>
<td>0.742</td>
<td>0.240</td>
<td>−0.774</td>
<td>0.240</td>
<td>−0.510</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>0.227</td>
<td>0.880</td>
<td>0.724</td>
<td>0.806</td>
<td>0.742</td>
<td>1.000</td>
<td>0.449</td>
<td>−0.525</td>
<td>0.449</td>
<td>−0.234</td>
</tr>
<tr>
<td>VO₂max [L/min]</td>
<td>−0.040</td>
<td>0.331</td>
<td>0.305</td>
<td>0.289</td>
<td>0.240</td>
<td>0.449</td>
<td>1.000</td>
<td>0.389</td>
<td>1.000</td>
<td>0.694</td>
</tr>
</tbody>
</table>

### Table 5. Values of Pearson’s ($R$) correlation coefficients of physical development and aerobic capacity indices in soccer players aged 15.6 years (N = 27)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BH [cm]</td>
<td>1.000</td>
<td>0.532</td>
<td>−0.115</td>
<td>0.612</td>
<td>0.770</td>
<td>−0.085</td>
<td>0.159</td>
<td>−0.394</td>
<td>0.159</td>
<td>−0.222</td>
</tr>
<tr>
<td>BM [kg]</td>
<td>0.532</td>
<td>1.000</td>
<td>0.432</td>
<td>0.970</td>
<td>0.950</td>
<td>0.797</td>
<td>0.408</td>
<td>−0.639</td>
<td>0.408</td>
<td>−0.318</td>
</tr>
<tr>
<td>BF [%]</td>
<td>−0.115</td>
<td>0.432</td>
<td>1.000</td>
<td>0.201</td>
<td>0.284</td>
<td>0.600</td>
<td>0.104</td>
<td>−0.340</td>
<td>0.104</td>
<td>−0.214</td>
</tr>
<tr>
<td>FFM [kg]</td>
<td>0.612</td>
<td>0.970</td>
<td>0.201</td>
<td>1.000</td>
<td>0.957</td>
<td>0.703</td>
<td>0.412</td>
<td>−0.606</td>
<td>0.412</td>
<td>−0.292</td>
</tr>
<tr>
<td>SMM [kg]</td>
<td>0.770</td>
<td>0.950</td>
<td>0.284</td>
<td>0.957</td>
<td>1.000</td>
<td>0.569</td>
<td>1.000</td>
<td>−0.626</td>
<td>0.368</td>
<td>−0.320</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>−0.085</td>
<td>0.797</td>
<td>0.600</td>
<td>0.703</td>
<td>0.569</td>
<td>1.000</td>
<td>0.368</td>
<td>−0.471</td>
<td>0.368</td>
<td>−0.215</td>
</tr>
<tr>
<td>VO₂max [L/min]</td>
<td>0.159</td>
<td>0.408</td>
<td>0.104</td>
<td>0.412</td>
<td>0.368</td>
<td>0.368</td>
<td>1.000</td>
<td>0.438</td>
<td>1.000</td>
<td>0.733</td>
</tr>
<tr>
<td>VO₂max [mL/kg/min]</td>
<td>−0.394</td>
<td>−0.639</td>
<td>−0.340</td>
<td>−0.606</td>
<td>−0.626</td>
<td>−0.471</td>
<td>0.438</td>
<td>1.000</td>
<td>0.438</td>
<td>0.931</td>
</tr>
<tr>
<td>PWC₁₇₀ [W]</td>
<td>0.159</td>
<td>0.408</td>
<td>0.104</td>
<td>0.412</td>
<td>0.368</td>
<td>0.368</td>
<td>1.000</td>
<td>0.438</td>
<td>1.000</td>
<td>0.733</td>
</tr>
<tr>
<td>PWC₁₇₀ [W/kg]</td>
<td>−0.222</td>
<td>−0.318</td>
<td>−0.214</td>
<td>−0.292</td>
<td>−0.320</td>
<td>−0.215</td>
<td>0.733</td>
<td>0.931</td>
<td>0.733</td>
<td>1.000</td>
</tr>
</tbody>
</table>
surprising ($p < 0.01$). Moreover, negative correlations were also found between BMI and relative VO$_{2\text{max}}$ ($p < 0.05$).

**Discussion**

The aim of this study was to examine relationships between anthropometric traits, body composition and aerobic capacity in selected young male soccer players aged 13–15 years at the targeted training stage. Since there have been few studies dealing with the relationships between anthropometric traits, body components and aerobic capacity indices in young soccer players, some of the noted correlations were partially compared with the results of elite soccer players.

It is well known that during progressive physical development increase anthropometric traits, body mass, skeletal muscle mass, heart and lung mass, hemoglobin level and blood volume as well as maturation of the nervous system. Together, all these changes determine the body’s aerobic capacity [4]. Research shows that the peak dynamics of BM growth in boys (20–25 kg) occurs between 12 and 16 years of age. Another 10 kg of BM is gained between the age of 16 and 20 [10]. It must be emphasized that fluctuations in BM are generally rare in young male soccer players with a slender body build in comparison to their non-training counterparts [21, 22]. In view of these data, the examined players in the present study were at the period of dynamic biological development.

On the basis of Polish population norms, it can be stipulated that the boys under study featured a slender body build, which was an indirect manifestation of ectomorphy. At the same time, greater increases in FFM in comparison with BH point to a tendency towards mesomorphy. This should be regarded as a positive manifestation of the soccer players’ somatic development since other studies showed that the mesomorphic type of body build was dominant in young male soccer players [8] with more frequent ectomorphy than in adult players [7]. Similar observations were made by Moreno et al. [23], who noted significantly lower BF% in male soccer players aged 9.0–14.9 years in comparison with non-training boys. In Gil et al. [24], 14–17-year-old advanced soccer players were taller, heavier and more slender than their non-selected counterparts.

Some authors found correlations between the age and body composition in adolescent soccer players [25, 9]. However, the direction of these correlations, e.g. in BH and BF%, was different for players in different age categories. For instance, Nikolaidis and Karydis [9] in their cross-sectional study among 290 soccer players aged 12.0–21.0 years, found a weak, although statistically significant, reverse correlation between players’ BF% and age. Although they found a positive correlation between the players’ BF%, FM and age, the increase of these two indices was not proportionate. The main conclusion of their study was that the under 17 (U-17) age category of soccer players is a critical point in the process of significant changes in the players’ FM and FFM: the FFM growth rate decreased while the FM growth rate became stabilized. The present study revealed a regular decrease of BF% in soccer players in consecutive years, which can be indirectly regarded as a positive effect of training because extensive body fat is always an overload that limits a soccer players’ motor skills (locomotion).

Vaeyens et al. [26] noted that aerobic capacity was the most important fitness component in elite soccer players below 15 and 16 years of age. They also found that the relative maximal aerobic capacity is reached by adolescent boys during the growth spurt [16]. Chamari et al. [27] noted in significant improvement 18 soccer players’ (14.0 ± 0.4 years) VO$_{2\text{max}}$ from 65.3 (± 5.0) to 70.7 (± 4.3) mL/kg/min after a two-month experimental training program. It should be stressed that both VO$_{2\text{max}}$ levels, before and after the training program, were very high. In a study on 34 soccer players aged 17.5 years (± 1.1), Chamari et al. [15] directly measured absolute VO$_{2\text{max}}$ at 4.3 L and relative VO$_{2\text{max}}$ at 61.1 mL/kg/min. In the study conducted by Stroyer et al. [28], the relative VO$_{2\text{max}}$ in 9 elite soccer players aged 12 years was 58.6 (± 5.0) mL/kg/min, and in their two-year older counterparts, it amounted to 63.7 (± 8.5) mL/kg/min. In view of those data, the absolute and relative VO$_{2\text{max}}$ results obtained in the present study may be considered average. Positive correlations between BM, FFM, SMM and absolute VO$_{2\text{max}}$ in consecutive years are confirmed by the referenced authors. However, the observed decrease in relative VO$_{2\text{max}}$ and negative correlations between BM, FFM, SMM and relative VO$_{2\text{max}}$ (mL/kg/min) remain rather difficult to explain. Although studies show that the relationship between anthropometric traits and VO$_{2\text{max}}$ is not proportionate [29], the decreasing relative VO$_{2\text{max}}$ in the examined soccer players must be unequivocally considered a negative trend in the context of modern soccer motor preparation requirements. The reasons for this may be inadequate implementation of the training program or misconceptions about aerobic training development. The results indicate a need to continue studies on soccer players at different ages and with diverse training experience in order to identify the causes and mechanisms of this negative phenomenon.

**Conclusions**

A harmonious level of anthropometric traits noted in the present study, which remains within the norm of the Polish population of boys, is an indicator of the proper physical development of the soccer players under study. The observed tendency towards mesomorphy in the players’ body build should be regarded as a positive...
manifestation of the boys’ somatic development in view of body build demands of modern soccer.

In terms of modern soccer motor preparation requirements, the obtained aerobic capacity indices should be considered average. The decreasing relative maximal oxygen uptake (VO$_{2\text{max}}$) in consecutive years in the young soccer players is definitely a negative trend, the causes of which still remain unclear.

The observed negative correlations between body mass, fat-free mass, skeletal muscle mass and relative maximal oxygen uptake (VO$_{2\text{max}}$) are difficult to explain.

The results of the present study clearly indicate inefficiencies of soccer training in terms of aerobic capacity development of players. The causes of these inefficiencies may involve inadequate implementation of the training program or incorrect assumptions of the aerobic capacity development program. In order to identify the reasons for decreasing relative VO$_{2\text{max}}$ values and to verify implemented aerobic capacity training loads, a thorough examination of coaches’ training diaries and training program assumptions is necessary.

References


Address for correspondence:
PhD Michał Boraczyński,
Faculty of Physical Education,
Józef Rusiecki Olsztyn University College,
ul. Bydgoska 33, 10-243 Olsztyn, Poland,
mobile/fax.: (89) 526-04-00, mobile: 533-101-720,
e-mail: boraczynski_michal@osw.olsztyn.pl
Using Lactate Threshold to Determine the Intensity of Marathon Running in Women Practicing Sports Unprofessionally

Wacław Mirek, Gradek Joanna, Mleczko Edward

Faculty of Field Sports, Department of Physical Education and Sports, University of Physical Education (AWF) in Krakow

Key words: women, lactate threshold test, marathon

Summary

Study aim. Determining objective indicators of marathon running intensity in women practicing sports unprofessionally, based on lactate test results.

Study design. Research was conducted in 2013–2015. The participants were 10 women aged 23 to 43 years who ran marathons unprofessionally. The level of sports (from the “amateur level” to 1st sports class) and training experience (3-8 years) was varied. The lactate threshold test [1] was carried out on the track at an athletics stadium in the week prior to the marathon. During its course, the determined speed and heart rate at lactate threshold were used to calculate the indicators of marathon running intensity. The times to run the whole distance of the marathon, as well as the speed at which the various kilometre-long sections were covered, came from the official statements of the competition. The heart rate during the exercise test as well as the sporting competitions were measured using the Sport-Tester. An analysis of the collected materials was conducted in order to determine the relationship between the individual and average measurements of running speed determined during the lactate threshold test and competitions using: absolute values of measurements, percentage indicators, Pearson’s correlation coefficient and regression equations. Calculations were performed using Microsoft Excel 2007.

Results. Based on the results of the statistical analysis we have found a high correlation between speed set at lactate threshold and the speed during the marathon run, which confirms the statistically significant Pearson coefficient correlation ($R_{xy} = 0.87$), and regression equation: $y = 1.096x - 0.3905$. Demonstrated in the same manner is the high consistency in the distribution of the intensity of the run on following sections of the route of the marathon, with particular emphasis on heart rate and speed recorded in the 1st and 2nd parts of the marathon ($R_{xy} = 0.97$). Detailed analysis of individual cases has proven that statistical findings may relate only to the athletes consistently carrying out the tactical assumptions. Among them were only the runners presenting a high level of sports (1st and 2nd class) and with greater technical and tactical experience in marathon competing.

Conclusions. 1. The results confirmed great usefulness of the speed and heart rate indicators, set before the competitions in lactate threshold “pitch test” in order for the women to carry out tactical and technical tasks while performing marathon running. 2. Due to the fact that during long runs at a constant speed there is an increase tendency in response rates of the cardiovascular system along with the duration of the effort, which is the body’s process of adaptation to changing energy needs, kinematic running indicators, determined in the lactate threshold test, should be considered as more reliable in the process of training and tactical as well as technical tasks performed at marathon competitions. 3. Similarly as in the case of men, in women performing marathon running unprofessionally, the lack of subordination of continuous running tactics and techniques to objective, potential physiological and kinematic indicators of continuing efforts for a long time, causes a limitation in obtaining the best possible results at sporting events.
Introduction

In sports, the score depends on factors that can be described as biological, psychological and impact of training [2]. They are linked by means of interaction. Most often, however, the latter is emphasized. According to some studies, they may influence the outcome of sports in 40-50% through improved functional, motor and mental capacity of a competitor [3]. In the practice of sports training for long-distance and marathon runners, long sought for are simple indicators of potential exercise capacity as well as the effects of training. The first group may include maximum oxygen uptake per minute. For a long time, its high level was considered as the main indicator of the possibility of obtaining a global sport result in long-term efforts [4, 5]. It was believed that the marathon results at the highest world level can be achieved by competitors with high VO₂ max (above 70 ml · kg⁻¹ · min⁻¹) [7]. In the best medium- and long-distance as well as marathon runners, values of this indicator fluctuated within the ranges: 69.7 ml · kg⁻¹ · min – 85 ml · kg⁻¹ · min [6, 7].

More detailed research on the physiological indicators in world sport event winners, already conducted in the seventies, changed the views on the role of maximal oxygen uptake in achieving success in track and field long-distance and marathon races. The winner of the marathon at the Olympic Games in Munich and the silver medalist in the same event at the Olympic Games in Montreal (Frank Shorter) was identified with an average level of VO₂ max 71.3 ml · kg⁻¹ · min [6, 7]. It turned out that an important determinant of the outcome of a long-term effort is not only aerobic capacity, but above all, the way it is utilized during physical exercise.

In the development of scientific principles for training long-distance runners, the attention of researchers has been focused not only on determining the level of VO₂ max, but above all, on developing methods affecting the level of its being practiced and diagnosed in the progress of training [6]. Theoretical assumptions and practical experiments indicated that the aim of sports training should be appropriate shaping of running techniques, i.e. such a manner of carrying out physical training should be appropriate shaping of running techniques, i.e. such a manner of carrying out physical activity that would allow for the task to be performed economically and efficiently [8].

Appropriately shaped continuous running economy is now regarded as the most important factor influencing the achievement of success in sports after reaching the extreme values of physiological predisposition phenotypic image during the course of sports training [6, 8–10]. Methods for its improvement in long-distance and marathoner runners are sought for in various ways [11]. Its various indicators are also given [12]. Most frequently, traditional measurement of heart rate during exercise at a specific intensity is used and interpretation of the indicator is conducted on the basis of the known percentage relationships between its value and maximal oxygen uptake [12–14]. Based on these assumptions, most marathoners take on the effort intensity in training and competitions of about 75–80% VO₂ max. There are also cases in which the limit was shifted to 85–90% VO₂ max (e.g. competitors such as: Derek Clayton, Frank Shorter, Alberto Salazar). Such a need was suggested in the more recent research by Scrimgeour et al. [15], but at the same time, indicating the high individual variability of physiological indicators in trained runners.

Identification and designation of two metabolic thresholds on the basis of the increase in lactate levels in blood and the accompanying changes in heart rate and respiratory minute volume were proved, at the turn of the century, to be very useful in training practice, mainly for long races and for the marathon [16, 17, 18]. Apart from individual differences, it was found that the first threshold¹ is most likely to occur with increasing levels of lactate in the blood, above the resting state (1.7 mmol · litre of blood⁻¹) with heart rate and VO₂ at 40–50% of the maximum value. The second threshold² occurs when the rate of formation of lactate is greater than the rate of its elimination (an average of about 4 mmol · litre of blood⁻¹), with heart rate and VO₂ at about 70–80% of the maximum value. From the onset of the anaerobic threshold (or lactate threshold/lactate inflection point) there begins a sharp increase in the concentration of lactate in the blood, reducing the ability to continue exercises without a decrease in intensity.

Determining the aerobic and anaerobic thresholds has become one of the primary methods of assessing aerobic efficiency and the ability to perform during prolonged exercise, mainly during the marathon. In selecting training loads the Maximal Lactate Steady State (MLSS) is employed, which defines the upper value of the concentration of lactate in the blood during work of constant intensity, i.e. when balance between production and neutralisation of lactate is maintained. It is important for training and marathon starts is to determine the speed at the MLSS. Most of the research conducted with this purpose consists of laboratory studies [1, 19], making it difficult to put the results obtained into training practice. Use of alternative diagnostic solutions in field conditions was very seldom [20–24]. Such method of diagnosing fitness (with emphasis on the economy of running) proved useful primarily in male amateur marathoners.

¹ Its names include: aerobic threshold, the point of optimum ventilation capacity, anaerobic metabolism threshold (AMT), the individual anaerobic threshold, first ventilator and lactate threshold, the initial increase in lactic acid.
² The names include: anaerobic threshold, onset of blood lactate accumulation-OBLA, the initial increase in lactic acid level, anaerobic metabolism threshold (AMT), individual anaerobic threshold, second ventilatory threshold, the second lactate threshold, aerobic-anaerobic compensation threshold, compensated metabolic acidosis threshold.
Using lactate threshold to determine the intensity of marathon running in women practicing sports...

[25, 26]. As for female amateur athletes, there has been no assessment so far of the effectiveness of determining the intensity of running in the marathon based on lactate threshold tests.

Aim of own research

The aim of the study was to verify projectability of the method for determining the optimum speed and heart rate during a continuous run, continued at the level of maximum acidosis balance (Maximal Lactate Steady State – MLSS), using the lactate threshold test [1] conducted in field conditions for women involved in non-profession marathon running.

Research hypothesis

The experiences of men training sports unprofessionally, with the use of physiological indicators defined at the level of the lactate threshold [1] to develop effective training and tactics of the marathon running guidelines, suggests the possibility to confirm the same role of the indicators determined at the Maximal Lactate Steady State (MLSS) threshold level for the implementation of the same type of tactical tasks and techniques of marathon running by women.

Research organization

In the week before the start of the marathon, on an athletic track, 10 women completed a test to determine the lactate threshold [1] and determine running speed and heart rate at its level.

Simultaneously, a questionnaire was conducted to obtain information from subjects regarding: their age, level of sports, the number of times competing in marathons, training experience.

Study design

Description of subjects

The study involved 10 female subjects chosen on the basis of nonprobability sampling who engaged in regular running training (three times a week), a part of recreational activities organised by the Masters club section of AZS AWF. The average age of the subjects was 33 years (R=20 years, 23 y. min. -43 y. max.) and their training experience in amateur sport ranged from 3 to 8 years (R=5 years).

Research methods and techniques

The following two reaserch methods were used:
1. Observation of the increase in heart rate and lactate concentration in the blood of female runners taking part in the lactate threshold test [1].
2. An interview survey used to collect information on the women’s age, personal life records in the marathon and training experience.

Test methodology

The subjects performed five level-grade interval runs on a treadmill, 6 minutes each, with a two-minute break, during which blood from the fingertip was collected to determine the concentration of lactate. The first exercise was carried out with the intensity of 50 beats below the maximum heart rate. In subsequent trials the intensity increased by 10 beats per minute. During the exercise, the task of the runners was to maintain a constant heart rate.

Once the blood samples were obtained, the increase in concentration of lactate was analysed with the help of Lactate Scout device by Senslab. The increase, determined to be at least 0.5 mmol/litre of blood, was considered to be both the Maximal Lactate Steady State (MLSS) and the lactate threshold.

Assessment of kinematic values of continuous runs

• The distance covered with imposed intensity was used to calculate the running speed, primarily at the lactate threshold.
• The official record from the sporting event documentation provided information on the results achieved by women participating in the lactate threshold test – the result in the marathon and the average speed with which the whole distance, the first and second part of the marathon were each covered.

Heart rate measurement

To measure the heart rate during exercise, both in interval runs during the test and during the course of the marathon Polar RS410 Heart Rate Monitor was used.

Methods of processing research material:

The following were calculated from the collected data:
• running speed (m/s) at every stage of the lactate test
• the average speed (m/s) over the distance of the whole marathon and its first and second parts
• arithmetic average of percentage (%) differences between the speed achieved in the marathon and the lactate test, the range of variation (min-max) and its value (R)
• Pearson’s simple correlation coefficient (RXY) was used to assess the strength of the relationship between:
  – training experience and the results achieved in the marathon
  – speed during the test conducted before the competition and the average speed during the competition
– running speed in the first and second half of the marathon
• regression equation between threshold speed and the average speed in the marathon.

Calculations were done using Microsoft Excel 2007.

Results

Level of sports and training experience of the studied women

As is clear from the data presented in Tab. 1 and Fig. 1, the personal bests of the studied women during the marathon were varied, but also characteristic for the assumed goals of performing recreational sports in the AZS AWF Masters Club section. For the whole group, the results stood at 03:37.26, with a large range of variation: R = 1:27.51 (min 2:53:12 – max 4:20:39). Analyzing the data presented in Figure 1, three groups of sports levels can be distinguished in terms of the variability of results, according to the classification standards of the Polish Athletics Association:
1. Amateur level: results of approx. 4 hours (B.M, W.M, K.B, T.B, K.I)
2. 3rd class sports level: norm 3:10:01 – 3:35:00 (E.K, P.K, K.E),
3. 2nd class sports level: norm 2:57:01 – 3:09:99 (S.I)
4. 1st class sports level: norm 2:40:00 – 2:56:99 (G.P)

Training experience and the marathon result

No correlation was found between the obtained marathon result and training experience.

Speed at lactate threshold and during a marathon

As can be observed from the data presented in Figure 2, two out of ten women tested achieved higher average speed in the marathon than during examination (0.22 m/s min. – 0.28 m/s max.) and four achieved speeds quite similar to one another (0.00 m/s min. – 0.05 m/s max). In other cases, the running speed of marathoners was lower by an average of 0.24 m/s (0.13 m/s min. – 0.36 m/s max.).

The power correlation calculated for threshold speed and speed during the marathon was moderate ($r_w = 0.87$). The applied test showed that the quantity of the Pearson correlation coefficient was statistically significant at $p \leq 0.001$, with the critical value $r (\alpha df) = 0.8721$ (with the number of degrees of freedom $df = n (10) – 2 = 8$), all of which made it possible to adopt the hypothesis of a statistically significant correlation.

Linear relationship between the independent (speed at lactate threshold) and dependent (speed during the marathon) variables can be confirmed by a graphic image of individual percentage indices reflecting the differences between the aforementioned variables, having taken the speed assessed at the lactate threshold as the point of reference (Fig. 3). What follows from the analysis of the data (Fig. 3) is that the variability of results (R) ranged between 20% (89% min. – 109% max.), however in most cases the differences did not exceed 4% (i.e., from 0 [100%] min. to – 4 [96%] max.).

Such relationships are even more clearly visible in the graphic representation of the interrelation between the speed assessed at lactate threshold and the speed dur-

---

Fig. 1. Top results in the marathon run of the studied women

The initials of the studied women are given in parentheses.
Using lactate threshold to determine the intensity of marathon running in women practicing sports...

Tab. 1. Basic characteristics of subjects

<table>
<thead>
<tr>
<th>Competitor</th>
<th>Age [years]</th>
<th>Experience [years]</th>
<th>Marathon result [h]</th>
<th>Speed</th>
<th>Marathon time</th>
<th>Difference 2nd – 1st [s]</th>
<th>HR marathon</th>
<th>% threshold speed</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.K</td>
<td>42</td>
<td>7</td>
<td>03:19:12</td>
<td>3.25</td>
<td>3.50</td>
<td>01:40:45</td>
<td>01:41:50</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>PK</td>
<td>23</td>
<td>8</td>
<td>03:20:42</td>
<td>3.23</td>
<td>3.50</td>
<td>01:37:06</td>
<td>01:43:36</td>
<td>390</td>
<td></td>
</tr>
<tr>
<td>K.E</td>
<td>43</td>
<td>8</td>
<td>03:22:35</td>
<td>3.56</td>
<td>3.53</td>
<td>01:37:01</td>
<td>01:42:11</td>
<td>310</td>
<td></td>
</tr>
<tr>
<td>W.M</td>
<td>29</td>
<td>3</td>
<td>03:54:19</td>
<td>3.13</td>
<td>3.00</td>
<td>01:52:50</td>
<td>01:51:29</td>
<td>-81</td>
<td></td>
</tr>
<tr>
<td>K.B</td>
<td>30</td>
<td>4</td>
<td>03:54:34</td>
<td>3.36</td>
<td>3.00</td>
<td>01:57:59</td>
<td>01:56:35</td>
<td>-84</td>
<td></td>
</tr>
<tr>
<td>K.I</td>
<td>26</td>
<td>3</td>
<td>03:57:57</td>
<td>3.27</td>
<td>2.96</td>
<td>01:55:49</td>
<td>02:02:09</td>
<td>380</td>
<td></td>
</tr>
<tr>
<td>M.B</td>
<td>40</td>
<td>6</td>
<td>03:59:57</td>
<td>2.98</td>
<td>2.90</td>
<td>01:58:04</td>
<td>02:01:54</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>T.B</td>
<td>39</td>
<td>8</td>
<td>04:20:39</td>
<td>2.98</td>
<td>2.70</td>
<td>02:08:07</td>
<td>02:12:32</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td>G.P</td>
<td>34</td>
<td>2</td>
<td>02:53:12</td>
<td>4.06</td>
<td>4.05</td>
<td>01:27:12</td>
<td>01:28:00</td>
<td>-72</td>
<td></td>
</tr>
<tr>
<td>S.I</td>
<td>26</td>
<td>6</td>
<td>03:11:16</td>
<td>3.68</td>
<td>3.67</td>
<td>01:35:35</td>
<td>01:35:41</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
The chart shows that points are arranged in close proximity to a straight line, very close to one another. Undoubtedly, this indicates a linear (but not functional) relationship between the dependent and independent variables. Therefore, it was possible to calculate a regression function together with its corresponding equation from the formula: \( y = a + bx \). The directional factor of the regression line \((b_{xy})\) and the \(y\)-intercept \((a)\) were then calculated. The finished regression equation based on the results of original research has the form \( y = 1.096x - 0.395 \). The analysis of the equation shows that the increase by 1 m/s in average threshold speed may cause an increase in speed during the marathon by 1.096 m/s (the end result must be then decreased by 0.395 m/s).

**Distribution of running pace over the marathon distance (42,195 metres)**

Figure 5 presents data on average speed achieved in the first and second part of the marathon by the female athletes tested. A comparison shows a very high degree of evenness of running pace over the whole marathon.
Using lactate threshold to determine the intensity of marathon running in women practicing sports...

Distance (42,195 metres). In the case of lower running speed, the difference oscillated in range of $R=0.17\text{ m/s}$ ($0.01\text{ m/s \ min. \ – \ }0.18\text{ m/s \ max.}$); the range of variation of differences was only slightly higher – $R=0.21\text{ m/s}$ ($0.01\text{ m/s \ min. \ – }0.22\text{ m/s \ max.}$) – when the second part of the marathon was taken into consideration. It shows, without any doubt, a good implementation of tactical guidelines and, in most cases, a proper interpretation of the lactate threshold test results (i.e. proper speed imposed). Only in runners K.I (amateur class), K.E and P.K (3rd sports class) could there be found a significant drop in running speed in the second part of the marathon ($>0.23$, $>0.18$, $>0.16\text{ m/s}$). In other cases the variability of results ($\pm$) oscillated in the range of $0.01$ – $0.09\text{ m/s}$ and only three marathoners (G.P – the best one; W.M and K.B – two amateur runners) were found to run the second part of the marathon slightly faster ($<0.06$, $<0.04$, $<0.04\text{ m/s}$).

If the range of differences between the speeds in the first and second part of the marathon is put into percentage values (Table 1), it can be seen to be at $R = 3.7\%$ ($0.3\% \text{ min. \ – } 6.8\% \text{ max.}$). Using a different indicator – time (s) of covering a specific distance (e.g. a marathon or a half marathon) – shows that the decrease in speed in the second part of the marathon – $R = 325\text{ s}$ ($65\text{ s \ min. \ – }390\text{ s \ max.}$) was clearer than the increase in

---

**Fig. 4.** Linear relationship between threshold speed and average speed achieved in the marathon by the studied women

\[
f(x) = 1.1x - 0.39
\]

**Fig. 5.** Differences in women’s running speed in the first and second parts of the marathon

---

**Table 1.** Differences in women’s running speed in the first and second parts of the marathon.

<table>
<thead>
<tr>
<th>1st marathon part</th>
<th>2nd marathon part</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.K</td>
<td>2.90</td>
</tr>
<tr>
<td>B.M</td>
<td>3.00</td>
</tr>
<tr>
<td>P.K</td>
<td>3.10</td>
</tr>
<tr>
<td>W.M</td>
<td>3.20</td>
</tr>
<tr>
<td>K.B</td>
<td>3.30</td>
</tr>
<tr>
<td>K.E</td>
<td>3.40</td>
</tr>
<tr>
<td>T.B</td>
<td>3.50</td>
</tr>
<tr>
<td>K.I</td>
<td>3.60</td>
</tr>
<tr>
<td>G.P</td>
<td>3.70</td>
</tr>
<tr>
<td>S.I</td>
<td>3.80</td>
</tr>
</tbody>
</table>
speed: $R = 12$ s (72 s min. – 84 s max.), which can be seen in Figure 6. Gains and losses can be assessed in similar proportions by expressing them in physical units of velocity (that is, in seconds per kilometre). Thus, the increase in speed was 3-4 seconds/km and the drop in speed was 0.3 seconds/km min. – 19 seconds/km max.

Statistical analysis indicated the occurrence of a clear correlation between speeds obtained in first and second part of the marathon which attests the significance of Pearson linear correlation $r_{xy}$ 0.97 ($p \leq 0.001$, with the number of degrees of freedom df N (10) – 2). It is also interesting that in this range of variability, lesser dispersion of results was observed in more advanced runners. As previously stated, it could be the result of imposing proper speed of continuous run, based in turn on the lactate threshold speed test.

Figure 7 and Table 1 show the relative differences in speed between covering the second and first part of

![Graph](image-url)
the marathon expressed in kinematic units (m/s). The differences were calculated in relation to the measurements taken at the lactate threshold. Comparative analysis shows that the most significant differences were found in runners practicing only amateur racing. Especially interesting is the distribution of speed in the first and second part of the marathon in women who sported impressive results in marathon (G.P: 2:53:12 [1st sports class] and S.I: 3:11:16 [3rd sports class]), very close to the threshold speed. In this case, the desired effect was the result of properly implemented tactical and technical guidelines (with the use of continuous running speed, which was selected on the basis of the lactate threshold test).

Such a view may be confirmed to a large extent by the results presented in Fig. 7 and Tab. 1. There, an analysis of relative indicators of the relationship between the average speed in the first and second part of the marathon, and the speed assessed in the lactate threshold test was placed. The analysis of the data shows that among the women tested, the individual indicators of potential (physiological and kinematic) capability of covering the first and second part of the marathon (assessed in the lactate threshold test) were taken greater advantage of by more experienced female runners – i.e., those classified according to the standards of Polish Athletics Association PZLA (G.P and S.I – 1st and 3rd sports class, respectively) and by only some of the amateur marathoners (BM, WM). In other cases, the marathoners tended to understate the potential to continue the run with imposed threshold speed (e.g. M.B, T.B, K.I) or significantly increase the limits assessed in the test before the competition (E.K, P.K). In either case (in contrast with experienced marathoners) running speed in the second part of the marathon was lower. This may suggest significant impact of a lacking technical and fitness preparation for continuous effort over a long period of time, while maintaining the imposed speed. An analysis of a commonly used indicator of intensity of effort and metabolic changes during long-term work – heart rate – was chosen to serve as a confirmation of a possible hypothesis.

The relationship between heart rate during a marathon and heart rate assessed at the lactate threshold

Figure 8. and Table 1. present the arithmetic means of heart rate, assessed in the lactate threshold test before a marathon, and average heart rate values, registered by 7 women on heart rate monitors during the event. In addition, differences (shown in percentages) between the results on heart rate monitors were illustrated as points.

The analysis of the data presented shows that only two cases – T.B and B.K – registered lower average heart rate during the marathon than the heart rate assessed in the lactate threshold test. In the light of earlier analyses of kinematic parameters measured both during the competition and during the test, it may be said that both women sported very poor times in the marathon (Fig. 1) and covered the whole distance (Fig. 2), as well as its first and second parts (Fig. 5) at a lower speed than the one imposed on the basis of the lactate threshold test. This could also result in their exercise capacity remaining unused. The hypothesis that these runners’ technical and fitness preparation was unsuited for long-term exercise should not be rejected either.

Among the remaining subjects, including the best one (G.K) a slightly higher value (by 2–3%) of the functional characteristic discussed was reported. This can be

![Fig. 8. Numerical and percentage relationships between the average heart rate during the marathon, established at lactate threshold](image-url)
considered normal, resulting from a number of reasons caused by usual physiological responses and stress during prolong physical exercises. The increase in heart rate during running with even pace is to be considered a normal phenomenon.

It is a well-known fact that the shift towards higher values of cardiovascular reactions at constant running speed (referred to as “cardiac drift”) is the result of processes that occur in the body during exercise. One of the main reasons for the shift is an additional movement of blood flow in different parts of the body as a result of muscular activity. With increasing work time there follows a change in the redistribution of blood circulating between the internal organs, muscles and skin layers. This requires providing additional energy and results in the reaction of the circulatory system. In the case of the marathoners, the increase of heart rate during continuous operation with uniform mechanical intensity should be linked also with thermoregulatory mechanisms, which start operating in order to protect the body from overheating. The process of hydrating the organism is also crucial when a very intense dehydration of the body is occurring.

To what extent the heart rate will intensify is also affected by physiological adaptation processes, taking place during training before sports competitions; adaptations include cardiac output (Q) and stroke volume (SV). Obviously, these indicators are not constant. Their functional efficiency depends on the volume of the heart (i.e. the end-diastolic volume or the number of millilitres of blood to be found in the ventricle) and the strength of myocardial contraction. Their reported growth must therefore be regarded as a perfectly natural physiological process that occurs during prolonged exercise.

The matter in hand (for the subjects of the study) is very interestingly illustrated by the dynamics of heart rate increase per kilometre of run (HR/km), presented in Fig. 9. The rhythm of the development of the phenomenon may be, to a large extent, a function of both objective processes occurring during physical exercise and the level of preparation for marathon, especially in terms of technique and tactics (which was mentioned earlier). In order to validate this hypothesis, the dynamics of change of the exercise intensity indicator (heart rate and running speed) in the first and second part of the marathon was analysed.

Figure 10 presents the differences in percentage values of heart rate and running speed for women in the second part of the marathon in relation to the values recorded in the first part of the marathon. Analysis indicates that they are rather insignificant and do not exceed 11% even in extreme cases. The interdependence of these measurements, established in the first and second part of the distance confirms high and statistically significant ($p \leq 0.001$) Pearson rank correlation coefficient $r_{xy} = 0.90$.

A close analysis of the data presented in Fig. 10 shows, however, that large individual differences in the
indicator discussed occurred in most subjects. In two instances, the increase in heart rate in the second part of the marathon was not accompanied by a decrease in running speed. Such a phenomenon was observed in the best competitor (G.P – 1 sports class) and in the aforementioned amateur marathoner (K.B) who, as far as technique, tactics and fitness are concerned, was very poorly prepared to participate in the marathon. In the case of G.P, the slight increase in heart rate should be associated with the previously discussed properties of the cardiac drift in prolonged exercise. On the other hand, the second case requires an interpretation linked with the way inexperienced marathoners solve tactical problems during the competition. The fact that K.B began the competition at a low speed and with low heart rate (Fig. 7), even below the value assessed at lactate threshold before the competition bears testimony to the validity of such approach. Subsequent stages of the marathon witnessed systematic increase in running speed which resulted in a significant increase in heart rate (Fig. 9) and a slight increase in speed (Fig. 10), however below the values assessed in the test.

** In two other cases, i.e. E.K and K.E, lower average heart rate and running speed were reported in the second part of the marathon. In the light of the analysis of kinematic indicators of the run, in relation to the value assessed in lactate threshold test (Fig. 7), it can be assumed that the cause could be found in over-intensification of effort in the first part of the distance and not following tactical directions. Both marathoners continued the first part at a speed higher than what was assessed in the lactate threshold test. This could be the cause of the collapse, after 30 kilometres, of their ability to continue with the self-imposed intensity, and required speed reduction (documented also by a decrease in heart rate in the final stages of the marathon (Fig. 9). It cannot be excluded either that a decline in the running speed of untrained marathoners was caused by their poor resistance, which was a result of growing fatigue caused by dehydration and overheating of the body. Additionally, fatigue was magnified by muscle groups impaired under the effects of the yet-uncompensated metabolic acidosis resulting from running at a speed greater than what was assessed at lactate threshold.

** The same factors should be considered the cause of the inversely proportional relationship between the increase in heart rate and decrease of the speed with which the second part of the distance was covered. This phenomenon was observed in three consecutive marathoners: T.B, B.M and P.K. In this case, what draws particular attention is the very uneven pace of the dynamics of heart rate change, especially in the early stages of the competition, possibly indicating a discrete acceleration of running pace.

Analysis of changes in heart rate of the subjects (Fig. 9) allows one to also note that in most cases, the adverse effects were caused by lack of technical and tactical experience in handling a marathon. Undoubtedly, this was in turn the result of (already signalled) insufficient training and scepticism towards the earlier tactical arrangements based on the results of the test. Taking into account all of the examples analysed, the correct model of accomplished tactical objectives (validating, in turn, creating benchmarks for their implementation in the marathon) is to be seen in kinetics and dynamics of change in time of the speed and heart rate of G.P (1st sports class marathoner), who represented higher sport level.
Discussion

Running is widely considered to be the most popular form of physical activity. Moreover, it is available for anyone who wants to engage in physical activity to improve health. The advantages of running have been appreciated by Americans already in the last century, as it was highlighted in the introduction to this study. Also in Poland, the number of running aficionados is growing larger. The number of people taking part in mass street runs and marathons or half marathons may attest to the popularity of running. Most recent editions of the Cracovia Marathon (five in total, from 2011 to 2015) saw the number of women to complete the marathon double, from 306 to 718. And it is not a shocking statistic: tens of thousands of men and women take part in the biggest marathon events in the United States. For example, in the New York Marathon in 2014, out of 50530 participants nearly a half (20,422, that is 40.4%) were women (http://web2.nyrrc.org/cgi-bin/start.cgi/mar-programs/archive/archive_search.html).

High interest in running, and its popularity (sometimes referred to as "joggingowanie" in Polish) result in emergence of clubs and sport sections devoted to this particular form of physical activity. An example of this might be the Masters section of the AZS AWF club in Krakow. For many years, the group of adult men unprofessionally practicing sports therewas the subject of interest for researchers from AWF Krakow, who deal with not only the cognitive aspects of sport activities in the elderly age, but also deal with the problem of application, which is to develop effective training methods and optimal technical and tactical models for the marathon. It is an important issue since the assumption is that undertaking such increased physical activity has to serve health on the one hand, and the other delay the processes of involution in elderly people [27].

So far, research problems concerning the participation of women from the Masters section in marathons were not analysed, and it is not restricted to Krakow. In order to meet the growing interest of women from Krakow in participating in marathon, it was decided to conduct a study whose purpose was to verify the prognostic value of methods of determining the optimal speed and heart rate for a constant run. The run would be continued at Maximal Lactate Steady State (MLSS), with the use of lactate threshold test [1], carried out in field conditions to meet the needs of unprofessional female marathoners. Numerous observations indicated that women prepare them selvesin adequately for participation in prolonged exercise and do not have a specific point of reference as to the imposition of an optimal intensity of running during sporting events, which would help achieve a score reflecting their functional potential and physical fitness.

Building on previous experience with determining the optimal intensity of running in the marathon for unprofessional male marathoners [23, 24], as well as on previous numerous solutions of cognitive and application problems in training long-distance runners [6–12, 17, 28–30], the present study sought to prove the hypothesis that the indicators assessed at Maximal Lactate Steady State (MLSS), can be equally useful for both women and men in realising tactical tasks and implementing marathon running techniques. Among the many physiological and kinematic indicators used for characterising the processes of fatigue and training, the two most accessible were selected: the heart rate and running speed.

To determine the prognostic value of heart rate and running speed for the development of optimal running intensity for 10 women competing in the marathon, the lactate threshold test was performed a few days before the start [1, 19]. The test belongs to a group of field tests used to determine the level of kinematic and physiological indicators at lactate threshold [20–24, 28–31]. Such a method has been successfully used to determine the optimal load for the body in athletic training and to determine the optimal intensity of physical exercise in competitions of various kinds, with particular emphasis on running (athletics). The choice of two properties was justified by the fact that during long events, one of the most important abilities is aerobic fitness and economy (technique) of movement, which will be decisive in the case of more competitors having a similar level of physiological indicators [6, 8, 9]. Fairly widespread and supported by studies [21] is the belief that physical exercise at lactate threshold can continue for even over 2.5 hours.

Relying on the results of statistical analysis of the original research it should be emphasised that there is a broad convergence between speed assessed at lactate threshold and the speed during the marathon. This relationship is documented very clearly by a statistically significant Pearson correlation coefficient \( r_{xy} = 0.87 \) and the calculated regression equation \( y = 1.096x – 0.395 \).

A similar intensity correlation between the discussed variables was found in world-class 50 kilometres race walkers [20–22] and in studies of unprofessional male marathoners [23, 24]. On the basis of this finding it could be concluded that the pace of the subjects, based on indicators of the lactate threshold test was almost even on the whole distance. Further confirmation may be found in statistically significant correlation coefficient \( r_{xy} = 0.97 \), heart rate and running speed in the first and second parts of the marathon.

Detailed analysis of individual cases has proven that statistical results can be deceptive. Training, as well as implementation of technical and tactical tasks in sports are individual and not universal in character. It is therefore necessary to complement the regularities detected
Using lactate threshold to determine the intensity of marathon running in women practicing sports... using methods typical of population studies with the results of a study of individual cases. Using it in present study showed that the proven, statistically significant intensity correlations could only refer to marathoners characterized by higher sports level. The cause of discrepancies in most subjects between their tactical assumptions based on the lactate threshold test and their execution in the marathon can be found in the small amount of experience of the women in the implementation of the pre-start guidelines and poor technical training enabling running continuously at a set speed. Lack of a sense of time and pace could cause either underestimation or overestimation of the indicators set in the test before the competition. The coordination abilities mentioned are characteristic for athletes with longer training experience [6, 14]. It results from training practice as well as from scientific research that only small variations of the average speed facilitate achieving good results [31,33].

The failures mentioned cannot deny the sense in determining the intensity of women’s marathon run on the basis of the test. As it turns out, this procedure can be effective only with consistently adhering to tactical guidelines and should be unreservedly used by female athletes participating in the marathon.

The results of the present study confirmed the known phenomenon – an increase in heart rate in the second part of the marathon, even in women running consistently at even pace. Therefore it appears that in determining the intensity of the continuous run, kinematic indicators may have higher practical value than physiological indicators identified in the lactate threshold test.

Conclusions

1. The results of the study confirmed great usefulness of speed and heart rate indicators, determined before the competition in the „the pitch test” lactate threshold test, used for the realization of women’s tactical and technical tasks while running a marathon.

2. Due to the fact that there is a tendency for response rates of the cardiovascular system to increase along with the duration of an effort, i.e. during long runs at a constant speed, which is an adaptation process of the body to changing energy needs, kinematic indicators of running, determined in the lactate threshold test, should be considered to be more reliable for carrying out the training process as well as tactical and technical tasks performed during a marathon.

3. Similarly as in the case of men, non-professional female marathon runners who do not subordinate the tactics and techniques of continuous running to the objective, potential physiological and kinematic indicators of continuing efforts for a prolonged period of time, limit the possibility of obtaining the best possible potential results at sporting events.

The study was carried out within the framework of University Physical Education in Krakow statutory research: “The effect of the endurance-type training load in men and women during their transvolutions and involutions of biological development on athletic performance in a marathon and indicators of physical fitness tested in the convention of health”. Project No. 36/BS/IS/2013.

Literature


Address for correspondence:
PhD Wacław Mirek,
Faculty of Field Sports,
Department of Physical Education and Sports,
University of Physical Education in Krakow Poland,
mobile: (12) 683-14-41
e-mail: waclaw.mirek@awf.krakow.pl
NEW PROCEDURE FOR EQUALIZATION OF POWERLIFTING RESULTS

Adam Haleczko

Retired employee of University School of Physical Education (AWF) in Wroclaw

Key words: weightlifting, Wilks formula, body mass, three variable formula

Abstract

This publication is a continuation of the author’s work regarding the conversion tables for results of bench press in disabled athletes [1, 2], which are currently used for competitions subordinate to the IPC (IPC Powerlifting). In the current year, a report containing a new equalization formula for the results in the Olympic weightlifting appeared on websites [3, 4]. Using these experience, the procedure applied to powerlifting is presented in this article. Due to its wide representation in previous studies, theoretical assumptions concerning the weightlifting competition in this article are limited to a brief discussion on the new method of result equalization adopted as the “Haleczko Formula”, its assessment and comparison with previously used conversions on the basis of the Wilks tables.

Introduction

In the four weightlifting competitions, bench press (including athletes with disabilities), Olympic weightlifting and powerlifting, the best female or male athlete is chosen regardless of their belonging to a given weight class. An instrument used for the equalization of opportunities in athletes belonging to a lighter category or of lower body mass are conversion tables containing factors, which, with the increase in body mass of the weightlifters relative to their size, lower the value of the results by their multiplication. The creator of the table currently used for the bench press and the Olympic weightlifting is Sinclair [5], for powerlifting – Wilks [6], and for the bench press in athletes with disabilities, the author of this publication [1, 2]. Due to the fact that several previous articles [1–28] were devoted to weightlifting, especially focusing on the significance of an athletes’ body mass on his/her result and studying the issues of this phenomenon in great detail, the main subject of this article is limited to exploring the new formula, its assessment and comparisons with Wilks tables. However, the referenced literature list includes items containing the theoretical basis on this issue.

Aim

Presentation of a new way to identify the best weightlifter.

Study design

Research material was comprised on the basis of belonging to a given weight category or body mass data, as well as information the results of the best male and female competitors in the world in the years 2011–2014, which was obtained from messages and rankings published on the Internet [29, 30]. 48 female competitors from 6 up to 84 kg categories and 56 male competitors from 7 up to 120 kg categories were taken into account. The heavier group consisted of 24 women from the 84+ kg category and 47 men from the 120+ kg category. The ranking lists of results based on body mass are given in the Appendix. Body mass of the lighter weightlifters was specified by the upper limit of individual categories. For the heavier athletes, the data contained in the messages was considered. Using experience in equalizing Olympic weightlifting results consisting of two competitions, it could be believed that powerlifting combining the results of three events -
the squat, bench press and deadlift - their total more than twice as high as Olympic weightlifting achievements – is more dependent on body mass. Hence, in survey calculations, double the body mass is assumed, however, as it turns out, adopting only its real value is correct. All results were calculated using Wilks conversions, treating them as integers without decimal places.

In the construction of variables, similarly as the Olympic weightlifting [3, 4], the output data (body mass and result) were supplemented by a third feature – the difference between these two variables. In creating formulas determining the value of coefficients, the analogous procedure as in the case of the Olympic weightlifting was applied – finding the right power by iteration [3, 4]. In contrast to the Olympic weightlifting, the higher degree of correlation between body mass and the results in heavy categories (Tab. 9 and 10) allowed for the application of the third variable in those groups as well. However, the characteristic trend for this formula, the decreasing result with increasing mass, was appropriate only for basic categories (up to 84 kg for women and up to 120 kg for men). In both of the heaviest categories, it proved to be too strong, excessively lowering the aligned results in these groups. The additions introduced to the formulas equalized the chances of the heaviest individuals in these groups. The new formulas enable the usage of computer programs, which greatly simplifies the process of identifying the best competitor.

**Formulas for calculating the coefficients of result equalization using the new formula:**

\[ WW = \frac{(Y - X)^{1 - Z}}{Y^Z} \times N \]  

or  

\[ WW = \frac{Y - Z}{[(Y - Z)Y]^Z} \times N \]  

**Women**

Up to 84 kg category

\[ WW = \frac{(Y - X)^{1 - Z}}{Y^Z} \times N \]  

or  

\[ WW = \frac{Y - X}{[(Y - X)Y]^Z} \times N \]

+84 kg category

\[ WW = \frac{(Y - X)^{1 - Z}}{Y^Z} \times N + (X - 85) \times 0.33 \]

or  

\[ WW = \frac{Y - Z}{[(Y - Z)Y]^Z} \times N + (X - 85) \times 0.33 \]

**Men**

Up to 120 kg category

\[ WW = \frac{(Y - X)^{1 - Z}}{Y^Z} \times N \]  

or  

\[ WW = \frac{Y - X}{[(Y - X)Y]^Z} \times N \]

+120 kg category

\[ WW = \frac{(Y - X)^{1 - Z}}{Y^Z} \times N = (X - 121) \times 0.5 \]

or  

\[ WW = \frac{Y - X}{[(Y - X)Y]^Z} \times N + (X - 121) \times 0.5 \]

Material elaborated by calculating basic statistical indicators and correlations (Tables 1–10).

**Results**

Further tables show the results of basic calculations. The data in Tables 1 and 2 show the results of calculations for female and male athletes from the lighter category. Juxtaposition of the results converted by both formulas allows for their comparison. An objective, yet adequate measurement for the evaluation of the effectiveness of the conversion is the “V” coefficient of variation [16, 17]. The closer it is to zero, the higher the quality of conversion. In women, volatility of this indicator was assessed according to Wilks, and it reached up to 6.1%, but when using the new formula, it was only 0.8%. In the group of male competitors, 3.6% and 0.4%, respectively.

It should be noted that the coefficients of variation are the basic criterion for the assessment of calculations used to select the champion in all weightlifting events; Tables 3 and 4, on the other hand, present calculation

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>X</th>
<th>Min.–Max.</th>
<th>S</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass [kg]</td>
<td>62.5</td>
<td>47–84</td>
<td>12.60</td>
<td>31.0</td>
</tr>
<tr>
<td>2</td>
<td>Result [kg]</td>
<td>534.47</td>
<td>417.5–670.5</td>
<td>74.26</td>
<td>13.8</td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass [kg]</td>
<td>476.97</td>
<td>370.5–599.5</td>
<td>63.70</td>
<td>13.4</td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula [kg]</td>
<td>595.8</td>
<td>630–689</td>
<td>36.20</td>
<td>6.1</td>
</tr>
<tr>
<td>5</td>
<td>Coefficients according to the new formula</td>
<td>1.2885</td>
<td>1.272–1.318</td>
<td>0.0102</td>
<td>0.8</td>
</tr>
<tr>
<td>6</td>
<td>Result according to the new formula [kg]</td>
<td>539.46</td>
<td>532.7–551.9</td>
<td>4.28</td>
<td>0.8</td>
</tr>
</tbody>
</table>
New procedure for equalization of powerlifting results

Table 2. Numerical characteristics of body mass and results in powerlifting for men in the 56–120 kg categories (N=56)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>( \bar{X} )</th>
<th>Min.–Max.</th>
<th>S</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass [kg]</td>
<td>85.7</td>
<td>59–120</td>
<td>20.4</td>
<td>23.7</td>
</tr>
<tr>
<td>2</td>
<td>Result [kg]</td>
<td>891.08</td>
<td>642.5–1075.0</td>
<td>134.88</td>
<td>15.1</td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass [kg]</td>
<td>805.38</td>
<td>583.5–955.0</td>
<td>115.80</td>
<td>14.4</td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula [kg]</td>
<td>606.7</td>
<td>558–669</td>
<td>21.7</td>
<td>3.6</td>
</tr>
<tr>
<td>5</td>
<td>Coefficients according to the new formula</td>
<td>1.1735</td>
<td>1.164–1.183</td>
<td>0.0047</td>
<td>0.4</td>
</tr>
<tr>
<td>6</td>
<td>Result according to the new formula [kg]</td>
<td>891.07</td>
<td>884.0–898.6</td>
<td>3.57</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Table 3. Numerical characteristics of body mass and results in powerlifting for women in the 84+ kg category (N=24)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>( \bar{X} )</th>
<th>Min.–Max.</th>
<th>S</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass [kg]</td>
<td>108.9</td>
<td>90–129</td>
<td>11.3</td>
<td>10.4</td>
</tr>
<tr>
<td>2</td>
<td>Result [kg]</td>
<td>619.48</td>
<td>515.0–753.0</td>
<td>67.46</td>
<td>10.9</td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass [kg]</td>
<td>510.5</td>
<td>398–632</td>
<td>61.8</td>
<td>12.1</td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula [kg]</td>
<td>507.3</td>
<td>414–601</td>
<td>48.7</td>
<td>9.6</td>
</tr>
<tr>
<td>5</td>
<td>Coefficients according to the new formula</td>
<td>1.2500</td>
<td>1.198–1.286</td>
<td>0.0190</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>Result according to the new formula [kg]</td>
<td>531.08</td>
<td>512.1–545.8</td>
<td>8.36</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Table 4. Numerical characteristics of body mass and results in powerlifting for men in the 120+ kg category (N=47)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>( \bar{X} )</th>
<th>Min.–Max.</th>
<th>S</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass [kg]</td>
<td>146.3</td>
<td>124–189</td>
<td>14.4</td>
<td>9.9</td>
</tr>
<tr>
<td>2</td>
<td>Result [kg]</td>
<td>999.20</td>
<td>750.0–1230.0</td>
<td>115.10</td>
<td>11.5</td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass [kg]</td>
<td>852.9</td>
<td>626–1062</td>
<td>107.5</td>
<td>12.6</td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula [kg]</td>
<td>555.5</td>
<td>428–669</td>
<td>61.2</td>
<td>11.0</td>
</tr>
<tr>
<td>5</td>
<td>Coefficients according to the new formula</td>
<td>1.1423</td>
<td>1.103–1.166</td>
<td>0.0135</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>Result according to the new formula [kg]</td>
<td>879.99</td>
<td>851.9–902.4</td>
<td>12.11</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Table 5. Numerical characteristics of body mass and results in powerlifting for women in different weight classes (N=8) and 84+ kg category (N=24)

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Result</th>
<th>Result according to the Wilks formula</th>
<th>Coefficient of variation of the result by the Wilks formula</th>
<th>Result according to the new formula</th>
<th>Coefficient of variation of the result by the new formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>445.5</td>
<td>603.9</td>
<td>6.0</td>
<td>537.5</td>
<td>0.6</td>
</tr>
<tr>
<td>52</td>
<td>468.4</td>
<td>588.3</td>
<td>7.0</td>
<td>537.0</td>
<td>0.8</td>
</tr>
<tr>
<td>57</td>
<td>510.9</td>
<td>595.9</td>
<td>5.2</td>
<td>539.3</td>
<td>0.6</td>
</tr>
<tr>
<td>63</td>
<td>588.4</td>
<td>624.5</td>
<td>5.1</td>
<td>544.6</td>
<td>0.7</td>
</tr>
<tr>
<td>72</td>
<td>601.9</td>
<td>597.5</td>
<td>5.1</td>
<td>541.2</td>
<td>0.5</td>
</tr>
<tr>
<td>84</td>
<td>621.7</td>
<td>564.8</td>
<td>5.2</td>
<td>537.1</td>
<td>0.6</td>
</tr>
<tr>
<td>84+</td>
<td>531.1</td>
<td>507.3</td>
<td>9.6</td>
<td>545.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>

data characterizing the results of women and men in the 84+ kg and 120+ kg categories. A higher degree of variability in those weightlifters’ results is caused by lower correlations between body mass and the result (9.6% for women according to Wilks and 1.6% according to the new formula, and 11.0 and 1.4% for men respectively). Evaluation of result equalization with the use of “V” coefficients of variation in each weight category are
Table 6. Numerical characteristics of body mass and results in powerlifting for men in different weight classes (N-8) and 120 + kg category (N-47)

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Result</th>
<th>Result according to the Wilks formula</th>
<th>Coefficient of variation of the result by the Wilks formula</th>
<th>Result according to the new formula</th>
<th>Coefficient of variation of the result by the new formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>672.6</td>
<td>587.0</td>
<td>6.0</td>
<td>887.2</td>
<td>0.4</td>
</tr>
<tr>
<td>66</td>
<td>760.8</td>
<td>605.0</td>
<td>4.0</td>
<td>891.2</td>
<td>0.3</td>
</tr>
<tr>
<td>74</td>
<td>836.5</td>
<td>605.4</td>
<td>3.6</td>
<td>892.9</td>
<td>0.3</td>
</tr>
<tr>
<td>83</td>
<td>914.3</td>
<td>612.1</td>
<td>3.2</td>
<td>899.3</td>
<td>0.3</td>
</tr>
<tr>
<td>93</td>
<td>968.8</td>
<td>611.5</td>
<td>2.2</td>
<td>893.3</td>
<td>0.2</td>
</tr>
<tr>
<td>105</td>
<td>1026.2</td>
<td>615.0</td>
<td>2.2</td>
<td>891.0</td>
<td>0.2</td>
</tr>
<tr>
<td>120</td>
<td>1058.4</td>
<td>600.8</td>
<td>1.4</td>
<td>886.9</td>
<td>0.1</td>
</tr>
<tr>
<td>120+</td>
<td>999.2</td>
<td>555.5</td>
<td>11.0</td>
<td>820.0</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Fig. 1. Differences in Powerlifting results – Wilks version and the new formula (women)
New procedure for equalization of powerlifting results

Presented in Tables 5 and 6. Their values in a group of competitors are very interesting (0.4, 0.3, 0.3, 0.3, 0.2, 0.2, 0.1). It can be noted that in particular categories, as body mass increases, consistency in co-occurrence of the features comprising the result increases as well. This phenomenon can be described as a tendency signaling the need for greater uniformity of the somatic-motor structure. Apart from the coefficients of variation, the differences between the two ways of equalizing results can be presented particularly clearly by graphic representation – using arithmetic means for each weight category (Figs. 1 and 2). The straight lines correspond to the arithmetic means of the equalized results. Curves indicate their deviations arising after the calculations are made using both formulas. The closer the curves are to the straight line, the more functional and effective is the method of selecting the best competitor.

Pearson's simple correlation coefficients presented in Tables 7–10 confirm the information obtained beforehand from the calculations of the “X” arithmetic means and the “S” and “V” variability measurements (Tab. 1–6). Particularly important are the (nearly uniform) values of the coefficients of correlation determining the relations between the results and body mass, and the difference between these variables (Tab. 7–10). Such significant relations validate the importance of the use of a third variable in the formula for identifying the best competitor. Low or even negative relations of the basic initial feature – i.e., of body mass with the results from lighter categories calculated with both formulas – are the

Fig. 2. Differences in Powerlifting results – Wilks version and the new formula (men)
outcome of the process of result equalization. A higher degree of relations between body mass and the end result in lower weight categories, and a lower degree of relations with results calculated using both formulas in comparison with heavier competitors, confirm the aforementioned uniformity of somatic-motor structure.

### Table 7. Correlation coefficients between body mass and results in powerlifting for women in the 47–84 kg weight classes (N=48)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>86</td>
<td>81</td>
<td>--25</td>
<td>08</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Result</td>
<td>86</td>
<td>99</td>
<td>20</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>81</td>
<td>99</td>
<td>28</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula</td>
<td>--25</td>
<td>20</td>
<td>28</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Result according to the new formula</td>
<td>08</td>
<td>57</td>
<td>65</td>
<td>83</td>
<td></td>
</tr>
</tbody>
</table>

All correlation coefficients multiplied by 100

$r_{0.05} = -25$

$r_{0.01} = -34$

### Table 8. Correlation coefficients between body mass and results in powerlifting for men in the 59–120 kg weight classes (N=56)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>95</td>
<td>93</td>
<td>29</td>
<td>--10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Result</td>
<td>95</td>
<td>99</td>
<td>51</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>43</td>
<td>99</td>
<td>54</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula</td>
<td>29</td>
<td>51</td>
<td>54</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Result according to the new formula</td>
<td>--10</td>
<td>22</td>
<td>28</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>

All correlation coefficients multiplied by 100

$r_{0.05} = -26$

$r_{0.01} = -34$

### Table 9. Correlation coefficients between body mass and results in powerlifting for women in the 84+ kg category (N=24)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>57</td>
<td>43</td>
<td>36</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Result</td>
<td>57</td>
<td>99</td>
<td>97</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>43</td>
<td>99</td>
<td>99</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula</td>
<td>36</td>
<td>97</td>
<td>99</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Result according to the new formula</td>
<td>34</td>
<td>96</td>
<td>99</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>

All correlation coefficients multiplied by 100

$r_{0.05} = -34$

$r_{0.01} = -50$

### Table 10. Correlation coefficients between body mass and results in powerlifting for men in the 120+ kg category (N=47)

<table>
<thead>
<tr>
<th>No.</th>
<th>Features</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>57</td>
<td>47</td>
<td>50</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Result</td>
<td>57</td>
<td>99</td>
<td>98</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>47</td>
<td>99</td>
<td>98</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Result according to the Wilks formula</td>
<td>50</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Result according to the new formula</td>
<td>54</td>
<td>99</td>
<td>99</td>
<td>98</td>
<td></td>
</tr>
</tbody>
</table>

All correlation coefficients multiplied by 100

$r_{0.05} = -28$

$r_{0.01} = -36$
New procedure for equalization of powerlifting results

The most objective information on the effectiveness of calculations are provided by world records. Tables 11–12 show the comparison of the two methods of identifying the best weightlifter among the world record holders. Results of both sexes equalized with the Wilks formula clearly prefer lighter categories. The exception among women is Larysa Soloviova (weight category 63 kg), the record holder in all lifts, who is also the best according to the calculations that use the new formula. Similarly Carl Yngvar Christensen (weight category 120+ kg) is the first among men, regardless of the calculation method; his result of 1,230 kg is clearly above those of other competitors. The assessment of a female competitor from the heaviest weight category comes as a surprise. Her result of 753 kg is the highest among women, and yet she comes in last according to Wilks scoring, while she still comes in a good third place according to the new formula. In basic categories, the best weightlifters are Soloviova (weighing 63 kg) and a man competitor weighing 74 kg. This situation is explained by most authors by the fact that the trend to overestimate the results in the middle weight categories is the consequence of a much larger number of competitors in those categories, which is associated with the normal distribution of body mass among the human population. Moreover, the biodynamic features of those competitors are the most favorable, as they have an advantageous active to passive tissue ratio [1, 2]. To summarize, all of the data testify for a much higher efficiency and objectivity of the new formula in the process of selecting the champion, regardless of their somatic conditions. As a final remark, it must be emphasized that this article has been created in cooperation with the university research centers— the Center for Scientific Information and the Computer Science Center.

### Conclusions

Taking into consideration all the elements, including those both substantive and technical in nature, making up the value of the new formula, it should be believed that it may be implemented into both the procedure for selecting the best competitors, as well as determining a team’s score.

<table>
<thead>
<tr>
<th>Category</th>
<th>Body mass [kg]</th>
<th>Result [kg]</th>
<th>Wilks formula</th>
<th>Place</th>
<th>New formula</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>45.60</td>
<td>483.5</td>
<td>660.3</td>
<td>3</td>
<td>543.1</td>
<td>7</td>
</tr>
<tr>
<td>52</td>
<td>51.36</td>
<td>530.0</td>
<td>660.7</td>
<td>2</td>
<td>544.9</td>
<td>4</td>
</tr>
<tr>
<td>57</td>
<td>56.30</td>
<td>555.0</td>
<td>644.0</td>
<td>4</td>
<td>544.7</td>
<td>6</td>
</tr>
<tr>
<td>63</td>
<td>62.62</td>
<td>638.5</td>
<td>685.7</td>
<td>1</td>
<td>549.6</td>
<td>1</td>
</tr>
<tr>
<td>72</td>
<td>69.25</td>
<td>642.5</td>
<td>639.2</td>
<td>5</td>
<td>546.7</td>
<td>2</td>
</tr>
<tr>
<td>84</td>
<td>78.62</td>
<td>670.5</td>
<td>617.9</td>
<td>6</td>
<td>544.9</td>
<td>4</td>
</tr>
<tr>
<td>84+</td>
<td>120.95</td>
<td>753.0</td>
<td>601.3</td>
<td>7</td>
<td>545.8</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Body mass [kg]</th>
<th>Result [kg]</th>
<th>Wilks formula</th>
<th>Place</th>
<th>New formula</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>58.06</td>
<td>761.0</td>
<td>659.1</td>
<td>2</td>
<td>896.0</td>
<td>5</td>
</tr>
<tr>
<td>66</td>
<td>66.00</td>
<td>815.0</td>
<td>639.9</td>
<td>4</td>
<td>896.0</td>
<td>5</td>
</tr>
<tr>
<td>74</td>
<td>73.32</td>
<td>905.0</td>
<td>657.4</td>
<td>3</td>
<td>898.6</td>
<td>2</td>
</tr>
<tr>
<td>83</td>
<td>82.58</td>
<td>942.5</td>
<td>629.1</td>
<td>6</td>
<td>896.7</td>
<td>3</td>
</tr>
<tr>
<td>93</td>
<td>91.70</td>
<td>1000.0</td>
<td>631.5</td>
<td>5</td>
<td>896.2</td>
<td>4</td>
</tr>
<tr>
<td>105</td>
<td>104.92</td>
<td>1050.5</td>
<td>627.8</td>
<td>7</td>
<td>893.5</td>
<td>7</td>
</tr>
<tr>
<td>120</td>
<td>119.50</td>
<td>1075.0</td>
<td>618.0</td>
<td>8</td>
<td>888.2</td>
<td>8</td>
</tr>
<tr>
<td>120+</td>
<td>168.02</td>
<td>1230.0</td>
<td>669.4</td>
<td>1</td>
<td>902.4</td>
<td>1</td>
</tr>
</tbody>
</table>
Literature

[29] www.powerlifting.pl/referees/wilks/wilks.html; 18. 05. 2015

Address for correspondence:
PhD Adam Haleczko
ul. Kotsisa 21/4, 51-638 Wrocław
E-mail: korzewa@interia.pl
Appendix

Body mass and results in women’s Powerlifting for 84+ kg category

<table>
<thead>
<tr>
<th>No.</th>
<th>Body mass (kg)</th>
<th>Score (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90</td>
<td>657.5</td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>515.0</td>
</tr>
<tr>
<td>3</td>
<td>93</td>
<td>557.5</td>
</tr>
<tr>
<td>4</td>
<td>98</td>
<td>562.5</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>647.5</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>562.5</td>
</tr>
<tr>
<td>7</td>
<td>101</td>
<td>615.0</td>
</tr>
<tr>
<td>8</td>
<td>103</td>
<td>547.5</td>
</tr>
<tr>
<td>9</td>
<td>103</td>
<td>550.0</td>
</tr>
<tr>
<td>10</td>
<td>106</td>
<td>647.5</td>
</tr>
<tr>
<td>11</td>
<td>107</td>
<td>637.5</td>
</tr>
<tr>
<td>12</td>
<td>107</td>
<td>650.0</td>
</tr>
<tr>
<td>13</td>
<td>108</td>
<td>580.0</td>
</tr>
<tr>
<td>14</td>
<td>110</td>
<td>662.5</td>
</tr>
<tr>
<td>15</td>
<td>110</td>
<td>562.5</td>
</tr>
<tr>
<td>16</td>
<td>111</td>
<td>595.0</td>
</tr>
<tr>
<td>17</td>
<td>112</td>
<td>597.5</td>
</tr>
<tr>
<td>18</td>
<td>116</td>
<td>715.0</td>
</tr>
<tr>
<td>19</td>
<td>117</td>
<td>515.0</td>
</tr>
<tr>
<td>20</td>
<td>121</td>
<td>753.0</td>
</tr>
<tr>
<td>21</td>
<td>124</td>
<td>612.5</td>
</tr>
<tr>
<td>22</td>
<td>128</td>
<td>721.0</td>
</tr>
<tr>
<td>23</td>
<td>128</td>
<td>705.0</td>
</tr>
<tr>
<td>24</td>
<td>129</td>
<td>696.0</td>
</tr>
</tbody>
</table>
Body mass and results in men’s Powerlifting for 120+ kg category

<table>
<thead>
<tr>
<th>No.</th>
<th>Body mass (kg)</th>
<th>Score (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>124</td>
<td>750.0</td>
</tr>
<tr>
<td>2</td>
<td>126</td>
<td>865.0</td>
</tr>
<tr>
<td>3</td>
<td>127</td>
<td>870.0</td>
</tr>
<tr>
<td>4</td>
<td>128</td>
<td>870.0</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>970.0</td>
</tr>
<tr>
<td>6</td>
<td>131</td>
<td>875.0</td>
</tr>
<tr>
<td>7</td>
<td>132</td>
<td>890.0</td>
</tr>
<tr>
<td>8</td>
<td>133</td>
<td>857.5</td>
</tr>
<tr>
<td>9</td>
<td>134</td>
<td>985.0</td>
</tr>
<tr>
<td>10</td>
<td>135</td>
<td>890.0</td>
</tr>
<tr>
<td>11</td>
<td>135</td>
<td>865.0</td>
</tr>
<tr>
<td>12</td>
<td>136</td>
<td>1130.0</td>
</tr>
<tr>
<td>13</td>
<td>137</td>
<td>982.5</td>
</tr>
<tr>
<td>14</td>
<td>137</td>
<td>1055.0</td>
</tr>
<tr>
<td>15</td>
<td>137</td>
<td>982.5</td>
</tr>
<tr>
<td>16</td>
<td>138</td>
<td>1030.0</td>
</tr>
<tr>
<td>17</td>
<td>138</td>
<td>830.0</td>
</tr>
<tr>
<td>18</td>
<td>138</td>
<td>1050.0</td>
</tr>
<tr>
<td>19</td>
<td>140</td>
<td>950.0</td>
</tr>
<tr>
<td>20</td>
<td>140</td>
<td>810.0</td>
</tr>
<tr>
<td>21</td>
<td>141</td>
<td>940.0</td>
</tr>
<tr>
<td>22</td>
<td>141</td>
<td>890.0</td>
</tr>
<tr>
<td>23</td>
<td>142</td>
<td>1072.5</td>
</tr>
<tr>
<td>24</td>
<td>142</td>
<td>1075.0</td>
</tr>
<tr>
<td>25</td>
<td>143</td>
<td>1170.0</td>
</tr>
<tr>
<td>26</td>
<td>145</td>
<td>1092.0</td>
</tr>
<tr>
<td>27</td>
<td>145</td>
<td>985.0</td>
</tr>
<tr>
<td>28</td>
<td>146</td>
<td>1070.0</td>
</tr>
<tr>
<td>29</td>
<td>146</td>
<td>985.0</td>
</tr>
<tr>
<td>30</td>
<td>147</td>
<td>1072.0</td>
</tr>
<tr>
<td>31</td>
<td>151</td>
<td>1035.0</td>
</tr>
<tr>
<td>32</td>
<td>152</td>
<td>940.0</td>
</tr>
<tr>
<td>33</td>
<td>156</td>
<td>905.0</td>
</tr>
<tr>
<td>34</td>
<td>158</td>
<td>1100.0</td>
</tr>
<tr>
<td>35</td>
<td>158</td>
<td>1067.5</td>
</tr>
<tr>
<td>36</td>
<td>158</td>
<td>1067.5</td>
</tr>
<tr>
<td>37</td>
<td>159</td>
<td>817.5</td>
</tr>
<tr>
<td>38</td>
<td>160</td>
<td>1132.5</td>
</tr>
<tr>
<td>39</td>
<td>160</td>
<td>1082.5</td>
</tr>
<tr>
<td>40</td>
<td>162</td>
<td>1187.0</td>
</tr>
<tr>
<td>41</td>
<td>162</td>
<td>1095.0</td>
</tr>
<tr>
<td>42</td>
<td>163</td>
<td>1132.5</td>
</tr>
<tr>
<td>43</td>
<td>164</td>
<td>1092.5</td>
</tr>
<tr>
<td>44</td>
<td>164</td>
<td>1175.0</td>
</tr>
<tr>
<td>45</td>
<td>168</td>
<td>1230.0</td>
</tr>
<tr>
<td>46</td>
<td>180</td>
<td>1005.0</td>
</tr>
<tr>
<td>47</td>
<td>189</td>
<td>1050.0</td>
</tr>
</tbody>
</table>
THE CALORIC EXPENDITURE OF SELECTED TOURIST ACTIVITY OF STUDENTS FROM OPOLE UNIVERSITY OF TECHNOLOGY

Daniel Puciato1 ADEF, Michał Rozpara2 CDE, Władysław Mynarski2 ADEF, Bożena Królikowska1 BEFG

1 Faculty of Physical Education and Physiotherapy, Opole University of Technology
2 Faculty of Physical Education, The Jerzy Kukuczka Academy of Physical Education in Katowice

Key words: motor activity, tourism, students, Opole

Abstract

Aim. To evaluate the calorie expenditure of various forms of tourist activity in students from Opole University of Technology.

Basic procedures. The material for the work are data obtained from research studies conducted in 2011–2012 at Opole University of Technology on students studying tourism and recreation. A total group of 217 people was tested, including 109 men and 108 women, aged 18 to 35 years, with tourist activity based on lowland hiking, mountain hiking and lowland cycling tourism. The research method used in the study was the participant direct observation, using a recording technique of movement kinematic parameters. The research tool was a single-axis accelerometer (Caltrac Monitor). Within the framework of the statistical analysis, basic statistical characteristics were calculated, the Mann-Whitney test was performed and one-way analysis of variance (ANOVA) was performed. Statistical inference was carried out at a given significance level of p < 0.05.

Main findings. Among the subjects, there were significant differences in the volume of physical activity between men and women. With regard to the intensity of physical activity, similar regularity was observed only in the case of lowland hiking. Among the surveyed men the highest caloric cost was related to lowland hiking, and the lowest to lowland cycling, while for women the highest caloric expenditure was associated with cycling, and the lowest with marches on flat ground.

Conclusions. The conducted research has confirmed the importance of application of objective methods for measuring physical activity, which should be used in a complementary way with subjective methods.

Introduction

Tourist activity is currently a very popular form of physical activity. The richness of its forms (walking, cycling, canoeing, horse-riding, lowland, mountain, water, etc.), easiness of performance, not too high cost and its outdoor nature makes it a great form of physical activity to be carried out by people of both sexes, all ages and health conditions [1–8]. It usually involves the implementation of medium or long-lasting physical exercises of medium intensity. Such activity is beneficial to one’s health, particularly with regard to the following systems: cardiovascular, respiratory, bone-joint and muscle as well as for the given areas: mental and social [9–13]. The positive health effects of physical activity, however, depend on whether it has adequate: volume, frequency
and intensity [14–15]. That is why the issue of reliable assessment of the performed physical exercise, preferably using one of the objective methods, e.g. accelerometry, is greatly important for both cognitive as well as applicative reasons [16].

Despite the existence of works on assessment of caloric expenditure while practicing various forms of physical activity [17–23], few of them refer to tourism activity [24–25]. There are also no studies which implement objective measurement of caloric expenditure while performing various tourist activities, in particular, the greatly popular today: hiking (lowland and mountain) and cycling (lowland). An interesting and rarely undertaken research problem is the potential differences in caloric expenditure size during performed tourist activity in both sexes. Reliable assessment of caloric expenditure during tourism activity is also of great practical importance. One of the major methodological problems of those conducting physical activities as part of physical education, recreation, sport or rehabilitation, is the implementation of optimal exercise loads, for the purpose of such activities. This applies to both the size of the loads, as well as their incorrect — inconsistent with the intensity curve of the effort, planning during the taught lesson (training, recreation and rehabilitation). Tourist activity is a form of physical activity that can be successfully used virtually in any of the presented areas of physical culture.

In the context of the given introductory comments, the main purpose of this article is an attempt to bridge the identified research and practical gaps. The aim of the work is to evaluate caloric expenditure related to the performance of various forms of tourist activity in students from Opole University of Technology. Through empirical research, it was decided to solve the following specific research questions:
1. What is the caloric cost of performing various forms of tourist activity in the surveyed students from Opole University of Technology?
2. Are there any differences in the size of caloric expenditure of the studied men and women?

Material and methods

The research material are data obtained from studies conducted in 2011–2012 in students from Opole University of Technology (specialization: Tourism and Recreation) who participated in the program migratory camps. The choice of this research group allowed to measure energy expenditure in comparable conditions for all the participants, taking the principle of cost-effectiveness into account. Each subject, carrying out a specific form of tourist activity, performed physical efforts in the field at the same: configuration, air temperature, atmospheric pressure, direct sunlight, etc. Quota selection of the samples was applied, the control characteristic being gender. The total of examined subjects equaled 217 persons (109 men and 108 women) aged 18 to 35 years.

Among the subjects, there were: 65 people (32 men and 33 women) performing lowland hiking, 79 people (40 men and 39 women) performing mountain hiking, and 73 people (37 men and 36 women) practicing lowland cycling tourism (Tab. 1).

The study in people performing lowland hiking was carried out while hiking around the Bierawa municipality (Opole province). Caloric cost was monitored for about an hour, and the ground up on which the subjects walked was mostly forested and flat. The trekking in the framework of mountain hiking tourism took place on the hiking trails of Beskid Śląski and Żywiecki, and the Świętokrzyskie and Opava Mountains. The measurements were carried out on trails of medium and high degrees of difficulty and, in each of the subjects, energy expenditure was monitored during at least 3 trips. Monitoring of calorie expenditure during lowland cycling took place, however, on intentionally selected routes in Śląsk Opolski, during 6 cycling trips, lasting an average of 6 hours per day. All participants were informed about the purpose and course of study and gave consent for participation.

The main research method used in the study was direct participatory observation, using kinematic movement parameter recording techniques. The research tool was the single-axis Caltrac Monitor type accelerometer, set to the “basic” (measurement of acceleration mainly in the movements of locomotive nature), while in the case of cycling tourism, the “bicycle-riding” option was used. The form in which the final presentation of the results for individual tests was standardized for comparison by calculating caloric cost of an hour-long performance of the given exercise form (kcal/h) and converting it as the number of kilograms of the respondent’s body mass (kcal/h/kg). The first of these parameters is treated

<table>
<thead>
<tr>
<th>Form of tourist activity</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowland hiking</td>
<td>32</td>
<td>33</td>
<td>65</td>
</tr>
<tr>
<td>Mountain hiking</td>
<td>40</td>
<td>39</td>
<td>79</td>
</tr>
<tr>
<td>Lowland cycling</td>
<td>37</td>
<td>36</td>
<td>73</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
<td>108</td>
<td>217</td>
</tr>
</tbody>
</table>
as a measure of the volume of the hour-long effort, the other as a measure of the intensity (effort).

Within the framework of statistical analysis, the following basic statistical characteristics were calculated: arithmetic means, standard deviations, coefficients of variation, the extreme values (minimums and maximums) of age, somatic parameters (body height, body mass and BMI) and physical activity parameters (volume and intensity). The significance of differences in volume and intensity of physical activity between the studied men and women was determined using the Mann-Whitney test. To evaluate the differences in caloric expenditure depending on the type of tourist activities performed, one-way analysis of variance (ANOVA) was used. Statistical inference was carried out at the assumed significance level of p < 0.05.

Study results

The average age of the studied men performing lowland hiking is 26.56 years, the youngest of them was 19 and the oldest 35. The average value of body height is 185.13 cm and 80.25 kg for body mass, and BMI 23.46 kg/m². The average volume of the physical effort performed during hiking was 334.68 kcal/h, while its intensity was 4.11 kcal/h/kg. It should be noted, however, that there is a relatively large variation of physical activity parameters compared to the average, as evidenced by the high coefficients of variation (34.08% and 27.35% respectively). Slightly younger than the participants of lowland hiking were students performing mountain hiking, the average age in this group being 24.18 years. Lower average values were also assumed by somatic parameters: 179.33 cm in body height, body mass 77.03 kg, and BMI 23.97 kg/m². The average volume of physical effort carried out during a hike in the mountains was 299.04 kcal/h, while the intensity was 3.87 kcal/h/kg.

For the purpose of the article, among the studied male participants, the youngest were students performing cycling tourism. Their average age was 21.81 years, the minimum 19 and maximum 24 years. The average body height in this group was 182.32 cm and 81.70 kg body mass, and BMI of 24.6 kg/m². The average volume of exercise performed while riding a bicycle was 293.19 kcal/h, while the intensity was 3.58 kcal/h/kg (Tab. 2).

The average age of women performing lowland hiking was 24.06 years, where the youngest studied woman was 18 and the oldest 31. The average body height was 179.06 cm and body mass 60.09, and BMI 20.75 kg/m². During the hour-long hiking on flat ground, the female representatives lost an average of

<table>
<thead>
<tr>
<th>Form of tourist activity</th>
<th>Variables</th>
<th>Statistical characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age [years]</td>
<td>26.56 ± 4.79</td>
</tr>
<tr>
<td>Lowland hiking tourism</td>
<td>Body height [m]</td>
<td>185.13 ± 4.64</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>80.25 ± 7.91</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>23.46 ± 2.55</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>334.68 ± 114.08</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>4.11 ± 1.13</td>
</tr>
<tr>
<td>Mountain hiking tourism</td>
<td>Age [years]</td>
<td>24.18 ± 4.10</td>
</tr>
<tr>
<td></td>
<td>Body height [m]</td>
<td>179.33 ± 5.69</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>77.03 ± 8.47</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>23.97 ± 2.60</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>299.04 ± 88.15</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>3.87 ± 0.99</td>
</tr>
<tr>
<td>Lowland cycling tourism</td>
<td>Age [years]</td>
<td>21.81 ± 1.39</td>
</tr>
<tr>
<td></td>
<td>Body height [m]</td>
<td>182.32 ± 6.28</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>81.70 ± 6.57</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>24.60 ± 1.89</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>293.19 ± 65.14</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>3.58 ± 0.71</td>
</tr>
</tbody>
</table>
166.58 kcal, 2.8 kcal when calculated per kilogram of body mass. The participants hiking in the mountains were slightly older, because the average age in this group was 25.25 years, the minimum age 20 and maximum 34. The average body height was 165.54 cm, body mass 60 kg, and BMI 21.94 kg/m². The average volume of the physical effort was 204.39 kcal/h and the intensity 3.45 kcal/h/kg, although the high coefficient of variation value of about 31% indicates a relatively large dispersion value of the variable. The youngest among the studied women (average 22.36 years, min = 20, max = 25) were those participating in lowland cycling. The average body height in this group was 167.03 cm, body mass 58.44 kg, and BMI 20.96 kg/m². For the studied women, cycling on a flat terrain was associated with an average caloric expense ratio of 222.99 kcal/h, which converted per kilogram of body mass is 3.82 kcal/h (Tab. 3).

Analysis of gender differentiate on, which was carried out using the Z-test, showed that with respect to the groups performing lowland hiking, mean values for all examined variables (age, body height and body mass, BMI, volume and intensity of exercise) were statistically significantly higher in men compared to women. In the case of the students performing mountain hiking and lowland cycling tourism, greatly significant differences in favor of men were noticed in the case of somatic param-

Table 3. Statistical variable characteristics in women for various forms of tourist activity

<table>
<thead>
<tr>
<th>Form of tourist activity</th>
<th>Variables</th>
<th>Statistical characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age [years]</td>
<td>24.06 ± 4.69</td>
</tr>
<tr>
<td></td>
<td>Body height [m]</td>
<td>170.06 ± 2.65</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>60.09 ± 6.38</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>20.75 ± 1.85</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>166.58 ± 25.17</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>2.80 ± 0.47</td>
</tr>
<tr>
<td>Lowland hiking tourism</td>
<td>Age [years]</td>
<td>25.25 ± 4.54</td>
</tr>
<tr>
<td></td>
<td>Body height [m]</td>
<td>165.54 ± 5.29</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>60.00 ± 9.47</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>21.94 ± 3.68</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>204.39 ± 64.92</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>3.45 ± 1.08</td>
</tr>
<tr>
<td>Mountain hiking tourism</td>
<td>Age [years]</td>
<td>22.36 ± 1.36</td>
</tr>
<tr>
<td></td>
<td>Body height [m]</td>
<td>167.03 ± 4.64</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>58.44 ± 6.63</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>20.96 ± 2.31</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>222.99 ± 52.64</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>3.82 ± 0.77</td>
</tr>
<tr>
<td>Lowland cycling tourism</td>
<td>Age [years]</td>
<td>24.06 ± 4.69</td>
</tr>
<tr>
<td></td>
<td>Body height [m]</td>
<td>170.06 ± 2.65</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>60.09 ± 6.38</td>
</tr>
<tr>
<td></td>
<td>BMI [kg/m²]</td>
<td>20.75 ± 1.85</td>
</tr>
<tr>
<td></td>
<td>Exercise volume [kcal/h]</td>
<td>166.58 ± 25.17</td>
</tr>
<tr>
<td></td>
<td>Exercise intensity [kcal/h/kg]</td>
<td>2.80 ± 0.47</td>
</tr>
</tbody>
</table>

Table 4. Sexual differentiation of variables in people for different forms of tourist activity

<table>
<thead>
<tr>
<th>Variables</th>
<th>Lowland hiking tourism</th>
<th>Mountain hiking tourism</th>
<th>Lowland cycling tourism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>–2.09</td>
<td>0.29</td>
<td>0.82</td>
</tr>
<tr>
<td>Body height [m]</td>
<td>–6.92</td>
<td>–7.17</td>
<td>–6.91</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>–6.76</td>
<td>–6.04</td>
<td>–7.34</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>–4.19</td>
<td>–3.35</td>
<td>–5.58</td>
</tr>
<tr>
<td>Exercise volume [kcal/h]</td>
<td>–5.82</td>
<td>–4.70</td>
<td>–4.22</td>
</tr>
<tr>
<td>Exercise intensity [kcal/h/kg]</td>
<td>–4.93</td>
<td>–1.61</td>
<td>1.57</td>
</tr>
</tbody>
</table>
The caloric expenditure of selected tourist activity of students from Opole University of technology.

Parameters (body height, body mass and BMI), and also for exercise volume. In both groups, the studied women were slightly older than men, and in the case of groups engaged in cycling tourism, the women also exercised a bit more intense physical efforts. However, the observed differences were not statistically significant (Tab. 4).

The results of one-way ANOVA indicate that in the groups of studied men, the greatest volume and intensity of physical exercise was characterized by physical activity performed during lowland hiking. Slightly lower average parameters were characteristic for mountain hiking, while the lowest average caloric expenditure occurred in the case of performing lowland cycling tourism. The female groups with the highest average caloric cost were related to cycling tourism, and slightly lower regarding mountain hiking, whereas the lowest was associated with lowland hiking tourism. The values of the F function were statistically significant in all of the analyzed cases (Fig. 1–4).

**Figure 1.** The volume of the physical activity of men in the context of their tourist activity.

**Figure 2.** The intensity of the physical activity of men in the context of their tourist activity.
Discussion

In the group of students engaged in lowland tourism, gender differentiation for all the considered variables was noted. Differences in age, body height and body mass between men and women were statistically significant. Large intergroup differences in age and somatic parameters found their reflection in the amount of expended energy while performing lowland hiking. In the group of men, the mean volume of the physical exercise reached the level of 334.68 kcal/h, while in women 334.68 kcal/h. After relativization of data per kilogram of body mass (exercise intensity), average sizes of about 4.11 kcal/h men and 2.80 kcal/h for women were obtained.
This may indicate that a decisive role in trying to explain the observed differences may have: age and the conditions in which the physical activity was implemented, i.e. a fairly smooth and flat terrain. The probable cause of gender differences in the size of caloric expenditure during mountain hiking and lowland cycling tourism were somatic parameters. In this study, the average value of body height, body mass and BMI in the males was significantly higher than in women. Analogous differences were not recognized for age or performed intensity of physical activity. Similar observations can be found in the empirical works of other researchers [26].

The intensity of the physical exercise undertaken by the studied students falls within the lower zone of exercise of moderate nature. Efforts from 3 to 6 MET are considered as moderate [27]. This is probably due to the fact that the tourist forms of physical activity carried out for the need of this study lasted an average of a few hours a day, so their intensity could not be too high. It is the specificity of tourist activity, especially in the mountains. It should be added that the accelerometer registers the acceleration of the body, which during the march in the mountains cannot be large especially since the tourist is additionally burdened with a backpack and goes uphill. This does not mean that the effort is not very intense, but these specifics are not registered by an accelerometer in mountain conditions. However, this should be taken into account in interpreting the results of the conducted research. A clearly greater physical activity intensity during mountain hiking excursions (6.5 kcal/h/kg in men and 5.4 kcal/kg/h in women) was reported in the study by Mynarski and Borek [25]. However, the subjects in their study were seasoned tourists who monitored their activity during ten full-day excursions in the Beskid Mountains. They only had hand luggage, and completed the trails an average of 20% faster than the estimated time given in tourist guides.

The caloric cost of various forms of active tourism is also interestingly presented. While in the case of men, the highest energy expenditure was associated with lowland hiking and the lowest related to cycling tourism, in respect to the studied women, reversed dependence was noticed. The highest volume and intensity of the physical efforts performed by the study participants involved cycling tourism, while the lowest lowland hiking. This may be due both to the fact that men pursuing hiking in the lowland area were metrically the oldest (average age 26.56 years) and the small sample sizes do not allow for conclusions regarding the general population.

The undertaken research undoubtedly confirmed the applicative significance of the use of objective methods for measuring physical activity, which include measuring caloric cost with the Caltrac Monitor type accelerometer. Unfortunately, the use of such methods and tools is virtually impossible on a mass scale, which results both from their high cost of purchase and utilization of such equipment and measurement procedures, as well as a large burden on the participants caused by their use, especially with regard to children and the elderly. In practice, the accelerometers should therefore be used in studies on small groups over longer periods of time. By contrast, subjective methods for assessing physical activity should be applied to mass, especially cross-sectional studies. In this group of methods, special attention deserves to be paid to the International Physical Activity Questionnaire used in our study [19, 28-29], which is considered one of the best tools in the world for assessment of population-based physical activity [30]. According to the authors of the study, both groups of methods (objective and subjective) should therefore be treated in a complementary way. This is because only reliable and systematic control of physical activity gives the opportunity to realize individual health training programs and is the basis for promoting physical activity as a public health strategy [31].

**Conclusions**

Analysis of the study results allows to formulate the following conclusions:

1. Among the studied students, the highest energy expenditure was related to performing lowland hiking tourism, the lowest – lowland cycling tourism, however, for the female students, the highest energy cost was during cycling, the lowest while marching on flat ground.
2. Among the studied students from Opole University of Technology, statistically significant gender diversity related to volume of physical exercise performed during active tourism occurred. In the case of physical exercise intensity, similar regularity was observed only in relation to lowland hiking tourism.
3. Research on energy expenditure during active tourism performance must be continued, and further observations should include a larger and more diverse population (age, lifestyle, health state, place of residence, etc.), and such forms of tourism activity, such as: canoeing or horse-riding. This would enable the creation of specific recommendations for those conducting physical activity classes in various areas of physical culture.
References


[12] Sarzala T, Szczepanowska E: Wpływ górskiej turystyki aktywnej i kwalifikowanej na zdrowie i samopoczucie osób zrzeszonych w zespołach specjalistycznego treningu fizycznego, w: Zarzycki P. (red.) Wybrane aspekty górskiej aktywności ruchowej w Polsce i na świecie. Wrocław: Studia i Monografie AWF, 2014; 120: 103–111. (The effect of active mountain tourism on health and wellbeing of participants in special physical training groups, In: Selected aspects of the mountain of physical activity in Poland and abroad)


The caloric expenditure of selected tourist activity of students from Opole University of technology

[26] Czajka K, Sławińska T: Struktura somatyczna oraz aktywność fizyczna w czasie wolnym młodzieży miejskiej i wiejskiej. Annales Universitatis Mariae Curie-Skłodowska, 2006; 60 (1): 333–337. (The structure of somatic and physical activity in leisure time urban and rural youth)


Address for correspondence
PhD Daniel Puciato
Opole University of Technology,
Faculty of Physical Education and Physiotherapy
76 Prószkowska Street, 45-758 Opole, Poland
phone: +48 77 449 80 00
e-mail: d.puciato@po.opole.pl
THE ATTITUDE OF BAVARIAN YOUTH TOWARDS SCHOOL PHYSICAL ACTIVITY

Krystyna Sawicka\textsuperscript{ABCD}, Beata Sikorska-Krzyzosiak\textsuperscript{CDEG}

Department of Tourism and Recreation, University of Business, Wroclaw

Abstract

\textbf{Study aim.} The aim of the study is to diagnose the attitudes of Bavarian high school students towards physical education classes, taking their environmental conditions and gender into account.

\textbf{Material and methods.} The study was conducted in 2015 among a group of 412 people – 14–15-year old students of secondary schools in Bavaria. In this group, there were 102 boys and 112 girls – residents of a big city (population over 500 thousand) and 93 boys and 105 girls - residents of a small town (population 14 thousand). In the study, we used the semantic differential attitude research questionnaire \cite{1}, modified by the author of this work. The aim of this study was to examine the severity of selected attitudes.

\textbf{Results and conclusions.} The studied youth evidenced positive attitudes towards physical education classes. They were rated as good, pleasant, interesting and successful. The gender of the subject is differentiated by the severity of attitudes towards physical education classes. The boys assess physical education classes as more pleasant and relaxing, lighter and fairer, while girls as more demanding. For young people from a big city, physical education classes are more interesting, whereas for male and female students from a small town, these activities are much lighter. For the other attitudes, no statistically significant differences were noted.

Introduction

One of the basic psychological determinants of physical activity for children and young people are the so-called attitudes that Zimbardo and Ruch \cite{2} describe as the relatively constant, emotionally tinted readiness to respond to a specific person, group of people or situation. Ajzen \cite{3}, Jarvis \cite{4}, Grabowski \cite{5} and others distinguish the three following components in the structure of attitudes:

– cognitive, thus knowledge about attitudes to which their opinions, beliefs, assumptions, uncertainties, etc. belong,
– emotional, thus feelings (positive and negative) towards the object of their formulated attitude,
– operational (behavioural), thus the tendency to act or the action towards the object of their formulated attitude.

In numerous German-language studies on attitudes towards school physical education classes, both the positive and negative emotional elements are particularly emphasized. Rethorst \cite{6} associates positive emotional responses towards school sports activities with, among others, satisfaction of students, their self-confidence and a feeling of happiness, which, in her opinion, may play a major role in shaping pro-somatic attitudes \cite{5} determining their systematic, extra-curricular physical activity. Thomas \cite{7}, Sawicki \cite{8} and others, enumerating the negative emotions associated with physical education classes, such as: anxiety, reluctance, disgust and anger, emphasize that their possible adverse impact on attitudes may not only be towards compulsory school classes but also sports performance in their free time.

It is also worth mentioning the action related element of attitudes towards school physical education. Gracz and Sankowski \cite{9} highlight verbal as well as nonver-
Attitudes are also characterized by many features that play a significant role in the process of school physical education. According to Grabowski [5], and Gracz and Sankowski [9], they include the strength of a given attitude, its direction (positive or negative) as well as stability, which in addition to the school physical activity of young people, are also determined by taking up recreational activity, which is the fundamental objective of physical education in the German educational system [10, 11, 12].

The most important determinants, as well as the differentiating attitudes of the youth towards school physical education should include gender, environmental conditions, age, social origin and others [10, 13].

The aim of the present study is to examine the nature and intensity of attitudes of Bavarian high school students towards physical education classes. The variables in the study include gender of the subjects and the environment from which they come.

Study design

Research questions

The following research questions were put forward in the study:

1. What is the attitude of the Bavarian youth towards school physical education classes?
2. Does the gender of the subjects differentiate the intensity of the attitudes towards school physical activity?
3. Do the environmental conditions of the subjects differentiate the intensity of the attitudes towards physical activity?

Study group

The study was conducted among a group of 412, 14–15-year old students of secondary schools in Bavaria. In this group, there were 102 boys and 112 girls – residents of a big city (population over 500 thousand) and 93 boys and 105 girls – residents of a small town (population 14 thousand). The youth participating in the study were selected in accordance with the principle of random sampling of the research sample (school classes). The research was conducted in 2015 by the authors of the present work.

Study methods

In order to examine the attitudes of Bavarian students towards school physical education classes, the attitude questionnaire technique was used. This technique is based on the construction of the so-called semantic differential [1], which provides 10 pairs of antagonistic determinations related to these activities (Table 1). Between the determination extremes for each pair, the students were to mark an “X” next to their own personal response on a scale consisting of 7 units from 1–7, depending on the severity of their attitudes towards the given trait.

Methods of statistical analysis

All the study results were analyzed using mathematical and statistical methods. The method of one-way variance analysis [14] was used in order to determine the significance of differences in the studied attitudes within the aspects of gender and environmental conditions.

### Table 1. The system of antagonistic pairs in the attitude questionnaire towards physical education classes

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>pleasant</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>unpleasant</td>
</tr>
<tr>
<td>relaxing</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>stressful</td>
</tr>
<tr>
<td>interesting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>boring</td>
</tr>
<tr>
<td>calm</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>energetic</td>
</tr>
<tr>
<td>successful</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>unsuccessful</td>
</tr>
<tr>
<td>fast</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>slow</td>
</tr>
<tr>
<td>good</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>bad</td>
</tr>
<tr>
<td>lazy</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>demanding</td>
</tr>
<tr>
<td>light</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>hard</td>
</tr>
<tr>
<td>unfair</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>fair</td>
</tr>
</tbody>
</table>
Results

Below are the results of research on the youths’ attitudes towards physical education classes. Presentation in the figures is based on my own questionnaire research.

The value of 2.36 for all respondents in the seven-graded scale demonstrates the dominance of pleasant feelings associated with physical education classes (Figure 1.) However, for boys, especially from a small town, this feeling is considerably stronger than for girls, as confirmed by analysis of variance ($F = 19.94, p = 0.001$). The fact that physical education classes are enjoyable for the young people can substantially contribute to greater participation in these activities and thus, achievement of the objectives set by modern physical education.

According to the data shown in Figure 2, for the studied boys from both towns, physical education classes are more relaxed in contrast to girls, who associate them with a little more tension. Analysis of variance revealed statistically significant differences in favor of boys ($F=42.96, p=0.001$), and the tested environmental conditions did not affect the severity of attitudes within this category. Based on the results of research, it may be assumed that in general, boys more easily endure hardship and tension associated with exercise as opposed to girls, who felt a higher anxiety level during physical education classes.

![Fig. 1](image1.png) The attitudes of students towards physical education classes as pleasant – unpleasant

![Fig. 2](image2.png) The attitudes of students towards physical education classes as relaxing – stressful
The studied youth view their school physical education classes as interesting (Figure 3). The results of analysis of variance showed that more interesting classes take place in the studied urban schools ($F=54.76$, $p=0.001$), while in the category of attitudes, there were no statistically significant differences with regard to the gender of the subjects.

The study results presented in Figure 4 indicate that for all subjects, regardless of gender and environmental conditions, physical education classes seem more energetic than calm, while no statistically significant differences regarding this attitude were shown.

Mostly, subjects demonstrated a strong stance describing their physical education classes as successful, as illustrated by the results in Fig. 5. Both in relation to the gender of subjects, as well as their environmental conditions, no statistically significant differences were noted. This may indicate not only the satisfaction of students from physical education classes alone, but also the appropriateness of the course of these activities, for which a properly prepared physical education teacher is primarily responsible.

Taking the teaching pace of the studied physical education classes into consideration, the youth were of the opinion that the classes are generally fast (Figure 6). For the boys, these activities seem somewhat slower, but analysis of variance showed no statistically significant differences with regard to this aspect.

In the category of physical education as good – bad, the studied young people definitely identified it as posi-
The attitude of Bavarian youth towards school physical activity

Fig. 5. The attitudes of students towards physical education classes as successful – unsuccessful

Fig. 6. The attitudes of students towards physical education classes as fast – slow

Fig. 7. The attitudes of students towards physical education classes as good – bad
From these opinions, it may be deduced that for the surveyed boys and girls, physical education classes may not only be a source of positive feelings towards physical activity but also confirmation that physical education is an important and necessary school subject.

Results from Figure 8 confirmed the general opinion of the studied male and female students stating that physical education classes are demanding. It should be emphasized that this attitude is stronger in girls, who unlike the boys, feel that they perform more work during physical education classes. In relation to this aspect, statistically significant differences (F = 20.89, p = 0.001) could be observed. The reason for discrepancies in those opinions may be, among others, the more favorable physical aptitude of boys and thus better adaptation of the organism to the effort.

As expected, the studied boys viewed physical education classes to be lighter than girls, for whom these activities are considered rather hard (value 4.05, Figure 9). Analysis of variance revealed statistically significant differences not only related to gender (F = 21.19, p = 0.001) but also to environmental conditions (F = 4.54, p = 0.03).

Taking all of the subjects into consideration, it was found that they assess their physical education classes as more fair than unfair (value 4.11, Figure 10). However, analysis of variance revealed that the surveyed boys evaluate their classes to be fairer than their female colleagues (F = 10.52, p = 0.0013).
Discussion

In this work, we studied German school students coming from a small town or big city in Bavaria in order to evaluate their attitudes towards physical education classes. This element is considered as one of the most important factors affecting the level of physical activity in both school physical education as well as performing sports by young people in their free time [10, 11, 15]. Research shows that the Bavarian youth have a generally positive attitude towards physical education classes. Most definitely, these classes were evaluated as good, pleasant, interesting and successful. Similar results in this respect were obtained by Gerlach et al. [1]. Also using the semantic differential research tool, they demonstrated that the German youth assessed activities mostly as successful and interesting. It should be noted that these attitudes are closely linked to mental sensations, which in the opinion of many authors, significantly contribute to developing and strengthening the positive attitudes of young people towards being physically active and thus, positively determine their participation in these activities [16, 17, 18]. In the process of physical education, approaches related to action or behavior (behavioral) are also of importance. In our study, the attitudes of students assessing physical education classes as energetic, fast and demanding should be emphasized. Comparable results were also obtained by Gerlach et al. [1], according to whom the studied German youth evaluate physical education classes as demanding and physically intense. It is worth highlighting the fact that the Bavarian youth assess physical education classes as fair. This may indicate not only a positive attitude towards these activities but also their proper organization, for which the physical education teacher is primarily responsible.

The positive attitudes of school children towards physical education may also be evidenced by opinions regarding other elements of the subject such as: obtained marks, favorite forms of classes, the position of physical education compared to other school subjects and more. These attitudes could be the subject of further research.

Conclusions

Based on analysis of our study results, the following conclusions can be formulated:
1. The studied youth exhibit a generally positive attitude towards physical education classes and for the most part, evaluate them as good, pleasant, interesting and successful.
2. The gender of the study participants is differentiated by their severity of attitudes towards physical education classes. The boys evaluate physical education classes as pleasant and relaxing, light and fairer than in the girls’ view, who assess these classes as more demanding.
3. The studied youth coming from a big city assess the physical education classes as more interesting than the participants coming from a small town, for whom these classes seem to be lighter. In the remaining categories of attitudes, no statistically significant differences were observed.
References


Corresponding author:
PhD Krystyna Sawicka
Department of Tourism and Recreation
University of Business in Wrocław, Poland
ul. Ostrowskiego 22
E-mail: sawickakb@aol.com
Phone: 0048 513 937 522