ANTROPOMOTORYKA
Journal of Kinesiology and Exercise Sciences (JKES)

Vol. 27, no. 2 (78), 2017
REGULATIONS FOR ARTICLE PUBLICATION

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.

Editorial office: Antropomotoryka
Al. Jana Pawła II 78, 31-571 Kraków, Poland.
E-mail: antropomotoryka@awf.krakow.pl

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 (anthropomotorics) 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).

Papers of high scientific value previously qualified for publication in another foreign journal may also be submitted, provided that the author obtains written consent to reprint the article from the foreign journal in which the text has been or will be published.

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.indexcopernicus.com/ic_publishers_panel_instrukcja_obslugi_dla_autorow.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.

Article preparation for publication in Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES)

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);
Statistical methods should be explained so that it can be easily described and the need for these changes must be justified. In the case of modifying already recognized methods, the applied changes must be given. If an original method or technique of research was already recognized, its name and address of its producer should be given. The name and 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) 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).

Full title of the work (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 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.

Regulations for article publication

• 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.
• Figures and tables should be placed on separate pages (See: Illustrative material);

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4 Antropomotoryka
Regulations for article publication

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)

Monographs published in electronic version

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

Articles 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 number.
Regulations for article publication

Articles not prepared in accordance with the requirements of the “Article publication requirements” will be returned to the author for improvement. The publisher reserves the right to remove linguistic defects or apply abbreviations.

The publisher reserves the right to adjust or condense the text, make improvements related to terminology standardization.

The publisher decides whether the article will be released for publication based on the reviewers’ opinions and the responses of the authors or lead author to the reviewers’ comments.

After translated, proofread and edited, the article is sent to the author(s) for approval. The publisher sets a one-week deadline for submission of further modifications by the author.

Before publication, the author responsible for correspondence with the publishing office will receive the article by e-mail (in PDF format), edited in accordance with the journal’s style template, to obtain consent for its publication.

At this stage of publishing, only minor, final modifications may be made. Delay in re-submission/consent may cause the article to be moved to the next issue.

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 Krakow. Address: ul. Jana Pawła II 78, 31-571 Kraków, Tel.: +48 12 683 1224; Tel.: +48 12 683 1278.
- Krakow Physical Culture Bookshop. Address: ul. Jana Pawła II 78, 31-571 Kraków, Tel./Fax: 48 12 681 36 22.

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 1. Differences (d) in body height and mass as well as BMI between student group A and B

<table>
<thead>
<tr>
<th>Group Variable</th>
<th>A</th>
<th></th>
<th>B</th>
<th></th>
<th>d</th>
<th>Significance level p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>21.5</td>
<td>3.2</td>
<td>22.0</td>
<td>1.5</td>
<td>–0.5</td>
<td></td>
</tr>
<tr>
<td>Body height [cm]</td>
<td>176.2</td>
<td>3.3</td>
<td>178.0</td>
<td>4.1</td>
<td>–1.8</td>
<td>0.567**</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>68.3</td>
<td>2.7</td>
<td>79.4</td>
<td>3.5</td>
<td>–11.1</td>
<td>0.005</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>22.3</td>
<td>2.2</td>
<td>25.7</td>
<td>2.8</td>
<td>–3.4</td>
<td>0.006</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:
EDITOR-IN-CHIEF’S FOREWORD

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EDITOR-IN-CHIEF’S FOREWORD

THE 78TH ISSUE OF ANTOPOMOTORYKA: CONFIDENCE AND RELIABILITY IN THE PRACTICE AND THEORY OF HUMAN MOTOR ABILITY, A CONTINUATION

The relations between theory and practice are quite tight in physics. Unfortunately, in biology, and – all the more – in psychology and in motor control, the theory is by far more distal to reality than in physics.

(Waclaw Petryński: A scientific evening with P. Feyerabend, C.S. Peirce, J.S. Bruner and T.S. Kuhn)

It would be difficult to disagree with the author of the above-motto, coming from his considerations found in the article titled A scientific evening with P. Feyerabend, C.S. Peirce, J.S. Bruner and T.S. Kuhn, stating that "(...) in biology, and – all the more – in psychology and in motor control, the theory is by far more distal to reality than in physics". It should be added, however, that more broadly, in the science of human motor ability, and perhaps also in empirical sciences, there is no better theory than good practice (as it has already been noted a long time ago!).

Scientific knowledge owes its high cognitive status to the fact that science is focused on acquiring the non-trivial truth, which is difficult to reach, but is both theoretically interesting and practically useful. It is truth which is first and foremost, theoretically interesting. It serves, after all, the theoretical function of explaining and understanding phenomena and processes taking place in the world. But it is also practically useful, serving to fulfil a second important - social function – one that is practical, and thus to anticipate the occurrence and course of phenomena. Prediction is termed as the function of practical learning due to the fact that without predicting what is to occur, there is no effective action, that is, transforming reality in accordance with human needs. Therefore, the specific practical function of science consists in providing social systems (including sports, physical education, recreation, rehabilitation or broad participation in physical culture) with knowledge and skills that ensure effective functioning. This is, first of all, technical and functional knowledge of predictive nature. There is no effective action without prediction. Explanation and understanding of phenomena would be impossible without the assumption that the attainable goal of science is real cognition, towards which science is headed. And how should this truth be understood? According to the reconstruction of Einstein and Popper’s stances, it can be assumed that scientific truth should meet at least five important cognitive values. These are: 1. Generality (high degree of generalisation), 2. Exactness, accuracy, precision (high degree of exactness, accuracy), 3. High informational content, 4. High logical simplicity, and 5. Epistemological certainty.

Yes, these five mentioned cognitive goals, reaching them, causes science to attain the non-trivial truth, i.e., theoretically interesting and useful at the same time, which allows learning to fulfil two important social functions: 1. Theoretical function consisting in a better understanding of the world and, 2. Practical function, to provide people with better, i.e. more and more accurate and more reliable, predictions for effective action.

Adding K. Popper’s accurate claim that the objective of science should be relatively considered, depending on the context of considerations, we have been trying fulfil the mission of presenting scientific knowledge regarding human motor activity on the pages of our Krakow Antropomotoryka – Journal of Kinesiology and Exercise Sciences (JKES) for more than a quarter of a century. In one section, we publish articles - the goal of which is to seek only the truth ("truth-entitlement"), and in another – the search for respectable explanations, or those only erecting claims about high information content ("content of theory"). I believe that our maintaining on the publishing market in Poland for such a long period of time and with such high competition, proves the legitimacy of prolonging this mission of the Krakow journal for coming years.

Undoubtedly, this is due to our faithful readers and colleagues. The author of the aforementioned, further column, has been a part of our journal’s circle for many years. It really is worth studying. According to the Editor-in-Chief’s comment, its content stimulates discussion on the mission of our journal and, more broadly, on the issue of status in the structure of scientific knowledge under the name of anthropomotorics (or as others would call it - motor theory). It is to be hoped that after reading the next empirical articles published in the 78th issue of Antropomotoryka, Journal of Kinesiology and Exercise Sciences (JKES), readers will share the earlier expressed
view on what is considered worthy of presentation in a journal of scientific profile.

In the section of Sport Sciences, in three articles, the authors draw attention to the importance of supporting decision-making during various situations in competitive sports. In the article titled Models of training race-walkers during the mezocycle of the direct preparation for starts based on the multi-criteria method of the analytic hierarchy process, the possibility of applying an interesting multi-criteria mathematical method in making decisions while developing a training model of a race-walker preparing for participation in the Olympics in Rio de Janeiro was used in Poland for the first time. The author of this method, as well as the Super Decisions and Expert Choice TM computer programmes available for calculations, was the American outstanding eminent mathematician, economist and politician – T. Saaty – who sadly, passed away last year.

The content of the article titled: Evaluating the level of creative support in teaching football game tactics emphasizes the need for implementation of modern decision-making methods in teaching tactics. Based on the results of a diagnostic survey conducted among Polish football clubs, attention was paid to the unsatisfactory state and conditions for conducting modern tactical training among young footballers.

In the work Leadership behaviours of coaches perceived by athletes in basketball and self-efficacy in youth sport, the importance regarding young athletes’ awareness of the role of a coach’s leadership in solving tactical tasks by them during a match is greatly highlighted.

The next two works included in the Sport Sciences section, refer to issues of training effectiveness concerning motor potential among athletes at various stages of sports championships. In the article Identification of somatic and functional variables determining the effectiveness of test games in various football training groups, the authors addressed the topic of improving somatic and motor potential of young football players’ technique. On the basis of empirical research, they proved that the effectiveness of technical solutions for a selected game fragment (1x1) is determined by different models of somatic and motor potential at various stages of ontogenetic development and sports advancement.

In the article Physiological and biochemical changes in adolescent Judo athletes caused by training during start period, the existence of the low impact of young judo athletes’ training on the level of maximal oxygen uptake and greater – on improving the maximal anaerobic power of their muscles is noted.

In the Exercise Sciences section, apart from the well-recognized problem of the positive impact of increased physical activity on somatic and motor development in children from a rural environment, in the article: The effect of physical activity level on body build and physical fitness of girls and boys aged 10-19, the results of two interesting experiments can be found.

In the work: Are lower limb electromyogram profiles symmetrical during a barbell squat? (A case study), the impact of physical load on changes in EMG profiles and motor patterns (values of angles in the lower limb joints) during the performance of a barbell squat with increasing load was considered. On this basis, the degree of symmetry of six homologous muscles (tibialis anterior, gastrocnemius medius, rectus femoris, biceps femoris, gluteus maximus and the erector spinae) was determined.

The research results allowed to determine the impact of increased load on the rise in asymmetry of the homologous muscle profiles. Furthermore, greater asymmetry of the subject during the squat with a maximal load caused worsening in movement smoothness.

In turn, based on the results of research presented in the article titled The influence of plantar short foot muscle exercises on foot posture and gait parameter in runners, it was proven that there is a positive effect of plantar short foot muscle exercises on their shape and gait technique in people practicing long-distance running at an amateur level.

Concluding a very brief review of the contents in the 78th issue of our scientific periodical, it is not appropriate for the editor to prove true the thesis posed at the beginning stating that in the nine articles, five of the listed objectives of scientific cognition have been achieved. It is believed that readers will give their positive opinion about the scientific knowledge included in the content. This will undoubtedly be great compensation for the effort put into the publication of this next issue of the Krakow scientific journal. The effort of the whole editorial staff who have been performing social work for years, and of the authors who in their articles, aimed to attain the non-trivial truth, i.e., theoretically interesting and simultaneously useful. In this way, for years we have been contributing to a better understanding of the essence of physical activity of man practicing sports, or even just physical exercises performed to improve oneself, and we provide knowledge about better and better, i.e. more and more accurate, predictions for effective action.

With such conviction, we hand over the next issue of our, now just Krakow, Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES), to our readers, wishing a positive intellectual experience.

Editor-in-Chief
Edward Mleczko
Eagles soar, but weasels never get sucked into jet engines.

Elf Sternberg

Introduction

In 1881 C. Darwin stated:

If worms have the power of acquiring some notion, however rude, of the shape of an object and over their burrows, as seems to be the case, they deserve to be called intelligent; for they act in nearly the same manner as would man under similar circumstances [1].

In 1906 H.S. Jennings argued that even the behaviour of Protozoa may be termed “intelligent” [2] In his work of 1915 E. Heron-Allen argued that one-cellular Foraminifera dispose of a kind of intelligence [3]. At that time, it sounded not simply revolutionary: it was a heresy! Heron-Allen has observed that the Foraminifera select only the grains of sand of specific parameters to build a test around their uni-cellular bodies. Still later, in 1941, L. Cuénot attributed some kind of intelligence to each cell of a living organism [4]. Accordingly, intelligence is not a “divine gift”, which only human individuals dispose of, but an information processing strategy ubiquitous in the world of living creatures.

In science, what might be termed “Foraminifera strategy” is often described, rather pejoratively, “eclectic”. However, whole science is in fact eclectic, because just the mental diversity underlies its fertility. On the other hand, methodologically pure „inbreeding” wallows in tautologies and finally leads to intellectual impotence.

It is worth noting that eclecticism makes the very heart of the greatest intellectual achievement of humanity, i.e., the culture. Thanks to invention of speech, it became possible to make use of valuable ideas, no matter, when and where they are conceived. In other words, lan-

Keywords: certainty, reliability, theory creation, inventiveness in motor control
guage enabled elimination of temporal and spatial constraints existing in reality identifiable by senses. In fact, the term “eclectic” is by no means pejorative.

Symptomatically, in such an approach the intelligence cannot be regarded as a highest developed information processing technique in living beings. This made a basis for specific definitions of intelligence, intuition and instinct [5], which together make a system (intellect), and not a sum. In fact, the intelligence is the most primeval of them. This testifies to the fact that in science terminology is not a passive tool for description, but an active instrument co-creating the science.

1. Truth, Freedom and (Motor) Science

In my papers from the series A scientific evening… I follow the same strategy as Foraminifera do. In this article, the first eligible “grain of sand” is the idea by P. Feyerabend that the development of human knowledge results from a specific interplay of Truth and Freedom [6]. In short, the sober Truth orders the achievements if human mind and makes them useful, whereas the day-dreaming Freedom makes the leading edge of intellectual progress. The former is rather safe, the latter – risky. This is expressed by another „grain of sand” – the motto to this paper.

The Freedom exists in the sphere of abstraction, the Truth – in reality. They are only indirectly dependent on each other. Where a specific resonance between Freedom and Truth occurs, the Science is being born; the term “resonance” in this respect has been used by M. Heller [7]. However, sober Truth underlies properly ordered science, whereas flighty Freedom – generously inventive philosophy. The former is intellectually stiff, the latter – flexible, so their ways only in some short fragments may fall into resonance – in those regions the science is being born – and then inevitably have to part of each other.

Such a relation underlies a general mechanism of science creation. In physics, the ways of Truth and Freedom run rather close to each other, hence detection of a specific resonance is quite easy. Probably because of this, just the physics developed explosively since 17th century. However, in living beings – and especially in humans – the mechanisms of such a resonance, underlying the motor behaviour, is much more complicated. The relations between Truth and Freedom are by far less obvious and much more complicated. Roughly, they are determined by many factors of various resonance frequencies. Sometimes only one of them falls into resonance with external influences. Such a resonance is being termed “parametric resonance” [8]. In motor control in humans, this is still more complicated, because particular parameters are also of various modalities (propiroceptive, contactceptive, teleceptive, verbal and symbolic) [5]. This is why this branch of science cannot rely on experimental observations to such an extent as, say, physics. Consequently, in motor control the share of mental speculations is by far greater than that of observations or measurements. Here the appeal of mathematician and physicist A. Sokal sounds especially instructively: Don’t ape the natural sciences! [9]. Sometimes apparent, superficial similarities may result with analogous relations being observed in reality, yet the mechanisms underlying the phenomena or processes under consideration may be diametrically different. This is why in motor control experimental research cannot support scientific reasoning to such an extent, as it is in physics.

2. Certainty, reliability and progress in science

However difficult its creation may be, just the abstract theory makes the very heart of science. This may be illustrated with the Street Lamp Analogy [10]. Let us develop this idea to a greater extent. The idea of “abductive reasoning pillar” of the lamp bases on theories of both C.S. Peirce [11] and J.S. Bruner [12]. In short, theory is being actively created by a scientist (Bruner) using the methodology of abduction (Peirce).

The “output end” of science may be regarded as a specific interplay of abstract certainty and real reliability [5]. The former is a “daughter” of theory, born as a result of deduction, which – by definition – is infallible. However, the latter is the “granddaughter” of theory, which should be unfailing. Unfortunately, abstract certainty not always is followed by practical reliability.

In science, the language is not a passive tool for reality description, but an active instrument for science creation [5, 13]. The differentiation of the terms “certainty” and “reliability” may underlie the specific model of science development. At first, newly created theory is being applied rather timidly (Fig. 1). Consequently, such an “underestimated theory” is not used in full and has some “application reserves”.

By the way. Such an interpretation of language may contribute to simplification of the division of language functions into communicative and representative, invented by N. Chomsky [14]. In fact, as the essence of such division may be regarded time perception. If linguistic representation concern items, phenomena or processes, which exist or happen “here and now”, this might be identified with the communicative function of language. It consists in simple assigning a specific word to a given item, phenomenon, or process. The other function – which may be roughly associated with the representative one as by Chomsky – includes the active time perception. It enables extending the verbal descriptions of reality beyond the limited scope of “here and now”, far into
A scientific evening with P. Feyerabend, C.S. Peirce…

past and into future. Especially the latter is responsible for probably the highest developed intellectual potentiality of a living creature: the ability to anticipation. Its meaning in motor control – the “model of desired future” – has been illustratively described by I.M. Feigenberg [15]. To sum up, one might imagine only one function of language – the representative one – with division into time independent and time dependent sub-categories.

Along with time passing, the new theory becomes more and more “tamed”. Consequently, one has to do with the process termed “testing the limits” [16]. As a result, finally the regions of actual certainty and possible reliability coincide with each other (Fig. 2). In such a model the limits of “possible reliability” and the “working reliability” overlap each other.

While looking at Fig. 2 one may learn that in such a model a theory is not an “absolutely versatile” mental structure, but it is tightly (though usually indirectly) associated with a specific portion of reality. Moreover, a specific interplay between certainty and reliability endows it with some flexibility.

The proposed interpretation of relation between certainty and reliability enables another look at the principle of refutability by K.R. Popper [17]. In this paper, we will treat him not as an unshakeable intellectual monument, but as an intellectual sparring-partner. In fact, not an unconditional esteem – however justified it may be – but a barbarian “sparring-partnerism” makes the “engine” of science development (and sometimes progress).

According to Popper, if a given theory does not produce reliability, then it should be rejected. This would be justified if a theory were a mental structure, shaped once and for all. However, according the constructivist paradigm by J.S. Bruner, a theory is rather freely shaped by a scientist. R.A. Schmidt wrote:

Since laws are the product of human creativity, different laws can be formulated by two different individuals who are examining the same observations. Laws do not automatically spring forth from the facts [18].

Accordingly, laws or theories are in fact rather “plastic” mental structures, liable to corrections. This makes a basis for “logic of loops” as by M. Heller [19]. Thus, an imperfect theory may be improved, and not necessarily refuted.

If a given theory works well in practice (i.e., produces reliability) then it becomes more and more trustworthy and… petrified. So the paradigms according to T.S. Kuhn are being born. They may become dangerous to scientific progress, because, as Kuhn – the author of theory of scientific revolutions – argued, “rules… derive from paradigms, but paradigms can guide research even in the absence of rules” [20]. Paradigmatic petrification foretells
the scientific revolution and destruction of a “stiff” paradigm. Let us remember that the inventive Freedom has to be flexible. Therefore, it cannot be harnessed by petrified Truth, and Science is being born only where Truth and Freedom go hand in hand. However, if stiff constraints of Truth become too hard for Freedom, the latter casts them off. Just this – the divergence of Truth and Freedom – makes the basis for Kuhn’s scientific revolution.

However, each theory is a simplification and, as a result, its field of validity is limited. When one tries to apply it beyond this field (Fig. 3, light grey ring), it produces actual certainty, indeed, but not the working reliability. The light grey ring in the Fig. 3, where the theory turns out to be irrelevant, makes the action space for a cognitive dissonance [21]. This stimulates one of the most marvellous mechanisms “invented” by evolution: the feedback [5].

Consequently, the process of testing the limits might be termed “pursuit of irrelevancy”. In the field of social sciences its equivalent is the Peter principle that “in a hierarchy, every employee tends to rise to his level of incompetence” [22].

If a given theory does not work in practice, then it does not necessary mean that the theory should be refuted (or “disproved”), but that it went beyond actual limits of its possible reliability (Fig. 3). Therefore, a “not-working theory” should be perfected rather, and not refuted, as it K.R. Popper suggested. In short, the dissonance should be killed, and not the theory. Only if this turns out to be impossible, the theory may be put into pasture or even buried. However paradoxically it may sound, perfection of a theory bases on the fact that it cannot be perfect, and thus opens the way for feedback.

By the way: Not accidentally, the word “disproved” has been written in quotation marks. Theory “resides” in the sphere of abstraction, hence it is valid by logical proof, and not by experimental verification. The latter may testify not to correctness of the theory, but to its applicability (or not) in practice.

Unfortunately, though the certainty seems to be obvious, the limits of applicability and reliability of a given theory are not easily visible. This was illustratively expressed by novelist J. Rydzewska, who wrote:

… and, besides, the Shreckinger’s cat not exactly was a joke, because at definite point such joke becomes truth, but nobody knows, where precisely that point lies, and why just there, and this lack of knowledge makes a problem, and yet the key to solving the problem [23].

This citation concerns the famous physical paradox termed “Schrödinger’s cat”. While applied the quantum physics logics to the phenomena and processes observable in reality, then one may imagine a cat, which is both

Figure 2. The well estimated theory; the possible reliability equals to working reliability and fully coincides with the actual certainty
dead and alive. In the world where we live, it is contradictory to the common sense. Consequently, in science the problem is not to “prove” or “disprove” the validity of a theory, but to delimit its field of applicability. Creation of quantum physics did not cause putting the Newtonian physics to the pasture. M. Heller remarked:

It is almost regularity in the history of physics that the mathematical structure of a given theory becomes known in full only when this theory has already been replaced with a new one [7].

The same author argued that the progress in science is possible only because of its self-limiting, i.e., looking for answering the questions that can be answered. In other words, the dark grey circle of working reliability should be extended gradually. However, this may happen only when the light grey ring of a “beyond limit certainty” exists. Just there appears necessity of improving the already existing theory, just there “resides” a cognitive dissonance, which might be termed “engine of development”. So, in science important are not only the successful scientists; also those unsuccessful are – even more – necessary to pave a way for progress. In this respect highly illustrative is the statement by L. Tomlin that “the road to success is always under construction”.

The light grey ring in Fig. 3 evokes one more reflection. An idea analogous to self-limiting of science by Heller [7] has been expressed by J. Cohen and I. Stewart, who stated that the “A Theory of Everything would have the whole universe wrapped up. And that’s precisely what would make it useless” [24]. This is why the existence of a cognitive dissonance is necessary for those who really create Science (with great “S”).

The situation as in Fig. 3 deserves a more detailed analysis. “Genuine scientists” do not accept going beyond the limits of working reliability; the dangerous region beyond these limits they term “not scientific” or “daydreaming”. If the phenomena from the light grey outer ring in Fig. 3 become more and more important in daily practice, the Kuhn’s scientific revolution becomes necessary. However, it may be done by “daydreamers”, and not by “genuine scientists”. This idea has been expressed by many Great Minds. According to H. Poincaré, “it is by logic we prove; it is by intuition we discover”. M. Planck argued, “Scientific discovery and scientific knowledge have been achieved only by those who have gone in pursuit of it without any practical purpose whatsoever in view”. Engineer W. von Braun stated: “Research is what I’m doing when I don’t know what I’m doing”. Polymath C.F. Kettering remarked that

![Figure 3. Overestimated theory; the actual certainty goes beyond the working reliability](image-url)
“An inventor is simply a fellow who doesn’t take his education too seriously”. Probably most frivolous and witty formulation of this idea comes from R. Feynman, who said that “Physics is like sex: sure, it may give some practical results, but that’s not why we do it”. However, though wallowing in the light-grey ring in Fig. 3.1 needs what may be termed “higher order thinking”, the way toward progress is lined with dead bodies of daydreamers, mercilessly exterminated by “genuine scientists”, armed with infertile, yet efficient scientific paradigms.

3. Theory creation in motor control

However difficult its creation may be, just the abstract theory makes the very heart of science. Not the “naked” experimental results obtained even with the most sophisticated technical laboratory equipment and flawlessy processed statistically. As it J. Cohen and I. Stewart stated, “At least 999 out of thousand scientific papers are about complex details, but the one that we treasure and for which we award a Nobel Prize is the one that reveals a new simplicity. It is as if simplicities are all around, but scattered rather thinly. Some scientists are rather good at laying hands on them; they must have the right kind of mind, seeing the world with unusual clarity. Albert Einstein specialized in big simplicities, and so did Paul Dirac, Gregor Mendel, and Dimitri Mendeleev” [24].

The latter needs a comment, coming also from J. Cohen and I. Stewart, who remarked that “A theory is a kind of code that transforms complicated messages from nature into much simpler ones” [23]. From such a perspective, the science as a whole may be regarded as a universal, all-embracing process of searching for simplicity. It makes the collected knowledge graspable for human minds and thus useful in practice.

Unfortunately, scientific simplicity cannot spring out automatically from the experimental results. It is a product of mind rather, and not an already existing item which needs only be discovered. In this respect, arduous, daring, risky scientific thinking is absolutely necessary. And unavoidable.

As already mentioned, in physics the “real body” of phenomena and processes and its “mathematical gown” so tightly fit to each other that new observations may be nearly directly transformed into theory correction and perfection. Unfortunately, the tangible reality, where the motor behaviour of living beings, including humans, takes place is so distant to its abstract representation – theory – that the observations cannot be translated directly into a theory and vice versa. To be brief, in biology and – all the more – in psychology and motor control, the “abductive pillar” as in Figs. 1 through 3, has to be by far higher than that in physics. Therefore, in motor control sheer “aping the natural science” seems to be especially fruitless, however technologically advanced and “fashionable” it can be. In short, the motor control scientific matter is far-far-sighted daydreamers, and not for learned laboratory workers, with their noses in computer monitors.

Conclusion

In a nutshell, while seen from the perspective presented in this paper, the creation of science consists in incessant going beyond the limit of dark grey “possible reliability” circle, in continuous wallowing in light grey ring as in Fig. 3. In this respect, let us remember the motto to this paper: “Eagles soar, but weasels never get sucked into jet engines”, which may be regarded as a leading idea of “genuine scientists”. Jet engine is mindless and indifferent to novelties – like Kuhn’s scientific paradigm. Unfortunately, the essence of motor science resides at such high regions of abstraction, where intellectual soaring is absolutely necessary. Therefore, one may confront the timid (and non-productive) aphorism by E. Sternberg with the brave (and productive) words of Yeshua Ha-Nozri – the character from “Master and Margarita” – that “Cowardice is the most terrible of vices”[25]. Also in science. Particularly in motor science.

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Author for correspondence:
Wacław Petryński
E-mail: w.petrynski@gwsh.pl
MODELS OF TRAINING RACE-WALKERS DURING THE MEZOCYCLE OF THE DIRECT PREPARATION FOR STARTS BASED ON THE MULTI-CRITERIA METHOD OF THE ANALYTIC HIERARCHY PROCESS

Grzegorz Sudoł¹ ADF, Wiktor Adamus² ADF, Edward Mleczko¹ ADFG

¹ Institute of Sports, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Poland
² Institute of Economics, Finance and Management, Faculty of Management and Social Communication, Jagiellonian University in Krakow, Poland

Keywords: 50 km race-walkers, direct preparation for start (DPS), multi-criteria method for decision support AHP

Abstract

Aim. In the sports training of the best competitors around the world, there are many ways to organize the direct preparation for a start. This training stage usually determines success. Despite such awareness, there is no knowledge as to which training system model can be considered the best in preparation for the most important sports event.

Selection of the most effective variant of a champion’s sports training system in direct preparation for the Olympic Games in the 50 km race-walk.

Basic procedures. In our research, we based on the assumptions of the multi-criteria Analytic Hierarchy Process (AHP), which was developed by T.L. Saaty. The goal of the work progressed steadily: the main criteria (training measures, renewal, volume, Substantive structure training, base) were determined and subcriteria were allocated to them. A multi-level structure of the problem was built in the form of a hierarchical tree with respect to the main objective. A special interview with questionnaire was developed utilizing Saaty’s 9-level fundamental comparison scale. These interviews were conducted with 14 coaches of the best athletes in Poland and the world in the 50 km race-walk. It’s the purpose of the study was to define the main criteria and subcriteria within the structure of hierarchical dominance (preferences, weights). The article gives the priority (weight) for all criteria and subcriteria as the geometric average of all the trainers’ answers. The subsequent step in finding the best way to prepare the athletes for the 50 km race-walk was to develop training models and choose the best alternative. The computer programmes Super Decisions and Expert Choice™ were used to perform calculations.

Results. Among the 5 established criteria, training measures were the highest ($P_{\text{train. meas.}} = 0.389$) for all experts (coaches). Analysis shows that training in the DPS is the most important criterion. The next two measures (Substantive structure training and base) were given equal priorities ($P_{\text{mat. str.}} = P_{\text{B}} = 0.180$). Less important was the volume ($P_{\text{vol.}} = 0.146$), and the least important – renewal ($P_{\text{ren.}} = 0.104$). The sum of the priorities is always 1 (100%). The highest global priority was achieved by the PE subcriterion (19.61%). Among the 4 decision alternatives (training models), the best turned out to be the model by the younger-generation Polish coaches.

Conclusion. The AHP is an adequate tool that demonstrates the findings well, therefore it may be suitable in choosing the most appropriate training alternative in the direct preparation for a start in the 50 km race-walk.
Introduction

Developing an optimal training system for top-level sporting events is the main task of champion training in every sports discipline. The importance of organizing direct preparation for the most important start is among the many components of time structure in sports training. This is a very important issue. In spite of this awareness, according to sports theorists [1], only 34-40% of athletes reach the peak of sports condition during the target event. Improperly planned or conducted training in direct preparation for a start (DPS) can waste the work put into the entire training macrocycle or even several years of it [2]. In turn, proper preparation of Polish champions in swimming and Track-and-Field for the most important event in the world demonstrated improvement in personal bests [2].

Most often in the improvement of time structure organization, simulation in several variants (3-5) of phases is considered: reconstruction, intensification and supercompensation, occurring in subsequent 7-day training microcircuits. In addition, the impact of such variables as: sport discipline, adaptability of the athlete, regulations, terms and conditions of the competition, are also considered. Based on theoretical assumptions and practical experience, it is a very impoverished set of factors determining the effectiveness of training developed in direct preparation for a start of the best athletes in the world. It is known that starting efficiency depends on taking a number of other factors into account. In sports theory [2, 3], they are grouped into 5 basic subsystems determining success in sports, such as:

1. qualification for sport: recruitment and selection,
2. prediction: development of the sports discipline, sports results and shaping sports careers,
3. infrastructure and financial security of training (base),
4. level of knowledge of the training staff (training championship),
5. central training link: training sessions, competitions (rivalry), renewal.

In attempting to develop an optimal variant of direct preparation for the start (in DPS) of a race-walker representing the championship international class, in our study we tried to use a different methodological approach to organizing the training system. It was based on the Analytic Hierarchy Process (AHP). Its creator was Prof. Thomas L. Saaty, honorary doctor of the Jagiellonian University, eminent mathematician, economist, psychologist and politician and long-time professor at the University of Pittsburgh.

The Analytic Hierarchy Process is one of the heuristic methods border-lining on two separate domains, practically combining elements of mathematics and psychology. The main domain of this method is to present non-measurable (elusive, intangible) things in numerical terms in the form of priorities. The results of the study allow us to choose a decision which, given the criteria chosen, will be the most favourable. This method is considered among the best in the world in the context of multi-criteria decision-making. It is successfully used in countries such as the U.S.A., Indonesia, China, Japan. It is also in continuous use as support and in making important decisions by, among others, NASA, the U.S. Army, the U.S. Navy, IBM, Boeing. Shell. It is also utilized in various fields of science and social life (economics and management, economics, technology, negotiation) to study multicriterial problems [5, 6].

In Poland, T.L. Saaty’s method of AHP was widely distributed mainly by Krakow researchers [7-10]. So far, it has not found much use in solving decision problems in sports. Assessing costs, benefits and threats of organizing the large international EURO 2012 sports event in Poland was based on its assumptions [11], and in modelling the restructurization of hockey recruitment and selection system in Nowy Targ, which was considered in the past “the capital of ice hockey Poland” a long time ago [12]. Thanks to this method, important arguments for the organization of the Olympic Winter Games in Krakow-Zakopane were also gained, which – unfortunately for various reasons, will not be organized in Poland or Slovakia (reuzszras.pl/relacja-z-konferencji).

The choice of method was thought out and dictated by the desire to break the belief that the sport training system is a complementary one in which all elements are of great importance. In the Analytic Hierarchy Process (AHP), the main criteria and their subtypes are distinguished by having a different contribution to explaining the phenomenon. Alike every multi-criteria and one-criterion method, the proposition of T.L. Saaty’s method also has its advantages and some limitations [6, 13]. It is characterized by simplicity, versatility, generality and flexibility. This makes it possible for those without mathematical education to use it. The methodological approach comes down to three principles: decomposition of the problem, expression of opinion by comparison and hierarchical composition (synthesis) of priorities. Research methods and standard tools are used. The use of the AHP method leads to the selection of the best model (in our case, direct preparation for starting in the Olympic Games) from different alternative versions.

Aim of own research

Selecting the most effective variant of a champion’s sports training system in direct preparation for the Olympic Games in the 50 km race-walk using the Analytic Hierarchy Process.
Models of training race-walkers during the mezocycle...

Research questions

1. What main and sub-criteria are currently preferred in the direct preparation for a start in the most important competitions around the world by the best coaches of champions in the 50 km race-walk?

2. Which training system model used in the direct preparation for starts in the most important competitions around the world used by trainers for the 50 km race-walk can be considered most effective in light of the results obtained using the Analytic Hierarchy method?

Material

Interviews were conducted with 14 coaches of 50 km race-walkers, representatives of the international championship class from Europe and Asia. 5 of them were from Poland, the others represented Slovakia, France, Russia, Belarus and South Korea. Each of them had substantive competence to speak about the research problem. Their opinions were used to determine priorities in the training system during the direct preparation of the athlete to start in the 50 km race-walk at the Olympic Games. The criteria for selecting trainers considered:

- at least four years of work experience with master class players,
- the race-walkers trained by them won championship titles at international competitions in the 50 km race-walk (e.g. European Championship, World Championship, participation in the team of World Cup winners).

Methods

The information was collected in accordance with the assumptions of T.L. Saaty’s Analytic Hierarchy Process (AHP) multi-criterion method [4, 14-18], taking under consideration the following methodological steps (Fig. 1):

- posing the problem and identifying the main objective,
- decomposing the problem consisting in building a problem in hierarchical form, where the overriding objective is placed at the top of the hierarchy, and the next level is occupied by criteria, then subcriteria, and at the lowest level of the structure, the so-called alternative decisions are placed,
- expressing opinions by experts via comparison – at each level of the hierarchical structure of the elements and pair-wise (“peer-to-peer”), in relation to the criteria placed higher in the hierarchy, Saaty’s fundamental scale was implemented used for comparisons,
- calculating conformity ratios (CR), i.e. the logic of verbal pair comparisons, the main criteria and partial sub-criteria,
- hierarchical composition of the problem consisting in multiplying the value of local criteria by the values of the global criteria, and then adding them to the values of the elements placed lowest. Values of the criteria – the so-called priorities, are obtained after normalizing the vector of their matrix,
- choice of alternatives (models) in order for an expert to compare them with one another using Saaty’s 9-grade scale,
- comparing the alternatives (peer-to-peer, relative to all subcriteria),
- choosing the best alternative.

Tools and techniques

The model of Analytic Hierarchy Process (Fig. 1) developed by T.L. Saaty was selected. Based on the methodological approach [14-18], the solution of the main research problem in the form of a hierarchical tree model is presented (Fig. 2). Its top-level structure comprises of: the precedent aim of the hierarchy, the next level represents criteria (sub-goals, attributes), the next subcriteria, sub-subcriteria subtypes and alternatives (Fig. 2).

Alternative decisions (variants, models, scenarios) formulated the lowest level of the model. This allowed hierarchical ordering of issue importance ranging from the highest to the lowest.

At the next step of the methodical procedure, the experts had to perform comparison of the degree of importance and the preference of the elements relative to the common criterion at a higher level at each hierarchical level. In the interview with the coaches (experts) of the best Polish and international athletes in the 50 km race-walk, Saaty’s 9-grade scale of comparison was applied [4, 19].

The respondent, answering a series of questions, had to give an opinion on which of the criteria is more important in relation to the main objective, and then which of the subcriteria is more important for the criterion, and if they are more important on a scale from balanced (1) to absolute superiority (9). The evaluator noted the preferences on the comparison table in pairs: criteria, dominance (advantage) of one criterion over the other on a verbal scale ranging from equal, weak, strong, very strong to absolute. If one criterion did not dominate the other with respect to the object of comparison (case of equivalence of the two criteria in the assessment), the evaluator marked equal dominance of the criteria (no superiority of one above the other). The score was recorded on the comparative table as “balanced”. The calculated weights for each criterion proved the rank of the individual components of the 50 km race-walkers’ training system in direct preparation for a start in important sports competitions.
Methods of research result analysis

Conformity ratios (CR) were calculated, i.e. the logic of verbal pair comparisons, the main criteria and the partial subcriteria that occurred during interviews with coaches. This was done using Saaty’s 9-grade scale [4, 19]. The permissible margin of error in the opinions should not exceed 10% (CR=0.1). Its excess was not permitted, similarly as 100% consistency in comparisons (CR=0) was unfavourable.

The weights of priorities for the criteria and subcriteria were determined using the Super Decisions and Expert Choice™ computer programmes. On their basis, the global priority was calculated, which is the percentage “share” of a particular subcriterion in the posed problem (the total process of training competitors in direct preparation for a start).

Formula: $P_{gi} = P_{ki} \times P_{Sj}$

where:

- $P_{gi}$ – weight (priority) “global” for $j$ of this subcriterion in relation to $i$ of the main criterion,
- $P_{ki}$ – weight (priority) $i$ of this criterion,
- $P_{Sj}$ – weight (priority) “local” $j$ of this criterion in relation to $i$ of this criterion.

In the final stage of searching for the best way to prepare for a start in the 50 km race-walk, alternative training models were identified and conducted using Saaty’s 9-grade scale, and the Super Decisions computer programme was used to determine the weight of alternatives in relation to the considered subcriteria. Finally, we chose the best alternative of training system for the champion’s...
Fig. 2. Diagram of Analytic Hierarchy Process model according to T.L. Saaty [19]

Fig. 3. Hierarchical tree of direct preparation for the start (DPS) of a 50 km race-walker according to Saaty’s method [4, 19]

Source: Own elaboration.

Note: the definitions of the names of criteria and subcriteria can be found in available textbooks on Track-and-Field [21] and sports theory [2].

Extra explanations: training measures used in the competitor’s training:

**DRWF** (overall race-walker endurance 1) – first level of intensity, to maintain previous training level, to perfect the functions of cardiovascular and respiration system. This level is in charge of removing fatigue product from the muscles. Physiologically it is the intensity below the oxygen balance.

**ORWF** (overall race-walker endurance – 2) – second level of intensity, to work in full oxygen balance, it has important impact on training level. It is one of the basic training work form of the competitor for 50 km.

**PE** (Pace Endurance) – third level of intensity, it is similar to special endurance. In practice there is the possibility to work in the continual, repeated or variable form with the intensity exceeding the oxygen balance, so the effort is not fully compensated with oxygen.

**Strength** – training muscle strength in race walking.

**Overall efficiency** – exercises of all basic muscle groups.
sport training system in the direct preparation for the Olympic Games in the 50 km race-walk.

**Research results**

The Fig. 3 show a description of the hierarchical tree model of direct preparation for the 50 km race-runner, which was created according to Saaty’s method [4], following consultation with experts (trainers, athletes, sports managers, club directors, sports theorists (experts in various disciplines). The main objective, which was to create the optimal training model in direct preparation (DPS) of the champion for the 50 km race-walk in the most important competitions (the Olympics, the World Championships), was placed at the peak. The next level consisted of 5 main criteria: training measures, renewal, volume, substantive structure training and base. 4-5 subcriteria for each of them were added at lower levels. Decision possibilities were placed at the lowest level, which include 4 alternative training models.

**Determination of criteria importance in relation to main aim of research**

As it can be concluded from the following table (Fig. 4), according to the experts’ opinions expressed via T.L. Saaty’s 9-grade scale, the highest priority in the mesocycle for the direct preparation of athletes performing 50 km race-walking (values given in percentages) in relation to the main objective which was developing the best training concept for starting in the most important sports event, was granted to training measures (P = 38.9%). The other main criteria were: (i) Substantive structure training and base (P = 18%) > volume (14.6%) > renewal (P = 10.4%) were given lower weights (value).

![Fig. 4. Values of main criteria regarding the direct preparation of a 50 km race-walker for a start](image)

**Criterion – training measures**

On the basis of the data presented in the table above, it was assumed that in determining the fitness of a walker during the direct preparation for a start in the 50 km race-walk, the experts gave the highest priority within the main training component to training measures, the subcriterion pace-endurance (PE) was given (P = 50.6%). Lower weight was given to: ORWE (P = 29.7%), while the remaining components of the training structure in direct preparation for starts were considered too insignificant for achieving success in major competitions: overall efficiency (P = 8.2%) > strength (P = 7.6%) > running (3.6%).

**Criterion – biological renewal**

Within the framework of the main criterion of biological renewal, the experts drew attention to the following subcriterion: nutrition (P = 54.0%). The remaining subcriteria achieved lower weight: physical therapy (P = 18.8%) > supplementation (P = 14.6%) > pharmacology (P = 12.3%).

**Criterion – training volume**

Of the subcriteria included in the training volume main criterion, which should be carried out in the week of direct preparation prior to the start, the experts gave the highest priority to the volume of 150-200 km/week (P = 43.95%) and its range of 100-150 km/week (P = 38.33%). Little recognition was given to high and low training load volumes of 200 km/week (P = 11.32%) and up to 100 km/week (P = 6.3%).

**Criterion – training Substantive structure training**

In the Substantive structure training main criterion of training, the experts emphasized the importance of the overall efficiency subcriterion (P = 59.77%). To our surprise, the subcriterion of technical preparation (P = 19.47%) was given relatively low priority and the remaining elements of the training structure were of low importance in the preparation for a start: mental preparation (P = 12.8%) and tactical preparation (P = 7.8%).

**Criterion – training base**

As it can be seen from the data on the significance of subcriteria within the base main criterion, the experts were particularly divided in expressing their opinions on priority distribution. Training personalization (P = 37.87%) obtained a slight advantage while the other subcriteria were similar with regard to given weight values: financial resources (P = 24.3%) > training monitoring (P = 19.6%) > place of training (P = 18.1%). Attention is drawn to the

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lack of interest regarding high-altitude training in the direct preparation phase (a subcriterion of place of training). Only some Polish and Slovakian coaches have emphasized the importance of training in specific climatic conditions to succeed in major sports competitions.

**Determining the reliability and logic of verbal pair comparisons**

In order to determine the logic and reliability of the verbal pair comparisons, the CR coefficients for main criteria and partial subcriteria were calculated [4, 19]. The 10% margin of error was not exceeded in any of the cases. The value of the compliance ratio was calculated using the Super Decisions* computer programme. The obtained results authorized further analysis of the collected material.

**Calculation of global priorities**

In Tab. 1, the values of subcriteria of local and global priorities in relation to the main criteria are presented. As it is known, global priorities mean the individual impact of each subcriterion on the main goal: the effectiveness of training in direct preparation for starting in the most important 50 km race-walk championship event.

On the basis of the analysis of their weights, large variation among the weights (priorities) of all subcriteria can be noticed. Of all the subcriteria considered, 3 exceeded 10% of the desired individual impact on the main goal: PE (P=19.6%) > ORWE (P=1.5%) > overall efficiency (P=10.8%). Significant subcriteria are also: nutrition (P=8.9%), 150-200 km/week (P=6.0%), training personalization (P=4.9%) and technical preparation (P=3.5%).

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<th>Global priorities</th>
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Source: Own elaboration.

Tab. 1. Juxtaposition of local priority values relative to main and global criteria in relation to the research aim

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Source: Own elaboration.
Seeking the best alternative sports training model for 50 km race-walkers in the direct preparatory period for starts in the most important sports event

The next stage of research was the development of alternative models of 50 km race-walker training in direct preparation for the most important sports event. Their creations are based on the results of previous research using the two highest weights given by the experts in the main criteria. It was assumed that their sum in local priorities should explain more than 50% of validity with respect to the main criteria. Table 2 also lists the global importance of these priorities. They provided a benchmark for expertly distinguishing 4 alternative training models and identifying their distinctive features.

1. **Polish model M-1** – represented by older-generation trainers with vast training experience. They can be counted among the creators of the “Polish school of race-walk training”.

2. **Polish model M-2** – comprised of a group of younger Polish trainers, including distinguished race-walkers. Among them was an Olympic champion and a group of experienced Polish coaches, recruited mainly from former race-walkers.

3. **Euro-Asian model M-3** – comprised of foreign coaches from Europe and Asia.

4. **French model M-4** – due to the criteria applied, only one French coach who was a World Championship medal trainer and a two-time European Champion in the 50 km race-walk were included.

Following analysis of the material aimed at bringing the considered subcriteria down to parallel numbers, the models were compared with each other using T.L. Saaty’s 9-grade scale. The obtained results were analyzed using the Super Decision computer programme. The calculated weights of alternatives regarding 21 subcriteria are presented in Tab. 3.

### Description of weights relative to subcriteria – result of ”peer-to-peer” models

**ORWE**

Regarding the subcriterion of overall race-walk endurance – **ORWE**

3, the best (62.5%) training alternative was the Euro-Asian model (M-3) (S.W., St.M.). Apart from the Polish model (M-1) of the older generation of trainers (K.K., I.M., B.B., M.S., L.L.), for whom the weight of the

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**Table 2. Description of decision alternatives of training models in DPS for 50 km race-walk**

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Models of training race-walkers during the mezocycle...

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Source: Own elaboration.

alternative relative to the subcriterion was set at 24%, it was relatively low in the remaining cases: M-2 (8.1%) and M-3 (5.3%).

**PE**

In the case of developing the race-walkers’ endurance – **PE**, the highest rank of alternatives (56.9%) was found in the M-2 Polish model of trainers from the younger generation (R.K., W.M., G.S., S M.). Apart from the M-3 model (2.6%), in other cases the share of alternatives relative to the subcriterion was more significant: M-4 (26.7%) and M-1 (11.3%).

**Running**

A very unusual form of movement for developing the walking technique, i.e. running, gained a relatively high weight of alternatives relative to the subcriteria: M-1 (36.7%), M-2 (30.7%) and M-3 (24.2%), with the exception of the French model M-4 (8.1%).

**Strength**

The highest weight (49.5%) in alternatives relative to the subcriterion of strength development was found in the French model (M-4). Their lower priority was found in models: M-2 (19.9%) > M-3 (16.4%) > M-1 (14%).

**Overall efficiency**

Similarly, as in the case of race-walker strength training, in the French model, the highest priority of the alternative relative to the subcriterion regarded overall efficiency (M-4) (39.5%), which was comparable to the Polish model of the older-generation M-1 coaches (35.5%). The lowest weight of the alternative was obtained by the model of Polish younger-generation coaches: M-2 (8.8%), and slightly higher weight was noted in the case of the Euro-Asian (16.1%) M-3 model.

**Nutrition**

The value of the alternatives’ priority relative to the subcriterion of nutrition showed that only the model of Polish senior trainers had the highest rank of alternatives (62.0%). The subsequent position was occupied by the French model (21.2%). Very low weight of alternatives was found in the model of Polish M-2 younger-generation coaches (6.7%) and in the Euro-Asian M-3 model (9.9%).
Supplementation
In the case of the significant subcriterion, i.e. the use of supplementation in the training of athletes (supplementation), it must be stated that the highest alternative was found in the M-2 model of young Polish coaches (67.2%), while the lowest was found in the French M-4 model (6.6%). The alternatives of the two following models slightly exceeded the value of 10%; M-1 (13.0%) and M-3 (10.6%).

Physical therapy
In reference to the subcriterion regarding the use of physical therapy by race-walkers, the best alternative (62.5%) was found in the French M-4 model (60.7%). The Polish M-2 training model (26.4%) was also of great importance. The M-1 Polish model (7.6%) and the Euro-Asian M-3 model (4.9%) were of the least priority.

Pharmacology
In the alternative relative to the pharmacology subcriterion, the highest weight was observed in the Euro-Asian M-3 model (71.3%). In the remaining models, the weights of alternatives were lower in the Polish models: 14.3% for M-1, 8.7% for M-2, and the French model: 5.5% for M-4.

Training volume up to 100 km/week
Evaluating the weight of alternatives in 4 training models with respect to the subcriterion, where the application of a low training volume up to 100 km/week was assumed, it turned out that there was an advantage of alternatives in the case of 2 models: M-2 (32.6%) and M-3 (36.2%); for the remaining models: Polish older-generation coaches: M-1 (16.3%) and the French M-4 (14.7%).

Training volume of 100-150 km/week
Considering the weight of alternatives relative to the criterion: training volume of 100-150 km/week, it turned out that there was a very clear advantage only in the French model: M-4 (59.0%). While there were very similar alternative weights in the Polish models: M-1 (18.4%) and M-2 (18%), the weak alternative appeared in the Euro-Asian model: M-3 (4.0%).

Training volume above 200 km/week
In the case of alternatives relative to the subcriterion of very high-volume training sessions, above 200 km/week, it turned out that their high value was revealed in the M-4 French model (50.3%) and the Polish M-1 model (31.8%). Similar weights of the alternatives in the Polish M-2 (8.8%) and in and Euro-Asian M-3 (8.9%) models were low.

Overall efficiency
The highest weight of alternatives relative to the subcriterion of overall efficiency, the name of which encompasses all measures used to develop a race-walker’s motor efficiency, was found in the Euro-Asian M-3 (52.7%) and Polish M-1 (30.6%) models. Lower values were found in the Polish M-2 model (12.3%) and the French M-4 model (4.3%).

Technical preparation
Apart from the M-4 French model (2.4%), relatively high alternative weights occurred in the M-1 (43.9%), M-2 (24.5%) and M-4 (24.5%) models relative to the technical preparation criterion.

Tactical preparation
Considering the weights of alternatives relative, the tactical preparation subcriterion, the significant advantage of the French M-4 model (71.2%) emerged. In the remaining models, the value of alternatives was low: M-2 (13.4%) > M-1 and M-3 (7.6%).

Mental preparation
Apart from the younger-generation Polish trainers M-2 (54.0%) and the Euro-Asian M-3 model (26.3%), in the remaining cases, the weights of alternatives relative to the mental preparation subcriterion were low: M-4 (13.1%) and M-1 (6.3%).

Training personalization
Data on training personalization indicate that only in the model of the younger generation of Polish trainers was it possible to find high weight of the alternative relative to the training personalization subcriterion (M-2: 54.9%). In addition, in the Euro-Asian model the value of the alternative was noticeable (M-3: 23.8%) and was low in the following models: French M-4 (14.6%) and Polish M-1 (6.4%).

Place of training
Analysis of the alternative weights relative to the place of training subcriterion allows to state that only in the M-1 model of senior Polish coaches and the Euro-Asian M-3 model were they at a similar, average level (38.4%). The French M-4 (14.2) and the M-2 Polish younger-generation coaches (8.7%) had low values.

Training monitoring
The highest weight of alternatives relative to training monitoring, a very important element of control in the training process, was found in the M-4 French model (52.7%) and the younger generation of Polish trainers: M-2 (30.5%). In the remaining cases, their values were low: in the M-3 (12.3%) and M-1 (4.3%) models.

Financial resources
In light of the results of our research, it turned out that the weight of alternatives relative to financial resources...
is very diverse in the 4 alternative training models. Surprisingly, they were the highest in the Polish model of older-generation M-1 coaches (66.8%). Other models had low values: M-3 – 16.9%, M-2 – 9.6% and M-4 – 6.2%.

As a result of the above, there were clear differences in the creation of models for the preparation of an athlete for the most important 50 km race-walk event.

**Selection of the best alternative training model**

In order to select the best alternative training model from among those considered, we further analyzed the weight of the alternatives relative to subtypes in the 4 training models using Saaty’s 9-grade scale. Raw calculations were analyzed using the Super Decision computer programme. The final results of selecting the best model are given in Tab. 4. In addition, the indicators for their normalization were calculated. The reference point was regarded as the highest priority value given to the model that reached the highest raw score (0.276). On the basis of data analysis, the model of younger-generation Polish coaches: the M-2 model, should be recognized as the best alternative training model in relation to the main objective of developing the most effective training programme in direct preparation for starting in the most important 50 km race-walk competition.

The following places were occupied by the Euro-Asian M-3 model> the Polish older-generation of trainers M-1 model> the French M-4 model, with only slight differences. The best alternative model was based on the coach training concept created by those who were outstanding athletes in the past. The multiple-time Olympic champion R.K. and European vice-champion G.S. could be found among them.

However, it should be noted that the differences between the models were small. They were within the range of 5% (min 0.226-max 0.276). In addition, it should be emphasized that in all models, the impact of the training concept on the training effect in direct preparation for a competitor’s start in the most important event did not exceed 30%.

**Summary and discussion**

The presented results do not have a reference point to similar ones documented in domestic or foreign literature. Although Prof. T.L. Saaty’s Analytic Hierarchy Process (AHP) model has been known for a long time and is successfully implemented in various areas of social life [5, 7-12, 18-20], in this publication, it is applied for the first time in order to develop an effective model of sport training for professionally competing athletes.

According to the methodological approach of the Analytic Hierarchy Process, it was agreed after discussion with the experts that the aim of research would be to try to create an effective concept of preparation for a start in the most important sports event of a 50 km race-walker, i.e. the Olympic Games or the World Championship. Thanks to information from 14 domestic and foreign coaches of the best 50 km race-walkers around the world and other experts in the organization of the training process in a very interesting athletic competition, the main and subcriteria allowing to fulfill the purpose of research and alternatives were identified.

With the use of AHP methodology and computer programmes, numerical values of local and global priorities were obtained in relation to the main criteria. Analysis of the values of the main criteria shows that our research has found their varied effect on the objective of study i.e. on the effectiveness of training in the direct preparation for a start in the most important 50 km race-walk event. The highest weight (in percentages) may be attributed to the *selection of training measures* \( (P = 38.9\%) \). Less weight was obtained by other criteria: *Substantive structure training and base* \( (P = 18\%) \), *volume* \( (P = 14.6\%) \), *renewal* \( (P = 10.4\%) \). This phenomenon has also been confirmed by the analysis of the value of global priority subcriteria. Only 3 of them exceeded 10% of the desired individual impact on training in the direct preparation for the start: *PE* \( (P = 19.6\%) \), *ORWE* \( (P = 11.5\%) \), *overall efficiency* \( (P = 10.8\%) \).

On the basis of the obtained results, it can be assumed that 14 trainers (experts) presented their own views on training solutions during the period of direct preparation.
Fig. 5. Weight comparison (%) of alternative training models (M-1, M-2, M-3, M-4) relative to subcriteria
Models of training race-walkers during the mezocycle…

for the most important event of the best race-walkers in the world. We may not rule out that this evidenced by the necessity to adapt the training system to the adaptive abilities of a particular athlete. It is also possible to see the confirmation of the already well-established regularity that trainability of an athlete is an individual and not population-based feature [22]. The stated phenomenon could also perhaps be the consequence of averaging the results of the opinions of 14 coaches (experts).

High expectations were associated with the creation of alternative training models and the results of their “peer-to-peer” comparison relative to the adopted subcriteria. However, it turned out that similarly as in the model created by 14 trainers, there is a large variety of approaches to solve the problem of effective preparation of a champion race-walker. This may be confirmed by the graphic illustration of the weight of 21 subcriteria in 4 training models (Fig. 5).

Despite the possibility of performing taxonomies of the models according to the value of alternatives with the aid of the Super Decision computer programme, and demonstrating that the model by the Polish younger-generation coaches is the most appropriate (Tab. 4), attention should be drawn to the small (5%) range of differences in alternative weights between models: min 0.226 – max 0.276. This leads to the perception that it would be tempting to develop new, more effective training concepts for future 50 km race-walking champions.

Conclusions

The results of our research, conducted using T.L. Saaty’s AHP multi-criteria hierarchy decision-making process, based on the strong foundations of cognitive psychology and mathematics, indicate the possibility of using this method to develop a concept of training in race-walking during the direct preparation for starts at competitions at the highest level.

In an applicative sense, it resulted that applied methods of training used by Polish and foreign trainers are not indisputable and can be implemented in the practice of preparing a champion for competitions at the highest rank.

Among the 4 alternative models considered: older generation of Polish trainers (M-1), younger generation of Polish coaches (M-2), Euro-Asian (M-3) and French (M-4) (M-2), the M-2 model comprised of younger generation Polish coaches resulted to be the best, however, the differences in alternative weights between models were minor.

Both the value of global priorities and the weight of alternatives relative to the subcriteria in the 4 training models allow to state that there is relatively small impact of the so-far implemented training systems of the world’s best race-walkers on their success during the most important competitions.

There is a need to develop new, more effective training concepts for future 50 race-walk champions.

References


**Author for correspondence:**

Grzegorz Sudol
Phone number: +48 602 395 532
E-mail: gsudol@interia.pl
EVALUATING THE LEVEL OF CREATIVE SUPPORT IN TEACHING FOOTBALL GAME TACTICS

Henryk Duda¹ABCDEFG, Aleksander Stuła² ABD

¹ Faculty of Sports and Recreational Games, Sports Institute, Department of Physical Education and Sports, University of Physical Education in Krakow, Poland
² Department of Physical Education and Physiotherapy, Opole University of Technology, Poland

Abstract

Aim. Teaching tactics in team games is a difficult process, because it requires not only the optimal preparation of the player in the physical and physical sphere, but above all, deliberate action in the sport. Situations that arise when playing football usually require selecting one of several possible decisions. Not all decisions are optimal. It is on the basis of the optimal decision that you can judge the advantages of a player and then interpret his/her abilities. In order to rationally solve a task in a game, a player must have the best knowledge about effective action, and such tactical preparation methods also need to be used so that the player can consciously and creatively participate in the training process. The purpose of research. To determine whether modern football clubs use tactical training based on creative support in teaching football tactics.

Basic procedures. The empirical material was collected by anonymous polls conducted among randomly selected football players in two age categories: juniors (140 CLJ players and MW leagues) and seniors (160 players IV and III leagues). Research was conducted in the years 2015-2017 in randomly selected Polish clubs, with the largest number (about 80%) being players from the Małopolska, Świętokrzyskie, Podkarpackie, Silesia, Opole and Lubuskie Provinces.

Results Main findings. Analysis of the research results shows that football players from the surveyed clubs are less likely to benefit from the knowledge transfer which facilitates learning tactics. The reason for this situation is not only due to the limited organizational conditions for rational training but can also have its basis in the competence of trainers. This problem is significant for young athletes, which can limit not only the smooth operation of the game but also hinder the process of full development of the player.

Conclusions.

1) Tactical training dominates traditional forms of instructions which limit a player’s conscious participation in the game.
2) Among trainers, there is a low level of knowledge about the use of tactics to help teach game tactics.
3) In order to make more use of tactic teaching aids, there is a need to include this learning direction in the training of coaches and football instructors.
4) Base conditions at football clubs limit the use of modern laboratory measures in teaching tactics.

Introduction

Teaching tactical actions in team games is a difficult process, as it requires not only optimal preparation of a player in motor and physical spheres, but above all, effective conduct for achieving the goals of a game [1]. Such a requirement in a sports game is related to the situational specificity of the game, which requires creativity in action – that is, conscious and purposeful task solving during a game [2] – Fig. 1.

The situations which arise during a football game, as a rule, make it necessary to choose from one of several possible decisions. Not all decisions are optimal. It is on the basis of the optimal decision that one can judge a player’s merits and then interpret his/her abilities.
In order to rationally solve tasks during a game, the player must have optimal knowledge on effective action [3], hence, it is required to use such methods in tactical preparation so that the player can consciously and creatively participate in the training process [2]. This means that tactical training should take the impact on a player’s intellectual sphere into account [4, 5]. It is believed that the training process should use effective methods of communicating messages regarding how to effectively solve tasks during a game, as they can facilitate fast and accurate decision making [6].

It seems that these conditions in teaching game tactics can be met through theoretical preparation using audiovisual means (video-camera-computer), performing the function of strengthening message transmission – e.g. teaching in simulated laboratory conditions [2, 7]. Also, the use of intellectual exercises (task-oriented, problem-based methods) can to a great extent develop a player’s creativity [2]. These methods are used with great conviction in the training of Western European footballers (the Netherlands, France, Germany), whose sports level sets the direction of training in modern football [8, 9]. It seems that the target-matter in such an organized training process is to achieve a high level of sports, i.e. the physical (motor), technical and mental development of a player, thus, his/her rational preparation with a wide spectrum of knowledge about the game, and in the conditions of sports competition, to make conscious and accurate decisions, making full use of one’s own disposition in the game [10]. By choosing this way of educating a player’s tactical training, nowadays in Poland, training content that includes creative programs is becoming more and more appreciated (in training materials for coaches this problem is often discussed). The Polish Football Association, in the newly developed National Programme [11], also emphasizes the obligation of such training. Taking the essence of creative preparation in the effective action of a player [1, 2] and requirements in modern training of football players in our country [11] into account, the study attempts to analyse tactical training in terms of shaping creativity in football players. It seems that recognizing this problem can significantly facilitate the process of rational management of footballers’ education.

Study aim

In this work, the tactical preparation of football players in the field of intellectual training (shaping creativity) in teams of randomly chosen clubs in Poland has been analysed. The aim of the research is to determine whether football clubs use modern trends in tactical training based on the means of creative support in teaching football tactics.

Research questions and hypotheses

Analyses of available research papers [1, 7, 12, 13] and the author’s own experiences allowed to formulate research questions.

Research questions:
1. Is support for a better understanding of the structure and essence of a player’s activity during a game used in the process of teaching game tactics?
2. Are training conditions for creative training used in the process of teaching tactical actions?

Research hypotheses:
1. Most trainers in teaching game tactics use traditional methods based on a spontaneous manner of passing
knowledge on the game during practical exercises, omitting the forms of knowledge transfer in laboratory conditions (fulfilling the function of support in teaching).

2. Among football players, there is a need to use intellectual support for the effective reception of information about actions during a sports competition.

**Study material and methods**

The research material consisted of players practicing football in two age categories: juniors (140 CLJ and MW league players) and seniors (160 players of IV and III league). Research in 2015-2017 was conducted in randomly chosen Polish clubs, of which the largest number (around 80%) were players from the Małopolskie, Świętokrzyskie, Podkarpackie, Śląskie, Opolskie and Lubuskie provinces.

The empirical material was collected via anonymous survey among randomly selected football players. The survey questions concerned the following issues:
- rational (action-based) manner of teaching football tactics,
- use of methods and means in providing information on the game,
- reasons for using (or not using) support methods in teaching game tactics,
- the legitimacy of using audiovisual measures in training players,
- knowledge and competence of the training staff in developing a rational teaching manner
- transfer of information about the game, taking the club tactical conditions allowing the use of support measures in teaching game tactics into account.

**Presentation and discussion of research results**

First, the material concerning knowledge of the subjects on creative support and the use of these methods in teaching game tactics was analysed (Tab. 1).

The opinion of the players is presented in the following manner:
1. all players
2. with division according to players: juniors (J) – seniors (S).

<table>
<thead>
<tr>
<th>Type of answer</th>
<th>1 (J)</th>
<th>2 (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>54 %</td>
<td>54.4%</td>
</tr>
<tr>
<td>NO</td>
<td>46 %</td>
<td>45.6%</td>
</tr>
</tbody>
</table>

The data contained in the table above show that almost 50% of respondents have not encountered support methods shaping action creativity while teaching game tactics. It can therefore be assumed that the process of teaching tactical actions may be limited due to its effectiveness.

Further analysis of the research results indicates that the junior group of players is characterized by greater knowledge of measures supporting creativity in teaching tactics. This is a very significant observation, indicating that in organized football training, the level of the training staff’s competence in training junior groups regarding the aspect of creative support in teaching tactical actions is more interested in this teaching direction. Although the values obtained are higher within this context than in previous studies [13], the obtained values are of low diagnostic value for the effective training of tactical actions.

The next juxtaposition of research results referring to the previous one concerns the actual use of support measures in teaching game tactics by coaches according to the opinions of the athletes (Tab. 2).

<table>
<thead>
<tr>
<th>Type of answer</th>
<th>1 (J)</th>
<th>2 (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>40.1%</td>
<td>50.2%</td>
</tr>
<tr>
<td>NO</td>
<td>59.9%</td>
<td>49.8%</td>
</tr>
</tbody>
</table>

From analysis of the presented data, it can also be stated that the use of support is at a low level. This may be due to the lack of trainers’ confidence to use such measures for effective training. This may also be due to the lack of trainers’ knowledge on the need for such activities in the effective teaching of game tactics – the necessity of a logical understanding of game activities for making accurate tactical decisions [14]. This problem may also result from the requirement for trainers to prepare materials for creative training, but this is illusive, as well-developed materials can be used many times [2]. If such assumptions were correct, then obviously this approach of trainers would be a mistake, because numerous studies [1, 2, 4, 7] indicate that the use of support measures shaping the player’s creativity not only facilitates the mastery of tactical actions but more thoroughly shapes the process rational decision making in game conditions. The obtained data also indicate (which is positive prognosis) that forms supporting the creative teaching of game tactics are applied to a greater extent in work with the youth. This value (51.4%), however, is still not satisfactory from the point of view of effectiveness in teaching game tactics and indicates high traditionalism in training.

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The level of effective football training is also influenced by the training base which allows the use of optimal means for tactical preparation. Fulfilling this condition can significantly shape a player’s creativity [13]. In Table 3, the possibility of implementing tactical preparation is illustrated, indicating the low possibility of using aids in the teaching process. The results of the research indicate a low possibility of using teaching support in laboratory conditions (computer or audiovisual labs), which may limit conscious analysis of the tactical structure, reducing the process of creative teaching [2]. Research values indicate that the main place to teach tactics is on a football pitch, which is often training on a poor-quality surface. This fact not only hinders the effective performance of motor activities but also confirms that the teaching of tactical actions is conducted without any intellectual preparation and done rather mechanically. A disturbing signal regarding the conditions of teaching game tactics is the fact that young players have worse educational conditions in this area, which in the future, does not promise good mastery of this game element.

In the opinion of the players, analysis of teaching game tactics, due to the teaching methods used, still confirms the low degree of using creative support while teaching game tactics (Tab. 4). The low percentage of developed didactic computer programmes, also based on animation, can be noticed, which according to [2], have great value in supporting the process of teaching tactics in sports games. A disturbing element in teaching tactical actions is the lack of detailed instructions in decision-making actions. In the research by Panfilia [2, 7, 12], the authors indicate that mechanical teaching of game tactics without a detailed understanding of goals does not only limit the understanding of these actions but also contradicts the essence of tactical teaching.

Additionally, the dominance of tactical training on training pitches, the conditions and surfaces of which leave much to be desired, is probably not conducive to mastering efficient interaction during a game. Also, the already mentioned low degree of utilizing teaching in laboratory conditions may improve the efficiency of the conscious participation of the player in the difficult process of teaching game tactics to a small extent [2, 7]. This analysis unambiguously indicates limited possibilities of using teaching aids. It follows that the trainers slightly diversify the difficult process of teaching game tactics. It seems that in the education of the surveyed players this state may, on the one hand, indicate low skills of professional trainers, and on the other, their routine (non-creative) workshop. The only justification for this state of affairs may be the limited base possibilities at sports clubs, in which to raise the level of training, the didactic and sports base must be unquestioningly raised (requirement for newly emerging football academies).

### Table 3. Place of carrying out tactical training

<table>
<thead>
<tr>
<th>Type of place</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Club rooms for theoretical classes</td>
<td>5.1%</td>
<td>9.2%</td>
</tr>
<tr>
<td>Club libraries</td>
<td>0.6%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Audiovisual rooms (projection of film materials)</td>
<td>3.3%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Computer labs with tactic teaching software</td>
<td>0.3%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Sports training pitches (poor-quality surface)</td>
<td>51.3%</td>
<td>69.9%</td>
</tr>
<tr>
<td>Main sports pitch (optimal surface)</td>
<td>3.9%</td>
<td>11.5%</td>
</tr>
</tbody>
</table>

### Table 4. Means used in teaching game tactics

<table>
<thead>
<tr>
<th>Means/tools</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical lectures on the rules of tactical action</td>
<td>5.2%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Presenting fragments of tactical actions (photos, developed video material)</td>
<td>16.3%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Training videos</td>
<td>5.1%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Computer programmes</td>
<td>1.2%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Materials developed on the basis of video-graphic technique</td>
<td>0.4%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Teaching game tactics through practical exercises with detailed instructions</td>
<td>24.7%</td>
<td>36.8%</td>
</tr>
<tr>
<td>Teaching game tactics through practical exercises without detailed instructions (schemes)</td>
<td>47.1%</td>
<td>51.1%</td>
</tr>
</tbody>
</table>

Further analysis on the type of measures used in teaching game tactics among the studied players shows (already confirms) the dominance of the traditional way of preparing players (Fig. 2).

It can be noticed that tactical training is dominated by forms of practical classes and current information transfer (“operating instructions”). It seems that the advantage of these forms of teaching and the low degree of using creative support methods can significantly limit the conscious participation of a player in the manner of solving tasks during a game (Panfilia 2000). Empirical data confirm the results of previous studies [13], and although the level of obtained results is slightly better for the current state of training, this level is still unsatisfactory. At this point, one should consider answering the question — what influences the poor diagnostic results obtained in the tests? Is it the low level of performed training activities, or the base conditions at the clubs of...
Evaluating the level of creative support in teaching football…

the studied players? It seems that a partial answer to the above questions may be the general summary of data regarding base conditions in the studied football clubs, professional competences of trainers and the use of didactic aids as support. Unfortunately, from the presented data (Fig. 1), the significant dominance of traditional methods in tactical training of a player can be noted. This fact indicates that the training staff bases more on mechanical ways of teaching the game, it also seems that the coaching workshop lacks coaching reflexivity. Such an attitude of the coaching staff in the teaching process may limit a player’s preparation in understanding the content of tactical tasks [1, 2].

The information (knowledge) in tactical exercises facilitates making the right decisions in motor actions, hence the requirement of conscious participation of a player in the process of tactical preparation is necessary [2, 7, 12, 15]. Therefore, it seems that this process can be greatly facilitated by laboratory-based exercises, for example game action simulation [13] treated as reinforcement in teaching game tactics. It also seems that this way of preparing the player can significantly improve the level of tactical training, thus contributing to their effectiveness in the game [16].

From analysis of the collected research material, it can be assumed that in Poland, despite significant accents of creative training in football players’ game effectiveness, there are still considerable deficiencies in this area. It seems that the problem of shaping creativity in players may result from ‘headworded’ notions [2]. It is talked about (training courses), but there is no development or adherence to methodological requirements in creative teaching of football players. At this point, the reason for such a situation should be considered. There may be many reasons, but according to the author, it is mainly due to the lack of competence in this field not only regarding trainers but also the institutions responsible for devising programmes and supervising the aspects of organized training of football players.

Conclusions

1) Tactical training is dominated by traditional forms of teaching which limits a player’s conscious participation in the game.
2) Among trainers, there is a low level of knowledge about the use of support resources in teaching game tactics.
3) Base conditions at football clubs limit optimal conditions for teaching game tactics (unfavourable terrain conditions, low level of modern laboratory tool usage).
4) In order to make greater use of the aids supporting teaching game tactics, there is a need to include this teaching direction in the training of coaches and football instructors.

1. Problem solving in teaching game tactics
2. Photos depicting particular phases of tactical actions
3. Video materials depicting the main detail of a tactical action
4. Video materials depicting the tactical action presented in slow-motion
5. Video materials depicting the tactical action presented in normal-motion
6. Using support in teaching tactical actions
7. Teaching tactical actions without support

Fig. 2. Ways of teaching game tactics
References


Author for correspondence:
Henryk Duda
E-mail: hendud@wp.pl
LEADERSHIP BEHAVIOURS OF COACHES, PERCEIVED BY ATHLETES IN BASKETBALL AND SELF-EFFICACY IN YOUTH SPORT

Iwona Janas

M.A., Ph.D. studies University of Physical Education, Krakow, Poland

Keywords: leadership behaviours, basketball coaches, self-efficacy, athletes

Abstract

Introduction. Leadership of a coach is mainly instrumental in enhancing the motivational state of a group [6], which is the ultimate basis of performance effectiveness. Research on the leadership process and athletes self-efficacy in sports may significantly contribute to the understanding of sport performance.

Aim. This project was initiated to describe and distinguish types of behaviours of basketball coaches in the opinion of players. The study included athletes' preferences for specific leader behaviours and the perceptions of their coaches' behaviour in relation to an athlete’s self-efficacy.

Basic procedures. The study covered 50 professional basketball players between the age of 16-18 years. The following scales were used for evaluation:

The Polish adaptation of the Leadership Scale for Sports (SPS) by Z. Wałach-Bisła [14], and the General Self Efficacy Scale (GSES) by R. Schwarzer, M. Jerusalem and Z. Juczyński [9].

Results. Statistical calculations revealed the compatibility of respondents in the analyzed parameters. The study results indicate a correlation between level of self-efficacy and the 2 sub-scans of the SPS questionnaire: training and instruction as well as democratic behaviour.

Conclusions. Coaches should be aware of athletes’ self-efficacy to be able to modify their behaviour accordingly.

Introduction

Modern sport represents many different forms of activity. It covers various forms of competition, goals and means of implementation [1]. Both in competitive and general sports, the presence of a person coordinating the work of a group of people is extremely important. The possibility of fulfilling this role is, according to Martens [2], a real privilege. Here, we are talking about a coach or a guide for young people on their sports path. The modern trainer is a specialist whose goal is to properly plan, organize and implement the training process, leading the athlete to full development and the highest achievements [3]. To accomplish this, the coach should have a number of leadership skills. Leadership is a fundamental aspect of sports achievements, especially in a team sport environment [4]. The definition of leadership clearly states that it is to influence the cooperation and coordination of the group members in their pursuit of a specific goal [5]. For many years, sports psychology has been interested in aspects related to the work of coaches. Leadership is essential in improving the motivational status of a group [6]. Chelladurai [7] proposed a multidimensional leadership model, which assumes that the effectiveness of a coach’s behaviour depends on the interaction between a player’s preferences for a specific behaviour of the leader and the requirements that arise. Therefore, he distinguished five dimensions defined as behaviours directed towards the leader’s relationship with a group of subordinated individuals.
The pursuit of achieving a player’s maximal effectiveness in sport has created the need to learn ways to lead the team, as well as to examine the variables that affirm individual beliefs of athletes. An example of such a feature that may be related to the coach’s leadership is perceived self-efficacy. Self-efficacy is a psychological construct about the individual’s awareness of the ability to achieve goals. It expresses the image of the competence of a unit, its equipment allowing to carry out intended activities [9].

According to Bandura, the conviction about the effectiveness of one’s own actions causes determination and perseverance in pursuing a goal, strengthening motivation for work. Low self-efficacy entails the fear of failure and failure to act [10]. Our own effectiveness can be seen as special self-confidence, affecting the types of actions taken. Behaviours that demonstrate self-efficacy are particularly evident in failures [11]. Hazelwood and Burke [12] investigated whether belief in self-efficacy plays an important role in predicting triathlon results by researching the ultra-endurance of a triathlon group. Analysis showed that self-efficacy had significant impact on athletes’ performance. Athletes with higher self-efficacy awareness worked better than those with lower efficiency levels. If the awareness of one’s own capabilities is reflected in sports results, it is worth checking on what the level of perception of effectiveness is dependent.

The aim of research was to determine interdependence between self-efficacy of basketball players’ perception and the coach’s perceived behaviour and their preferences towards the coach. Based on the Multidimensional Leadership Model according to Chelladurai [8] and according to the separate research objective, the following research questions were formulated:

1. Are there any differences between the expectations of the tested athletes and their subjective opinion on the behaviour of the coach?
2. What leadership behaviours do people with high self-efficacy prefer?
3. What leadership behaviours do people with low self-efficacy prefer?

**Material and Methods**

50 competitors from three different teams actively playing basketball participated in the study. The tested basketball players were people aged 16-18, playing in competitions qualified into the 2nd Women’s League. The average team experience was 5.62 years. The minimum criterion for training experience was 2 years, due to the author’s assumptions that only after 2 years of training can female athletes form a certain opinion about a given coach and evaluate the examined aspects. The specificity of the group is that the athletes, despite their young age, take part in the 2nd Women’s League, i.e., senior competitions. In addition, most of them take part in youth competitions for their age categories at the same time. Accord-

### Table 1. Dimensions of coaching behaviours on the basis of Chelladurai’s Multidimensional Leadership Model [8]

<table>
<thead>
<tr>
<th>Coach behaviour dimension-variable</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teaching and Instruction</td>
<td>Coach’s behaviour aimed at improving athletes’ results by instructing the players, providing instructions on the work of the team. Activities involving training in the field of technology and tactics of a given sports discipline. The aim of the behaviour is to strive to activate the player’s physical potential. Instruction mainly regards providing constructive comments on made mistakes and how to improve them.</td>
</tr>
<tr>
<td>2. Democratic Behaviour</td>
<td>Coach’s behaviour aimed at improving the athletes’ results by instructing the players, providing instructions on the work of the team. Activities involving training in the field of technology and tactics of a given sports discipline. The aim of the behaviour is to strive to activate the player’s physical potential. Instruction mainly regards providing constructive comments on the made mistakes and how to improve them.</td>
</tr>
<tr>
<td>3. Autocratic Behaviour</td>
<td>Coach’s behaviour associated with independence in making decisions and emphasizing the authority towards athletes. This is the dominant form of behaviour consisting in emphasizing power within the team.</td>
</tr>
<tr>
<td>4. Social Support</td>
<td>Coach’s behaviour characterized by care for the good of athletes and an individual approach to the athlete. It includes maintaining positive group atmosphere and sincere interpersonal relationships with its members. Thanks to this behaviour, the players are aware that they can receive help from the coach in the event of such a need. The variable also indicates behaviours that go beyond matters strictly related to the performed sports discipline and also includes personal favours of a coach for players, informal social events, encouraging confessions.</td>
</tr>
<tr>
<td>5. Positive Feedback</td>
<td>Coach’s behaviour strengthening the athlete, thanks to the use of the reward method for good results. It is based on providing relevant feedback on how well a player is training or performing tasks. The variable also applies to the presentation of recognition and respect by the trainer, even in the presence of third parties.</td>
</tr>
</tbody>
</table>
Leadership behaviours of coaches, perceived by athletes…

...ing to coaches, their participation in senior competitions is to serve the purpose of gaining experience. This is in line with the rules of the league games. The study was carried out in summer (June-August) during meets and sports camps preparing for the 2017/2018 season. In each case, the team’s coach agreed to the performance of the test, and in the case of underage players, the author obtained parental consent. The research project was carried out by the author personally, and the questionnaire was voluntary and anonymous.

The study used two measurement methods:

The Generalized Self-Efficacy Scale (GSES) by R. Schwarzer, M. Jerusalema and Z. Juczyński [13] and the Polish version of the Leadership Scale for Sports – a questionnaire for examining coaching behaviour by Zuzanna Walach-Biśta [14]. To answer the research questions about the self-efficacy of basketball players, the following scales were applied: The Generalized Self-Efficacy Scale (GSES) by R. Schwarzer, M. Jerusalema, which was prepared in Polish version by Z. Juczyński [13]. The scale consists of 10 statements that are part of one factor. It measures the strength of the general belief of the individual regarding the effectiveness of dealing with difficult situations and obstacles. He refers to the concept of self-efficacy created by A. Bandura. The general indicator, after transformation into standardized units, is interpreted in accordance with the characteristics of the sten scale. Results between 1-4 stens are rated as low, 5-6 average and 7-10 as high. The variables mentioned in the test are related to each other and the conviction about self-efficacy also applies to self-acceptance and an optimistic attitude. It can therefore be assumed that the perception of self-efficacy is a determinant of intentions and actions from various areas of human behaviour. Consequently, it is assumed that the higher the level of self-efficacy, the higher goals are set by the individuals and the more they are involved in them. This increases resistance to failure. Participants responded by selecting one of four answers, where: 1 corresponds to NO; 2 – rather NOT; 3 – rather YES; 4 – YES. The sum of all points gives a general indicator of self-efficacy, which can be in the range of 10-40 points. The higher the index, the higher the sense of self-efficacy [13]. The psychometric equivalence of the tool in terms of reliability and accuracy was tested. To assess the reliability of the scale, Cronbach’s alpha alignment coefficient was used – reaching the high value of 0.828.

The second tool allowing to answer the research questions is:

The Sport Leadership Scale (SPS), which is a selective, reliable and accurate diagnostic tool. The original version of the tool diagnosing a coach’s leadership was created by P. Chelladurai and S. D. Saleh [8] and was called the Leadership Scale for Sport (LSS). On the basis of factorial analysis, five factors called dimensions were determined: Teaching and Instruction, Democratic Behaviour, Autocratic Behaviour, Social Support Behaviour and Positive Feedback Behaviour. The original Sport Leadership Skill Scale is a questionnaire consisting of three parts: Athlete perception, Athlete preference and Coach self-assessment. The study uses a Polish adaptation of the tool that incorporates only the first two parts. The tool consists of 40 items, which distinguish five dimensions of a coach’s behaviour: Training and Instruction – 11 items, Democratic Behaviour – 8 items, Autocratic Behaviour – 7 items, Social Support – 7 items and Positive Feedback – 7 items. Twice, the tested athletes give answers about the same 40 coach behaviours: first with the instructions “I would like my coach…”; later with the instruction “My coach…”. Thanks to this structure of the questionnaire, it is possible to determine the discrepancy between the expectations of athletes and the perception of the actual behaviour of coaches towards them. Zuzanna Walach-Biśta suggests that the Sport Leadership Scale should be used only to examine the preferences or opinions of athletes on the subject of coaching behaviour, without using the self-descriptive version for coaches [14]. The information provided by Z. Walach-Biśta proves that in four of the five subscales analysing the preferences of athletes and in three subscales analysing the behaviour of the coach perceived by athletes, Cronbach’s alpha index reached the value of 0.70 and higher.

The study observed Cronbach’s alpha coefficient which was calculated for each of the Sports Leadership Scale subscales. The results are high and acceptable which proves the reliability of individual subscales, as they remain at the level of 0.605 in the case of expected Social Support, and reached 0.861 in the case of actual Democratic Behaviour.

The dimension not meeting the expected requirements, similarly as in the original version, is the one of Autocratic Behaviour. Cronbach’s alpha score is in this case was 0.512.

It was also verified that the exclusion of a particular items does not significantly increase Cronbach’s alpha internal consistency ratio.

Research results

In order to examine the existing general differences between the three teams, the Eta-squared test was used, which did not show differences between the teams (the relationship between the team and individual variables does not exceed 0.054 in any of the cases).
Table 2. Indicators of measurement reliability of Cronbach’s alpha variables in own study

<table>
<thead>
<tr>
<th>GSES</th>
<th>Alfa</th>
<th>After exclusion of gses3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Players’ expectations regarding „Teaching and Instruction“</td>
<td>0.733</td>
<td>0.828</td>
</tr>
<tr>
<td>Players’ expectations regarding „Democratic Behaviour“</td>
<td>0.786</td>
<td></td>
</tr>
<tr>
<td>Players’ expectations regarding „Autocratic Behaviour“</td>
<td>0.512</td>
<td></td>
</tr>
<tr>
<td>Players’ expectations regarding „Social Support“</td>
<td>0.605</td>
<td></td>
</tr>
<tr>
<td>Players’ observations regarding „Teaching and Instruction“</td>
<td>0.751</td>
<td></td>
</tr>
<tr>
<td>Players’ observations regarding „Democratic Behaviour“</td>
<td>0.794</td>
<td></td>
</tr>
<tr>
<td>Players’ observations regarding „Autocratic Behaviour“</td>
<td>0.861</td>
<td></td>
</tr>
<tr>
<td>Players’ observations regarding „Social Support“</td>
<td>0.806</td>
<td></td>
</tr>
<tr>
<td>Players’ observations regarding „Positive Feedback“</td>
<td>0.715</td>
<td></td>
</tr>
</tbody>
</table>

Are there any differences between the studied female athletes’ expectations and their subjective opinion on the subject of the coach’s behaviour?

The research conducted on the female-players showed slight differences between preferred and perceived frequency of behaviour. This means that the athletes have higher expectations towards coaches compared to how they perceive their behaviour in reality during training and matches.

The respondents attributed the greatest importance in the context of leadership to Training and Instruction, thus emphasizing the coach’s behaviour of strictly training nature towards players, in particular, including task definition and explanation, both in terms of expectations (M = 4.3) as well as subjective opinions about the actual behaviour of their coaches (M = 4.2). An equally high average of responses was noted in the assessment of actual preferences (M = 4.22) and observations (M = 4.06) in comparison to so-called Positive Feedback, i.e. the contents provided by a coach, including appreciation for an athlete’s good work and positive results, and expressing recognition.

The values obtained in the study show the preferences of players for Democratic Behaviour on the part of the coach (M = 3.66) and reluctance towards Autocratic Behaviour (M = 2.18). A similar situation occurs in the case of reality evaluation. Most of the athletes perceive the coach’s behaviour as taking their opinion into account and indeed, according to the respondents’, less behaviour of the coaches is focused on the abuse of power and demanding absolute obedience to them. The studies used Spearman’s rho correlation due to the small sample size (N = 50).

What kind of leadership behaviours do individuals with a high sense of self-efficacy prefer?

The correlation between the self-efficacy and the expected coach behaviour which is strictly training in nature (Coaching and Instruction = 0.358) and Positive Feedback from the coach (0.417). This proves that the higher the respondents evaluate their own effectiveness, the higher their expectations for instructing on the part of the coach and receiving positive feedback. This then means that the players are aware that the coach controls their progress. The basketball players expect both specific instruction and evaluation of the task.

It should also be mentioned that the expectations of the players in terms of Training and Instruction as well as Positive Feedback are correlated (0.669). The more the players willingly undertake tasks ordered by the coach, the more they expect positive effects of their actions and are happy to expect behaviours in which the coach expresses appreciation for their achievements, also in the presence of other people. If they are willing to listen to directions about their work, the more they learn the positive sides of their activities thanks to coaches’ insights.

What kind of leadership behaviours do individuals with a low sense of self-efficacy prefer?

The results of the research show that the lower the self-efficacy of the respondents, the higher the expectations of behaviours related to instructing, and vice versa, the higher their self-efficacy, the more the athletes expect guidance from the coach in training and matches. The same is true for expectations regarding the democratic approach and receiving feedback. The more the level of self-efficacy decreases, the less often the basketball players expect the above behaviours. The analysis did not show a significant relationship between self-efficacy and...
Leadership behaviours of coaches, perceived by athletes...

### Table 3. Mean values (M) and standard deviation (SD) of variables describing preferred behaviours of coaches in the opinion of the female players

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>6.56</td>
<td>4.22</td>
<td>3.61</td>
<td>2.22</td>
<td>3.54</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.55</td>
<td>0.43</td>
<td>0.55</td>
<td>0.51</td>
<td>0.74</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>7.18</td>
<td>4.30</td>
<td>3.60</td>
<td>2.15</td>
<td>3.44</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.7</td>
<td>0.46</td>
<td>0.54</td>
<td>0.41</td>
<td>0.66</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>6.88</td>
<td>4.37</td>
<td>3.76</td>
<td>2.17</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.76</td>
<td>0.34</td>
<td>0.69</td>
<td>0.59</td>
<td>0.46</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>6.88</td>
<td>4.30</td>
<td>3.66</td>
<td>2.18</td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.66</td>
<td>0.41</td>
<td>0.59</td>
<td>0.50</td>
<td>0.62</td>
</tr>
</tbody>
</table>

### Table 4. Mean (M) and standard deviation (SD) of variables of actual behaviours of coaches in the opinion of the female players

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>6.56</td>
<td>4.16</td>
<td>3.38</td>
<td>2.34</td>
<td>3.53</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.55</td>
<td>0.47</td>
<td>0.82</td>
<td>0.64</td>
<td>0.93</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>7.18</td>
<td>4.28</td>
<td>3.60</td>
<td>2.49</td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.7</td>
<td>0.39</td>
<td>0.66</td>
<td>0.86</td>
<td>0.67</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>6.88</td>
<td>4.15</td>
<td>3.46</td>
<td>2.21</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.76</td>
<td>0.43</td>
<td>0.83</td>
<td>0.68</td>
<td>0.38</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>6.88</td>
<td>4.20</td>
<td>3.48</td>
<td>2.35</td>
<td>3.38</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.66</td>
<td>0.43</td>
<td>0.76</td>
<td>0.73</td>
<td>0.69</td>
</tr>
</tbody>
</table>

### Table 5. Correlations between sense of self-efficacy and expected leadership

<table>
<thead>
<tr>
<th>GSES</th>
<th>Exp_lead_train</th>
<th>Exp_lead_democr</th>
<th>Exp_lead_autocr</th>
<th>Exp_lead_sup</th>
<th>Exp_lead_feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSES</td>
<td>1</td>
<td>0.358</td>
<td>0.421</td>
<td>-0.233</td>
<td>0.074</td>
</tr>
<tr>
<td>Exp_lead_train</td>
<td>0.358</td>
<td>1</td>
<td>0.22</td>
<td>-0.13</td>
<td>0.133</td>
</tr>
<tr>
<td>Exp_lead_democr</td>
<td>0.421</td>
<td>0.22</td>
<td>1</td>
<td>-0.196</td>
<td>0.339</td>
</tr>
<tr>
<td>Exp_lead_autocr</td>
<td>-0.233</td>
<td>-0.13</td>
<td>-0.196</td>
<td>1</td>
<td>0.298</td>
</tr>
<tr>
<td>Exp_lead_sup</td>
<td>0.074</td>
<td>0.133</td>
<td>0.339</td>
<td>0.298</td>
<td>1</td>
</tr>
<tr>
<td>Exp_lead_feed</td>
<td>0.417</td>
<td>0.669</td>
<td>0.254</td>
<td>-0.284</td>
<td>0.163</td>
</tr>
</tbody>
</table>

### Table 6. Correlations between sense of self-efficacy and actual leadership

<table>
<thead>
<tr>
<th>GSES</th>
<th>Ac_lead_train</th>
<th>Ac_lead_democr</th>
<th>Ac_lead_autocr</th>
<th>Ac_lead_sup</th>
<th>Ac_lead_feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSES</td>
<td>1</td>
<td>0.346</td>
<td>0.551</td>
<td>-0.12</td>
<td>0.2</td>
</tr>
<tr>
<td>Ac_lead_train</td>
<td>0.346</td>
<td>1</td>
<td>0.382</td>
<td>-0.015</td>
<td>0.372</td>
</tr>
<tr>
<td>Ac_lead_democr</td>
<td>0.551</td>
<td>0.382</td>
<td>1</td>
<td>-0.392</td>
<td>0.384</td>
</tr>
<tr>
<td>Ac_lead_autocr</td>
<td>-0.12</td>
<td>-0.015</td>
<td>-0.392</td>
<td>1</td>
<td>0.128</td>
</tr>
<tr>
<td>Ac_lead_sup</td>
<td>0.2</td>
<td>0.372</td>
<td>0.384</td>
<td>0.128</td>
<td>1</td>
</tr>
<tr>
<td>Ac_lead_feed</td>
<td>0.245</td>
<td>0.675</td>
<td>0.256</td>
<td>0.088</td>
<td>0.176</td>
</tr>
</tbody>
</table>
cy and the female players’ preferences for autocratic traits of a coach. The correlation assumes the value of -0.233.

In turn, when interpreting the results of research, a negative correlation was found between the expected Autocratic Behaviour and Positive Feedback. This means that the greater the expectations of autocratic attitudes, the less the female players accentuate their preferences towards praise and words of appreciation from their coach. Then, the athletes are aware that the trainer gives constructive attention but know that positive words must be deserved through hard work. We can assume that the tasks are performed due to internal beliefs, without the expectation of praise from the trainer.

Correlations between the GSES test and the female players’ preferences to accept a coach’s behaviour related to Social Support among the tested players do not indicate a significant relationship. An analysis of research shows, in turn, a dependence in which the basketball players showing greater expectations of democratic attitudes represented by the coaches admit that Social Support is equally important to them (0.339) and they expect it from their coaches. It is also clear that Democratic Behaviour excludes an autocratic approach regarding both the preferences and perceptions of players.

Discussion

A coach performs leadership functions; however, it seems that it is a role more imposed on coaches than directly arising from their nature [15]. Prominent coaches show some common features in terms of personality, leadership skills or motivation, but one should be aware that there is no unique set of features for all coaches achieving high scores [16]. Although research shows that athletes generally prefer Democratic Behaviour, in many cases, coaches choose Autocratic Behaviour in making decisions [17].

Among all the examined teams, there was a slight difference between the preferred and perceived frequency of behaviours. This means that the athletes have higher expectations towards the coaches compared to how they perceive their behaviour in reality during training and matches. The tested basketball players with a high sense of self-efficacy expect Democratic Behaviour from their coaches in the context of leading a team. It can be assumed that those who are aware of their abilities are more likely to see themselves as co-responsible for the fate of their team and would be more willing to participate in the creation of training processes. Chelladurai [18], in research on 196 leading basketball players, wrestlers and athletes from university clubs, noted that the perception and evaluation of leadership style were inconsistent with the expectations of players, which negatively reflected on the team’s mood and consistency. The players’ moods deteriorated significantly when they negatively assessed coaching and teaching methods. Differences between the style of leadership, attitudes and behaviour of the coach preferred by the players clearly affect their feelings, results and satisfaction. Therefore, coaches should — if possible — take the expectations of players into account [16].

Training and Instruction as well as Positive Feedback are correlated with each other. The more the researched players willingly undertake tasks ordered by the coach, the more they expect positive effects of their work and are happy to expect behaviours in which the coach expresses appreciation for their achievements. If they are willing to listen to constructive criticism about their work, the harder it is for them to find good aspects of their previous actions thanks to the coach’s insights. Research conducted on competitors from other sports disciplines (judo, kayaking, Track-and-Field, and others) has shown that athletes with a greater sense of self-efficacy prefer Democratic Behaviour of coaches more than others, as well as their support [19].

With regard to the obtained results, the further direction of research on a larger sample size may be to evaluate the coaches who allow team members to participate in the decision-making process regarding the team and training course, and at the same time, creating conditions to check the resourceful skills of players. And hence, to examine whether their sense of their own effectiveness increases thanks to this.

One should be aware that the dimensions of trainers’ leadership behaviours used in this article do not prove a univocal style of team leadership. Therefore, on the basis of the tools used, we cannot state that the coach is characterized by democratic leadership. The tools provide information on the preferences or observations of the players regarding particular behaviours that may indicate, for example, a democratic nature of the coach’s approach. However, it is known from practice that a coach’s work is based on multidimensional activity. Therefore, each of these dimensions has its share in the creation of sports reality, however, with a different intensity. The person taking on the role of a coach should be aware that s/he is responsible of putting events in action via other individuals. Martens [2] summarized leadership as “knowing what course to take, to give others guidance on what they should do, while visualizing the final effect of their actions”.

Conclusions

1. The main task of a coach, in addition to instructing players and giving guidance in the discipline being practiced, is generating positive feedback on the ath-
Leadership behaviours of coaches, perceived by athletes...

...one may have reservations that the training process will not be sufficiently effective.

4. The players’ expectations and perception of behaviour that is democratic in nature is related to the high level of self-efficacy of the basketball players. Therefore, it can be assumed that a coach’s behaviour allowing participation in making decisions is a direction aimed at increasing the players’ resourcefulness and raising their awareness in coping with unforeseen situations.

References


Author for correspondence:
Iwona Janas
E-mail: iwonajanasa@interia.pl
IDENTIFICATION OF SOMATIC AND FUNCTIONAL VARIABLES DETERMINING THE EFFECTIVENESS OF TEST GAMES IN VARIOUS FOOTBALL TRAINING GROUPS

Janusz Jaworski1 ACD, Leszek Gargula1 ACD, Dariusz Tchorzewski2 CD, Krzysztof Durlik3 AB, Ewelina Kołodziej4 E

1 Department of Sports Theory and Kinesiology, Institute of Sport Sciences, Faculty of Physical Education, University of Physical Education, Krakow, Poland
2 Department of Winter Sports, Institute of Sport Sciences, Faculty of Physical Education, University of Physical Education, Krakow, Poland
3 "UEFA A" Coach
4 M.A., Ph.D. studies, University of Physical Education, Krakow, Poland

Keywords: football, sport training, recruitment and selection

Abstract

Aim. The aim of the work was to search for somatic and functional conditions of the effectiveness of 1x1 test games among football players in three training groups. Material and methods. The research group consisted of 42 football players. The scope of research covered somatic features, energy-based and neurosensory capabilities. In total, 24 variables were analysed for each athlete. In order to assess the impact of individual structural and functional parameters on the game effectiveness indicators, multiple determination coefficients were used.

Results. The analysis of the significance of Spearman’s rank correlation coefficients between game effectiveness performance indicators and the tested variables allowed 11 variables to be introduced into the multiple regression model. The proposed models determine performance indicators in a range from about 62% to 72% for youngsters, from 63% to 88% for younger juniors and from 64% to 88% for seniors.

Conclusions. The analysed indicators of game effectiveness in the group of youngsters and juniors were most strongly determined by the level of circulatory and respiratory endurance.

Introduction

Identification of the main determinants conditioning the achievement of high effectiveness in football is a difficult task, which is why it is often undertaken by trainers, researchers and scientists. This is mainly related to the various tasks athletes perform in different positions during a match [1].

According to Soroka [2], in modern football, the effectiveness and accuracy of passes are key elements of game effectiveness. Similar conclusions were formulated by Duda [3], who stated that the final result of a game is influenced by a higher rate of passing effectiveness. In turn, Buraczewski et al. [4] observed that the winning teams differed primarily in the effectiveness of shots and set pieces. In the literature, one can also find analyses showing the effectiveness or lack thereof among footballers due to tactical preferences, as well as reliability characteristics of individual players in the effectiveness of maintaining the ball for a prolonged period of time [5].
Analysis carried out by Szwarc and Kromka [6], Szwarc and Chamer [7], Clemente [8] based on the observations of the World and European Championships, presented the relationships between behaviour of the tested athletes during 1x1 duels, and the resultant match showed that in the case of running and possession of the ball, the priority for the players was to maintain it, and then to gain distance on the playing field. However, the unfavourable result caused the players to primarily gain the field as soon as possible, and then create a situation for scoring.

Many scientists have carried out research in the field of fitness preparation within the aspect of game effectiveness among footballers. Jastrzębski [9] believes that during matches, a footballer’s effort is characterized by interval endurance work, in which oxygen processes prevail. It seems reasonable to say that the capability for long-term work can be one of the factors determining effectiveness of the game. Szafraniec et al. [10] subjected the players to primarily gain the field as soon as possible, and then create a situation for scoring.

The main goal of this report is to look for variables determining the effectiveness of footballers’ game depending on age and training experience. The following research questions were posed in the work:

- Which of the tested somatic traits and selected motor skills are of decisive importance in shaping the performance indicators of 1x1 test games among footballers?
- What is the system of variables determining the effectiveness of 1x1 test games at particular stages of sports training?
Material and methods

The research was carried out in April and May 2015 among the following football clubs: MTS Piast Skawina, Wiślanie Jaśliskowice and Skawinka Skawina. In total, 42 players were examined in 3 age-related categories. The boys born in 2002 and 2003 were qualified into the D1 category of youngsters [25]. The category of younger juniors [25] consisted of those born in 1999 and 1998, while the group of seniors comprised of players aged 19-32. The average training experience for the group of youngsters oscillated between 3 and 5 years ($\bar{x} = 3.71$, SD = 0.80). It was slightly longer in juniors and included a range from 4 to 7 years ($\bar{x} = 5.21$, SD = 0.77). The longest training experience was observed in the group of seniors, which ranged from 8 to 15 years ($\bar{x} = 12.43$, SD = 2.23).

Scope of research

The research included basic somatic parameters: body height, sitting height, thigh and lower leg circumferences, body mass, body fat (percentage of fat content was determined), agility – determined by the depth of the trunk forward bow in a seated position [26]. Based on the results obtained, the following were also calculated: fat mass (FM), lean body mass (LBM) and BMI index. For somatic measurements, the tools included in the Martin instrumentation and the TANITA TFB-551 scale were used. All measurements of body mass were made with an accuracy of 100 g, while for body height, 1 mm.

The scope of research also included selected motor fitness tests:

a) Standing long jump [26]. The measurement was conducted using a measuring tape with an accuracy of 5 cm. Based on the results, maximal anaerobic work (MPA) was calculated, which can be treated as an approximate measure of the lower limb maximal anaerobic power [27].

b) 2 kg medicine ball above-the-head throw. The measurement was conducted using a measuring tape with an accuracy of 10 cm. This test allowed to determine the value of maximal anaerobic capacity of the upper limbs [27].

c) Run along a 3 x 5 m “envelope” – as a quick muscle mobilization capacity test [28]. During the test, the subject ran the planned course route 3 times as fast as possible. 2 trials were performed, the better result was recorded.

d) Zig-zag run; 10 x 3 m course – as a test of speed abilities. 2 attempts were made, the better result was recorded. On the basis of the obtained results, the maximal anaerobic power was calculated [29].

e) 10 m standing start run – as a test of speed abilities. Each subject performed 2 attempts, the better result was analysed.

f) Zig-zag endurance test (beep test) – as an endurance test [26]. The result of the test was the distance run.

g) Sits from lying in 30 seconds – analysed as the dynamic force of the abdominal muscles [26]. The result of the test was the number of repetitions.

Taking the classification of motor coordination skills into account [16, 28, 30, 31, 32], the scope of the tests also included this type of ability. In the tests, the following specific coordination tests of motor skills recommended for footballers were used: the ability to combine movements, spatial orientation, feeling movement rhythms, static balance, kinesthetic differentiation, adaptation and shifting movement activities. A detailed description of the tests can be found in the work by Ljach and Witkowski [33].

In order to evaluate the effectiveness of actions during the game, 1x1 test games were carried out according to the proposals of Ljach and Witkowski [33]. They made it possible to quantify the effectiveness of the players’ actions both in the defence and attack. During all duels, the referee of the competition was responsible for recording the course of the match. The 1x1 pitch was mapped out on a square plan with a 20 m side. The playing field was divided into two halves. The goals that were used during the test matches were 1.5x1 m. The goal was only counted if the shot was taken from the opponent’s half. The athletes played according to the peer-to-peer system. For victory in a single competition, 3 points were awarded, 1 for a draw, and 0 for a loss. The duel between the two players lasted 2 minutes; after 1 minute, the players switched sides. If the ball left the game square, it was introduced back in from the place where it left the pitch. When changing the sides and performing penalty kicks, the game time was paused. For each offense, a penalty kick performed from the middle of the pitch to an empty goal was dictated.

Methods of statistical analysis

In order to answer the posed research questions, the following methods of statistical analysis were used:

1. Based on the analysis of 1x1 games (peer-to-peer within a given age category), quantitative characteristics of performance for each player were distinguished. The following were analysed [33]:

   a) the total number of points scored by individual players in the games – interpreted as an indicator of the comprehensive effectiveness of the game both in the defence and attack (WKS),

   b) the difference between the number of scored and lost goals in all played matches – which was interpreted as the difference between the player’s effectiveness in the offense and defence (SOD),
c) the number of goals scored in all 1x1 games, which is interpreted as the player’s effectiveness during the attack (SA),

d) the number of missed goals, meaning the player’s effectiveness in the defence game (SD).

2. Spearman’s rank correlation coefficients were calculated between game effectiveness indicators and somatic parameters as well as fitness and coordination skills.

3. The initial list of variables was set with a certain “excess”, based on literature analysis. Next, the preliminary procedure for eliminating variables was introduced into the multiple regression model. The features most correlated with the explained (dependent) variable and not simultaneously correlated with each other were selected [34].

4. In order to analyze the influence of particular morphological and functional features on the level of game effectiveness, multiple determination coefficients were calculated. The procedure of progressive selection for variables introduced into the model has been adopted. The variable was introduced into the model only when it was possible to reject the hypothesis about its zero share (F-Snedecor statistics, \( p \leq 0.05 \)). \( F \geq 4 \) was assumed as the threshold for entering the variable into the multiple regression model.

### Results

Based on the significance of Spearman’s rank correlation coefficients between the game effectiveness indicators and the analysed variables, those that were ultimately introduced into the regression model were selected. The features most correlated with the explained (dependent) variable and not correlated with each other were chosen. The applied procedure eliminated the number of variables introduced into the multiple regression model. Finally, among all the independent variables (conditioning indicators of game effectiveness at individual stages of sports training), the following models were introduced into the multiple determination model: 10 m run, 10 x 3 m run, beep test, sit from lying, medicine ball throw, ‘envelope’ run, MPA jump, agility, balance, kinesthetic differentiation, adaptation.

The determined linear regression equations for all analysed training groups are presented in Table 1. The proposed models determine game effectiveness indicators from almost 62% to as much as 88%. It should also be emphasized that all proposed models were statistically significant.

<table>
<thead>
<tr>
<th>Table 1. Multi-linear regression equations for game effectiveness indicators in particular training categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statistical parameters</strong></td>
</tr>
<tr>
<td>Linear regression equation</td>
</tr>
<tr>
<td>YOUNGSTERS</td>
</tr>
<tr>
<td>Linear regression equation</td>
</tr>
<tr>
<td>R(^2) [%]</td>
</tr>
<tr>
<td>( p )</td>
</tr>
</tbody>
</table>

| YOUNGER JUNIORS | | | |
| Linear regression equation | \( y = 0.0344 \) beep test - 39.3165 | \( y = 0.041 \) beep test + 1.791 agility - 159.653 | \( y = 0.0258 \) beep test - 19.2564 | \( y = -0.01231 \) beep test - 1.10860 agility + 3.19317 envelope co-ordination run + 2.90864 |
| R\(^2\) [%] | 72.81617 | 80.27187 | 63.76818 | 88.45917 |
| F | 32.14376 | 22.37883 | 21.12002 | 26.82117 |
| \( p \) | 0.00104 | 0.00133 | 0.00616 | 0.00043 |

| SENIORS | | | |
| Linear regression equation | \( y = 0.2742 \) differentiation + 1.5800 beep test - 4.9373 run 10 x 3 m + 122.0494 | \( y = 2.4174 \) differentiation + 2.3580 beep test - 6.1467 run 10 x 3 m + 108.3122 | \( y = 5.3110 \) differentiation - 6.1467 run 10 x 3 m - 43.8928 | \( y = 3.6447 \) run 3 x 10 m - 1.0332 beep test - 82.0325 |
| R\(^2\) [%] | 88.45738 | 86.77338 | 74.06602 | 64.68143 |
| F | 25.54484 | 22.06792 | 15.72401 | 6.706804 |
| \( p \) | 0.00053 | 0.00099 | 0.000595 | 0.008721 |

In bold \( p \leq 0.05 \); Designation of game effectiveness indicators as in the “Material and methods” section.
In the group of youngsters (Tab. 2), the analysed game effectiveness indicators were most strongly determined by the level of cardiopulmonary endurance (beep test). Such regularities were obtained for each of the indicators in question. The highest percentage of volatility translation was noted for game effectiveness indicators in the offense (about 71%), and the lowest for the effectiveness of the defensive game (about 42%). For two indicators (SOD and SD), the results of kinesthetic differentiation regarding strength parameters also qualified into the model, and thus, a specific coordination capacity. They explain approximately 11% and 20% (respectively) of the analysed indicators' volatility. It should be noted that for the SOD indicator, the value of the F statistic is higher than the accepted criterion (F≥4), but the variable has been introduced into the model at a p value slightly exceeding the assumed level of significance.

In turn, the variability percentage of the last game effectiveness indicator (SD) is formed by three parameters. The first re-emerging here is the circulatory-respiratory factor – explaining about 68% of the variability of the indicator. The composition with agility significantly increases the value of the determination coefficient (by more than 15%), while integration of the next value determining the quick muscle mobilization ability (running along the ‘envelope’) leads to a slight increase in this ratio (by about 5%). The whole system of variables representing energy-based abilities and agility explains the defensive game effectiveness at the level of approx. 88%.

### Table 2. Coefficients of multiple determination between game performance indicators and the tested variables in the youngster group

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Variable introduced into model</th>
<th>Spearman's R</th>
<th>R²</th>
<th>R² change</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>WKS</td>
<td>Beep test</td>
<td>0.789688</td>
<td>0.623607</td>
<td>0.623607</td>
<td>19.88154</td>
<td>0.000781</td>
</tr>
<tr>
<td>SOD</td>
<td>Beep test</td>
<td>0.784027</td>
<td>0.614699</td>
<td>0.614699</td>
<td>19.14445</td>
<td>0.000904</td>
</tr>
<tr>
<td></td>
<td>Kinesthetic differentiation</td>
<td>0.851789</td>
<td>0.725544</td>
<td>0.110845</td>
<td>4.44260</td>
<td>0.058806</td>
</tr>
<tr>
<td>SA</td>
<td>Beep test</td>
<td>0.845070</td>
<td>0.714144</td>
<td>0.714144</td>
<td>29.97920</td>
<td>0.000142</td>
</tr>
<tr>
<td>SD</td>
<td>Beep test</td>
<td>0.654276</td>
<td>0.428077</td>
<td>0.428077</td>
<td>8.981837</td>
<td>0.011129</td>
</tr>
<tr>
<td></td>
<td>Kinesthetic differentiation</td>
<td>0.792059</td>
<td>0.627357</td>
<td>0.199280</td>
<td>5.882519</td>
<td>0.033684</td>
</tr>
</tbody>
</table>

In bold p≤0.05; Designation of game effectiveness indicators as in the “Material and methods” section.

### Table 3. Coefficients of multiple determination between game effectiveness indicators and tested variables in the group of younger juniors

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Variable introduced into the model</th>
<th>Spearman's R</th>
<th>R²</th>
<th>R² change</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>WKS</td>
<td>Beep test</td>
<td>0.853323</td>
<td>0.728161</td>
<td>0.728161</td>
<td>32.14376</td>
<td>0.000104</td>
</tr>
<tr>
<td>SOD</td>
<td>Beep test</td>
<td>0.852985</td>
<td>0.727584</td>
<td>0.727584</td>
<td>32.05021</td>
<td>0.000105</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>0.895945</td>
<td>0.802718</td>
<td>0.075134</td>
<td>4.18930</td>
<td>0.065337</td>
</tr>
<tr>
<td>SA</td>
<td>Beep test</td>
<td>0.798550</td>
<td>0.637681</td>
<td>0.637681</td>
<td>21.12002</td>
<td>0.000161</td>
</tr>
<tr>
<td>SD</td>
<td>Agility</td>
<td>0.913980</td>
<td>0.835359</td>
<td>0.154810</td>
<td>10.34319</td>
<td>0.008216</td>
</tr>
<tr>
<td></td>
<td>Envelope run</td>
<td>0.943111</td>
<td>0.889458</td>
<td>0.054099</td>
<td>4.89398</td>
<td>0.051366</td>
</tr>
</tbody>
</table>

In bold p≤0.05; Designation of game effectiveness indicators as in the “Material and methods” section.
A diametrically different model structure is observed in the senior fraction. Apparently, the meaning of a variable representing specific coordination abilities is drawn here. The first to enter the model, even in the case of 3 indicators, is kinesthetic differentiation of strength parameters. The linear regression equation suitable for this training group is presented in Table 1. The proposed models determine game effectiveness indicators within the range of just above 64% to as much as 88%. In all cases, the proposed models are statistically significant.

A detailed configuration of the model in the analysed group of seniors is presented in Table 4. The results of 3 variables are eligible for the game effectiveness index model: kinesthetic differentiation, cardiorespiratory strength and the 10 x 3 m run (the ability to quickly mobilize the muscle). Together, they explain about 88% of the volatility of the indicator in question. Also in the model for SOD, 3 variables are revealed. Kinesthetic differentiation ability is once again located in first place - explaining about 70% of the variability of the indicator. The introduction of another variable (cardiopulmonary endurance) causes an increase by approximately 10%. In turn, all dependent variables explain SOD at a level of about 86%. However, for game effectiveness in the attack model, 2 variables were introduced: kinesthetic differentiation as well as circulatory and respiratory endurance. Together, they explain about 74% of the volatility. In turn, for the defence game effectiveness indicator, only 2 variables were implemented in the model: the 10 x 3 m run – representing speed abilities, and the beep test – characterizing cardiovascular and respiratory system efficiency. This model only explains about 64% of the volatility of the indicator in question.

### Table 4. Coefficients of multiple determination between game effectiveness indicators and tested variables in the group of seniors

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Variable introduced into the model</th>
<th>Spearman’s R</th>
<th>( R^2 )</th>
<th>( R^2 ) change</th>
<th>( F )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>WKS</td>
<td>Kinesthetic differentiation</td>
<td>0.821812</td>
<td>0.675374</td>
<td>0.675374</td>
<td>24.96565</td>
<td>0.000311</td>
</tr>
<tr>
<td></td>
<td>Beep test</td>
<td>0.883546</td>
<td>0.780654</td>
<td>0.105279</td>
<td>5.27966</td>
<td>0.042199</td>
</tr>
<tr>
<td></td>
<td>10 x 3 m run</td>
<td>0.940517</td>
<td>0.884573</td>
<td>0.103919</td>
<td>9.00296</td>
<td>0.013332</td>
</tr>
<tr>
<td>SOD</td>
<td>Kinesthetic differentiation</td>
<td>0.838777</td>
<td>0.703547</td>
<td>0.703547</td>
<td>28.47863</td>
<td>0.000177</td>
</tr>
<tr>
<td></td>
<td>Beep test</td>
<td>0.897600</td>
<td>0.805686</td>
<td>0.102139</td>
<td>5.78202</td>
<td>0.034948</td>
</tr>
<tr>
<td></td>
<td>10 x 3 m run</td>
<td>0.932080</td>
<td>0.888773</td>
<td>0.063087</td>
<td>4.80745</td>
<td>0.053103</td>
</tr>
<tr>
<td>SA</td>
<td>Kinesthetic differentiation</td>
<td>0.790781</td>
<td>0.625334</td>
<td>0.625334</td>
<td>20.02854</td>
<td>0.000759</td>
</tr>
<tr>
<td></td>
<td>Beep test</td>
<td>0.860732</td>
<td>0.740860</td>
<td>0.115525</td>
<td>4.90382</td>
<td>0.048836</td>
</tr>
<tr>
<td>SD</td>
<td>10 x 3 m run</td>
<td>0.720965</td>
<td>0.519790</td>
<td>0.519790</td>
<td>12.98906</td>
<td>0.003619</td>
</tr>
<tr>
<td></td>
<td>Beep test</td>
<td>0.804247</td>
<td>0.646814</td>
<td>0.127024</td>
<td>3.95616</td>
<td>0.072149</td>
</tr>
</tbody>
</table>

In bold \( p<0.05 \); Designation of game effectiveness indicators as in the “Material and methods” section.

### Discussion

The main purpose of this report was to search for somatic and morpho-functional variables conditioning the effectiveness of actions during 1x1 test games in football players at various stages of sports training.

The influence of somatic features on the final result in football championships, in light of many publications [35, 36, 37, 38], seems not to be fully recognized. In our own research, none of the somatic features in individual training categories showed any significant correlations with the analysed indicators of footballers’ game effectiveness. In turn, relationships between the players’ effectiveness parameters and the results of energy-based tests (10 m run, 10 x 3 m run, beep test, sit from lying, medicine ball throw, ‘envelope’ run, MPA calculated on the basis of the standing long jump, agility, balance, kinesthetic differentiation, adaptation) were identified. In terms of fitness capabilities, first of all, the influence of aerobic endurance and speed abilities on the comprehensive effectiveness of a player’s game at particular stages of training was revealed. These results correspond to the surveys carried out on Portuguese players aged 11-14 in the central part of the country [39] and in Turkey [40]. In both reports, fitness abilities (speed, endurance and strength) played a significant role in the effectiveness of a player’s performance.

In light of the cited literature, it should be concluded that the individual energy-based properties of the body of football players have great impact on the level of sports performance.
championship and effectiveness during the game. The cardiorespiratory function should be considered as a key element in the range of fitness abilities. Taking into account the results of the last Football World Cup in Brazil in 2014, a relationship between the occupied place in the ranking and the distance covered by the athletes of individual teams should be assumed [41]. In our own studies, in the case of younger juniors and juniors, the impact of fitness (especially circulatory and respiratory endurance) on game effectiveness indicators has already been clearly highlighted. In turn, taking into account the senior team, the dominance of the coordination potential in this group of athletes was noticed. This data is confirmed in the results of Kalinowski’s research [42], in which the boys achieved the worst results of goal shots after the Cooper test. Therefore, it should be assumed that in this training group, coordination abilities play an important role in effective execution of a play. Paying attention to the neuro-functional side of a player’s motor ability, relationships with 1x1 game meet the scientific assumptions place upon motor co-ordination and balance (significant Spearman rank correlations). These studies are confirmed by the publication of Garguli and Duda [43], who analysed the level of indicators of the aforementioned properties and their impact on the effectiveness of 15-18-year-old football players from the School of Sports Championship in Krakow based on a two-year coordination training programme (experiment).

A 1x1 duel is a spectacular part of a football match. According to many authors, the methods based on a 1x1 game efficiency was mainly located within the ability of kinesthetic differentiation, motor adaptation and balance (significant Spearman rank correlations). The quoted literature is only a small part of the general state of knowledge about the influence of various determinants on the effectiveness of football games. Thus, there is a need for further detailed penetration in this area of the studied discipline.

Conclusions

On the basis of the presented research results, the following conclusions can be formulated:

1. The detailed configuration of models developed on the basis of multidimensional statistical analysis (multiple regression) showed that the analysed game effectiveness indicators in the group of youngsters and younger juniors were most strongly determined by the level of circulatory and respiratory endurance. For each indicator, cardiorespiratory endurance also qualifies for the model, which explains about 10% of its variability.

References


Identification of somatic and functional variables…


Author for correspondence:

Janusz Jaworski
E-mail: janusz.jaworski@awf.krakow.pl
Authors’ contribution:
A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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PHYSIOLOGICAL AND BIOCHEMICAL CHANGES IN ADOLESCENT JUDO ATHLETES CAUSED BY TRAINING DURING THE START PERIOD

Jan Jaszczanin1 ADE, Wojciech Przybylski1 FG, Waldemar Moska1 DG, Egle Kemeryte-Riaubiene2 BDC, Grzegorz Chruściński1 EF

1 Gdansk University of Physical Education,
2 Lithuanian University of Educational Sciences, Faculty of Sports and Health Education

Keywords: judo athletes, VO₂max, lactate concentration, Wingate test

Abstract

Aim. The objective of the present study was to estimate and compare dynamics of physical fitness indices of judo athletes and non-training persons aged 11-17 years during this stage of ontogeny and their importance of the body’s functional adaptation.

Basic procedures. The study involved 47 judo athletes, 11-17 year-olds, who were divided into three age groups: GP 11-13 years, n=16; GP 14-15 years, n=16; GP 16-17 years n=15, and 48 schoolchildren not involved in sports: GK 11-13 years, n=16; GK 14-15 years, n=15; GK 16-17 years, n=17. Aerobic and anaerobic capacity was studied in all groups. The initial studies were carried out in January and follow-up studies were conducted six months later.

Results: Power indicators increased in all groups, but the judo athletes’ anaerobic capacity was significantly higher compared to the other groups. Judo athletes’ simulation fights resulted in increased La concentrations, pH changes and heart rate alterations, whereas the level of changes depended on athletes’ age, training and training experience. Comparison of maximal oxygen uptake parameters of judo players and untrained children of the same age did not reveal significant differences between these groups. The athletes aged 12 and 16 years presented significantly higher anaerobic prevalence in comparison with untrained children. The differences indicate that anaerobic performance potential in older judo athletes (16 years old and above) is increased, which is reflected by higher intensity and elevated exercise loads as well as training experience.

Conclusions: No significant differences were reported in terms of VO₂ max between the study groups. The indicators of anaerobic performance of children training judo (W/kg, W average/kg, time to attain max power, time to maintain max power) were significantly better in comparison to their untrained peers. The maximum loads (Wingate test, especially in simulative judo fights) caused a significant increase in La levels accompanied by a decrease in pH in the chosen growth period.

Introduction

Athletes, the type of training coupled with the physical load (intensity and duration of training) activates well-understood adaptation processes to physical activity. Adaptive changes are more pronounced during growth and affect the establishment of motor functions [1, 2] as well as the formation of specific mental and behavioural patterns, including the ability to pursue personal goals, etc. [3-6]. However, some reports suggest that the physiological parameters of training loads [7, 8] in adolescent males are also important during upbringing [9, 10]. This is of special importance in terms of combat or contact sports, which can be reflected in behaviour outside the combat arena, as one would trust the acquired skills be used for sport.
Inadequate duration and training intensity, premature establishment of a focused sport, and too many competitions are some of the most basic factors encouraging talented youth to resign from further training [11, 12]. The choice of training load should consider the biological age of the young male, which is sometimes difficult from a practical point of view. Furthermore, the biodynamic structure of the training loads is far from the specialized motor activity observed in sport competitions. This is one of the most important factors of dis-coordination, especially in fatigue accumulation. This can lead to motor system damage, decreased physical training progress, or even signs of regression. Therefore, the lack of success can result in aversion to training and quitting the sport, and it may also cause biological dysfunction of fundamental processes responsible for body growth [13, 15]. The aforementioned factors may be more pronounced in combat sports, as, due to specifics of these disciplines, there is constant contact with a partner also aiming for success.

Therefore, the appropriate load, training content, intensity and training methods are still a relevant issue in the context of the biological and psychophysiological aspects of the young body, especially in regard to school sports. Additionally, general and specialized school multi-directional scientific research, and their multi-parameter analysis might lead to implementation of changes in schools.

The goal of the present study was to estimate and compare dynamics of physical fitness indicators in judo athletes and non-trained persons age 11-17 during this stage of ontogeny and their importance in the body’s functional adaptation.

**Material and methods**

Research involved 47 judo athletes, 11–17 year olds, who were divided into three age groups. The initial tests were performed in January while follow-up studies were conducted six months later. Judo training was carried out at a frequency and duration dependent on age. Detailed anthropometric data are summarized in Table 1.

**Condition standardization for study procedures**

The study protocol was conducted at a specialized judo gym and sports field with a running track. The actual tests were conducted after a 10-15 min warm-up consisting of stretching exercises. The warm-up ended 2 minutes directly before the trial. Temperatures in the wrestling gym ranged between 20 and 22°C. The study was conducted in the afternoon. The study was approved by Bioethics Committee at the Regional Chamber in Kaunas, Lithuania.

**Study design**

During the initial and follow-up studies, which were repeated after six months of training (controls were subject to the same time frame), the following parameters were tested: body mass was assessed before meals using a medical scale according to procedure requirements; heart rate (HR) was assessed using a PH-600 Sport recording device (Polar INC, Finland), lactate blood concentration (La) was measured with a photometer LP 20 LKM-140 (Lange, Germany); and acid-base homeostasis (pH) was evaluated using the Bayer 160 analyser (Germany).

Anaerobic capacity was evaluated using the Wingate laboratory test (Bar-Or, 1987). The test was performed twice on a Monark (894E, PEAK BIKE, Sweden) cycle ergometer at baseline and after six months. Before the 30-second test began, every participant did a standard warm-up for five minutes with the load of 60 rpm (1W/kg). After a two-minute break, each participant performed the proper exercise test consisting of paddling for 60 seconds at a maximal speed, and the load was adjusted according to body mass (0.075 x kg). The following parameters were assessed during testing: maximal power (W), maximal relative power (W/kg), relative average power (W/kg), time to attain max power (s), time to maintain max power (s).

In order to assess maximal oxygen uptake, the indirect method of VO_{2max} assessment was utilized (Astrand, 1992) (Fig. 1).

**Table 1. Comparison of average basic anthropometric parameters of the judo athlete (GP) and non-athlete (GK) groups**

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Judo athletes (GP)</th>
<th>Control (GK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants</td>
<td>I group n-16</td>
<td>II group n-16</td>
</tr>
<tr>
<td>age (years)</td>
<td>11.4 ± 0.3</td>
<td>13.5 ± 0.2</td>
</tr>
<tr>
<td>height (cm)</td>
<td>155.4 ± 8.2</td>
<td>164.3 ± 4.5</td>
</tr>
<tr>
<td>body mass (kg)</td>
<td>36.5 ± 4.8</td>
<td>58.7 ± 7.6</td>
</tr>
</tbody>
</table>
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Figure explanation:
Before the warm-up, the following parameters were assessed: heart rate (HR), lactic acid concentration (La) and pH.
The warm-up duration was 10 minutes.

Load was performed on the cycle ergometer until refusal (exhaustion).

The power and heart rate were assessed directly after the exercise, and during post-exercise rest – after 1 minute, 2 minutes and 3 minutes.

HR, La and pH were assessed after a 3 minutes rest.

Overall aerobic capacity was determined indirectly by performing the Cooper test for 600 meters (for boys at the age of 11) or 1,000 m (for the boys 12 years or older), and the distance results were also calculated according to this test.

At the end of a six-month judo training period, simulated judo fights were conducted according to the requirements of judo competition rules: for 5 minutes (the time of the 1st round).

Statistical analysis
The Mean values (X), mean error (Sx) and standard deviation (SD) were calculated for each group. The statistical significance between the groups (p) was estimated with the Student t-test. The result p < 0.05 was considered statistically significant. All calculations were conducted in Microsoft Excel 2000 and Statistica programmes.

Results
Comparison of maximal oxygen uptake parameters (l/min, mL/kg/min) of judo athletes and untrained children of the same age did not reveal significant differences between these groups (p > 0.05). Initial results (a) and the results of repeated trials (b) indicate no significance (p > 0.05).

Despite no statistical significance being found (p > 0.05), trials repeated after six months indicate that increases in VO2max and HR were higher in the judo subjects as compared to controls. In the groups with the oldest participants (GP 16-17 and GK 16-17), VO2max was higher in comparison to the youngest group (GP 11-13 and GK 11-13). Changes in HR in all groups were not statistically significant (p > 0.05), although in the untrained group, HR tends to decrease with age.

In order to assess the physical performance of the school children 600 m (11 years or younger) and, 1,000 m (12-15 years) runs, as well as the Cooper test were performed. In the untrained groups aged 15 to 17 years, the improvement in results of the 1,000 m run were significantly lower than in the judo athletes (p < 0.05).

Heart rate at rest (HR) amounted to 72-85 beats/minute and was within the normal range. Heart rate after exercise oscillated between 184 and 192 beats/minute. During the rest period following exercise, greater HR diversification was observed (after the first minute, 96-164 beats/min; after the second minute, 78-138 beats/min; after the third minute, 66-97 beats/min) in both: the first and the repeated test. Nevertheless, among subjects aged 16-17, differences between groups were lower (Tab. 3).

Judo athletes aged 12 and 16 years presented significantly higher anaerobic prevalence in comparison to untrained children (Tab. 4). Thus, the year-long training of judo athletes under the age of 12 did not significantly improve their anaerobic capacity (p > 0.05). Whereas, significant differences (p < 0.01) in these parameters (Wmax/kg, Wmax average/kg, t to attain Wmax (s) and t to maintain Wmax (s), in comparison to the untrained children at the same age, were observed in subjects aged 12 and older however, in 12-year-old judo participants and untrained children, the increase was non-significant (p > 0.05). In all cases, performing the Wingate test resulted in an increase in lactate concentration (La), however, in 12-year-old judo participants and untrained children, the increase was non-significant (p > 0.05).
Table 2. Maximal oxygen uptake (VO₂max), heart rate of judo athletes (GP), and untrained children (GK) between the age of 11 and 17 (GK)

<table>
<thead>
<tr>
<th>Subjects</th>
<th>VO₂max (ml/kg/min)</th>
<th>HR beats/min*</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>GP 11-13</td>
<td>3.01±0.8</td>
<td>3.21±0.4</td>
<td>-</td>
</tr>
<tr>
<td>GP 14-15</td>
<td>3.90±0.5</td>
<td>3.98±0.5</td>
<td>-</td>
</tr>
<tr>
<td>GP 15-16</td>
<td>4.21±0.6</td>
<td>4.33±0.4</td>
<td>-</td>
</tr>
<tr>
<td>GK 11-13</td>
<td>2.3±0.84</td>
<td>2.32±0.92</td>
<td>-</td>
</tr>
<tr>
<td>GK 14-15</td>
<td>3.34±0.48</td>
<td>3.48±0.38</td>
<td>-</td>
</tr>
<tr>
<td>GK 15-16</td>
<td>3.76±0.74</td>
<td>3.84±0.62</td>
<td>-</td>
</tr>
</tbody>
</table>

Explanation: a – preliminary study; b – repeat study.

Table 3. HR dynamics in judo athletes between the age of 11 and 17 during exercise and recovery

<table>
<thead>
<tr>
<th>HR</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11</td>
</tr>
<tr>
<td>X</td>
<td>82.42</td>
</tr>
<tr>
<td>SD</td>
<td>12.30</td>
</tr>
<tr>
<td>max</td>
<td>98</td>
</tr>
<tr>
<td>min</td>
<td>68</td>
</tr>
</tbody>
</table>

Before the Wingate test, La concentration in untrained children amounted to 1.78±0.38 mmol/L, in judo athletes 1.81±0.41 mmol/L, while after the Wingate test, La concentration increased to 7.8±1.06 mmol/L and 8.14±1.18 mmol/L, respectively (p > 0.05). In the older, untrained subjects, at the age of 16, La concentration before the test amounted to 1.62±0.38 mmol/L, and in judo athletes – 1.72±0.81 mmol/L, whereas after the test, it was 9.2±1.2 mmol/L and 11.8±1.4 mmol/L (p < 0.05) respectively.

In order to assess the influence of specialized loads on judo athlete’s muscle metabolism, simulative judo fights were used. These fights resulted in increased La concentrations, pH changes and heart rate alterations, whereas the level of changes depended on the age of judo athletes training and experience (Table 5). It should be noted that changes in the aforementioned parameters were more pronounced than those observed after the Wingate test.
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The differences indicate that anaerobic performance potential in older judo athletes (16 years old and above) is increased, which is reflected by a higher intensity and elevated exercise loads as well as training experience.

Discussion

Adaptive changes regarding cardiovascular, neuro-muscular, respiratory, as well as cellular metabolism and function while under the influence of physical exercise are relatively well studied in adult athletes. A adaptation of a young body to training load is not as well understood. During growth, a period during which the body is strained in general, an appropriate training load should be chosen in order not to affect the natural maturation processes. Due to this fact, the question of how a still-biologically-forming body will react to the training load used in various sports remains unanswered [13]. This is addressed in relatively few scientific reports, especially with regard to combat sports also called "contact sports", such as judo, wrestling and boxing [14].

The dynamic changes of aerobic and anaerobic performance of judo players during adolescence is a good indicator of the functional adaptation of motor organs, the cardiovascular system and metabolic processes, etc. (Tab. 3-5). Judo training requires fast and powerful effective elements and maximum isometric force muscle work [5, 6, 14]. Due to such muscular work, the development of hypoxia disrupts muscle metabolism. It should also be mentioned that during the course of judo matches, tactics, intensity, and variability may be forced by the opponent, resulting in specific changes in planned fight tactics. Furthermore, intensity, duration and the number of training loads may be higher than the individual physiological (biological) extent of the growing body’s adaptation. It may lead to biological dysfunction of the growing body [1, 8, 18, 19].

Training loads, especially starting loads in judo, are mostly anaerobic or anaerobic-aerobic with complete anaerobic periods due to holding of the breath (e.g. suffocation). As a result, there is an increase in lactate concentration and acid-alkaline homeostasis. The cardiovascular system, as well as the activity of other systems, is affected, thereby producing signs of fatigue. These changes make it more difficult to perform technical elements and implement tactical assumptions, leading to reduced physical effectiveness. Moreover, during tournaments, the participants often fight more than one combat per day, and the fight count may even reach five a day. This requires significant aerobic and anaerobic prevalence. With such loads, the potential of aerobic performance is especially important for rest after exercise.

Berthoin et al. (2003) indicated that aerobic prevalence of adolescent judo athletes and untrained children

Table 4. Parameters of judo athletes and untrained children – maximal anaerobic performance at ages 12-16 (according to the Wingate test)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of cycles (n/30 s)</th>
<th>Total work of a single cycle (J)</th>
<th>Total work (KJ)</th>
<th>Max (W)</th>
<th>Max relative to attain max power (W/kg)</th>
<th>Max average to maintain max power (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GK11-13</td>
<td>42.3± 4.8</td>
<td>161.8±24.8</td>
<td>7.34±1.2</td>
<td>283.8±52.3</td>
<td>7.38±0.8</td>
<td>6.3±0.48</td>
</tr>
<tr>
<td>GP 11-13</td>
<td>44.1± 5.2</td>
<td>172±23.4</td>
<td>8.26±12</td>
<td>294.4±49.6</td>
<td>8.64±0.7</td>
<td>7.6±0.46</td>
</tr>
<tr>
<td>GK16-17</td>
<td>56.2± 4.1</td>
<td>244.6±34.5</td>
<td>16.32±2</td>
<td>618.4±69.4</td>
<td>9.72±0.6</td>
<td>8.33±0.6</td>
</tr>
<tr>
<td>GP 16-17</td>
<td>60.8± 4.2</td>
<td>268.2±38.2</td>
<td>18.16±1</td>
<td>649.3±39.4</td>
<td>12.98±0.5</td>
<td>10.4±0.5</td>
</tr>
</tbody>
</table>

Explanation: * – p<0.01.

Table 5. Changes in pH, La concentration and HR of judo athletes before and after simulative judo fights

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Body MASS (kg)</th>
<th>pH</th>
<th>La (mmol/L)</th>
<th>HR (beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP 11-13</td>
<td>47.5±4.6</td>
<td>a</td>
<td>7.41±0.03</td>
<td>1.89±0.39</td>
</tr>
<tr>
<td>GP 14-15</td>
<td>58.2±6.3</td>
<td>a</td>
<td>7.18±0.02</td>
<td>1.84±0.43</td>
</tr>
<tr>
<td>GP 16-17</td>
<td>67.9±6.8</td>
<td>b</td>
<td>7.15±0.04</td>
<td>1.63±0.39</td>
</tr>
</tbody>
</table>

Explanation: a – before the beginning of the fight; b – three minutes after simulative fight start. The trials were conducted during a period of general physical activity training.

The differences indicate that anaerobic performance potential in older judo athletes (16 years old and above) is increased, which is reflected by a higher intensity and elevated exercise loads as well as training experience.
is at a similar level. Research conducted by Åstrand [1] determined that VO₂max in trained 12-year-old boys amounts to 2.5 L/min, for 13-year-olds – 3.04 L/min, and 14-year-olds 3.25 L/min. The results of our research indicates that the VO₂max of judo athletes and untrained children of the same age are at the similar level. Based on the literature [1, 2] VO₂max stabilizes at approximately the age of 20. According to our own studies, the differences in VO₂max between judo athletes aged 16-17 years and non-sportsmen was not significant.

In the discussed period of ontogenesis, the parameters of power (W), maximal power and maximal power duration increase in the older subjects undergoing judo training. These results suggest functional adaptation of the nervous and muscular systems of young athletes performing specialized motor activity. Furthermore, it is difficult to compare the results of laboratory studies with those at a fighting competition (different motion structure). The answer to this question may be provided under conditions that closely match the start activity, i.e. specialized exertion tests. This can be tested by conducting research that assesses maximal anaerobic performance of children training judo when compared to their untrained peers. Higher concentrations of lactate in the training subjects suggest the specialized training effort used in judo contributes to increased anaerobic metabolism potential. The anaerobic performance dynamics of judo athletes occurring in training and starting cycles depends on multiple factors. First, the content of judo-specific training and start loads (specific complexes of motor acts applied during training that closely match start conditions) is important as well as the biodynamic of performance, duration and intensity level (power) [18, 19]. Individual variability of anaerobic performance potential may be confirmed by genetic studies [20, 21]. Performance dynamics also rely on the individual levels of aerobic and anaerobic performance regarding genetically determined quantitative indicators of muscular fibre ratios [22], and the level of hormonal changes at particular ontogenesis periods of the body [9, 17, 21]. Other factors that affect performance dynamics include: either an increased or insufficient amount and intensity of training load; using training content and biostucture of motion acts other than those at the start (especially in the period of targeted specialized preparations) applied without consideration; motor predispositions and performance levels; and not using appropriate periods of individual rest after exercise during training sessions [16]. This is just a simplified suggestion concerning adolescent athlete training.

Conclusions

VO₂max indices of judo athletes and untrained children of the same age are at a similar level for all the studied ages. This data leads to the conclusion that in young Judo athletes, training the aerobic training process did not receive enough attention, but it could help during the recovery period. No significant differences were reported in terms of VO₂max between the study groups.

The anaerobic performance indicators of children training in judo (W/kg, W average/kg, time to attain W max, time to maintain W max) were significantly better in comparison with untrained peers.

The maximum loads (Wingate test, especially in simulative combats) caused a significant increase in La levels accompanied by a decrease in pH at the chosen period of growth.

The Wingate test is apparently not fully adequate in assessing the anaerobic potential of judo players compared to stimulation activity.

Conflict of interest

The authors declare no conflict of interest.

References

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Author for correspondence:
Jan Jaszczanin
E-mail: nijojan@gmail.com
ARE LOWER LIMB ELECTROMYOGRAM PROFILES SYMMETRICAL DURING A BARBELL SQUAT? (A CASE STUDY)

Krzysztof Kmiecik¹, Henryk Król² ADEFG, Grzegorz Sobota² BC

¹ Student of scientific circle, Department of Biomechanics, Jerzy Kukuczka University of Physical Education in Katowice, Poland
² Department of Biomechanics, Jerzy Kukuczka University of Physical Education in Katowice, Poland

Keywords: barbell squat, EMG, muscle symmetry

Abstract

Aim. The action of the central nervous system that controls neuromuscular functions are reflected by electromyogram (EMG) profiles of muscle activity of those which are basic. However, there seems to be a relationship between the EMG profiles and movement patterns (e.g., values of lower limb joint angles). We would like to find out how EMG profiles and movement patterns changes during the squat movement with increasing loads, and especially, to determine the degree of symmetry of selected homologous muscles. Due to the lack of critical information addressing symmetry, we studied the EMG profiles of six homologous leg muscles (i.e. tibialis anterior, gastrocnemius, rectus femoris, biceps femoris, gluteus maximus and erector spinae) during the squat movement depending on load size.

Basic procedures. For this purpose, we checked the usefulness of the multimodular measuring system (SMART-E, BTS). The system consisted of 6 infrared cameras (120 Hz) and a wireless module to measure muscle bioelectric activity (Pocket EMG). The Smart Analyser software was used to create a database allowing the chosen EMG profiles and movement patterns to be compared. Eleven healthy men participated in this study; however, two were selected for analysis. The first of subject was 36 years old (body mass 82 kg; body height 180 cm; 1RM in full squat 140 kg). The second was 28 years old (body mass 90 kg; body height 183 cm; 1RM in full squat 110 kg).

Results and main findings. The subjects performed consecutive sets of a single repetition of the full squat with increasing load (70, 80, 90 and 100% 1RM of the anticipated maximum weight) until the appointment of one maximum repetition. For analysis, however, only samples with moderate and maximal loads (70% and 100% 1RM, respectively) were selected.

Conclusions. The mean of the absolute values regarding differences in the amplitude magnitudes of individual pairs of homologous muscles was taken as a measure of symmetry of the EMG profile. The load increase during the squat contributed to an increase in profile asymmetry of the lower limb homologous muscles pairs. The slightly lesser asymmetry may have caused worsening movement fluidity.

1. Introduction

Subjects of trails in which a squat with maximum load is performed often show changed motor patterns compared to those trials with moderate loads. Such altered patterns have also been demonstrated, for example, in people with anterior cruciate ligament injury during gait, functional movements and regular rehabilitative exercises [1-3]. This may be partly due to temporary sensorimotor disturbances. The action of the central nervous system, controlling neuromuscular functions, reflects the profiles of electrical activity of major muscle contractions (elec-
tromyograms – EMG), in this case, of the lower limbs. Thus, it seems that there should be a connection between EMG profiles and motor patterns.

According to Yang and Winter [4], “… movement is the effect of interactions between muscle tension, controlled by the central nervous system, and mechanical requirements of the motor task”. An understanding of how the nervous system responds to changes related to the mechanical requirements of the task is necessary to understand motor control. The mechanical requirements of a squat with an increasing load vary considerably. For this reason, they can be a good example in examining the relationship between these requirements and the behaviour of the nervous system.

The electrical activity of a muscle is a reflection of both the exit from the neuron terminals (from the nervous system) and the entry into the mechanical system. Hence, the size of EMG amplitudes and their course over time can provide information on both of these systems. Changes in EMG amplitudes during a barbell squat were examined by, among others, Gullett et al. [5] and Contreras et al. [6], but they presented only the results of the global measurement – average EMG for all phases: descent and ascent. Such a global measurement could mask significant differences in EMG at particular phases. Therefore, there is a real need to more accurately determine EMG changes in squats with different loads, both in terms of size of the amplitude and time of their occurrence.

In order to determine whether the EMG profile of a given limb is appropriate, it should be compared with some control, for example the opposite limb, or with the profile of a specific population. The opposite limb is a potentially valuable control, because it is possible to avoid population variables as well as others (e.g. squat speed). However, to ensure that the given homologous muscle profiles are actually different, their symmetry/asymmetry should be quantified.

Robertson et al. [7] presented EMG linear envelopes as profiles of muscle activity during the entire squatting movement, which were normalized for the maximum contractions of each subject, but did not raise the issue of symmetry. In another article, Yavuz and Erdağ [8] did the same, presenting EMG profiles as the average electrical activity of selected muscles at constant time intervals. However, Arsenault et al. [9] had already paid particular attention to the problem of symmetry when they showed the high correlation between shapes of entire courses of previously straightened and filtered EMG signals for the homologous rectus femoris and soleus muscles in adults during gait. In the opinion of Ünpuu and Winter [10], while aggregate data (e.g. global mean values for entire characteristics [11]) reflect proper symmetry based on statistical analysis, they cover up the asymmetry of individuals. In addition, by presenting data on the movement of a single individual, it is possible to identify such elements of movement technique (i.e. motor pattern) that are associated with achieving better results [12-13].

Due to the lack of critical information on symmetry, we examined EMG signals of six homologous lower limb muscles when squatting with a barbell. We would like to learn how EMG profiles and squat movement patterns change along with a change in load, and to determine the degree of symmetry/asymmetry of six selected homologous muscles.

2. Material and methods

2.1. Characteristics of the subjects

This work is a fragment of a doctoral dissertation in preparation. Eleven healthy men recreationally performing strength exercises voluntarily participated in the research conducted at the Biomechanics Department of Jerzy Kukuczka University of Physical Education in Katowice. However, since the evaluation and improvement of the technique (way of performing) sports activities always refer to a specific person, the work presents the characteristics of symmetry of homologous muscles and the motor pattern for two exemplary representatives of strength sports. The first of the subjects is 36-year-old A.M., who has 15 years of training experience, weighs 82 kg and is 180 cm tall. The second is 28-year-old R.N., with 4 years training experience, weight 90 kg and height 183 cm. Approval of the University Bioethics Committee for Scientific Research at the Jerzy Kukuczka University of Physical Education in Katowice was obtained.

2.2. Research protocol and procedures

In the measurement session, the subjects squatted with a barbell of increasing weight until establishing one maximal repetition – 1RM. In the case of A.M., the weights of the lifted bar was 100, 115, 130 and 140 kg, respectively, and R.N., 80, 90, 100 and 110 kg, respectively. Only the samples of extreme loads (70 and 100% 1RM, i.e. 100 and 140 kg respectively for the first and 80 and 110 kg respectively for the second one) were selected for the analysis.

The research involved squatting with the “free” barbell, held in back of the shoulders. In baseline position, the subjects set their feet to the width of their shoulders, with the toes turned slightly outwards. The squatting movements started from an upright position, by bending in the hip, knee and ankle joints, then shifting to the lowest lower position. After reaching the desired depth of the squat, the subjects raised themselves back to an upright position. The lumbar spine was kept in a neutral position throughout the entire ascent period, and the

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trunk remained in an almost vertical position at this time. The feet of the subjects were stably and firmly placed on the ground so that during the entire squatting movement, their whole sole adhered to the surface. At the appropriate depth of the squat, the thighs slightly crossed the line parallel to the ground, at which time the hip and knee joints were greatly bent. The subjects squatted with the barbell in a calm, controlled manner, to the lowest position (descent phase), and then without stopping, smoothly and quickly raised up to full extension of the knee and hip joints (ascent phase). Two strong individuals with several years of experience in resistance training, secured (belayed) the subjects in the case of a potentially incorrect attempt.

2.3. Registration of parameters

To record the parameters of the athlete and barbell movement, while squatting with the barbell on the shoulders, the Smart-E measuring system (BTS, Italy) was used, which was simultaneously programmed for multidimensional motion analysis. In short, the system consists of six infrared cameras and a wireless module for measuring the bioelectric activity of Pocket EMG muscles. In addition, the Kistler 9182C force platform (KISTLER, Switzerland) was used. Electrical activity was recorded using surface electrodes for muscles on both sides of the body (homologous): tibialis anterior (TA), the medial part of gastrocnemius medialis (GMed), the long head of the biceps femoris (BF), rectus femoris (RF), gluteus maximus (GMax) and the lumbar section of erector spinae (ES). The electrodes were placed above the sites of muscle motor activity, in accordance with the European SENIAM recommendations for surface electromyography [14]. A full description of the used measurement tools and procedures as well as methods of processing the obtained signals were presented in earlier works as part of the cyclic Seminars of Sport Biomechanics and Rehabilitation [12-13, 15-16]. This modern system allows analysis of motion based on comprehensive image registration of motor function technique (here a squat), including the measurement of kinematic and kinetic parameters (external motion structure [17]) as well as bioelectric activity of the muscles at work (internal structure). All measurements, and thus obtained characteristics, were temporarily synchronized by using a main processor. The research material collected in this way will be thoroughly analysed in the preparation of the doctoral dissertation. In this work, the EMG profiles of only selected muscles were analysed, as well as the characteristics of angles in the knee joints (motor patterns) of the two participants examined, which are the subject of our current research.

2.4. EMG data reduction and testing procedure

The raw EMG signal was filtered (Butterworth filter band 20-250 Hz), straightened and smoothed using the root-mean-square (RMS) method with a 100 ms mobile window. The mean value was calculated from RMS EMG in millivolts, separately for the descending and ascending phases of each barbell squat. For this purpose, the Smart Analyzer programme (BTS, Italy) was used. In order to compare the activity between homologous (compatible) muscles and obtain biologically important data, normalization of maximal voluntary contractions (MVC) was performed for each muscle, in accordance with the procedures described by Konrad [18]. Measurements of the 3-second maximal contraction of each muscle were performed in static conditions, and the intervals between them were 1 minute long. EMG [% MVC] data for all muscles were divided into descending and ascending phases.

In order to determine the degree of symmetry of homologous muscles, the modulus (absolute value) of differences in normalized EMG values between the pair of homologous muscles at 100 time-normalized points was calculated first. These data were then averaged for the whole squatting movement and for each phase separately. Thus, the symmetry degree of the EMG profiles was determined by means of two measures: the mean of modules of amplitude differences between individual pairs of homologous muscles for the squatting movement (MMAD) and the mean for two phases of movement calculated in the same way (descent – MMAD and ascent – MMAD, respectively). A larger value of these measures indicates lower symmetry of the EMG profiles of the compared muscles, and vice versa, the smaller value indicates greater symmetry. All calculations were performed using an Excel spread-sheet.

3. Results

Assuming MMAD, MMAD and MMAD as a measure of homologous muscle symmetry was justified due to the great similarity of the EMG profile shape in particular muscle pairs (Fig. 1 and 2).

The calculated MMAD measurement values for particular homologous muscle pairs in trials with the 70 and 100% 1RM loads are presented in Tab. 1 and 2.
Figure 1. EMG profiles normalized according to amplitude and time [% MVC] for three pairs of homologous lower limb muscles (TB – tibialis anterior, GMed – gastrocnemius mediale, RF – rectus femoris) of subject A.M. Attempts at squat movement (during the descent and ascent phases) were performed with the following loads: A) 70% 1RM and B) 100% 1RM

Table 1. Mean of modules of amplitude differences – MMAD [% MVC] for the pairs of homologous muscles of lower extremities of A.M. subject. Attempts of squat movement were performed with a 70 and 100% 1RM (one repetition maximum) load. Explanation of followings symbols in the text.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>70% 1RM</th>
<th>100% 1RM</th>
</tr>
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<tbody>
<tr>
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</tr>
<tr>
<td>GMed</td>
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<td>4.0</td>
</tr>
<tr>
<td>RF</td>
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<td>17.5</td>
</tr>
<tr>
<td>BF</td>
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<td>14.2</td>
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<tr>
<td>GMax</td>
<td>96.5</td>
<td>77.1</td>
</tr>
<tr>
<td>ES</td>
<td>32.3</td>
<td>40.8</td>
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</tbody>
</table>
Are lower limb electromyogram profiles symmetrical during... 

**Figure 1.** EMG profiles normalized according to amplitude and time [% MVC] for three successive pairs of homologous lower limb muscles (BF – biceps femoris, GMax – gluteus maximus, ES – erector spinae) of subject A.M.. Attempts at squat movement (in the descent and ascent phases) were performed with the following loads: A) 70% 1RM and B) 100% 1RM.

**Table 2.** Mean of modules of amplitude differences – MMAD [% MVC] for the pairs of homologous muscles of lower extremities of R.N. subject. Attempts of squat movement were performed with a 70 and 100% 1RM load. Explanation of followings symbols in the text.

<table>
<thead>
<tr>
<th>Muscle</th>
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<th>100% 1RM</th>
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<tbody>
<tr>
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<td>10.3</td>
</tr>
<tr>
<td>GMed</td>
<td>9.2</td>
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<tr>
<td>RF</td>
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<tr>
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<tr>
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<tr>
<td>ES</td>
<td>16.1</td>
<td>30.0</td>
</tr>
</tbody>
</table>

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Figure 2. EMG profiles normalized according to amplitude and time [% MVC] for three pairs of homologous lower limb muscles (TB – tibialis anterior, GMed – gastrocnemius mediale, RF – rectus femoris) of subject R.N. Attempts at squat movement (in the descent and ascent phases) were performed with the following loads: A) 70% 1RM and B) 100% 1RM

Table 3. Mean of modules of amplitude differences [% MVC] for the pairs of homologous muscles in descent and ascent phases (MMAD\textsubscript{des} and MMAD\textsubscript{asc}, respectively) of squat movement of A.M. subject. Attempts of the squat were performed with a 70 and 100% 1RM load. Explanation of followings symbols in the text.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>70% 1RM</th>
<th>100% 1RM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Descent phase MMAD\textsubscript{des}</td>
<td>Ascent phase MMAD\textsubscript{asc}</td>
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<tr>
<td>ES</td>
<td>21.1</td>
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</table>
Are lower limb electromyogram profiles symmetrical during…

**Table 4.** Mean of modules of amplitude differences [% MVC] for the pairs of homologous muscles in descent and ascent phases (MMAD_{des} and MMAD_{asc}, respectively) of squat movement of R.N. subject. Attempts of the squat were performed with a 70 and 100% 1RM load. Explanation of followings symbols in the text.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>70% 1RM</th>
<th>100% 1RM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Descent phase (MMAD_{des})</td>
<td>Ascent phase (MMAD_{asc})</td>
</tr>
<tr>
<td>TB</td>
<td>9.5</td>
<td>6.5</td>
</tr>
<tr>
<td>GMed</td>
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<td>9.7</td>
</tr>
<tr>
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<tr>
<td>BF</td>
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<tr>
<td>GMax</td>
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<td>18.0</td>
</tr>
<tr>
<td>ES</td>
<td>15.4</td>
<td>16.9</td>
</tr>
</tbody>
</table>
Data from Tab. 1 indicate that subject A.M., in the 100% 1RM test, is generally characterized by higher asymmetry (increase in the MMAD value) than in the squat with a 70% 1RM load. In the case of the *tibialis anterior* muscle, the MMAD value was almost twice as high; however, with respect to the *gluteus maximus* muscle, it was smaller. For the other four muscles, the MMAD value was also higher during the squat with a 100% 1RM load, although not as much as for the *tibialis anterior* muscle (Tab. 1). The second stage of the squat was usually accompanied by a larger MMAD increase for individual muscles (Tab. 3, MMAD₂), with the exception of the *gastrocnemius medialis* muscle.

In relation to the second subject (R.N., Tab. 2), the MMAD value for one of the muscles (*erector spinae* – ES) was almost twice as high during the squat, and the second one (*gluteus maximus* – GMax), almost one and a half times higher than obtained in the trial with a moderate load (70% 1RM). There were, however, 2 muscles (*rectus femoris* – RF, *biceps femoris* – BF) for which the MMAD value in the squat with 100% 1RM load was slightly smaller. Nonetheless, it cannot be said that the increase in the accepted measure of symmetry occurred mainly during the ascent phase (Tab. 4), it was rather uniform.

4. Discussion

In the past, profiles (graphs) of lower limb electromyograms showing muscle activity were used to assess gait as a measure of disorders (abnormal) in neuromuscular function [19] and when walking at different rates [4]. However, we were interested in the profiles of muscle activity during a full squat with a barbell on the shoulders and with an increasing load. Amplitude values and the temporal EMG profile were used considering functional symmetry of homologous muscles of the left and right lower limb, i.e. bilateral or two-sided muscles. On the basis of such profiles, some differences can be detected, too subtle, however, for their direct observation.

To determine whether the EMG profile of the specific lower limb muscle is appropriate, it was compared with the profile of the homologous muscle of the other limb.Arsenault et al. [9] quantitatively demonstrated (based on correlation coefficients) the high degree of symmetry in EMG profiles for the population on the example of horizontal gait in a strongly differentiated group of subjects, i.e. for the totalled (global) mean values of all the characteristics (grand ensemble averages [4, 7, 11]) of two homologous muscles (*rectus femoris* and *soleus*). In our case, the second limb was a good foundation for comparison, because it was possible to avoid population variables, and at the same time, to show the impact of load size on symmetry.

With reference to the squat, Robertson et al. [7] presented linear envelope electromyograms as muscle activity profiles. They were normalized for the maximal voluntary contractions of each subject. Recently, similar characteristics were obtained for performing a squat with a barbell by Yavuz and Erdag [8]. The shapes of our RMS EMG [% MVC] characteristics, obtained separately for the left and right lower limbs (Fig. 1 and 2) also show high agreement with these envelopes. This allowed to determine the symmetry degree of the homologous muscle activity.

For this purpose, the normalized characteristics of RMS EMG were compared at points temporally normalized. For individual homologous muscle pairs, the mean of modules of amplitude differences from all points is the measure of symmetry of EMG profiles. Taking the entire squat movement with the 100% 1RM load into account, the subject A.M. is characterized by lower symmetry of the profiles of the homologous muscles tested, compared to the 70% 1RM load, because the MMAD value for these muscle pairs is higher, except for the GMax muscle (Tab. 1). For subject R.N., in the case of two muscles (RF and BF), slightly higher MMAD values were for the 70% 1RM load (Table 2). Although A.M. was characterized by a slightly higher increase in the average difference of amplitudes for individual muscles during the ascent phase (greater asymmetry, Tab. 3., MMADasc), for R.N., the distribution was already more even and the increase took place during both the 1st and 2nd phases of the squat (Tab. 4).

Nonetheless, there is a relationship between EMG profiles showing muscle activity and motor patterns in people performing various activities of everyday life. On the example of people with trauma of the anterior cruciate ligament, Trulsson et al. [20] showed that during gait, specific, altered movement patterns are associated with deviations in muscle activity between the damage and undamaged side. They stated that "... in order to identify altered motor patterns, reliable, valid and quantitatively observable assessments are needed." However, we believe that "quantitative observation evaluation" is not enough – measurements need to be performed.

In this study, as has been mentioned several times, a full shoulder barbell squat with moderate and maximal loads was analysed, and the characteristics of the knee joint angle were considered as the motor pattern. Yavuz and Erdag [8] mention the change in hip joint pattern along with an increase in trunk inclination during the performance of squats with a maximum load. However, this has not been verified in our analysis. Nevertheless, large differences were found in the compared temporal characteristics of the angle in the knee joint of the two subjects (A.M. and R.N.) with a 100% 1RM load, which can be seen in Figure 3 (during the ascent phase).
This is also confirmed by the recordings conducted using an additional digital camera, in which the knee joint and the hip girdle rotations (once in one direction and then in the opposite) occur during A.M.’s ascent phase. The image of these movements is, among others, the mentioned, irregular angle change (decreases and increases) in the knee joint. The loss of movement fluidity [17] visible in the case of subject A.M. may be associated with slightly higher asymmetry of activity (i.e. slightly higher MMADdes values compared to MMADDasc), the main muscles propelling and stabilizing the knees and the hip girdle (RF, BF, GMax and ES). However, similar differences also occurred in A.M. during the trial with the 70% 1RM load.

According to Arendt-Nielsen et al. [22], clinical and experimental results indicate that during gait, this motor activity is modulated by musculoskeletal pain, probably as a reflex. Perhaps in the case of squatting with a barbell on the shoulders, such a factor modulating the pattern of this movement is the very high load during the 100% 1RM test (high intensity of this exercise). Although the technique of movement (sports) is recommended to remain independent of the intensity of the exercise [23], from the observation of many coaches, it follows that if the load reaches the limits of athletes’ ability, they can change the movement pattern of the performed exercise. And this is probably the case of the squat examined for A.M.

5. Conclusions

The increase in the size of the load during the barbell squat caused an increase in the asymmetry of the selected homologous muscles of the lower limbs. Its expression is the higher MMAD values in both presented cases (subjects A.M and R.N.). However, the data for the first subject deserve particular attention, in which the greater asymmetry occurred mainly during the ascent phase (higher MMADdes values in comparison to MMADDasc). Subject R.N. was characterized by a more uniform MMAD distribution in both phases.

The relationship of EMG profiles with motor patterns may be indicated by the characteristics of knee joint of both subjects during the ascent phase of the squat with a 100% 1RM load (Fig. 3). A.M. rotated his knees and hip girdle several times while ascending with the barbell (once in one and once in the other direction), which resulted in less smooth movement (uneven change of angle in the knee joint). Perhaps it is a consequence of greater asymmetry in the key fragments of EMG profiles of the main knee and hip girdle muscles involved in squats performed with a maximal load.

6. Acknowledgements

The research was possible thanks to the financial support of the Ministry of Science and Education as well as Jerzy Kukuczka University of Physical Education in Katowice.

References


THE INFLUENCE OF PLANTAR SHORT FOOT MUSCLE EXERCISES ON FOOT POSTURE AND GAIT PARAMETERS IN LONG-DISTANCE RUNNERS

Iwona Sulowska1 ABCDEF, Anna Mika1 ABCDEF, Łukasz Oleksy1,2 ABCDEF

1 Department of Clinical Rehabilitation, University of Physical Education in Krakow, Krakow, Poland
2 Oleksy Physiotherapy, Łańcut, Poland

Keywords: short foot muscles, foot muscle exercise, Foot Posture Index, gait

Abstract

Aim. The aim of this study was to evaluate the influence of exercises of plantar short foot muscles on foot posture and gait parameters in long-distance runners.

Basic procedures. The study involved 48 long-distance runners aged 21-45 years. The runners performed short foot muscle exercises daily for 6 weeks. The Foot Posture Index (FPI-6) and gait parameters (G-walk) were measured twice: at baseline and after 6 weeks of exercises.

Result. Lower values of the Foot Posture Index (FPI-6) were observed. In the assessment of gait parameters, runners obtained lower cadence, walking speed, stride length and %stride length/height. Gait cycle duration was increased.

Conclusions. Exercises strengthening short foot muscles have beneficial effects on foot alignment by change of foot posture from slight pronation towards a neutral foot. Change of gait parameters may indicate improvement of motor control and shifting natural and comfortable walking speed towards lower values. The short foot muscle exercises should be included as part of the daily training programme of runners.

Introduction

Running is one of the most common forms of activity. Due to the easy accessibility and positive influence on physical condition, the popularity of this discipline is constantly growing. However, it can cause injuries and overloads, especially in the lower limbs [1]. Based on the results available in literature on the subject, it is estimated that from 27 to 70% of people running recreationally and professionally suffer trauma per year. Nearly 50% of injuries affect the knee joint. The most frequently reported complaint is the patellofemoral syndrome, followed by the iliobibial band syndrome, meniscus damage and patellar tendinitis. Almost 40% of the remaining injuries are in the foot, ankle and lower leg. The plantar fasciitis, Achilles tendinitis, and medial tibial stress syndrome can be mentioned here. In contrast, damage above the knee joint accounts for less than 20% of all trauma suffered by runners [2].

During walking and running, there are three levels of movement within the lower limb: frontal, sagittal and transverse. During first contact with the ground, three phenomena occur: shock absorption, stabilization of the joints and flexible adjustment of the foot. Shock absorption is achieved by bending in the hip and knee joints and pronation in the ankle joint. This allows to reduce impact force. Pronation is a combination of dorsal flexion of the ankle, eversion of the rearfoot (calcaneus) and forefoot abduction, and occurs in the first half of the support phase while walking or running [2]. Pronation causes...
some degree of relaxation between the tarsal bones, and then other mechanisms stabilizing the arches of the foot, which facilitates the adaptation of the foot to the ground and increases its elasticity [3]. This is especially important for long-distance runners, as they are exposed to long-term loads. Research indicates that pronation is a favourable phenomenon in running, provided that it does not go beyond the physiological limits and is not continued after the middle support phase is over [4].

Both posture of the foot inclining towards excessive pronation or supination are indicated in the literature as a risk factor for injury [5, 6]. The type of the foot determines its mobility and affects the kinematics of the lower limb joints. The reduced longitudinal arch of the foot is associated with its greater mobility than in the case of pes cavus [7-9]. In most cases, injuries in people with flat feet are the result of greater susceptibility to tissue damage associated with exceeding physiological ranges of motion [10] or incorrect compression of the subtalar and transverse talar joint [11]. On the other hand, in people with an elevated foot arch, lower mobility rate can be observed, which predisposes to injuries associated with weakening cushioning mechanism and increasing pressure on the plantar surface of the foot while walking or running [12, 13].

Analysis of foot posture is an important element in the comprehensive assessment of runners. The most commonly used diagnostic methods include orthopaedic, anthropometric, plantoconturographic or functional examination methods [14-16]. However, one of the more easily available and simple to use tools is the Foot Posture Index, which provides comprehensive foot assessment in all areas, including the plantar and dorsal surfaces of the foot. It has wide clinical application in assessing the risk of injuries in athletes [17, 18]. The test is carried out in static conditions – in a standing position, however, research indicates the existence of a strong relationship between the final result of the test and the mobility of the rearfoot during gait [20]. Analysing individual parts of the FPI-6, the largest correlations with the results of the dynamic study occur in the evaluation of the medial longitudinal arch of the foot and the assessment of the calcaneus in the frontal plane [21].

Comparing kinematics of the lower limbs during gait in people with a neutral foot and with a tendency to pronation, greater mobility during the support phase in the second case can be observed. In particular, these differences are visible in the mobility of the calcaneus during propulsion. In the frontal plane, a larger extent of the eversion and the total range of mobility of the rearfoot are observed [22-24]. Also, metatarsus and forefoot mobility in people with a lowered longitudinal arch is increased and lasts longer than in the case of a neutral foot [22-25].

Dynamical stability is a key element during movement [26]. Resistance to exogenous and endogenous disturbances of balance is a prerequisite for proper gait. The vestibular organ, the sight organ and the sensorimotor system are responsible for the control of stability. The latter is created by skin and deep sensory receptors, particularly from the plantar surface of the foot and the area around the ankle. Therefore, the correct distribution of foot load is an element affecting dynamic stability control and is a condition for proper gait [27].

In dynamic conditions, such as walking or running, stability allows to continue the functional movement, despite the occurring external and internal destabilizing forces. Dynamic stability analysis should take into account the changing moments of muscle strength and changes in the position of body segments in space [28]. Studies to date indicate that the measurement of the variability value in terms of kinematics and temporal-spatial parameters can be used to estimate dynamic stability control [29, 30]. It is assumed that increasing the variability of these parameters, and thus reducing the repeatability of individual strides, reduces stability. The variability of these parameters depends on the speed of walking, which may suggest the influence of speed on stability [31, 32]. Gait speed may depend on many factors – among others, on the age, height or strength of lower limb muscles. These factors affect maximal gait speed in particular [33]. When moving at a comfortable (natural) speed, the variability of the temporal-spatial and kinematic parameters of walking is the smallest, and, thus motor-control ability is the largest [34]. Both walking at higher and lower speeds increases the variability of its parameters [32, 35, 36]. There are, however, scientific reports indicating an improvement in dynamic stability while walking at a slower speed, despite the increase in its variability. Researchers suggest that the neuromuscular control system is more effective in controlling exogenous and endogenous balance disturbances during slow gait than in the case of movement at higher velocities [34, 37].

Individuals who practice long-distance running are exposed to long-lasting loads, which is why shock absorption during running and walking is a key mechanism in this group. The correct posture of the foot is a contributing factor [4]. The results of previous studies by the authors, as well as the works of other authors, indicate that foot posture is beneficial for exercise of the short plantar muscles of the foot surface [38-40]. There are no reports in the literature on the relationship between changes in foot posture under the influence of exercises with dynamic stability and changes in the gait pattern. The aim of this study was to assess the impact of short foot plantar exercise on foot posture and gait parameters in people practicing long-distance running at an amateur level.
Material and methods

1. Description of the study group

48 people (17 women and 31 men) aged from 21 to 45 years (32.5 ± 6.81), regularly engaging in long-distance running at an amateur level, took part in the study. The respondents ran from 20 to 100 kilometres per week (average 42.19 km ± 18.54 km). Runners were qualified for testing after meeting the inclusion criteria and taking the exclusion criteria into account. The following inclusion criteria were adopted: age within the range of 20-45 years, regular running training with weekly kilometre amount of not less than 20 km and consent to participate in the research. In contrast, the exclusion criteria were: age below 20 years or over 45 years, lack of consent to participate in research, lack of regular running training (less than 20 km weekly), deformations within the foot or injuries to the musculoskeletal system 6 months prior to testing.

The study participants performed exercises activating the short muscles of the plantar surface of the feet for 6 weeks. During this time, the runners performed their current running training, which was monitored by the researchers and did not change throughout the duration of the experiment. Measurements of selected parameters were performed before the start of training and after six weeks of exercise. Each runner was instructed on the purpose and course of the study and expressed his/her written consent to participate in the project. Prior to the study, the approval of the Bioethics Committee at the Regional Medical Chamber in Krakow was obtained for conducting the medical experiment (No. 40/KBL/OIL/2015 dated 15 April 2015). The study was registered in the Australian and New Zealand Clinical Trials Registry (ANZCTR) international database for clinical trials.

2. Research tools

2.1. The Foot Posture Index (FPI-6)

The Foot Posture Index is used for comprehensive and multi-levelled assessment of the feet. It consists of six parts, evaluating the various elements of the fore- and rearfoot:

1) Talar head palpation,
2) Supra and infra lateral malleolar curvature,
3) Inversion/eversion of the calcaneus,
4) Prominence in the region of the talonavicular joint,
5) Height and congruence of the medial longitudinal arch,
6) Abduction/adduction of the forefoot on the rear foot [19].

Each of these elements is evaluated on a scale from -2 to +2. Negative values indicate supination and positive values demonstrate pronation. The neutral position of the foot is classified as 0. The total sum of points allows for overall assessment of foot posture according to the following classification:

- from -12 to -5 points – foot with increased supination,
- from -4 to -1 points – foot with light supination,
- from 0 to +5 points – neutral foot,
- from +6 to +9 points – foot with light pronation,
- from +10 to +12 points – foot with increased pronation [19].

Studies conducted by Oleksy et al. [19] indicate that this tool is characterized by high repeatability of measurements for the same researcher. The value of the measurement repeatability coefficient R between the first and second test for all evaluated parameters was from 0.89 to 0.96.

2.1.1. Talar head palpation assessment

The talar head was examined by touch on the lateral and medial sides. It was the only measured based on palpation assessment and not visual evaluation [19].

2.1.2. Supra and infra lateral malleolar curvature observation

The researcher observed the supra and infra lateral malleolar curvature. Those which are correct should be equal. In the foot with increased supination, the supra lateral malleolar curvature is more concave than infra curvature. In the case of pronation, the opposite occurs. [19].

2.1.3. Inversion/eversion assessment of the calcaneus

Inversion/eversion assessment of the calcaneus. This measurement was based on visual assessment of calcaneus in the frontal plane. Angular measurements were not required [19].

2.1.4. Prominence assessment in the region of the talonavicular joint

In the neutral foot, the surface of the skin in this area is flat. This area becomes curved if the head of the talus is adducted, which occurs in the case of pronation. When the foot is in supination, the TNJ area is concave [19].

2.1.5. Height and congruence assessment of the medial longitudinal arch

Assessing the medial longitudinal arch of the foot, its height and posture were taken into account. In the neutral foot, the curvature of the arch is relatively even and resembles a segment of the circumference of a circle. When the foot is in pronation, the arch is lowered and flattened in the medial part. However, in the case of supination, the curvature is more acute in the rear part [19].

2.1.6. Abduction/adduction assessment of the forefoot on the rear foot

The researcher assessed the forefoot position by looking at the long axis of the heel from the back. In the neu-
tional foot posture, the forefoot is noticeably even on both sides of the heel. In the case of pronation, lateral toes are more visible, and in supination – the medial ones [19].

2.2. BTS G-walk motion sensor

The BTS G-Walk motion sensor (G-Sensor®, BTS Bioengineering S.p.A., Italy) was used to assess temporal-spatial parameters, motion symmetry, propulsion and pelvic movements. The belt along with the motion sensor was placed at the height of the fifth lumbar vertebra. The tool is a portable system for functional motion analysis, using three-axis accelerometers, magnetic field sensors and gyroscopes. The assessment of trunk movements allows the assessment of individual components of the gait pattern [41-43]. The test results indicate high repeatability of measurements using accelerometers (the intra-class correlation coefficient of ICC ranged from 0.7 to 0.97) [44].

For the needs of the present study, the “Gait” protocol was used, which determined the gait pattern based on a special algorithm analysing heel and toe detachment as well as normalizing acceleration and pelvic angles during the gait cycle.

During the test, consisting of walking a 70-meter section, the following parameters were obtained:
- speed;
- cadence (strides/min);
- step and stride length;
- step width;
- gait cycle duration;
- support and swing phase duration;
- single and double support phase duration;
- symmetry index;
- propulsion;
- pelvic mobility.

Data from the device were transferred to a computer via Bluetooth [45].

3. The set of exercises

Each study participant received a set of exercises activating the short plantar muscles of the feet. After the first test, the runners were taught how to perform the exercises correctly. In addition, they received instructions in writing.

The set included several exercises that were performed daily by the subjects, including their performance in writing.

3.1. Exercises

- Vele’s Forward Lean – consisted of maximal forward inclination from a standing position, with arms along the trunk, keeping the body in one line and not detaching the heels from the ground [46,47].
- Reverse Tandem Gait – consisted of walking backwards, setting one foot after the other. First, the metatarsus was loaded and then the heel was added [46, 47].
- Short Foot Exercise – they consisted in shortening the foot in the anterior-posterior dimension by bringing the metatarsal bone heads towards the heel, and then – in shortened foot position – clamping the three support points. The toes remained relaxed during this time, and the foot rested on the ground. Increasing the level of difficulty consisted in changing the position. The first exercise was performed while seated, the second was performed in a standing position, while in the third exercise, a half-squat was additionally performed [46, 47].

Exercises on the sensorimotor cushion – the set included several exercises in a single and double standing position. The exercises with the Thera-band type tape – strengthening the muscular-ligamental apparatus around the ankle joint, took the movements of flexion and extension and pronation and supination with resistance into account.

4. Statistical analysis

Statistical elaboration was performed using the STATISTICA 12.0 PL programme. Normality of variable distribution was checked using the Shapiro-Wilk test. ANOVA was used to assess the significance of differences among studied variables in the evaluation of gait parameters, while in the case of the Foot Posture Index (FPI-6), the non-parametric Wilcoxon test was used. Differences were considered statistically significant if the test probability level was lower than the adopted level of significance ($p < 0.05$).

Results

1. Foot Posture Index (FPI-6)

After 6 weeks of exercise, lower values of the Foot Posture Index (FPI-6) were observed. These changes were statistically significant regarding all the components of the indicator within the left (Fig. 1) and right foot (Fig. 2). A statistically significant change was also observed as a result of the overall FPI-6 index. In the first examination, the median value was 6 in the left foot and 5 in the right one. After the implemented training session, these values decreased to 2 in the left foot ($p=0.00000$) and to 2 in the right one ($p=0.00000$).
The influence of plantar short foot muscle exercises on foot...

**Fig. 1.** The Foot Posture Index – results at baseline and after 6 weeks of exercising for the left lower limb. Values are expressed by median +/- quantile range

FPI 1 – Talar head palpation; FPI 2 – Supra and infra lateral malleolar curvature; FPI 3 – Inversion/eversion of the calcaneus; FPI 4 – Prominence in the region of the talonavicular joint, FPI 5 – Height and congruence of the medial longitudinal arch, FPI 6 – Abduction/adduction of the forefoot on the rear foot

\( p^* \) between baseline and 6th week

**Fig. 2.** The Foot Posture Index – results at baseline and after 6 weeks of exercising for the right lower limb. Values are expressed by median +/- quantile range

FPI 1 – Talar head palpation; FPI 2 – Supra and infra lateral malleolar curvature; FPI 3 – Inversion/eversion of the calcaneus; FPI 4 – Prominence in the region of the talonavicular joint; FPI 5 – Height and congruence of the medial longitudinal arch; FPI 6 – Abduction/adduction of the forefoot on the rear foot

\( p^* \) between baseline and 6th week
2. G-walk inertial sensor

After 6 weeks of training, the runners obtained statistically significantly lower cadence, walking speed, stride length and stride length/height in the assessment of temporal-spatial gait parameters (Tab. 1). Gait cycle duration significantly increased (for the left and right lower limbs) (Tab. 1). No significant changes were observed for other parameters (Tab. 1).

Discussion

The aim of the study was to assess the impact of plantar short muscle exercises on foot posture and gait parameters in individuals practicing long-distance running at an amateur level. The results obtained indicate that the six-week training had a positive effect on the foot posture. The applied exercise programme also influenced the change of some of the temporal-spatial gait parameters. There are no reports in the literature on linking the change in the foot posture under the influence of exercise with dynamic stability and the change in gait pattern. This is the first work to undertake the topic.

Among many risk factors for injuries in runners, one group is those related to the foot. These include disorders of biomechanical or anatomical structure of the foot, reduced flexibility, muscular imbalance or weakened strength. As external factors, the type of substrate

### Table 1. Change of gait parameters after 6 weeks of exercises

<table>
<thead>
<tr>
<th>Parameters</th>
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<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadence [strides/min]</td>
<td>116.42 +/- 10.56</td>
<td>114.18 +/- 9.26</td>
<td>0.028171</td>
</tr>
<tr>
<td>Speed [m/s]</td>
<td>1.30 +/- 0.19</td>
<td>1.24 +/- 0.23</td>
<td>0.019630</td>
</tr>
<tr>
<td>Stride length [m]</td>
<td>1.34 +/- 0.17</td>
<td>1.30 +/- 0.18</td>
<td>0.022088</td>
</tr>
<tr>
<td>Stride length/height [%]</td>
<td>80.66 +/- 20.07</td>
<td>76.31 +/- 16.13</td>
<td>0.006880</td>
</tr>
<tr>
<td>Gait cycle duration L [s]</td>
<td>1.04 +/- 0.10</td>
<td>1.06 +/- 0.10</td>
<td>0.018043</td>
</tr>
<tr>
<td>Stride length L [% stride length]</td>
<td>50.71 +/- 1.45</td>
<td>50.53 +/- 1.67</td>
<td>ns</td>
</tr>
<tr>
<td>Support phase duration L [% gait cycle]</td>
<td>63.69 +/- 3.22</td>
<td>63.52 +/- 2.63</td>
<td>ns</td>
</tr>
<tr>
<td>Swing phase duration L [% gait cycle]</td>
<td>36.31 +/- 3.22</td>
<td>36.48 +/- 2.63</td>
<td>ns</td>
</tr>
<tr>
<td>Double support phase duration L [% gait cycle]</td>
<td>12.97 +/- 3.04</td>
<td>12.81 +/- 2.42</td>
<td>ns</td>
</tr>
<tr>
<td>Single support phase duration L [% gait cycle]</td>
<td>37.47 +/- 2.64</td>
<td>37.90 +/- 2.44</td>
<td>ns</td>
</tr>
<tr>
<td>Gait cycle duration R [s]</td>
<td>1.04 +/- 0.10</td>
<td>1.06 +/- 0.10</td>
<td>0.022126</td>
</tr>
<tr>
<td>Stride length R [% stride length]</td>
<td>49.29 +/- 1.45</td>
<td>49.48 +/- 1.67</td>
<td>ns</td>
</tr>
<tr>
<td>Support phase duration R [% gait cycle]</td>
<td>62.56 +/- 2.72</td>
<td>62.15 +/- 2.48</td>
<td>ns</td>
</tr>
<tr>
<td>Swing phase duration R [% gait cycle]</td>
<td>37.44 +/- 2.72</td>
<td>37.85 +/- 2.48</td>
<td>ns</td>
</tr>
<tr>
<td>Double support phase duration R [% gait cycle]</td>
<td>13.20 +/- 2.62</td>
<td>12.74 +/- 2.25</td>
<td>ns</td>
</tr>
<tr>
<td>Single support phase duration R [% gait cycle]</td>
<td>36.35 +/- 3.18</td>
<td>36.56 +/- 2.55</td>
<td>ns</td>
</tr>
<tr>
<td>Symmetry index</td>
<td>94.08 +/- 6.23</td>
<td>93.50 +/- 6.54</td>
<td>ns</td>
</tr>
<tr>
<td>Propulsion L [m/s²]</td>
<td>7.19 +/- 1.94</td>
<td>6.74 +/- 1.95</td>
<td>ns</td>
</tr>
<tr>
<td>Propulsion R [m/s²]</td>
<td>7.15 +/- 1.95</td>
<td>7.10 +/- 2.17</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic flexion-extension – Symmetry index</td>
<td>16.73 +/- 48.35</td>
<td>18.55 +/- 53.34</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic flexion-extension – range L [°]</td>
<td>2.49 +/- 0.97</td>
<td>2.23 +/- 0.73</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic flexion-extension – R range [°]</td>
<td>2.49 +/- 0.92</td>
<td>2.23 +/- 0.70</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic lateral flexion – Symmetry index</td>
<td>96.87 +/- 7.02</td>
<td>98.15 +/- 1.90</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic lateral flexion – L range [°]</td>
<td>7.26 +/- 2.62</td>
<td>7.80 +/- 2.38</td>
<td>0.046617</td>
</tr>
<tr>
<td>Pelvic lateral flexion – R range [°]</td>
<td>7.37 +/- 2.64</td>
<td>7.88 +/- 2.43</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic rotation – Symmetry index</td>
<td>92.83 +/- 15.11</td>
<td>96.21 +/- 6.60</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic rotation – L range [°]</td>
<td>8.45 +/- 3.44</td>
<td>8.03 +/- 2.93</td>
<td>ns</td>
</tr>
<tr>
<td>Pelvic rotation – R range [°]</td>
<td>8.51 +/- 3.33</td>
<td>8.07 +/- 2.94</td>
<td>ns</td>
</tr>
</tbody>
</table>

*p – between baseline and 6th week  
ns – not statistically significant  
L – left lower limb  
R – right lower limb

Iwona Sulowska, Anna Mika, Łukasz Oleksy
and footwear can be mentioned [48]. An unfavourable factor is the foot posture inclining both towards excessive pronation and supination [5,6]. It is connected with the influence of foot posture on its mobility and kinematics of the lower limb joints [7-9]. Pronation is a combination of dorsal flexion of the ankle, evasion of the rearfoot (calcaneus) and forefoot abduction, and occurs in the first half of the support phase while walking or running [2]. Proper foot pronation is a mechanism that provides shock absorption and adaptation to the unevenness of a surface [49]. In the case of excessive pronation, greater mobility in the support phase can be observed. In particular, these differences are visible in the mobility of the calcaneus during propulsion. In the frontal plane, a larger extent of eversion and the total range of mobility of the rearfoot are observed [22-24]. Also, metatarsal and forefoot mobility is increased [24, 25] and lasts longer than in the case of a neutral foot [23]. Injuries in people with excessive pronation and reduced longitudinal arch of the foot related to this are most often the result of greater susceptibility to tissue damage due to exceeding physiological ranges of motion [10] or incorrect compression of the subtalar joint and transverse talar joint [11].

However, in people with elevated medial longitudinal arch and tendency towards supination, its smaller mobility can be observed, which predisposes to injuries associated with weakening the cushioning mechanism [12] and increasing pressure on the plantar surface of the foot while walking or running [13].

In this work, the Foot Posture Index (FPI-6) was used to assess foot posture and changes occurring under the influence of the training programme, assessing the six elements of the fore- and rearfoot. Using this made it possible to classify the foot into one of three types: neutral, pronating or supinating [19]. After six weeks of training, foot posture improved from pronation towards a neutral foot. These changes concerned the right and left foot, showing statistical significance within all assessed elements and the total score. In the authors’ previous studies, in which the effectiveness of two types of exercises activating the plantar short muscles of the foot in long-distance runners was compared, the FPI-6 was also used. Similarly to the present work, improvement in the posture towards a neutral foot was observed [40].

There are also other reports in the literature regarding the use of the Foot Posture Index among people practicing long-distance running. Cowley and Marsden [50] assessed the change in this index and the height of the navicular bone of the runners who covered the half-marathon distance. The first measurement was carried out a week before the competition. The subjects were instructed not to perform training on that day. The second measurement took place after the runner crossed the finish line. Researchers observed a reduction in the navicular bone of both feet after the run. The value of the FPI-6 index in the left foot significantly increased (on average by 1.7), and thus, the pronation level increased. In the right foot, this value increased slightly (by 0.3 on average).

Similar studies have been carried out by Escamilla-Martinez et al. [51] who assessed foot posture with the FPI-6 before and after a run at a moderate speed (3.3 m/s), sustained for sixty minutes. Pressure distribution measurements of the plantar foot on the surface were also conducted. The research involved a group of thirty regularly training men. The obtained results also indicate a tendency of the feet to change pronation after long-term loading in the form of a running training. The value of the FPI-6 index increased on average by two points in both feet. The pressure on the medial side of the heel and under the head of the second metatarsal bone increased, and the longitudinal arch of the foot decreased. The results obtained by the researchers confirm the necessity to use exercises activating internal foot muscles on the plantar side and strengthening the longitudinal arch of the foot in runners.

The efficiency of the foot muscles on the plantar surface of the feet was evaluated by Mulligan et al. [39], who studied the impact of Short Foot Exercise on the medial longitudinal arch and dynamic functions. A navicular drop test was used. After an eight-week training period, the researchers observed improvement – they recorded lower values for navicular bone descent after shifting to a standing position, and thus, a smaller range of pronation. Own research confirms these results. Although the navicular drop test was not used, similar parameters were assessed (prominence in the region of the talonavicular joint and talar head palpation). In both of them, statistically significant changes were observed with a visible tendency towards improvement from pronation towards a neutral position.

Jung et al. [38] also evaluated the effectiveness of exercises activating the short plantar surface of the foot, to exercises involving additional long flexors. The advantage of the Short Foot Exercise was demonstrated - the electromyographic activity of the toe abductor muscle was significantly higher, and the value of the arch angle of the foot was lower in comparison to the results obtained during the second exercise. The results suggest, therefore, that the Short Foot Exercises have a more beneficial effect on strengthening the toe abductor muscle, which is the largest of the internal muscles of the foot. The increase in its activity may contribute to the reduction of the medial angle of the longitudinal arch, and thus, to raising the arch of the foot. In our research, a significant change in this parameter, which is part of the FPI-6, was also observed under the influence of exercises.
The original training programme designed by the authors used in this study was aimed at activating the short plantar muscles of the foot with the smallest activity of external muscles. The Short Foot Exercises developed by Professor Janda are commonly known, consisting in shortening the foot in the anterior-posterior dimension by bringing the metatarsal bone heads towards the calcaneus, while the fingers maintain relaxed and the foot rests on the ground [38]. These exercises restore strength and proper muscle tone and strengthen the medial longitudinal arch of the foot, which increases the stability of the ankle [52, 53]. They also have a positive effect on proprioception and postural stability. It is recommended to do barefoot exercises in order to ensure as much stimulation of the sensorimotor system [54].

The sensorimotor system is, next to the eye and vestibular organs, one of the basic mechanisms responsible for controlling stability and restoring balance. The system is made up of skin and deep sensory receptors, especially from the plantar surface of the foot and around the ankle. Proper distribution of the load on the feet is therefore an element affecting the control of dynamic stability and is a condition for proper gait [27].

Stability is a key element during movement [26]. In dynamic conditions, such as walking or running, it allows an individual to continue the functional movement, despite the occurrence of external and internal destabilizing forces. Dynamic stability analysis should take into account the changing moments of muscle strength and changes in the position of body segments in space [28].

To estimate dynamic stability control, it is possible to measure the variability of gait kinematics and temporal-spatial parameters [29, 30]. The variability of these parameters is the smallest when walking at natural speed, comfortable for a given person. It is assumed that the increase in variability, which occurs in the case of faster and slower gait, is associated with a decrease in stability [31, 32]. Paradoxically, however, with age, a reduction in walking speed is very often observed [55]. In the elderly, the perception of sense organs that control the balance and stability of the posture is weakened – the organ of responsibility for sight, the vestibular organ and the receptors of superficial and deep feeling [56]. It seems, therefore, that moving at a slower speed is aimed at improving the control of dynamic stability, which is in contradiction with the previously quoted assumptions about the variability of gait.

This paradox is explained in a paper by Dingwell and Marin [37]. The authors compared dynamic stability and variability of gait parameters depending on its speed. In this research, the starting point were scientific reports indicating the relationship between gait speed and its variability. Even earlier, Winter [35] observed that there is an individual variable and individual speed of movement, at which energy expenditure and variability of gait parameters are the smallest. Oberg et al. [32, 36] assessed changes in selected parameters depending on the speed at which the examined person moves. Faster gait was associated with lengthening strides and increased ranges of motion in the knee and hip joints. However, lower walking speeds are accompanied by smaller ranges of motion in the joints and lower generated moments of muscle strength [57-59].

11 young, healthy individuals participated in the study by Dingwell and Martin [37]. Prior to the actual test, the preferred walking speed (PWS) was determined for each participant. The task of the subjects was to move on a mechanical treadmill at speeds at 60%, 80%, 100% 120% and 140% of PWS, respectively. Selected parameters were evaluated using the VICON system for three-dimensional motion analysis. It was observed that their variability was the smallest when walking at the speed preferred by the subject. This variability increased with the change of walking speed, both in the direction of lower and higher values.

Local dynamic stability was quantitatively determined using the Lyapunov method [60]. The results obtained by the authors indicate an improvement in dynamic stability during walking at a slower speed, despite the increase in its variability. Researchers suggest that the neuromuscular control system is more effective in controlling exogenous and endogenous balance disturbances during slow walking when moving at higher speeds.

A similar study was conducted by England and Granata [34]. They assessed the variability of temporal-spatial and kinematic parameters of gait when moving at speeds corresponding to 20%, 40%, 60% and 80% of walking speed (Vf), calculated using the Froude number, taking the forces of inertia and gravity into account [61]. According to available studies, the natural and comfortable walking speed is 0.42 Vf, while running is initiated at the speed of 0.70 Vf [62,63]. Local dynamic stability was determined, similarly as in Dingwell and Martin’s study, using the Lyapunov method [60]. The results obtained in the England and Granata study confirmed that when moving at a comfortable (natural) speed, the variability of temporal-spatial and kinematic parameters of gait is the smallest. Both walking at greater and lower speeds increases the variability of its parameters. However, the authors suggest that dynamic stability may be poorly represented by the size of the variation in gait. Lyapunov’s analysis indicated greater local stability of all joints at a lower speeds.

In this study, a change in some temporal-spatial parameters of gait was observed after the 6-week programme of exercises activating the short plantar muscles of the foot surface. In the second examination, significantly lower cadence, gait speed, step length and a lower value of...
The influence of plantar short foot muscle exercises on foot…

the index expressing the ratio of stride length to body height were recorded. The duration of the gait cycle significantly prolonged. Other parameters did not change significantly. Perhaps this is related to the conditions under which the measurements were carried out. Walking on a flat surface may not be a demanding task for healthy individuals. Hence, the lack of registered changes due to training in percentage distribution of the gait cycle phases or in propulsion.

According to the previously quoted research results of different authors, when moving at a natural speed, the variability of temporal-spatial parameters is the smallest. On the other hand, walking at both higher and lower speeds increases the variability of its parameters. In our research, runners walked more slowly, with a shorter steps and smaller cadence after the applied training. Thus, the preferred walking speed, comfortable for a given person, changed. No changes in the proportion of the swing or support phases indicate that the gait pattern remained the same as before the workout.

Slower gait is a common strategy to increase dynamic stability and reduce the risk of falling, especially in elder individuals. However, studies conducted by Hak et al. [64] indicate that, in this case, the reduction in gait speed is not important. The response to the balance disorder and the mechanism allowing its preservation is shortening step length, increasing cadence and step width.

Changes in gait parameters observed in our research may be the result of improved motor control. It can be assumed that the applied foot exercises, through their impact on proprioceptors, contributed to the improvement of the sensorimotor system as a mechanism ensuring control of dynamic stability. The improvement of foot posture in statics, visible in the form of the FPI-6 index value change, could also translate into improvement in motor control. Further research in this field is recommended.

The heterogeneity of the group – the age of the respondents ranged from 21 to 45 years, and their weekly training ranging from 20 to 100 km, may be indicated as a limitation of this study. Another factor was the lack of subjects with foot supination in the study group, and therefore, it was impossible to assess what changes in runners with this type of foot posture would be triggered by the applied training programme.

Persons who practice long-distance running are exposed to long-lasting loads, which is why this group has key mechanisms that absorb shock during running and walking. Correct foot posture is a contributing factor [4]. The results of our research confirm that the short plantar muscle exercises of the foot surface improve foot posture towards a neutral position. The applied exercise programme also influenced changes in some of the temporal-spatial parameters of gait. After the applied training programme, the runners walked slower, took shorter steps and their cadence decreased. The transfer of natural, comfortable gait for a given person towards lower values may be the result of improved motor control, obtained through the influence of the applied exercises on the sensorimotor system.

Exercising the short plantar muscles of the foot surface is crucial for athletes, especially those who are exposed to long-lasting loads. Unfortunately, these exercises are usually overlooked in athletes’ training. Therefore, more attention should be paid to adequate and optimal involvement internal muscles of the plantar surface of the foot in runners. Further research is recommended regarding the impact of these exercises, taking differences in the foot posture and among athletes of other disciplines into account.

Conclusions

1. Lower values of individual components and the total result of the Foot Posture Index suggest that the applied short plantar muscle exercises of the foot surface cause a statistically significant improvement in their posture from pronation to a neutral position.

2. The observed changes in temporal-spatial parameters of gait in the form of a statistically significant reduction in its speed, cadence and step length, as well as lengthening the gait cycle, may indicate improvement in motor control and a shift of the comfortable natural walking speed towards lower values.

3. Based on the obtained results, performing exercises activating the short plantar muscles of foot surface is recommended as a permanent element of daily training in long-distance runners.
References


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Author for correspondence:
Iwona Sulowska
Phone number: +48 12 683 11 34
E-mail: iwona.sulowska@awf.krakow.pl
THE EFFECT OF PHYSICAL ACTIVITY LEVEL ON BODY BUILD AND PHYSICAL FITNESS OF GIRLS AND BOYS AGED 10-19

Helena Popławska1 ABDEF, Adam Wilczewski1 ABC, Agnieszka Dmitruk1 ABDE, Wojciech Holub2 BCEF

1 Department of Physical Education and Sport in Biała Podlaska, Józef Piłsudski University of Physical Education in Warsaw, Poland
2 Department of Tourism and Health in Biała Podlaska, Józef Piłsudski University of Physical Education in Warsaw, Poland

Keywords: physical activity, physical development, physical fitness, children and adolescents

Abstract

Aim: The study was aimed to evaluate the somatic build and physical fitness of children and adolescents aged 10-19 depending on their physical activity.

Basic procedures: The survey was conducted in the years 2008-2009 among 925 girls and 1,016 boys aged 10-19 years, attending rural and urban schools in the Biała Podlaska county. The following basic anthropometric measures were taken: body height, body mass, arm and shank circumference, thickness of three skinfolds (over the triceps, over the scapula and over the iliac crest). The Body Mass Index (BMI) was computed from values of body height and mass measurements. Numeric values of somatotypological components were calculated as well; these including: endomorphy, mesomorphy and ectomorphy. Physical activity was evaluated based on the trials of the European Physical Fitness Test battery, and was stratified according to a 3-level scale: low activity – up to 1 hour, moderate activity – between 1 and 3 hours, and high activity – 4 and more hours. In groups of the physical activity of girls and boys, values of somatic traits and results of motor tests were normalized with the use of equations indicating dependencies of mean values and standard deviations from age, according to Stupnicki et al. [1]. Significance of differences between the studied groups was evaluated using ANOVA analysis of variance with the “post-hoc” Newman-Keuls test.

Results: The surveyed girls and boys with the highest physical activity were characterized by the lowest values of somatic traits, except for body height, and by the best results of physical fitness. Greater differences between results were observed in the girls.

Conclusions: A correlation was demonstrated between the physical activity and somatic build and physical fitness of the surveyed girls and boys.

Introduction

In the modern world, one can observe a continuous decline in physical activity in favour of passive forms of spending free time. This phenomenon applies to people of all ages, including children and adolescents [2-4]. Young people’s level of participation in physical activity during their free time is insufficient and far from the recommended 60 minutes a day of moderate to high physical activity [5].

Research at the Institute of Mother and Child in Warsaw [6] shows that only every tenth student in Polish schools meets the guidelines for physical activity. A common phenomenon is exemption from Physical Education classes accepted by parents. Young people spend a significant number of hours on activities related to low energy expenditure. According to a study by Stankiewicz et al. [7], Polish children spend an average of 2 hours a day in front of a TV screen, and 1.4 hours in front of a com-
puter screen, i.e. a total of 3.4 hours a day. This exceeds the recommended time for these activities which should be no longer than 2 hours a day [5].

Low physical activity and the prevalence of a sedentary lifestyle are the causes of many health problems, which are becoming more and more common among children and adolescents. There is growing obesity among in younger and younger children, and this causes a significant risk of being overweight or obese in adulthood as well. In children and adolescents with excessive body mass, arterial hypertension, type 2 diabetes and postural defects can be observed [8-10], as well as more cases of neuroses and behavioural disorders [11]. A low level of physical activity also has negative effects on the structure and functioning of some organs and systems [12], reducing physical fitness [13].

The aim of the study was to evaluate the somatic structure and physical fitness of children and adolescents aged 10-19 depending on their level of physical activity.

Material and methods

The research was carried out between 2008-2009. It included 925 girls and 1,016 boys aged 10-19 years from rural and urban schools of the Biała Podlaska county (north-eastern part of the Lublin province). The schools in which the research was conducted were deliberately selected – they were the same schools that were randomly selected for research 10 years earlier (KBN Grant No. P05D02314). The research was carried out in the following rural schools: in Cicibor, Janów Podlaski, Komarno, Konstantynów, Leśna Podlaska, Rokitno and Zalesie, and in municipal schools in Biała Podlaska and Miejszyc Podlaski. Prior to the study, consent informing about the purpose and scope of the research was obtained from the AWF Ethics Committee in Warsaw, school authorities and parents or guardians of the children who were involved in the study.

During the research, basic anthropometric measurements were conducted in accordance with the requirements of the International Biological Research Committee [14]. They concerned measurements of the following somatic features: body height, body mass, arm and shank circumferences, thickness of three skinfolds (above the triceps muscle, below the shoulder blade and above the iliac crest). The body mass index (BMI) was calculated using height and body mass values. In addition, the numerical values of somatotypic components were calculated: endomorphs, mesomorphs and ectomorphs using the Sheldon method modified by Heath and Carter [15].

Physical fitness was assessed by performing trials included in the European Physical Fitness Test [16]. This work uses the results of measurements defining the following motor skills: static force (measurement using a hand dynamometer), explosive force (standing long jump distance), trunk strength (number of performed sits from lying position), agility (10 x 5 m zig-zag run time), speed of the upper limb movements – tapping (alternating touching two appropriately spaced discs), flexibility (trunk forward bow while seated), balance (number of repetitions needed to stay on a beam for one minute), functional strength (overhang with arms bent).

The work also uses the method of diagnostic survey with an original questionnaire, based on which information regarding the date of birth of each examined person (enabling calculation of calendar age) and their physical activity. In this study, the only information used from the questionnaire was the number of hours spent on physical activity per week apart, from Physical Education classes. The level of physical activity was rated on a 3-point scale: low activity – up to 1 hour, moderate – from 1 to 3 hours, high activity – 4 hours and more.

Statistical calculations were preceded by determination of the distribution value regarding the analysed somatic traits and the results of motor tests. Body height belonged to the features with normal distribution. The other parameters were logarithmically transformed to obtain normal distribution. In the physical activity groups of girls and boys, the age of the subjects was precipitated by normalizing the values of somatic features and the results of motor tests with the aid of different equations for mean dependencies and standard deviations from age according to Stupnicki et al. [1]. When evaluating the statistical significance of differences between separate groups, ANOVA analysis and the Newman-Keuls post-hoc method were used.

Results

Analysing the percentage distribution of the studied girls and boys depending on physical activity levels, it was noted that the highest percentage of the surveyed girls and boys declared from 1 to 3 hours a week (moderate physical activity) spent on physical activity. Only 40% of the girls and a quarter of the boys declared low physical activity levels. Merely 14.5% of the girls and 28% of the boys spent four and more hours on physical activity (Tab. 1).

Analysing the values of normalized somatic features in groups separated on the basis of physical activity showed that in girls, there were no significant differences in body height. Among the other analysed somatic features, the group with high physical activity was characterized by the lowest values of body mass, BMI, arm and shank circumference, while between the groups with low and moderate activity, there were no clear differences in somatic structure. This is confirmed by the results of ANOVA: statistically significant differences occurred mainly between groups of girls with low and high physical activity levels (Fig. 1, Tab. 2).
### Table 1. Number of surveyed girls and boys in groups distinguished on the basis of physical activity level (number/percentage)

<table>
<thead>
<tr>
<th>Sex</th>
<th>Up to 1 h (low activity)</th>
<th>1-3 h (moderate activity)</th>
<th>4 h and above (high activity)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Girls</td>
<td>380</td>
<td>41.08</td>
<td>411</td>
<td>44.43</td>
</tr>
<tr>
<td>Boys</td>
<td>264</td>
<td>25.98</td>
<td>467</td>
<td>45.97</td>
</tr>
</tbody>
</table>

### Table 2. Results of ANOVA analysis of variance conducted for dependencies between physical activity, somatic build and physical fitness of girls and boys

<table>
<thead>
<tr>
<th></th>
<th>Girls</th>
<th>Boys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ANOVA Newman-Keuls test</td>
<td>ANOVA Newman-Keuls test</td>
</tr>
<tr>
<td></td>
<td>I-II</td>
<td>I-III</td>
</tr>
<tr>
<td>height</td>
<td>0.50</td>
<td>1.34</td>
</tr>
<tr>
<td>mass</td>
<td>2.66</td>
<td>0.24</td>
</tr>
<tr>
<td>BMI</td>
<td>3.97</td>
<td>0.44</td>
</tr>
<tr>
<td>arm circumference</td>
<td>1.59</td>
<td>0.10</td>
</tr>
<tr>
<td>shank circumference</td>
<td>2.61</td>
<td>0.24</td>
</tr>
<tr>
<td>endomorphism</td>
<td>3.85</td>
<td>0.20</td>
</tr>
<tr>
<td>mesomorphism</td>
<td>3.80</td>
<td>0.66</td>
</tr>
<tr>
<td>ectomorphism</td>
<td>3.46</td>
<td>0.30</td>
</tr>
<tr>
<td>hand strength</td>
<td>3.26</td>
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</tr>
<tr>
<td>balance</td>
<td>4.32</td>
<td><strong>4.13</strong></td>
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<tr>
<td>tapping</td>
<td>12.53</td>
<td><strong>5.75</strong></td>
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<td>agility</td>
<td>5.60</td>
<td><strong>3.71</strong></td>
</tr>
<tr>
<td>long jump</td>
<td>8.78</td>
<td><strong>4.15</strong></td>
</tr>
<tr>
<td>sit from lying</td>
<td>8.49</td>
<td><strong>4.13</strong></td>
</tr>
<tr>
<td>overhang</td>
<td>3.58</td>
<td>2.59</td>
</tr>
<tr>
<td>10 x 5 m run</td>
<td>7.69</td>
<td><strong>4.23</strong></td>
</tr>
</tbody>
</table>

I – group with low physical activity (up to 1 h)  
II – group with moderate physical activity (1-3 h)  
III – group with high physical activity (4 h and above)  
* statistically significant differences at confidence level of \( p \leq 0.05 \)

In boys, it was noticed that subjects with low physical activity obtained the highest normalized values of the analysed somatic features with the exception of body height. The group with high physical activity, similarly to girls, was characterized by the lowest values of body mass, BMI, shoulder and shank circumference, but statistically significant differences occurred only in the case of BMI (Fig. 2, Tab. 2).

In this work, the type of body structure examined using the Heath and Carter method was also determined [15]. Girls with high physical activity were characterized by low endomorphism and mesomorphism, and the highest values of ectomorphs. Similarly as in the case of somatic features, there were no significant differences between the two remaining groups (with low and moderate physical activity) regarding the type of body structure, which is confirmed by the Newman-Keuls test results – the differences were statistically significant, but only between the first and third, and second and the third groups separated on the basis of physical activity (Fig. 3, Tab. 2).

Boys with low physical activity levels were characterized by the highest values of normalized endomorphs and mesomorphs, and the lowest ectomorphs. The group with moderate physical activity levels had body component values close to the average norm of all groups, while the boys who were physically active, similarly to girls, had the lowest values of endomorphism and mesomorphism, and the highest ectomorphs (Fig. 4, Tab. 2).
Fig. 1. Normalized values of somatic traits of girls in groups with various levels of physical activity

Fig. 2. Normalized values of somatic traits of boys in groups with various levels of physical activity
Apart from somatic build, physical fitness was assessed in girls and boys representing different levels of physical activity. There was a greater variation in the results for girls than the boys. Girls with high physical activity levels obtained the best results in all analysed motor trials except for balance. Girls with low physical activity proved to be the least physically fit. Differences in the results were statistically significant in all the analysed physical fitness tests, and the Newman-Keuls test showed the significance of differences mainly between the first and second, and the first and third groups of girls (Fig. 5, Tab. 2).

In boys, there was a similar pattern of dependence between physical activity and fitness, but the normalized values were lower than in the girls. The smallest intergroup differentiation was observed in hand strength and flexibility. The statistical significance of differences occurred only in the long jumps, sits from laying and the overhang, which mainly resulted from the very low results of boys with low physical activity (Fig. 6, Tab. 2).

Fig. 3. Normalized values of body build components of girls in groups with various levels of physical activity

Fig. 4. Normalized values of body build components of boys in groups with various levels of physical activity

Fig. 5. Normalized values of physical fitness tests results for girls in groups with various levels of physical activity
Discussion

Undertaking physical activity is of particular importance during the development of the human body, that is during childhood and youth. To ensure physical and mental health during this period, all forms of physical activity are desirable. In combination with changes in external environment, it is a factor modelling the morphological and functional state of an organism. Applied for a longer period of time, it causes adaptive changes that include both physical and mental characteristics. Understanding the determinants of physical activity is the basis for taking action to counteract the decline in its level in children and adolescents [17].

Conducted research shows that about 45% of girls and a similar percentage of boys from Biały county allocate from 1 to 3 hours per week, and up to 1 hour per week as much as 41% of girls and 26% of boys, to extracurricular physical activity. Most of the subjects do not meet the criteria of recommended physical activity. A similar situation was noted in the research carried out at the Institute of Mother and Child in Warsaw, concerning physical activity of school youth aged 9-17 [6]. Almost a quarter of respondents perform moderate physical activity for a minimum of 60 minutes less than 3 days a week, and only about 20% high physical activity 4 and more hours a week.

Physical exercise causes many beneficial changes in the human body. It stimulates general development and determines physical fitness, which is highly dependent on training. Physical activity influences, among others, bone growth in children and adolescents, strengthens and stabilizes joints and has positive influence on muscularity while reducing the amount of adipose tissue. Regularly performed physical activity affects pace of development, as well as dimensions of the body. Already after a few months of moderate, but regularly undertaken physical exercise, children performing motor activity classes have greater height and weight gain, they mature earlier and are more resilient to infections [13]. In our own research, there was no correlation between physical activity and body height. In the other analysed somatic traits (body mass, arm and shank circumference) and BMI values, the groups of girls and boys with high physical activity were characterized by the lowest values of these features. In girls with low activity levels, high values of the analysed somatic features were observed, especially in the case of BMI, while in boys, there were no differences in somatic structure between groups with low and moderate physical activity.

Physical activity is closely related to physical fitness, but the strength of this relationship is seldom studied. In our own research, it was observed that girls and boys who spend more time on physical activity are characterized by a higher level of physical fitness. The above-mentioned relationship was observed in the results of all fitness tests except for balance. Girls and boys with low physical activity turned out to be the least physically fit. Similar relationships are indicated in the case of research among boys aged 13-15 from Radom [18]. The boys with a higher level of physical activity obtained better results in all attempts included in Zuchory’s Physical Fit-
The effect of physical activity level on body build and...  

Conclusions
1. A relationship was found between physical activity and somatic build as well as physical fitness of the studied girls and boys.
2. The boys and girls with high physical activity levels were characterized by the lowest values of somatic features except for body height, and had the best results of physical fitness.
3. Greater variation in the results was observed among girls.

References

Author for correspondence:
Helena Poplawska
Phone number: +48 83 342 87 38
E-mail: helena.poplawska@awf-bp.edu.pl

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