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.

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Manuscript registration takes place in accordance with the instructions for authors: http://970.index-copernicus.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.
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Texts submitted for publication should be written in English or Polish in accordance with the following editorial requirements:

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

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

The main body of the text (in English and Polish)

The main body of the text should include the following parts:

Introduction. Introduction acquaints the reader with the subject of the article and places it against the background of existing research (literature review).

At the end of the Introduction, the aim, research problems and hypotheses should be clearly stated.

Material and methods. An accurate description of the research subject (material) should be presented in the methodological part. The number of subjects, their age, sex and other characteristics of the participants should be indicated. Additionally, information regarding the conditions of testing, time and methods, techniques and research instruments, with particular emphasis on the description of the used apparatus should be given. The name and address of its producer should be given. If an original method or technique of research was used, it should be described precisely by presenting its validity and reliability (reproducibility). In the case of modifying already recognized methods, the applied changes must be described and the need for these changes must be justified. Statistical methods should be explained so that it can be easily determined whether they are properly suited for the purpose of research. The author of the review or meta-analysis should provide methods of searching for materials, methods of selection, etc.

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

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

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

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

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

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

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

Repetition of the reference to the same publication is done by its earlier established number. References of attachments are organized according to the order of their citation in the body of the text. Citing two or more publications should be included in square brackets in chronological order of their publication.

Explanatory notes or supplementary text should be numbered using the Oxford Referencing System, maintaining consistency throughout the article.
Examples

Monograph by no more than six authors:


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


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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


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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:


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Example:


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  - **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>Me</th>
<th>SD</th>
<th>B</th>
<th>Me</th>
<th>SD</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>
<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></td>
<td>0.567</td>
<td>*</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></td>
<td>0.005</td>
<td>*</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></td>
<td>0.006</td>
<td>*</td>
</tr>
</tbody>
</table>

NS – statistically non-significant difference

*  – p<0.05; ** p<0.05; ***p<0.001

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- 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.
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- Abstracts and full texts in English and Polish are posted on the following websites: http://www.antropomotoryka.pl/ and http://970.indexcopernicus.com/.
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Indeed, it is already the 75th issue of our Antropomotoryka journal, and its 25th year on the publishing market. Perhaps for modern readers, the name Antropomotoryka may be too simplistic, which is, to a degree, a case in point. The current English subtitle Journal of Kinesiology and Exercise Sciences (JKES) should be permanently added. The current editor-in-chief and former secretary of the editorial board remembers the birth of the semi-annual scientific journal Antropomotoryka in 1991. Its history has been complex, and its past subtitles had been varied. One of them, used in the last century – The Journal of Human Kinetics – lived on to become a newly established scientific journal, whose score (IF) in the Institute for Scientific Information (ISI Master Journal List) is increasingly higher. A manoeuvre of this sort, insignificant, it would seem, had serious consequences for the existence of Antropomotoryka, which was under the threat of being closed down. Thanks to the perseverance of those who were at its birth and the strong support of the University Schools of Physical Education in Krakow and Wroclaw, the journal is still an important bridgehead for researchers that have the correct understanding of human motor activity (men in action), and do not follow the man-machine view advocated by a French physician and philosopher JulienOffray de La Mettrie (1709-1751) in his still popular and cited 1748 treatise L’homme-machine.

It is difficult to assess whether sticking to the principles of the interpretation of human motor activity adopted quarter of a century ago and forming the Polish vision of a scientific discipline called Antropomotoryka is beneficial to the image of the discipline on the international arena. Its defence may be its higher score according to the criteria used by the Ministry of Science and Higher Education, as well as a higher Index Copernicus Value. What further assures us in the assumed direction of development is the interest in publishing in Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES), despite the continuously rising requirements put forward by both the editorial board and the reviewers. Perhaps it is owed to the fact that the articles are published in an electronic form with a DOI (digital object identifier); knowing the DOI of a particular publication enables one to access the publication on the Internet and download it.

Proof in favour of such a thesis on the causes of the unrelenting interest in publishing in the journal may be the papers published in the 75th issue. Following the adopted taxonomy, the research problems have been divided into four sections: Fundamental and Applied Kinesiology, Exercise sciences, Sport Exercise and Varia.

The first section contains an article developed under the guidance of a well-known, Wroclaw-based researcher of the theory of human motor ability; the beginning of his research dates as far back as the time of Jan Mydlarski and his historically first tool to measure the physical fitness of schoolchildren (Tabelemiernikasprawnosci fizycznejdlaodziezyochondzolnej, 1935). The paper entitled New formula for the selection of the best competitor in the bench press deserves particular mention. It was released by the contributors after the unexpected death, albeit in a ripe old age, of the author of the formulas for judging competitions in weightlifting performed by disabled competitors. It is not only a testament to his scientific activity but, above all, an important supplement to the sports performance evaluation criteria in a very difficult Paralympic competition. With much difficulty do the decision makers of world sports acknowledge the fact that the current score tables for the refereeing rules, highly professional mathematically, are authored by a Pole, Adam Haleczko. It took the author several years to obtain the consent of the authorities to call such criteria “HaleczkoFormula”. It is a rarity, however, that the information is added that the source for the method are cited 1748 treatise L’homme-machine.

The second section contains the papers without acknowledging the source from which it is derived. This is quite a legal phenomenon. Damage is caused to Antropomotoryka, since how many times it is cited is important for any journal to advance in rankings. Well, such is the fate of Polish magazines published in the Polish language. They are not paid enough attention, even when they publish works at the level comparable to the works created by Nobel Prize winners. It can be assumed that the new scoring formula (“The New Haleczko Formula, as named by its creator) included in the article New formula for the selection of the best competitor in the bench press, in addition to its proper form in English, will be connected to the journal, now published in English. This is in accordance with the Polish copyright law.
It is not easy to write about Adam Haleczko, of the man who had been a faithful collaborator of Antropomotoryka, Antropomotoryka. Journal of Human Kinetics, Antropomotoryka. Kinesiology and Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES). His constant creative and inspiring scientific ideas, especially to the young researchers of human motor skills from Wroclaw, sent to our magazine. It was not easy to say goodbye to him at the Wroclaw cemetery, even more so that we still expected more, in accordance with the Olympic motto: Citius, Altius, Fortius. And in this race, he was inexplicably forgetting about himself and giving way to others. We could always count on his unconditional support. A good man and a great scientist, he had the right to say near the end of his life the following about those to whom he had devoted himself and burnt like a candle: “strange people, loved so much, yet unable to love”.

The loneliness of the long distance runner had not led him to honours, nor had it earned him any degrees. And yet he was such a prolific writer. His name was not mentioned when he dared to be the best of the best, and, to paraphrase the words of Jan Kochanowski, the father of Polish poetry, “ascended the beautiful Kaliope’s mountain steep, the place that hitherto bore no sign of Polish feet.” Giving a Polish name in the formula of judging international Olympic weightlifting competitions for the handicapped comes with difficulty. Most often only the initials are mentioned – AHA. The intricacies of life of the Lvov-born, Polish researcher of human motor abilities from Wroclaw, will be discussed in a separate obituary dedicated to his memory.

The Sport Exercise section contains another paper — An analysis of muscle tension in tandem track cyclists, that is devoted to people with disabilities who train professionally in the Olympic sport - track cycling in category B tandem: the blind and visually impaired. The goal of the authors was to look for relationships between exercise stress during training and the work done by muscles. The study was undertaken at a stadium track. Muscle tension was evaluated with the BTS FREEEMG300 surface electromyography (BTS Bioengineering, Italy). Electrodes were applied to the left biceps femoris (LBF), right biceps femoris (RBF), left gastrocnemius (LGC), right gastrocnemius (RGC), left rectus femoris (LRF), right rectus femoris (RRF), left tibialis anterior (LTA) and right tibialis anterior (RTA) muscles according to SENIAM guidelines. Electromyography (EMG) data were processed with a SMART analyzer, 1.10.0225 version, with the use of a 20 Hz high-pass Butterworth filter, 450 Hz low-pass Butterworth filter, full-wave rectification and root mean square with a 300ms interval. The results show the relationship between cycling technique and the results of the electromyographic measurements.

In the article about a sports master entitled Using predictive models for forecasting the career of a champion during the period of relative stability of results in race-walking, a method was developed by the authors who, based on the already well-known functional relation $y=f(x)$ between the duration of sports careers of athletes practicing professionally “measurable” athletic competitions and sports result, presented a way to look for a function to determine the approximate value of the relationship between the evolution of sports results and subsequent years of sporting career of a walker. A concrete example shows the possibility of using a model of sports master’s sporting career development to predict its further progress at the stage of relative stabilisation of results.

The aim of another research, presented in the article Can winner be recognized by body composition? - A study on elite taekwon-do athletes was to identify the characteristics of the model champion in another Olympic event - taekwon-do ITF. On the basis of anthropometric measurements, age and training seniority required to obtain a master level in the abovementioned sport, as well as using statistical methods, the indicators typical for athletes successful in sporting event organized in Poland were established.

Based on the analysis presented in the work The role of motivation in amateur basketball it should be concluded that developing a master model should also take into account psychological predispositions. The study showed that people playing in teams that occupied leading positions in amateur basketball league had higher levels of introjection and every other predominantly autonomous types of motivation, especially integration and internal motivation, than the players of teams occupying the last places in the rankings. On the other hand, the players did not differ significantly in the level of external motivation. It was also found that players who had higher levels of intrinsic motivation, devoted more time to practising basketball.

It is no longer a secret that the source of success in sports lies not only in a well-planned and carried out training, but also in proper nutrition of athletes. The paper Quantitative and qualitative assessment of diet and nutritional status in elite professional race-walkers during the preparatory period presented a method of nutritional diagnosis in athletes preparing to participate in the Olympics. Nutrition turned out to be a very important part of sports training. The results presented in the research testified that both quantitative and qualitative dietary mistakes had been made during the preparatory period in the elite group of athletes training competitive race walking.
Irregularities found concerned lack of balanced rations in terms of some nutritional contents, not only in relation to the increased demand in the case of athletes, but also in relation to the standards for the young men in the Polish population. Quantitative and qualitative assessment of the diet of the athletes showed the incomplete implementation of the objectives of the Swiss sports nutrition pyramid, the model recommended for people engaging in high physical activity. Eliminating the observed deficiencies resulted in better sporting achievements.

Sciatica is a fairly common ailment hindering much more than just the realization of the training tasks of an athlete. Its causes may have different sources. The authors of the article *The rheological properties of the blood in patients with sciatica* tried to seek for diagnostic opportunities of the phenomenon in the rheological examination of blood. A very detailed analysis of blood morphology and an index of elongation led the authors to the conclusion that "the changes that occur when pressure is put on the L4, L5, S1 spinal nerves adversely affect the rheological changes of the blood in patients with sciatica, and are most likely caused by associated symptoms such as arthritis, fever or paresis of the legs."

Traditionally, it is the call of our faithful collaborator to join at the table the preeminent scientists that encourages readers to read the latest issue of *Antropomotoryka*. This time we were invited to: *A scientific evening with N.A. Bernstein, A. Einstein, S. Hawking and D.R. Hofstadter*.

Wishing our readers a good intellectual journey, not only with science at the international level, but also with seven scientific pieces of research based on the results of empirical studies of sportsmen and for sports, I want to announce, unfortunately, the last of the anniversary issues of *Antropomotoryka*, published today under the English title *Journal of Kinesiology and Exercise Sciences (JKES)*.

*Editor-in-chief*

Edward Mleczko
NEW FORMULA FOR THE SELECTION OF THE BEST COMPETITOR IN THE BENCH PRESS

Adam Haleczko \(^1\) ABCDEF, Leszek Korzewa \(^2\) BCE, Ewa Misiolek \(^2\) BCE

\(^1\) Retired employee of the University School of Physical Education in Wroclaw, Poland
\(^2\) Department of Athletics and Gymnastics, University School of Physical Education in Wroclaw, Poland

Key words: weightlifting, score equalization, Wilks tables, three-variable formula

Abstract

Aim. This paper constitutes a continuation of research on score equalization in the bench press, and of the studies on athletes with disabilities conducted several years ago. In 2003, we presented score equalization coefficients in competitions under the IPC. These tables, designed for the period 2003-2007, are valid to this day. The current study is devoted to the construction of an efficient formula for healthy athletes and concerns the selection of the best competitor regardless of weight class. In weightlifting, such action is called score equalization.

Basic procedures. The collected material is comprised of the results of high-level competitors from the years 2011-2015, eight in each category. In creating the models, we used the three-variable formula validated in previous studies, requiring no adjustments in terms of the categories up to 84 and 120 kg. The obtained results are supplemented with calculations of Wilks coefficients. In terms of the heavy weight classes, the trend of decreasing performance with increasing body mass was adjusted. For the comparison of both formulas we used graphs, numerical data included in the coefficients of variation and differences between the world records after their conversion using both formulas. In addition, comparison indicating the effectiveness of equalization in three competitions of weightlifting is presented. Outstanding results in the middle-weight classes, and the weaker in the extremes categories, should be explained by the normal distribution of body mass typical of the population, although some authors believe that this is the result of allometric scaling.

Conclusions. The New Formula, being much more effective in score equalization, can successfully replace the outdated Wilks tables.

Introduction

In order to compare the achievements of athletes differing in body size and performing disciplines in which this affects the results, weight categories were introduced. In weightlifting, selection of the best athlete regardless of weight category, is done by the conversion of scores – this is called score equalization. Currently, two score conversion models are used in sports - the Sinclair \([1]\) in Olympic weightlifting and the Wilks \([2]\) in powerlifting and the bench press. The first publication on the equalization of scores in bench pressing was published in 2001 \([3,4]\). The paper was intended for disabled athletes participating in competitions subordinate to the International Paralympic Committee (IPC). These tables, designed for the period 2003-2007, are valid to this day. The current work is devoted to designing a score equalization formula for healthy competitors. In the two previous weightlifting competitions, supplementing the data with a third variable significantly improved the quality of assessing the athletes' level of sports in comparing their achievements, regardless of their category \([5,6,7]\).
Study aim

The construction of equalization coefficients and those improving the effectiveness of selecting the best competitor in comparison to the previously used Wilks tables.

Material and methods

The material consists of bench press scores obtained from the Internet achieved at high-level competitions in the years 2011-2015 (World Championship) [8]. The study participants comprise of 8 women in each of the six categories (47-84 kg) and 30 women in the 84+ kg category, and 8 men in each of the seven categories (59-120 kg), and 42 in the 120+ kg category. Body mass for both sexes in terms of the lighter categories were adopted in accordance with the upper limit of their inclusion criteria for each weight category. In terms of the heavy-weight category, we included data from the competition announcements. All results were supplemented by Wilks conversions of coefficients to the nearest 0.5 kg. In creating a formula for equalizing the scores, as in the two previous events, the data were supplemented by a third variable - the difference between the score and body mass. In designing the models, similarly as before, the choice of the correct power was done using the iterative method [5,6,7]. In the heavy-weight categories, similarly as in powerlifting, the patterns were created with correction of the decreasing trend along with the increasing weight of the athletes. To obtain further information about the effectiveness of the two formulas, comparisons were done with the use of graphs and coefficients of variation considered as the basic numerical criterion of calculation efficiency. Moreover, we have presented the differences in the rankings achieved after the conducted activities. Outstanding performance in the middle-weight classes and the weaker in the extreme categories is explained by the normal distribution of body mass in the population. This is not, however, the only opinion in this case. Some authors believe that the cause of promotion in the middle categories and in the extreme – a decrease in the results, is allometric scaling. This is a mathematical procedure which allows comparison of the variables determining the physiological results, such as strength in individuals with different body sizes by reference to anthropometric variables such as body mass. It also enables comparisons of the results of individuals or groups. Among the well-known authors and proponents of this version, Batterham and George [9] should be mentioned. Their opinion is undermined by Dooman and Vanderburgh [10] explaining that this is due to significant differences in the number of competitors. A similar opinion is stated by Batterham and Moore [2], assuming that the extreme categories are represented by half the number of weightlifters in the middle categories. However, they also recognize the impact of the allometric method. Hunter et al. [11] distinguish two trends, both weakening the results in heavy-weight categories, while one of them also harms athletes from the light-weight categories.

Similarly as in previous studies [5,6,7], the new procedure - Haleczko’s Formula – is named after its author. In publications, the term New Formula and Haleczko’s Formula are used interchangeably.

Formulas for calculating equalization coefficients using the New Formula

WW – score equalization coefficient
X – body mass
Y – score
Y – X – difference between score and body mass
Z – assumed power
118.92; 118.92 + (X – 85) × 0.5; 197;
197 + (X – 121) × 0.71 – coefficient conversions to kilograms.

Women
Categories up to 84 kg
WW = \( \left( \frac{Y - X}{Y} \right)^{0.552} \times 118.92 \)
84+ kg category
WW = \[ \left( \frac{Y - X}{Y} \right)^{0.552} \times 118.92 \) + \((X - 85) \times 0.5\)

Men
Categories up to 120 kg
WW = \( \left( \frac{Y - X}{Y} \right)^{0.5485} \times 197 \)
120+ kg category
WW = \[ \left( \frac{Y - X}{Y} \right)^{0.5485} \times 197 \] + \((X - 121) \times 0.71\)

For all the categories, computer programmes were prepared in order to simplify and thereby speed up the procedures of identifying the best competitors.

Results

The main objective of the study was to create an objective formula for converting results, increasing the efficiency of choosing the best athlete. The actions leading in this direction are illustrated by graphs (Figs. 1 and 2). The curved lines passing through the points corresponding to the arithmetic average of results for each particular weight category express the distance from the straight lines, which in turn, represent arithmetic averages of the
results of all categories. The greater the distance of the category from the straight line (average of total scores), the worse its equalization, the closer it is - the better. If the points of all categories were on the straight line, this would be the ideal equalization. The effectiveness of score equalization can also be presented in numerical form - coefficients of variation - the basic criterion for selecting the best competitor [11]. As in the graphs, the smaller distances, in this case the lower coefficient values, express more efficient conversion. The importance of introducing a third variable is indicated by significant correlations of both basic traits: mass and the result with differences occurring between them, wherein they are slightly higher in men (Tab. 1 and 2). Significant differences are observed in the trait correlations of the competitors representing the lighter and heavier categories. The values of correlation coefficients in Tables 3 and 4 illustrate the only slight effect on the results of the initial body mass of the heavy-weight athletes, and much greater impact on the equalized scores. This can be treated as the appropriate selection of the manner of score conversion for these weight categories.

Table 5 shows the two discussed formulas in terms of their practical value in equalizing the scores in all three weightlifting competitions. In the analyzed competition, coefficients of variation are 8.1% for women, while for men - 3.7%. They are much higher than in the Olympic weightlifting or powerlifting. The reasons for this are the performance of only one mandatory motor task in the bench press and the outdated Wilks conversion tables [2,12]. More favourable is assessment done with the New Formula; female competitors - 4.4% and 2.2% for

![Fig. 1. Differences in bench press scores – Wilks version according to the New Formula (women)](image)

![New Formula](image)
Fig. 2. Differences in bench press scores – Wilks version according to the New Formula (men)

Table 1. Correlation coefficients between body mass and scores in bench press of women (N - 48)

<table>
<thead>
<tr>
<th>No.</th>
<th>Traits</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>91</td>
<td>73</td>
<td>34</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Score</td>
<td>91</td>
<td>95</td>
<td>68</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>73</td>
<td>95</td>
<td>86</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Score according to the Wilks formula</td>
<td>34</td>
<td>68</td>
<td>86</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Score according to the New Formula</td>
<td>14</td>
<td>52</td>
<td>76</td>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>

All correlation coefficients were multiplied by 100

$r_{ext} = .28$

$r_{ext} = .36$
the male athletes. The greater volatility of the women’s results is affected by sexual dimorphism manifested in their weaker upper body [13]. The lowest difference compared to men is observed in the Olympic weightlifting, in which the results, to a large extent, depend on the work of the muscles of the lower limbs which are stronger than the upper ones [13].

Essential information about evaluating the highest achievements are provided by world records (Tab. 6). In terms of female categories, in comparisons we may notice an exchange in the first two places in terms of the 57 and 84+ kg categories, and agreement in the last position. In men, the order of the first three places is identical (120+, 74, 83 kg). The outstanding scores in terms of the average female category: 57 kg, and 74 kg for men, and which also exist in other disciplines of weightlifting [5,6,7], support the view that this is associated with normal mass distribution in populations. The consequence is that a larger number of athletes start in the middle categories, and much less in terms of the extremes. Consequently, their equalized results are higher in the first case, and in the second

### Table 2. Correlation coefficients between body mass and scores in bench press of men (N -.56)

<table>
<thead>
<tr>
<th>No.</th>
<th>Traits</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>93</td>
<td>80</td>
<td>50</td>
<td>-08</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Score</td>
<td>93</td>
<td>97</td>
<td>77</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>80</td>
<td>97</td>
<td>88</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Score according to Wilks formula</td>
<td>50</td>
<td>77</td>
<td>88</td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>5</td>
<td>Score according to the New Formula</td>
<td>-08</td>
<td>30</td>
<td>53</td>
<td>76</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Correlation coefficients between body mass and scores in bench press of women in 84+ kg category (N - 30)

<table>
<thead>
<tr>
<th>No.</th>
<th>Traits</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>27</td>
<td>-27</td>
<td>07</td>
<td>-19</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Score</td>
<td>27</td>
<td>85</td>
<td>98</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>-27</td>
<td>85</td>
<td>94</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Score according to Wilks formula</td>
<td>07</td>
<td>98</td>
<td>94</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Score according to the New Formula</td>
<td>-19</td>
<td>87</td>
<td>97</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Correlation coefficients between body mass and scores in bench press of men in 120+ kg category (N - 42)

<table>
<thead>
<tr>
<th>No.</th>
<th>Traits</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body mass</td>
<td>14</td>
<td>-29</td>
<td>01</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Score</td>
<td>14</td>
<td>91</td>
<td>97</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Difference between the result and body mass</td>
<td>-29</td>
<td>91</td>
<td>93</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Score according to Wilks formula</td>
<td>01</td>
<td>97</td>
<td>93</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Score according to the New Formula</td>
<td>38</td>
<td>96</td>
<td>77</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

All correlation coefficients were multiplied by 100

$r_{.05} = .26$

$r_{.01} = .34$

$r_{.05} = .36$

$r_{.01} = .46$
they are significantly weaker, which is clearly visible in the supplemented graphs (Figs. 1 and 2). Given the importance of such a situation for the decision, which is more appropriate? – allometric modelling or including the number of people significantly differing in body mass, we included a graph based on the anthropometric picture of Poland from the fifties (Fig. 3). This may merely provide an example of the formation of the body mass numbers of persons comprising the population from the middle and opposite ends of the distribution of this characteristic. Nevertheless, assuming that these people greatly differing in body mass influence the results, Vanderburgh and Batterham’s opinions on the mutual impact of these factors cannot be excluded [2].

Table 5. The effectiveness of choosing the best weightlifter, depending on the used formula (criterion - the coefficient of variation)

<table>
<thead>
<tr>
<th>No.</th>
<th>Competition</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sinclair’s Wilks</td>
<td>New</td>
</tr>
<tr>
<td>1</td>
<td>Bench press</td>
<td>8.1</td>
<td>4.4</td>
</tr>
<tr>
<td>2</td>
<td>Olympic weightlifting</td>
<td>3.3</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>Powerlifting</td>
<td>6.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table 6. The world records set on 15 Mar. 2016 converted and rated by the Wilks formula and the New Formula

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Score</th>
<th>Wilks formula</th>
<th>Place</th>
<th>New Formula</th>
<th>Place</th>
<th>Cat.</th>
<th>Score</th>
<th>Wilks formula</th>
<th>Place</th>
<th>New Formula</th>
<th>Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>131.5</td>
<td>179.31</td>
<td>5</td>
<td>155.67</td>
<td>5</td>
<td>59</td>
<td>205.0</td>
<td>178.70</td>
<td>8</td>
<td>274.42</td>
<td>7</td>
</tr>
<tr>
<td>52</td>
<td>138.0</td>
<td>172.80</td>
<td>7</td>
<td>153.29</td>
<td>6-7</td>
<td>66</td>
<td>240.0</td>
<td>188.09</td>
<td>7</td>
<td>281.12</td>
<td>6</td>
</tr>
<tr>
<td>57</td>
<td>165.0</td>
<td>193.07</td>
<td>1</td>
<td>160.54</td>
<td>2</td>
<td>74</td>
<td>300.0</td>
<td>217.68</td>
<td>2</td>
<td>293.92</td>
<td>2</td>
</tr>
<tr>
<td>63</td>
<td>175.0</td>
<td>189.62</td>
<td>3</td>
<td>159.59</td>
<td>3</td>
<td>83</td>
<td>310.0</td>
<td>209.22</td>
<td>3</td>
<td>290.77</td>
<td>3</td>
</tr>
<tr>
<td>57</td>
<td>175.0</td>
<td>182.72</td>
<td>4</td>
<td>157.09</td>
<td>4</td>
<td>93</td>
<td>318.0</td>
<td>200.18</td>
<td>5</td>
<td>285.26</td>
<td>4</td>
</tr>
<tr>
<td>84</td>
<td>200.0</td>
<td>179.04</td>
<td>6</td>
<td>153.29</td>
<td>6-7</td>
<td>105</td>
<td>335.5</td>
<td>200.60</td>
<td>4</td>
<td>282.10</td>
<td>5</td>
</tr>
<tr>
<td>84+</td>
<td>235.0</td>
<td>191.17</td>
<td>2</td>
<td>163.86</td>
<td>1</td>
<td>120</td>
<td>343.0</td>
<td>197.33</td>
<td>6</td>
<td>274.22</td>
<td>8</td>
</tr>
<tr>
<td>120+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>120+</td>
<td>401.5</td>
<td>218.58</td>
<td>1</td>
<td>295.03</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 3. The distribution of body mass in the Polish population in the years 1955-1956
Summary

In the intention of the author, the Wilks Formula, introduced in 1997, based on the polynomial of the 5th degree conveying the correlation between body mass and the “legitimate scores” (not being the actual results) of the strength possibilities of world-class athletes, was to eliminate excessive influence of a small number of athletes in the extreme weight categories, as well as the results distorted by doping [2]. Although the Wilks Formula was not analyzed in terms of its theoretical justification [2], over the years it has fulfilled its objectives. Today, it should go down in history. Replacing it with the New Formula - objective and characterized by much greater efficiency in score equalization - will depend on activists.

Conclusions

The New Formula, both graphically and numerically, displays much more effective score equalization than the Wilks coefficients. The new way of calculating results allows for more objective and fair selection of the best athlete. Hence, it is totally reasonable to replace the outdated tables with the New Formula for calculations and to include it in the regulations of the Federation.

Appendix

Body mass and scores in women’s bench press in 84+ kg category

<table>
<thead>
<tr>
<th>No.</th>
<th>Body mass [kg]</th>
<th>Score [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>91</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>94.3</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>95</td>
<td>152.5</td>
</tr>
<tr>
<td>4</td>
<td>96.5</td>
<td>130</td>
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<tr>
<td>5</td>
<td>98.4</td>
<td>147.5</td>
</tr>
<tr>
<td>6</td>
<td>98.7</td>
<td>190</td>
</tr>
<tr>
<td>7</td>
<td>98.9</td>
<td>147.5</td>
</tr>
<tr>
<td>8</td>
<td>100.1</td>
<td>192.5</td>
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<td>101.1</td>
<td>145</td>
</tr>
<tr>
<td>10</td>
<td>104.3</td>
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</tr>
<tr>
<td>11</td>
<td>105.7</td>
<td>167.5</td>
</tr>
<tr>
<td>12</td>
<td>106.6</td>
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<td>13</td>
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<td>107.5</td>
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<tr>
<td>16</td>
<td>108.1</td>
<td>185</td>
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<tr>
<td>17</td>
<td>108.6</td>
<td>180</td>
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<tr>
<td>18</td>
<td>109.3</td>
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<td>165.1</td>
<td>182.5</td>
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<td>No.</td>
<td>Body mass [kg]</td>
<td>Score [kg]</td>
</tr>
<tr>
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<td>----------------</td>
<td>------------</td>
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<tr>
<td>30</td>
<td>153.3</td>
<td>367.5</td>
</tr>
<tr>
<td>31</td>
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<td>380</td>
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<td>32</td>
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<td>33</td>
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<td>35</td>
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<td>342.5</td>
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<td>38</td>
<td>163</td>
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<td>39</td>
<td>163.2</td>
<td>355</td>
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<td>300</td>
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<tr>
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<td>325</td>
</tr>
<tr>
<td>42</td>
<td>180.5</td>
<td>340</td>
</tr>
</tbody>
</table>
New formula for the selection of the best competitor...

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[12] www.powerlifting.pl/referees/wilks/wilks.html; 18.05.2015

Author for correspondence:
Leszek Korzewa
E-mail: korzewa@interia.pl
AN ANALYSIS OF MUSCLE TENSION IN TANDEM TRACK CYCLISTS

Karolina Kopacz 1 ABCDEF, Magdalena Fronczek-Wojciechowska 1 ABCDF, Szymon Galczynski 1 AB, Szymon Prusaczyk 2 AB, Gianluca Padula 1 AG

1  “DynamoLab” Academic Laboratory of Movement and Human Physical Performance, Medical University of Lodz, Poland
2  Department of Trauma and Orthopedic Surgery, A. Sokolowski Specialist Hospital in Walbrzych, Poland

Key words: electromyography, sports medicine, tandem cycling, objective movement analysis, muscle tension

Abstract

Aim. The aim of the present study was to evaluate the level of muscle tension in tandem track cyclists on a trainer and the track.

Basic procedures. Two tandem pairs were evaluated: one consisting of 2 women and the second of 2 men. Surface BTS FREEEMG300 electromyography was used to measure the muscle tension of the left and right biceps femoris, left and right gastrocnemius, left and right rectus femoris, and left and right tibialis anterior.

Main findings. The greatest difference was observed in resting state in the right tibialis anterior muscle. The greatest differences between minimum and maximum values were noticed in the right biceps femoris on the trainer and right tibialis anterior on the track.

Conclusions. 1. Muscle tension is higher on the track than on the trainer. 2. Any amount of muscle imbalance can impair cycling biomechanics and result in the loss of valuable seconds during competitions.

Introduction

New objective technologies, including motion analysis systems and kinesiological electromyography, are commonly used in cycling to adjust the position of a cyclist on the bike [1-3], to define lower limb muscle strength [4] and to identify muscle synergies acting while pedalling [5]. Brown et al. [6] used four functional phases to identify pathological muscle functions and activities taking place during pedalling in post-stroke patients with unilateral lower extremity dysfunction.

Pedalling is an activity which affords insight into the response of the central nervous system to changing workloads and musculoskeletal responses to dynamic interactions [8]. Generally, during one hour of training, a cyclist can perform more than 5,000 pedal movements [7]. In tandem cycling, the first athlete is called the pilot, captain or steersman, while the second rider is called the stoker, navigator or rear admiral. In the case of the tandem cyclist, both the pilot and stoker should work together. Any changes in the position of either athlete leads to differences in muscle tension and pedal force imbalance. The Wingate sprint test revealed that moving forward on the saddle reduced biceps femoris activation [9] due to a backward shift of the pedal force vector, leading to the knee joint moment from extension.
to flexion. Along the same lines, moving backward on the saddle also caused changes in joint coordination and pedalling technique, as well as muscle tension and recruitment. The most obvious change is demonstrated by the lower contribution of the hamstring muscles occurring as a result of increased knee flexion angle [1]. A surface electromyography study by Sanderson et al. [10] revealed that the activity of the gastrocnemius medialis and soleus was significantly lesser in lower saddle positions. Similarly, Ericson et al. [11] observed that gastrocnemius medialis and medial hamstring activity increased at higher saddle settings.

Fregly et al. [12] reported that ergometers do not have the same stiffness and damping as a classic racing bicycle. Moreover, Bertucci et al. [13] noticed that road cycling and the Monark ergometer flywheel differ with regard to the kinetic energy and crank internal load which stimulate the cyclist. Hence, the present study was performed on the track and a trainer - the subject's own bicycle rather than with the use of a cycloergometer.

The aim of the study was to evaluate the level of muscle tension in tandem track cycling on a trainer and the track.

Material and Methods

Two tandem pairs, one male and one female, were examined twice on the cycling trainer and on the track. Mean values related to female tandem are following: age: 30±1 years, weight: 59±2.5kg, height: 1.61±0m, while for male tandem mean values are: age: 34±1 years, weight: 73±13kg, height: 181.5±6.5m. Each pair consisted of a pilot without any disability and a stoker with an eye disability. The stoker from the female tandem suffered from aphakia, nystagmus and myopia. The stoker from the male tandem suffered from myopia and impairment of vision. Both people from each tandem had worked together for more than 5 years. The distance covered by subjects during the examination was 4x250m. The study was undertaken at a stadium track. Muscle tension was evaluated with the BTS FREEEMG300 surface electromyography (BTS Bioengineering, Italy). Electrodes were applied to the left biceps femoris (LBF), right biceps femoris (RBF), left gastrocnemius (LGC), right gastrocnemius (RGC), left rectus femoris (LRF), right rectus femoris (RRF), left tibialis anterior (LTA) and right tibialis anterior (RTA) muscles according to SENIAM guidelines. Electromyography (EMG) data were processed with a SMART analyzer, 1.10.0225 version, with the use of a 20 Hz high-pass Butterworth filter, 450 Hz low-pass Butterworth filter, full-wave rectification and root mean square with a 300ms interval.

Summary statistics: mean and standard deviation (SD) were calculated. The Shapiro-Wilk test was used to evaluate the distribution of the measured parameters. The dependent samples from the t-test and the Wilcoxon signed-rank test were used to identify differences between groups. The accepted level of significance was $\alpha = 0.05$. Microsoft Excel 2010 and Statistica 10 were used for all analyses.

Results

The mean values observed on the track were higher than those measured on the trainer (Table 1). The greatest difference (23µV) was observed in the RTA muscle.

Table 2 presents the differences in muscle tension between the pilot and the stoker in the female and male tandem pair. In the female tandem, the smallest differences were observed in case of the LRF on the trainer (93%) and on the track (1%). The largest differences concerned the LTA on the trainer (191%) and RRF on the track (80%). In each case, the higher muscle tension values referred to the second cyclist, the athlete with the disability. The smallest differences between the pilot and the stoker of the male tandem team were observed in case of the RGC on the trainer (30%) and on the track (2%). The largest differences concerned the RTA on the trainer (113%) and the RBF on the track (74%). The higher values were reached by the pilot, the person without disability, in three out of four cases.

Table 3 lists the differences in muscle tension between the left and right leg for all cyclists. For the pilot in the female tandem, a difference less than 10% (6%) was observed between the LBF and RBF, as well as the LRF and RRF on the trainer (-4%). Additionally, the smallest differences were found in the BF muscles at the track (19%), while the biggest differences were found in the TA muscles (80%) on the trainer and the GC muscles (50%) at the track. For the stoker cyclist, the smallest differences, not exceeding 10%, were observed between the LBF and RBF muscles on the trainer (-4%), and the GC muscles at the track (-5%). The largest differences were found for the GC muscles (41%) on the trainer and TA (63%) at the track.

For the pilot on the male tandem team, the smallest differences were observed comparing LGC and RGC muscles on the trainer (-23%) and on the track (11%), while the greatest differences were observed for the TA on the trainer (-67%) and BF muscles at the track (110%). For the stoker, the smallest differences, not exceeding 10%, were observed between LBF and RBF muscles on the trainer (-9%). The smallest difference in muscle tension on the track was observed in the GC muscles (-16%), whereas the largest differences were seen in the TA muscles on the trainer (197%) and the track (128%).
An analysis of muscle tension in tandem track...

**Table 1.** Descriptive statistical values for mean muscle tension evaluated on the cycling trainer and the track

<table>
<thead>
<tr>
<th>muscle [µV]</th>
<th>N</th>
<th>Trainer mean</th>
<th>SD</th>
<th>Track mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBF</td>
<td>4</td>
<td>23</td>
<td>13</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>RBF</td>
<td>4</td>
<td>27</td>
<td>22</td>
<td>33</td>
<td>16</td>
</tr>
<tr>
<td>LGC</td>
<td>4</td>
<td>27</td>
<td>12</td>
<td>36</td>
<td>14</td>
</tr>
<tr>
<td>RGC</td>
<td>4</td>
<td>32</td>
<td>21</td>
<td>39</td>
<td>20</td>
</tr>
<tr>
<td>LRF</td>
<td>4</td>
<td>29</td>
<td>12</td>
<td>44</td>
<td>14</td>
</tr>
<tr>
<td>RRF</td>
<td>4</td>
<td>34</td>
<td>20</td>
<td>46</td>
<td>25</td>
</tr>
<tr>
<td>LTA</td>
<td>4</td>
<td>30</td>
<td>20</td>
<td>41</td>
<td>18</td>
</tr>
<tr>
<td>RTA</td>
<td>4</td>
<td>32</td>
<td>14</td>
<td>55</td>
<td>31</td>
</tr>
</tbody>
</table>

**Table 2.** Differences [%] in muscle tension [µV] between the pilot and the stoker in the female and male tandem team during cycling

1st: pilot without disability
2nd: stoker with disability

<table>
<thead>
<tr>
<th>muscle [µV]</th>
<th>The female tandem</th>
<th>The male tandem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trainer 1st</td>
<td>2nd</td>
</tr>
<tr>
<td>LBF</td>
<td>10 22</td>
<td>119 33</td>
</tr>
<tr>
<td>RBF</td>
<td>10 21</td>
<td>98 39</td>
</tr>
<tr>
<td>LGC</td>
<td>19 44</td>
<td>135 42</td>
</tr>
<tr>
<td>RGC</td>
<td>30 61</td>
<td>104 63</td>
</tr>
<tr>
<td>LRF</td>
<td>24 45</td>
<td>93 56</td>
</tr>
<tr>
<td>RRF</td>
<td>23 60</td>
<td>164 42</td>
</tr>
<tr>
<td>LTA</td>
<td>14 41</td>
<td>191 48</td>
</tr>
<tr>
<td>RTA</td>
<td>25 48</td>
<td>93 64</td>
</tr>
</tbody>
</table>

**Table 3.** Individual differences in muscle tension between the left and right leg in the female and male tandem team

<table>
<thead>
<tr>
<th>muscle [µV]</th>
<th>Female tandem</th>
<th>Male tandem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pilot</td>
<td>stoker</td>
</tr>
<tr>
<td></td>
<td>trainer</td>
<td>track</td>
</tr>
<tr>
<td></td>
<td>mean %</td>
<td>mean %</td>
</tr>
<tr>
<td>LBF</td>
<td>10 6</td>
<td>33</td>
</tr>
<tr>
<td>LGC</td>
<td>19 62</td>
<td>50</td>
</tr>
<tr>
<td>RGC</td>
<td>30 63</td>
<td>61</td>
</tr>
<tr>
<td>LRF</td>
<td>24 -4</td>
<td>56</td>
</tr>
<tr>
<td>RRF</td>
<td>23 42</td>
<td>60</td>
</tr>
<tr>
<td>LTA</td>
<td>14 80</td>
<td>48</td>
</tr>
<tr>
<td>RTA</td>
<td>25 64</td>
<td>48</td>
</tr>
</tbody>
</table>

A positive value in % means higher muscle tension for the left side in comparison to the right side.
Discussion

Burke et al. [14] reported no difference in the percentage or area of slow-twitch and fast-twitch fibres in the vastus lateralis muscle in a group of competitive cyclists. A comparison of 11 elite male cyclists with another 11 less successful male cyclists identified that the percentage of fast and slow fibres does not affect competitive success.

Correct muscle tension and activity have great influence on the pedalling movement. One pedalling cycle can be divided into a power phase, beginning with the crank at the 12 o’clock position and ending at the 6 o’clock position (0-180° of the crank position), and a second or recovery phase, beginning at the 6 o’clock position and ending at the 12 o’clock position (180-360° of the crank position) [2, 7, 15]. For the power component, knee extension is very significant. The rectus femoris is the most important knee extensor muscle in this movement, especially in the first 60° of the power phase, even though the flexion action in the hip is contrary to the dominant extension occurring at the same time. The rectus femoris is also responsible for the hip flexion motion during the recovery phase. The gluteus maximus is the muscle mainly responsible for hip extension between 0 and 45° of the crank position, but is supported by the hamstrings as the crank moves from 45 to 125°. After the crank exceeds 125°, the hamstrings work alone to extend the hip. The hamstrings play the main role in knee flexion. At the 70° crank position, they generate a crank turning effect in the knee. Houtz and Fischer [16] noticed that the duration of rectus femoris activity was almost twice as large as the activity of the hamstrings, and that varying the height of the bicycle seat had no effect on the timing of muscular activity: it only affected the effort which should be generated during exercises. They found the tibialis anterior muscle to be acting between 270-360° of the recovery phase and 0-88° of the power phase, when the hip and knee reach maximum flexion.

According to Fonda et al. [17], the tibialis anterior muscle plays a role in the stabilization of the talocrural joint and is active throughout the cycle, with peak activity at about 280°. The main function of the flexor and extensor muscle group is to generate energy for pedalling. The rectus femoris and tibialis anterior muscles mainly provide energy at the end of the recovery phase and assist transition to the subsequent cycle. The hamstrings, gastrocnemius medialis and lateralis muscles work at the end of the power phase to help the transition to the recovery phase. The main role of the rectus femoris/tibialis anterior and hamstrings/gastrocnemius muscles is to improve the efficiency of energy transfer between the segments. The plantar flexors, the gastrocnemius lateralis and medialis, and the dorsal flexors muscles work together to stabilize the talocrural joint in the power phase, especially when the forces reach their peak and transfer the force to the pedals [17, 18].

As mentioned above, the knee extensors are the main group of muscles providing force for the crank in the power phase. Improper training and unbalanced muscle tension may increase the risk of injury [19]. Our findings reveal that differences exist in muscle tension between the left and right sides for both the pilots and the stoker. This muscle imbalance, which reached 197% at the track, can lead to muscular and joint dysfunction. Even micro-overload can also increase the probability of injuries. Asymmetry in muscle tension in the biceps femoris muscles can lead to disorders in movement trajectory during hip extension in the power phase and knee flexion in the recovery phase. A lack of symmetry in the rectus femoris muscle tension may result in disorders of movement trajectory during hip flexion in the recovery phase and knee extension in the power phase. Asymmetry in the gastrocnemius muscle tension may cause movement trajectory disorders in knee flexion in the recovery phase and knee extension in the power phase. Asymmetry in the gastrocnemius muscle tension may cause movement trajectory disorders in knee flexion in the recovery phase and knee extension in the power phase. Asymmetry in the gastrocnemius muscle tension may cause movement trajectory disorders in knee flexion in the recovery phase and knee extension in the power phase. Asymmetry in the gastrocnemius muscle tension may cause movement trajectory disorders in knee flexion in the recovery phase and knee extension in the power phase.

Muscle imbalances can impair pedalling efficiency. Differences in muscular activity in tandem pairs can cause the improper transfer of energy to the cranks and pedals, and may lead to overloading one of the cyclists. Every imbalance can result in the loss of seconds which are vital to every professional athlete.

Conclusions

In conclusion, the current results indicate that muscle tension is higher on the track than the trainer, and any amount of muscle imbalance can result in poorer cycling biomechanics and the loss of valuable seconds during a competition.
References


Author for correspondence:
Karolina Kopacz,
E-mail: karolina.kopacz@umed.lodz.pl
Phone number: +48 42 272 57 76
USING PREDICTIVE MODELS FOR FORECASTING THE CAREER OF A CHAMPION DURING THE PERIOD OF RELATIVE STABILITY OF RESULTS IN RACE-WALKING

Edward Mleczko, Grzegorz Sudol, Joanna Baj-Korpak

1 Faculty of Physical Education and Sport, University School of Physical Education in Krakow, Poland
2 Faculty of Health and Social Sciences, Pope John Paul II State School of Higher Education in Biala Podlaska, Poland

Key words: Track and field, Race Walking, Time-Series Data, econometric model, predicting, non-linear regression method, technique of least-squares.

Abstract

Aim. The issue of forecasting records in measurable sports disciplines has a very long tradition. For this purpose, methods known in mathematical statistics and econometrics are used. To date, approximation theory has not been used to predict the future course of the sports careers among athletes reaching phases of relative stabilization in their results. In this study, we presented our own proposal for adapting predictive models in solving the signalled problem.

Basic procedures. Time series of the best results obtained during the 21-year sporting career of the three-time Olympic participant were analyzed. Using the method of least squares for approximation of the results obtained up until the end of the observation, based on the developed curve (parabola) and the nonlinear 2nd grade model \( y = ax^2 + bx + c \), we estimated further prospects for the development of sports championship in race-walking for 20 and 50 km distances.

Research results. Characteristics of the sports biography provided valuable results to understand the development trends of the contemporary model of a champion in professional sports and to develop training and recruitment concepts for future sports champions.

Conclusions. Predictive models should be used both for forecasting the development of sports disciplines and planning the development of careers of players reaching a phase of relative stability in sports performance.

I. Introduction to the research issue

The issue of forecasting the development of sports performance in individual disciplines - or also sports championship - in measurable sports competitions has a very long tradition. For this purpose, methods known in mathematical statistics and econometrics were used. A special role is attributed to the method of approximation. Already at the beginning of the second half of the 20th century, it was used to determine the general trends in the development of sports disciplines [1]. Great hopes were linked to the possibility of using mathematical methods for modelling the careers of athletes in “measurable” sports disciplines. In older works, Matveev...
[2], Wierchoszanski [3], Wazny and Brylka [4] refer to the application of the method of least squares in the approximation of nonlinear curves, showing the relationship between sports results and subsequent years of sports training. However, it turned out that it was only useful for short-term predictions of sports results [1]. Currently in track and field, many different models for decision-making and forecasting are used. The possibility of using different types of forecasting models to solve the indicated problems in sports, ranging from simple linear and nonlinear regression models to very sophisticated analytical methods based on artificial intelligence, are discussed by Maszczyk in great detail [5]. The analysis method of artificial neural networks presented in the empirical part of the mentioned work has proved to be a more reliable prognostic tool of the development trend of the best results in world in track and field events than traditional modeling methods. Most commonly, models forecasting the development of selected track and field competitions are created, however - both in Poland and abroad – they implement traditional methods [6-12]. Research on the development of forecasting using artificial neural networks is less advanced [13]. Apart from the earlier mentioned publication [5], only a few others can be found on the development of predictive models using the above mentioned Methods of Artificial Neural Networks (MANN). They relate to the development trend of the results in swimmers and young javelin athletes [14-18]. Leaving the issue that forecasting is never certain aside, in this respect of reliance, it is believed that a more accurate forecast of the result development (e.g. in track and field) can only be placed within a short time frame - up to 5 years [5].

It should also be noted that both in the case of using analog models, as well as the neural predictive inference procedure, it is carried out to determine (in a more or less accurate manner) the development trend of global or regional results. In sports theory, in order to determine the developmental trends, the results achieved at a certain time by a selected group of competitors are used, or the variability of records achieved by different athletes in a specific period of time. It can therefore be assumed that they are typical cohort studies. Their effect applies to a specific group of athletes, not a specific player.

In our study, we used a different methodological approach. Based on the already well-known phenomenon of functional dependency \( y = f(x) \) between the outcome of sports and the duration of the sports careers of players professionally practicing "measurable" track and field competitions [1], it was decided to use assumptions of approximation theory in order to:

- match the curves determined on the basis of empirical points ("experimental") in a way that on the basis of the obtained data, they indicate the relationships between the development of the results in subsequent years of sports training of a specific player in the most representative way;
- look for such a function that can be used to determine the approximate value of the relationship between the pace of sports results development and consecutive years of sports training performed by a specific competitor.

In such a method, it is assumed that the approximating function will run as close as possible to all the empirical points, thus, it must be "matched" in the best possible way. We consciously resign from the requirement of accuracy occurring in interpolation. Using the method of approximation, there is no necessity for the approximating function to pass through the experimental points [19, 20]. In search for the approximating function that will be characterized by a second and third degree polynomial, or in exponential form, the least square method was used [21-23]. It is most commonly used in statistics.

From a methodological point of view, the applied research approach is similar to the previously discussed methods of forecasting sports results. The difference is not using the average values of measurement results [5]. Of course, in this case, the intentional choice of the sample and analysis of individual cases - the results of one player – does not allow for generalization of the results.

Leaving aside the above-mentioned problem, the possibility of using the applied research procedure should be indicated. In a cognitive sense, there is a possibility to explore and describe the curve of the theoretical development pace of sports results for the studied athlete. Based on the obtained information on the changes of the forecasted phenomena over time, a mathematical description of the dynamics can be created as linear trends for certain periods and the entirety of the vector of time can be designated. On the other hand, taking into account the applicative aspect, the existing possibility to predict the further development of results at a certain stage of ontogeny of the studied athlete should be emphasized. In the assumed research procedure, the point of reference of such a prognosis should be clearly defined. In our own process of building predictive models (econometric), such a location was considered as the stage of relative stabilization in results, in which the competitor’s personal best can be found. Why must it be taken into account?

The used conventional tools (analog) force limitations. Creating a model of the trend function in a particular competitor must be carried out according to a specific procedure for designating data carriers. In individual cases, they are made up of past events. Knowledge of them is the condition and provides a chance to develop
Using predictive models for forecasting the career...
II. Material and methods

In the research, analysis was conducted of the variability of results in the course of G.S.’s 21-year-long sports career in race-walking - one of the best international-class Polish athletes, with particular emphasis on: the period of beginning competitive sports by the sports master, the pace of development of results for men’s classic race-walking distances (20 and 50 km), the phase of relative stabilization in results and from this point of prediction, further sports development. The material required for researching the assumed study aims was collected using the method of document analysis. We took into account data needed to achieve the research objective from training journals, as well as the tables on the following websites: www.iaaf.org and www.pzla.pl.

Description of the studied athlete

Biographical data

G. S., Polish track and field athlete, specializing in race-walking, was born on 28 August 1978 in Nowa Deba. During his 24-year sports career, he was a three-time Olympian at the Olympic Games in Athens in 2004 (50 km - 7 m.), in Beijing in 2008 (50 km - 9 m.) and in London in 2012 (20 km - 24 m.). This race-walker represented Poland at the World Championships, European Championships, the European Cup and the World Cup. His biggest success was winning the silver medal at the European Championships in Barcelona in 2010 and the bronze medal at the World Cup one year earlier (Berlin 2009).

G. S. is a graduate and scientific-academic employee of the University School of Physical Education in Krakow.

Main stages of sports championship development

1. Youngster

Competitive race-walking by G. S. was preceded by a brief training apprenticeship in endurance racing. Specialized trainings in race-walking were started by the tested athlete at the age of fourteen (1992). Initially, he did not achieve spectacular successes in the scale of the country. During the Polish Youngsters Championships in Lodz, as a 15-year-old, he won 4th place.

2. Jr

After two years of practicing race-walking professionally in the category of younger junior, G.S. debuted in the 1996 junior category of the Polish national team, in a large international event, which was the World Junior Championships, ranking 7th place for the distance of 10 km with the time of 42:12:26. A year later, starting at the race-walking European Championships in Ljubljana, at a distance of 10 km, he achieved the result of 43:55, which ranked the Polish athlete in 10th place. In the following season, still as a junior, he made his debut in the World Cup in the senior category in the race-walking at 20 km. He achieved 70th place, but the result (1:25:47) earned by the junior was the best result in the history of the country (the unofficial Polish record).

3. Youth

During the first years of his career in the youth category, G.S. mainly took part in 20 km races, but he did not achieve much international success. However, he won the Polish Championships for this age category (1998-2000).

4. Senior

A. 2001-2004 Olympic cycle

Initially, as a senior, G.S. did not achieve significant success. It was only in 2002 that he appeared at the competition winning the meeting in Podiebrady walking the longest distance of 50 km and obtaining a very good result for his debut: 3:50:37. During the European Championships in Munich at the same distance, he was 10th (3:54:37). One year later, at the World Championships he was disqualified by the judges. He completed the Pre-Olympic season with a successful start for the distance of 50 km, winning competitions in Vienna (3:55:37). In 2004, debuting at the Olympic Games (OG) in Athens, the race-walker achieved a high 7th place for the distance of 50 km with the time: 3:49:09.

B. 2005-2008 Olympic cycle

In the first year after the Olympic games, the athlete had a series of unsuccessful starts for 20 and 50 km distances. In 2006, he came in 10th at the European...
Championships, and in 2007, he was 21st at the World
Championships. His results achieved for the distance of 50 km were very stagnant. Particularly unsuccessful
was the start for the 50 km prestigious competition in
Osaka - with the result of 4:07:47, G. S. finished as 21st.
Winning the 2007 Polish Championship in race-walking
for the distance of 50 kilometers with the time 3:55:21,
he proved his legitimate aspirations to take part in the
Olympic Games in Beijing. In the second Olympic start,
G. S. was one of the leading athletes for a long time,
eventually achieving 9th place with the time 3:47:18.

C. 2009-2012 Olympic cycle

In 2009, one of the most important successes of
G. S. should include the victorious performance in race-
walking for 50 kilometers at the World Championships,
which ended in achieving 3rd place at the finish line. The
second post-Olympic year turned out to be even more
successful. In 2010, in the 50 kilometer race-walking
distance, G. S. became a runner-up at the European
Championships held in Barcelona. After this success, the
athlete was nominated in the Sports Review Plebiscite
as the athlete of the year. One year later, at the World
Championships in Daegu, after covering more than 30
kilometers, he had to withdraw from walking the 50 ki-
lometers due to injury. In the pre-Olympic and Olympic
zat, the athlete failed to complete any competitions at
the longest distance (50 km). Maintaining a high level of
performance of starts for the 20 km race (1:20:58) and
winning this distance in the Polish Championships, he
confirmed his legitimate aspirations to participate in the
third Olympics. In London, he finished in 24th place with
the time of 1:22:40 for the 20 km race. Two months after
the start in the Olympics, G. S. became the German for
the distance of 50 kilometers (3:46:00).

D. A year out of the 2013-2016 Olympic cycle

The new Olympic cycle and, at the same time, the
next Olympic aspirations seemed viable. In 2013, G.S.
took part in the World Championships in Moscow,
where he set his new personal best for the distance of 50 km with the time 3:41:20, finishing the race in
6th place. The following years were not so lucky for
the three-time Olympian, and did not allow him to real-
ize such ambitious plans. Despite this, during his entire
sporting career, presented briefly, the sports personal-
ity of G. S. appears to be unique and worthy of a mas-
ter of sports.

Methods

1. During the first stage of empirical research, in order
to determine the dynamics of the development of
sports results of the studied athlete, we used a time
series (dynamic), in which we considered the lev-
els of the dependent variable – the sports result - as
a function of time.

On the basis of data structured in such a way, we
determined:

- the age of beginning race-walking,
- the beginning of the period of relative stabilization of
athletic performance,

2. We calculated the Temp Indicators of Development
(TID%) for the sports results concerning the 5-50 km
distances, using the following formula:

\[ \text{TID} \% = \frac{x_{\text{res}}}{x_{\text{max}}} \times 100 \]

assuming that:

- \( x_{\text{res}} \) = results obtained for 5-50 km distances in consecu-
tive age groups (1-n)
- \( x_{\text{max}} \) = personal best for 5-50 km distances

3. Based on the already well-known phenomenon of
functional dependency \([y = f(x)]\) between the du-
ration of athletes’ sports careers, practicing profes-
sionally “measurable” track and field events [1] and
the sports result, it was decided to use the assump-
tions of approximation theory in order to:

- match the curves to the empirical points (“experi-
mental”), the relationship between the evolution
of the results in individual years of G. S.‘s sports
training, which can represent the acquired data in
the best way,
- look for a simpler function to determine the ap-
proximate values of the relationship between the
evolution of sports results and subsequent years
of the sports career.

It was assumed that the approximate function
should occur as closely as possible to all the points
and be the best fit for them. In this case, the require-
ment of accuracy interpolation is given up, in which it is
necessary to go through all the approximate functions
of the experimental points. In the search of the func-
tion capable of approximation (second degree polyno-
mial or exponential), in our study we used the method
of least squares, which is the most commonly used
method in statistics [26].

In this way, the result of the following measurement
of \( y_j \) is presented as the sum (unknown) of the measured
value \( x \) and measurement error \( \varepsilon_j \):

\[ y_j = x + \varepsilon_j \]

From value \( \varepsilon_j \), it was expected that the sum of squares
was the smallest:

\[ \sum_j \varepsilon_j^2 = \sum_j (x - y_j)^2 = \min \]
Assuming that:

\[ FC_{\text{max likelihood}} = \sum_{k=1}^{N} \varepsilon_{k}^{2} = \ldots = \varepsilon^{T} G_{y}^{-1} \varepsilon = \frac{1}{\sigma^{2}} \varepsilon^{T} \varepsilon = \frac{1}{\sigma^{2}} \sum_{k=1}^{N} \varepsilon_{k}^{2} \]

where:

\[ G_{y} = \text{[cov(y)]}^{-1} = [C_{y}]^{-1} = \begin{bmatrix} \sigma_{1}^{2} & 0 & \ldots & 0 \\ 0 & \sigma_{2}^{2} & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & \sigma_{N}^{2} \end{bmatrix}^{-1} = \begin{bmatrix} 1 & 0 & \ldots & 0 \\ 0 & 1 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & 1 \end{bmatrix} \]

There is the need to use an assumption of Gaussian nature of measurement errors in successive moments and the assumption that the subsequent measurements are independent. The next methodical steps of the general formula:

\[ FC_{\text{method of least sq.}} = \sum_{k=1}^{N} \varepsilon_{k}^{2} = \sum_{k=1}^{N} [y_{k} - y(a, t_{k})]^{2} = \min \]

Assuming that:

\[ FC = \varepsilon^{T} G_{y} \varepsilon, \text{ where } \varepsilon = [\varepsilon_{k}] = [y_{k} - y(a, t_{k})], k = 1, 2, \ldots, N, G_{y} \text{ is the inverse of the diagonal covariance matrix for the } y_{k} \text{ measurement signal for independent samples.} \]

The aim is to obtain an estimate of the parameter vector \( a = [a_{1}, a_{2}, \ldots, a_{n}] \) for which \( FC = \min \).

In our study, it was assumed that in the first approximation of the expression \( y(a, t_{k}) \) (in general nonlinear) will develop into the Taylor series in the selected, as accurately as possible, starting point \( a = a_{0} \). Then, the development should be limited to a linear factor, and on this basis, the first approximation will be calculated \( a_{1} = a_{0} + \Delta a \). The procedure was repeated until it satisfied the chosen criterion, i.e. obtaining the minimum value of the objective function.

It should be noted that in the selection of functions relative to the volatility of raw results in the time vector, it was taken into account that the linear model wrongly approximates the course of the sports careers because it represents a constant direction (growth) of the development of their sports careers – the results would be improved in the same way throughout the whole sports career, which in practice, does not occur. Therefore, for the analysis, a nonlinear model was chosen - 2nd degree polynomial - the graph of which is a parabola. In this model, there are three parameters describing non-linear trends.

General formula: \( y = ax^{2} + bx + c \), where:

- \( a \) - parameter with the variable \( x^{2} \);
- \( b \) - parameter with the variable \( x \);
- \( c \) - constant of the equation

\( x \) - years of training; \( y \) - results achieved by the athlete.

The sign of parameter \( a \) indicates in which direction the parabola arms are facing:

- If \( a > 0 \), then the parabola arms point up:
- If \( a < 0 \), then the parabola arms point down:
Using predictive models for forecasting the career...

- Factor $a$ of the quadratic function $y=ax^2+bx+c$ determines the span of the arms; the smaller $a$ is, the wider the parabola.
- Coefficient $b$, along with coefficient $a$, determine the coordinates of the vertex of the parabola:
  \[ x_v = \frac{-b}{2a} \]
  Factor $c$ defines the intersection of the parabola with the $0y$ axis.

After selecting a function of the trend using the method of least squares and assessing its parameters, the quality of the resulting model was evaluated.

Assessing the fit of the model to empirical data is done to check whether the model explains the formation of the explained variable to a sufficiently high degree. This was performed using different measures of the model compliance with empirical data. The basic measures of this type are: the standard deviation of the residuals, the coefficient of random variation, the taper factor and the coefficient of determination. For calculations, we used the EXCEL calculation package http://office.microsoft.com/pl-pl/excel/.

### III. Results

#### 1. Time series of results at different distances in the 21-year-long athletic career of the race-walker

Table 1 shows the development of record-breaking results in subsequent years of sports training of the Polish international championship class race-walker. Their high position in the world can be attested by comparing the personal best for the distance of 50 km (marked in green), set in 2013, to the data presented in Figure 1, in which we may find comparison of the ranking results achieved by race-walkers around the world during the same year and for the same distance. The comparison shows that the result of G.S. was near the limit of the range of results in the 1-50 class.

<table>
<thead>
<tr>
<th>Age</th>
<th>Year</th>
<th>3 km</th>
<th>5 km</th>
<th>10 km</th>
<th>20 km</th>
<th>50 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1993</td>
<td>0:15:22</td>
<td>0:25:26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1994</td>
<td>0:14:43</td>
<td>0:22:56</td>
<td>0:45:42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1995</td>
<td>0:12:42</td>
<td>0:22:07</td>
<td>0:42:46</td>
<td>1:35:10</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1996</td>
<td>0:12:09</td>
<td>0:21:08</td>
<td>0:41:46</td>
<td>1:30:21</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1997</td>
<td>0:11:59</td>
<td>0:20:50</td>
<td>0:41:26</td>
<td>1:25:47</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1998</td>
<td>0:19:40</td>
<td>0:42:19</td>
<td></td>
<td>1:29:39</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>1999</td>
<td>0:20:16</td>
<td>0:41:44</td>
<td>1:28:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>2000</td>
<td>0:19:40</td>
<td>0:41:55</td>
<td>1:25:02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>2001</td>
<td>0:19:36</td>
<td>0:40:08</td>
<td>1:24:37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>2005</td>
<td>0:18:55</td>
<td>0:39:01</td>
<td>1:21:01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>2008</td>
<td>0:19:35</td>
<td>0:39:28</td>
<td>1:23:01</td>
<td>3:45:47</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>2011</td>
<td>0:19:09</td>
<td></td>
<td>1:20:51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>2012</td>
<td>0:11:21</td>
<td></td>
<td>1:20:58</td>
<td>3:46:00</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>2013</td>
<td>0:12:09</td>
<td>0:19:03</td>
<td>0:40:01</td>
<td>1:20:46</td>
<td>3:41:20</td>
</tr>
</tbody>
</table>

*Source: own elaboration based on the website: http://www.iaaf.org/athletes/poland/grzegorz-sudol-56340)*

* records set on athletics track; official personal bests marked by colour
It should be noted, that although they were not the results of the highest rank, they may indicate G.S.’s sports potential. Many times, he proved that even though his results were not situated high in the world rankings, he performed very well tactically and achieved places in the world ‘top ten’. An example of this were two consecutive Olympic games, during which he reached 7th and 9th place, or the European Championships in Barcelona, where he became the European runner-up. This may prove that the tested athlete is, nowadays, a typical example of a model champion in race-walking.

Analyzing the time series (Tab. 1), in which the levels of the variable should be discerned: sports results (ordinate – y) as a function of the duration of the sports career (abscissa – x), in the whole vector of time (1993-2003) paving the path to sports championship, we can state:

− Continuity of practicing race-walking sports, starting with the youngster (age 14-15) up to the senior category (age 35).
− Applying the earlier race-walking specialization type after short condition and technique preparation (1-3 years) for the 3-20 km distances.
− Beginning starts in race-walking within the youngster and younger junior category from 3-20 km: 3-5 km – youngster age 14-15, 10 km – younger junior age 16, 20 km – younger junior age 17.
− Lack of, apart from the longest distance of 50 km, preparation period for competing in a typical Olympic competition for the long-distance - 20 km.
− Greatly delaying (age 24, senior category) first starts in walking for 50 km distances.
− The occurrence of a long, progressive period of sports results development: 5-20 km distance – 13 years, 50 km – 8 years.
− Marking of the symptoms of sports regression only for the shorter distances (5-10 km) at the final periods of observation.
− Maintaining a high level of sports results in walking for a long period of time (apart from the 3 km: 5-20 km – 9 years and 50 km – 6 years.
− In 2013, improvement in personal bests for classic distances (20 and 50 km), Hus at the age of 35 and after 21 years of specializing in race walking.

2. Models of G.S.’s sports performance development pace and prediction of results for race-walking distances (5-50 km)

A. The pace of result development in race-walking at 5-50 km distances for G.S.

Individual indicators of the pace of result development of the athlete G. S. in race-walking distances 5-50 km were determined using the percentile, fixed base index of dynamics of development. Their course in a function of the duration of the sports career (15-35 years) is shown in Figure 2 and Table 2. Based on the analysis of data, a very similar trend of development for all distances can be stated. It was revealed with the greatest

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1 A subsequent specialization in race walking for 50 km.

2 Due to the questionable issue of maintaining walking techniques by the senior in accordance with the applicable regulations for the developed speed at the short distance of 3 km and the occasional use of that distance in G.S.’s start policy, it is difficult to respond to the dynamics of the development of results in race-walking over this distance, and in particular, to the records from the final stage of the contemplated observation period. G.S.’s record result in race-walking for the distance of 3,000 meters reported by the IAAF (11:21:32) was established at the age of 35!
Using predictive models for forecasting the career...i

force during the last period of observation, i.e. when the vector of the level of relative stabilization for all distances and the starting tendency to regress with different force could be very clearly determined.

B. Forecast for the sports championship development during the period of relative stability of results in race-walking of the world-class master athlete

In accordance with the adopted research aim, the predictive models of results were build for all distances in which the master competitor took part in race-walking in the subsequent years of training. The basis of their formation was formed by the results suggesting the existence of non-linear dependencies (the parabola in a function of time). Accordingly, regression models were used (non-linear), determined using the regression function summing the form of:

$$y = ax^2 + bx + c$$

After linearization of the model and coefficient estimation of the model using the classic least squares method, the predictive curvilinear models were calculated, characterizing the theoretical, individual track of development of sports championship in the extended time vector of results development at a given distance of race-walking, which could result in a very good fit of empirical data to the model and thereby, its high prediction. The effect of such a research procedure indicating its applicative aspect is presented below.

Table 2. Progression of G.S.’s results presented as percentages for particular distances relative to personal best (100%)

<table>
<thead>
<tr>
<th>Years/distance</th>
<th>5 km</th>
<th>10 km</th>
<th>20 km</th>
<th>50 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>82.5</td>
<td>85.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>85.5</td>
<td>91.2</td>
<td>84.9</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>89.5</td>
<td>93.4</td>
<td>89.4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>90.8</td>
<td>94.2</td>
<td>94.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>97.8</td>
<td>92.2</td>
<td>90.1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>93.3</td>
<td>93.5</td>
<td>91.8</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>97.8</td>
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<tr>
<td>9</td>
<td>96.5</td>
<td>97.2</td>
<td>95.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>94.0</td>
<td>92.2</td>
<td>95.8</td>
<td>95.8</td>
</tr>
<tr>
<td>11</td>
<td>95.5</td>
<td></td>
<td>98.0</td>
<td>93.9</td>
</tr>
<tr>
<td>12</td>
<td>96.8</td>
<td>92.3</td>
<td>98.9</td>
<td>96.6</td>
</tr>
<tr>
<td>13</td>
<td>100.0</td>
<td>100.0</td>
<td>99.7</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>99.1</td>
<td>92.4</td>
<td>95.2</td>
<td>96.1</td>
</tr>
<tr>
<td>15</td>
<td>96.8</td>
<td>95.2</td>
<td>96.3</td>
<td>94.0</td>
</tr>
<tr>
<td>16</td>
<td>96.6</td>
<td>97.3</td>
<td>98.0</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>98.3</td>
<td>98.9</td>
<td>98.7</td>
<td>99.4</td>
</tr>
<tr>
<td>18</td>
<td>98.1</td>
<td>99.4</td>
<td>99.9</td>
<td>99.5</td>
</tr>
<tr>
<td>19</td>
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<tr>
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<td>99.3</td>
<td>97.5</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
50 km race walking

Figure 3 shows the graph of a polynomial function, the formula of which assumed the form of a second degree quadratic function: \( y = -0.031x^2 - 0.069x + 236.8 \)

It is comprised of parameters, the value of which was created with the established time series of results in race-walking at a distance of 50 km, obtained by the competitor G. S. in the course of his 21-year-long sports career. Analysis of the data shows that the quadratic function describes a parabola with the tip pointing down. The sign of the coefficient “a” determines this; a negative value in the measurement of time is equal to (-).

As it can be conclude from the analysis of estimated parameters, there is a large difference between the results deriving from the method of approximation and actual results, especially in the early years of starts for 50 km: the 11th, 15th year of sports training and the 2nd and 5th year of starts for 50 km. Using the proposed predictive model: the result for 50 km [min] = \(-0.031 \text{ (career [years])}^2 - 0.069 \text{ (career years)}\) + 236.8 it could be assumed that in the Olympic year 2016, the athlete could achieve the result 3:39:23 and improvement of the personal best in 50 km race-walking.

20 km race walking

Figure 4 presents a graph of the quadratic function (quadratic trinomial): \( y = 0.047x^2 - 1.714x + 96.9 \)

Compiled on the basis of the time series results in the race-walk for 20 km, which G.S. achieved in consecutive years of his sports career (21 years of practicing sport professionally). According to the presented data, the function: the result at 20 km [min] = 20 km [min] = 0.047(\text{career [years]})^2 - 1.714 \text{ (career years)}\) + 96.90 was based on a much longer time vector of sports results than race-walking for 50 km. In addition, the individual points of the theoretical curve of sports development was based on the lower dispersion of empirical results. Larger derogation from the trajectory of the developed function was marked only - in plus - in the 5th year of competition and - in minus - in the 12th and 13th year of practicing race-walking. It should also be noted that in accordance with the Cartesian coordinate system, the quadratic function was created on the Euclidean plan, which is described by a parabola with the apex pointing upward (in accordance with the return of the OY axis). It is the result of the fact that the sign of parameter “a” is positive, thus it indicates a negative time value (-), or \(a<0\). This also implies that the parabola indicates the possibility of involution periods in the development of sport performance results. For this reason, the prediction of the result for the Olympic year would be less successful than in the case of race-walking for a distance of 50 km. According to it, the athlete could achieve the result of - 1:22:38, in 2016 in race-walking for 20 km and therefore, a result worse than the personal best.

Figure 5 presents a graph of the quadratic trinomial: \( y = 0.009x^2 - 0.407 + 44.37 \), developed on the basis of the time series of results in race-walking at a distance of 10 km, obtained by the competitor G.S. in the course of his 21-year sports career. As previously stated, starts at this distance were already undertaken by the athlete as a younger junior and continued to the end of the observation period, i.e. until 2013. The relatively long time vector
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**Figure 4.** The graph of quadratic function: $y = 0.047x^2 - 1.714x + 96.9$, created with the established time series of results obtained by the competitor G.S. in the course of his 21-year sports career in race-walking for the 20 km distance.

**Figure 5.** The graph of quadratic function: $y = 0.009x^2 - 0.407 + 44.37$, created with the established time series of results obtained by the competitor G.S. in the course of his 21-year sports career in race-walking for the 10 km distance.

taken into consideration in the creation of the predictive model could help to increase the prognostic value of the parameters of the quadratic function. However, attention should be paid to the greatest dispersion of obtained results in relation to the theoretical curve, characterizing the model of predictive function in the previously previously presented models. The value of the prediction based on the function model: the result of 10 km [min] = 0.009 (career [years])² - 0.407 (career [years]) + 44.37. This allows to state a collapse om the pace of sports development for this distance after 2013. The decisive factor for this was the negative indicator “a”, which was obtained in the point estimation. The parabola apex is directed upwards, which makes the prediction value negative. On the basis of the created predictive model, it should be assumed that the competitor in the Olympic year could achieve a result of 39.47 in the race-walk for 10 km, and therefore, a result worse than the personal best (39.01).

**C. 5 km race-walking**

As noted earlier, for comparison, there was also a predictive model developed for the results in race-walking for the 5 km distance obtained by the competitor...
G.S. in the course of his 21-year career. It was calculated from the previously presented time series of record results in each year of training. According to the data shown in Figure 6, the Europe runner-up competed at the distance of 5 km from the first year of competitive sports in the youngster category. Therefore, similarly as in the predictive model for 10 km, it extended to the longest period of the time vector of results, which is the basis for the construction of the function \( y = 0.023x^2 - 0.714x + 24.34 \).

The chart created on its basis is presented in Figure 6. On the basis of comparison of the created theoretical curve of the results development pace throughout the course of the 21-year sports career of competitor G.S. to the actual value of the results obtained at the time, it should be stated that the trajectory of the theoretical curve is located very close to the corresponding points that characterize the actual value of the achieved results. On this basis, it could be concluded that the prognostic value of the constructed model is very high.

Analysis of the quadratic function parabola graph: 5 km result [min] = 0.023 (career [years])² - 0.714 (career [years]) + 24.34, presented in Figure 6, shows that with a high degree of probability, it can be assumed that at a distance of 5 km, the tendency towards regression of sports level was very clearly marked. This can be suggested by the value and direction of coefficient "a" of the quadratic function with the upwards apex. Its apogee was determined at the point of the 12th year of participating in competitive sports and starting in race-walking competitions. It is worth noting that at this time, on other distances, the stage of relative stabilization of the sports level was just beginning and the tip of the parabola was postponed.

By analogy to the cross-country competition, it could be assumed that the tendency towards the process of faster regression of results for short distances was due to the effect of loss of speed abilities in a human’s older age [27-29].

Such a hypothesis seems probable, because in the characterized regression period of sport level, which was set in the predictive model, the competitor was already 26! It can also be confirmed by the level of involution tendencies of results at other distances revealed in the calculation of quadratic trinomial. On the basis of the direction and value of the parameter of the quadratic function "a", the following rank order of involution trends can be determined in the results for the race-walking distances performed by the tested athlete: 5 km>10 km>20 km>50 km. It seems that the revealed finding, having its source in the biological development processes, should be taken into account in training process assumptions. It could have also influenced, regardless of the awareness of such a need, G.S.’s decision to start specializing in the 50 km race-walking distance at that period of his 12th year of training sport.

Apart from the above-mentioned effects of developmental processes, it can be assumed that the extent of the regression, embedded in the mentioned function in the Olympic year, could have resulted in lowering the best result obtained in the race-walking for the 5 kilometer distance in the Olympic year (2016) to the level of: 20:27.
IV. Summary and discussion

In this study, such tasks were undertaken: determining the development trend of selected features of a modern race-walking champion model and the creation of individual models of the athletic performance dynamics and forecasts of results development in race-walking for 5-50 km distances of the medalist at the European and the world championships. The effects of the conducted query of the available documents in the archives of the tested athlete and the data on websites provided materials and allowed to carry out their analysis using methods, techniques and research tools applied in other studies. Thanks to them, the obtained data enabled verification of the adopted research hypotheses, allowing identification of new opportunities to use research results in sports practice.

Referring to the cognitive objectives, it should be stated that the results of the athlete’s sports biography analysis and his development of athletic performance during more than 20 years of practicing walking sports led to the study of the modern master model in the above mentioned track and field event. Top features of the undisputed sports career, which included record and titles of the Polish Champion and medals at World and European Championships, confirmed the adopted research hypothesis and show the younger generation of athletes the way to obtain a championship level in the 21st century.

On the basis of the collected evidence, it should be assumed that in the case of G.S., the development course of results, leading to achievement of world-scale, championship levels, was achieved meandering, and its finale in the form of personal bests in race-walking at the classic distances (20 and 50 km) occurred mainly in the last year of observation - in the senior category at the age of 35, and at distances of 10 and 5 km - at the age of 27. So, it was a long and winding road. Referring to the proposed model of result dynamics by Matveyev [30], it can be stated that it was uneven in nature. Confirmation of this can be the created characteristics of G.S.’s development pace if results for all distances.

It is difficult, however, to detect three-year macrobiorythms in G.S.’s athletic career, found in the dynamics of the result development of sports champions at the end of the 20th century [30] or other stages distinguished by Volkov and Ion [31]. The uneven improvement tendency in the Olympic year was very poorly marked, which gave rise to the so-called sports ontogeny division in the senior period of the examined athlete into four-year cycles. By measuring the time vector from the beginning of training competitive sports (1993) to achieving record results in race-walking for 20 and 50 km distances (2016), its value can be estimated at 21 years, and in race-walking at the 5 and 10 km distance - 13 years.

A similar phenomenon of a long period of “maturing to the sport” was observed by Ozimek [24] in studies of Olympians from the end of the twentieth century, and also Sachnowski [32], Matveev [30] Szustin [33], Bauer [34] and Sozariski et al. [35]. Based on the original Sachnowski concept [32] as well as the modified one [24], it can be assumed that the 21-year period needed to obtain personal bests can be classified into the medium variant of “maturing to sport”, and a 13-year time interval was within the accelerated development variant of a sports champion. The first one of these was typical for long-distance runners and sprinters in track and field events in the final decades of the 20th century [24]. Referring to the above stages to reach the record results to those similar found in athletes engaged in different disciplines at the beginning of the second half of the 20th century, [36] it should be noted that the period needed to achieve record-breaking results by masters in the said sport discipline was very clearly lengthened.

Therefore, it should be assumed that the facts from the European vice-champion’s sports biography confirm the correctness of sports championship development at the turn of the 20th and 21st century, and lead to confirmation of the adopted hypothesis of our research stating that in the model of a modern sports champion, a tendency to achieve personal bests by older athletes is revealed. The results of the biographical analysis of the tested competitor question the approach suggested in the works of prominent sports theorists [37-39], stating that material had already been collected which would allow to disprove the validity of the “primitive approach” formulated in the 70s and 80s of the 20th century regarding starting the sports specialization by young athletes applying the principle of: “the sooner, the better” [24]. From our own research it can be concluded that G. S. undertook sports training at the age of 14 and after a year of technical preparation, he already successfully and competitively practiced a technically difficult sports discipline. At a similar age, the Olympic champion in race walking RK also joined this training group. Also in his training, after a short period of time (2-3 years), the variant of specialization was used in the Olympic race walking competition at the distance of 20 km. However, in both of the sports champions, attention is drawn by the typical practice of postponing race walking at the 50 km distance, as already mentioned earlier. G.S. started at this distance for the first time at the age of 26, after a 12-year period of starts at different distances. A similar phenomenon could be seen in the concepts of sports training in other Polish race-walkers. It would therefore suggest that the results of our study allowed us to determine the typical Polish variant of training future champions in race-walking at 20 and 50 km: earlier specialization in race-walking at 20 km and later specialization in race-walking at 50 km.
Without criticising the existing views of sport theorists, suggesting the need to postpone the specialization of a candidate for a sports champion [24, 39-43], it should be noted that in light of the results of our research, based on the facts of the sports biography of G.S. and the Olympic champion R.K., the above mentioned position may be debatable. Early specialization in race-walking for the 20 km distance did not prevent G.S. or the Olympic champion RK to achieve significant success in the senior category. The recognised phenomenon contradicts the proclaimed “certainties” in contemporary sport theory that the early initiation of specialized sports does not guarantee success in sports [24]. The resulting conclusions lead to falsification of the assumptions made in the research hypothesis that in the biography of a contemporary sport champion, a tendency to postpone specialization in a particular sport discipline is revealed.

In sport theory it is stated that one of the most characteristic features of the road to athletic championship is the occurrence in the course of a career of a long period of result stabilization at the highest level. According to Sachnowski’s research [32] and, above all, Ozimek’s [24], in the extreme ranges it can reach up to 16 years. Such a phenomenon was also greatly visible in the description of time series of results obtained by the studied competitor. With the exception of results for the 3 and 50 km distances, a long period of relative stabilization in the dynamics of sports development of the race walker was noticed (12 years). Own research results, therefore, confirm another hypothesis that in the biography of a contemporary sport master there is a revealed tendency to extend the period of relative stabilization at high sport level.

Determined using the approximation method and the method of least squares, the quadratic function and its graphical presentation did not confirm the adopted hypothesis that the feature of the dynamics of results development of an athlete reaching the championship level at all distances in race-walking (5-50 km) will be a small amplitude of the rhythm of result variation in consecutive years of sports training, as well as the determined on this basis - the difference in the track of the empirical curve variation determined using the interpolation method and the theoretical curve determined by approximation. The interpretation of the results confirmed the Matveev’s thesis [30] of the abrupt pace of development on the road to the sports championship, whose shape is set by a parabola.

It should be noted, however, that in the proposed predictive model of sports level development for a particular athlete, a relatively long time vector of the set of the base variables from the ontogenesis period was taken into consideration: 12–21 years, which could result in a good fit of the empirical data to the mathematical model. The consequence of this can be a high degree of predictive value of further sports development of the tested athlete.

However, from a number of methodological studies, it is known that forecasting is always debatable. The forecast result depends on the material, on the basis of which it was developed and on the applied calculation algorithm [13, 44-48]. Selection of the appropriate variables is also important because of the need for processes of learning the model and testing it [13, 48]. In our study, we adapted a mathematical model to predict the sports result development of a particular athlete. Consequently, the issue of material selection - very important in determining the “population predictions” - was not necessary. In the first stage of research, the time series (dynamic) was established, in which the levels of variable were tested, the results obtained by a particular athlete as a function of the duration of the sports career. In this situation, one can omit the validation process of variables and output variables taken into account in the model because it is based only on a case study. The selection of the calculation algorithm may be debatable. The processes of learning the model and testing it in exponential, linear and nonlinear models may be different.

In the forecasting of results over a longer period of time, a very interesting method to predict world records was proposed by two scientists from the former Soviet Union [31]. Assuming that the development of world records for the 5 and 10 km distances has an irregular course, they assumed that intervals can be distinguished, the course of which can be described using a logarithmic function and described with the equation: $T_{rec} = T_{rec}^0 \times e^{\kappa t}$, where: $T_{rec}$ - consecutive world record (rec), $T_{rec}^0$ - initial (init) result, $e$ - base of the logarithms, $\kappa = k \cdot$ constant speed of record improvement, $t$ - the period from the beginning of the establishment of world records. In turn, converting the axes of the arithmetic scale $x$, $y$ into a logarithmic scale, when comparing record logarithms with logarithms from the year of its establishment, was followed by conversion from the exponential line to a simple one [31]. Such an interesting mathematical solution found followers in the development of forecasts for other athletics events [46]. Yet, another way to solve the problem of prediction in a shorter period of time was proposed by Maszczynk [5]. To do this successfully, he used a modern analytical method based on an artificial neural network.

In our study, it was necessary to match the selected calculation algorithm to the created time series of the athlete’s results. After initial examination of the graph presenting variability of the empirical curve of result dispersion, it was decided to match a nonlinear model to its characteristics (parabolic function for a long period of time). It should be noted that such development models are used to create time series on the basis of...
which a prediction of the results is made as a function of time. As the explanatory variable (independent), we adopted a time variable. It is not the direct cause of changes in the values of the forecasted variables (as a sports result). It synthesizes, however, the impact of unknown factors and makes it possible to describe the changes in a quantitative way. In this study, such issues were not discussed: the problem of determinants reproduced using the method of approximation of the trends regarding the phenomenon of result development, nor its prediction. This may be the subject of further research. It should also be noted that so far, the proposal to use predictive models (econometric) and the mathematical description of the individual pace of result development of athletes performing medium and long distance runs at a champion level, can only be found in one study [25]. Certainly, the usefulness and relevance of the proposed method will be verified by practice. One should be aware that despite numerous attempts to elaborate on the development trend of sports results based on linear and nonlinear models, there are not effective systems that reflect the actual course of events in the future. It is difficult to predict all the factors affecting the phenomenon, and also random factors can disrupt even the most accurate mathematical calculations. Apart from this risk associated with the use of statistics and econometrics in practice, it seems that it is worth using strict methods in coaching practice. For sure, the results obtained through them can effectively support the necessary intuition and common-sense behavior in sports training.

Conclusions

1. A description of the sports related biography can provide valuable results for understanding the development trends of the contemporary model of a champion in professional sports and the implications for developing training and recruitment concepts of future sports champions.
2. The proposed prediction models for forecasting individual development trends of sports results can be used to characterize the development dynamics of the achievements of an athlete during his/her sports ontogeny, as well as in a practical sense, show further athletic prospects at the stage of relative stability of results.

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Author for correspondence:
Grzegorz Sudol
E-mail: gsudol@interia.pl
CAN WINNER BE RECOGNIZED BY BODY COMPOSITION? – A STUDY ON ELITE TAEKWON-DO ATHLETES

Jacek Wasik¹ ABDEF, Michal Zych¹ BEG, Cezary Michalski¹ BEG, Wiesław Pilis² CDEF, Tomasz Gora¹ BEG, Karol Pilis¹ DE

¹ Institute of Physical Education, Tourism and Physiotherapy, Jan Dlugosz University, Częstochowa, Poland
² Institute of Physiotherapy, Public Higher Medical Professional School in Opole, Opole, Poland

Key words: taekwon-do, performance sport, somatic indices coaching/practical training

Abstract

Aim. Identification of significant features characteristic of best athletes (champions) which distinguish them from athletes representing a lower level of sports achievements is becoming an increasingly important issue in view of the further development of taekwon-do.

Basic procedures. The following were determined for the studied athletes: age using the Tanita BC-418 MA body composition analyzer, time period of taekwon-do practice, weight, height, BMI (body mass index), BMR (basal metabolic rate), FAT (fat content), FFM (fat free mass) and TBW (total body water). Those variables were analyzed in the winners (champions) of particular weight classes against all the other participants of the study (n=55) and against their particular weight class to which a given participant belonged on the basis of a confidence interval at the level of 95%.

Results. The study showed that the athletes of particular weight classes differed within the scope of their BMR and the analyzed somatic indexes (p<0.001), and the champions of particular weight classes did not differ from the other practitioners participating in the study. Further analysis has shown that the significant features distinguishing the champions from the other contestants within specific weight classes are their age, how long they have been practicing taekwon-do, their height, BMI and BMR.

Conclusions. It has been concluded that although there are statistical differences concerning BMI and somatic indexes between taekwon-do practitioners of different weight classes, it is possible to identify the features characteristic of the best taekwon-do athletes differentiating them from those less advanced.

Background

Success in competitive sport belongs to athletes showing a specific level of physical fitness, significant somatic features, proper motor and psychological skills and abilities as well as appropriate experience who are identified in a selection process [1-3]. Subsequent stages of development and training adaptation abilities of the organism occur as a result of systematic training and monitoring of the training process [4]. Only then do
the most significant features deciding about the sports championship development level in a given sports discipline become apparent. In many sports disciplines, an allometric model has been introduced so that the influence of different variables on the results achieved can be eventually specified. In this model, the value of the power generated by athletes involved in a survey or their sports results achieved are determined with the use of biological, psychological values or elements of the gathered experience on the basis of established dependencies and mathematical equations [5,6]. It has been noticed that body mass [7], maximum generated power [8,9], maximum organism oxygen consumption [10,11] or ergometric rowing speed [12] are significantly important in this model of dependencies. Allometric dependencies of generated strength and muscle power as well as obtained results were described in a particularly detailed way in relation to body mass in weight lifting [9,13,14].

In taekwon-do - ITF (International Taekwon-do Federation), contestants compete in five different events: formal patterns, sparring, power tests, special techniques [15,16] and also in pre-arranged sparring [17]. Each of these events requires specific somatic features of the athlete and the values of generated strength and power are of significant importance here [18]. In order to reduce disproportions within the scope of those motor skills and promote equal opportunities to achieve top levels of sports skills and abilities for athletes of different somatic features. In ITF taekwon-do it was decided to introduce weight classes determined by athletes’ body weight. However, it was further noticed that apart from body weight, some other somatic features are significant when it comes to achieving good results in taekwon-do in the case of young taekwon-do athletes [19], and similarly in the case of elite taekwon-do practitioners [18]. An uncomplicated way of measuring and calculating somatic features can be encouraging in identifying features important in the selection process and then, in their achievement of top sports results in taekwon-do.

The objective of this study is to identify which of the somatic features analyzed in this study along with age and length of time of taekwon-do practicing, to a significant extent, are characteristic of best taekwon-do athletes who took part in 2014 Polish Championship in the traditional taekwon-do ITF while accounting for the male weight class division.

Methods

Subjects

The study was conducted on ITF taekwon-do athletes, who in the selection process qualified for participation in the Polish Championship in 2014. Altogether, the analysis involved 61 male athletes (age 23.6±5.9 years; height 175.9±22.3 cm; weight 74.3±12.7 kg).

The study included only those competitors who for 48 hours before the official weighing preceding sporting events weighed no more than 2 kg above the applicable limit specified for a given weight category. and 24 hours prior to the official weighing applied the standard mixed diet and drank an amount of isotonic drinks (1.5/50 kg/24h) normalized to body mass. In this way, an attempt was made to avoid excessive dehydration and to stabilize isotonic body fluids to minimize differences in the body tissues electrical impedance fluctuations in order to provide greater accuracy of body composition measurements [20]. The measurements were made one day before the competition between 6:00.00-9:00 p.m.

Protocol

Body mass and composition measurements were carried out through electrical impedance with the use of the Tanita BC-418 MA body composition analyzer. The following parameters were measured: weight, BMI (Body Mass Index), BMR (Basal Metabolic Rate), FAT (fat content), FFM (Fat Free Mass), TBW (Total Body Water content in the organism). Moreover, the athletes’ ages were also recorded along with how long a particular athlete has practiced taekwon-do. Body height was determined using the ADE MZ10023 Measure Telescopic Growth.

Statistics

The arithmetic mean and standard deviation were calculated for the abovementioned data. The athletes participating in the pilot survey were divided into six weight classes and for each of these classes, the champion was specified. The difference between arithmetic means for particular weight classes within the scope of all the features analyzed in this study were specified using one-way analysis of variance for which Tukey post hoc test was applied. For all the athletes together, as well as separately for each weight class, confidence intervals at the level of 95 % were calculated on the basis of estimations not taking the champions into consideration here. Then, particular features of the champions were analyzed against confidence intervals determined for the whole group (n=55) or the particular weight class of each champion. In the case when the value of a given feature of a champion/champions was not located within the specified confidence interval (-95.00 % to 95.00 %), then it was declared to be statistically different from the one analyzed in the group or the weight class. When the value of a specific feature of a champion/champions was located within the limits of the confidence intervals specified for a particular variable, then it was regarded as non-significant in relation to the group or weight class.
Results

The features of all the taekwon-do athletes taking part in the study are presented in Table 1. The features of the athletes in particular weight classes are presented in Table 2.

The variance analysis of the data in Table 2 shows that significant differences occurred within particular weight classes for all the features except age and the time period of practice ($p<0.001$).

In Table 3, the post hoc statistic values for particular variables analyzed in the study are presented. Bold print was used to mark statistically significant values. Within the scope of the athletes’ age and the time period of taekwon-do practice, there were no significant differences between the weight classes; however, within the scope of the weight, all the classes were significantly different from one another while for the other variables, the differences were significant only in relation to some of the compared weight classes.

In Table 4, the values of the analyzed variables in the champions of particular weight classes are presented. Their significant dispersion, apart from age and the time period of taekwon-do practice, was determined by athletes’ different weights.

When particular features of the 6 champions of all the weight classes i.e. age, height, weight, the time period of taekwon-do practice, BMI, BMR, FAT, FFM, and TBW were presented against the other 55 athletes, it became evident that those individual values did not exceed the 95% confidence level limits regarding any specified feature of the whole group of athletes included in the study and those differences were recognized as statistically non-significant.

However, when the said variables of particular champions were compared to their particular weight class, it was noticed in numerous cases that particular features of a champion were localized outside the limits of confidence intervals (-95.00% to 95.00%), which was regarded as a statistically significant difference and was marked in Table 5 with an arrow.

### Table 1. Characteristics of all the male athletes participating in the study (n=61)

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>23.6</td>
<td>175.9</td>
<td>74.3</td>
<td>11.48</td>
<td>23.20</td>
<td>1834.77</td>
<td>13.28</td>
<td>63.17</td>
<td>47.18</td>
</tr>
<tr>
<td>SD</td>
<td>5.9</td>
<td>22.3</td>
<td>12.7</td>
<td>4.45</td>
<td>2.76</td>
<td>201.95</td>
<td>3.94</td>
<td>11.16</td>
<td>6.90</td>
</tr>
</tbody>
</table>

### Table 2. Arithmetic means and standard deviations along with significance of differences of variables for the athletes under study in relation to weight class division

<table>
<thead>
<tr>
<th>Weight class [kg]</th>
<th>x</th>
<th>Age [years]</th>
<th>Height [cm]</th>
<th>Weight [kg]</th>
<th>Time period of practice [years]</th>
<th>BMI [kg/m²]</th>
<th>BMR [kcal]</th>
<th>FAT [%]</th>
<th>FFM [kg]</th>
<th>TBW [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>57 n=5</td>
<td></td>
<td>mean 23.4</td>
<td>166.4</td>
<td>56.2</td>
<td>12.4</td>
<td>20.3</td>
<td>1535.4</td>
<td>8.9</td>
<td>51.2</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 5.86</td>
<td>3.8</td>
<td>0.2</td>
<td>3.6</td>
<td>1.0</td>
<td>80.3</td>
<td>1.5</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>63 n=10</td>
<td></td>
<td>mean 20.5</td>
<td>172.2</td>
<td>62.0</td>
<td>10</td>
<td>21.1</td>
<td>1672.9</td>
<td>10.1</td>
<td>55.7</td>
<td>40.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 5.2</td>
<td>6.2</td>
<td>0.7</td>
<td>4.5</td>
<td>1.5</td>
<td>82.8</td>
<td>2.9</td>
<td>1.7</td>
<td>1.2</td>
</tr>
<tr>
<td>70 n=16</td>
<td></td>
<td>mean 23.1</td>
<td>178.4</td>
<td>68.5</td>
<td>12.3</td>
<td>22.2</td>
<td>1741.5</td>
<td>11.9</td>
<td>60.3</td>
<td>44.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.3</td>
<td>6.2</td>
<td>1.3</td>
<td>4.1</td>
<td>1.6</td>
<td>71.4</td>
<td>2.6</td>
<td>1.9</td>
<td>1.4</td>
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<tr>
<td>78 n=11</td>
<td></td>
<td>mean 23.7</td>
<td>179.5</td>
<td>75.5</td>
<td>10.7</td>
<td>23.5</td>
<td>1853.5</td>
<td>13.7</td>
<td>60.2</td>
<td>49.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 4.1</td>
<td>4.3</td>
<td>1.9</td>
<td>5.2</td>
<td>1.3</td>
<td>51.0</td>
<td>2.7</td>
<td>16.4</td>
<td>5.6</td>
</tr>
<tr>
<td>85 n=10</td>
<td></td>
<td>mean 25.8</td>
<td>183.2</td>
<td>83.4</td>
<td>11.1</td>
<td>24.9</td>
<td>1958.9</td>
<td>16.6</td>
<td>69.6</td>
<td>50.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 6.5</td>
<td>2.7</td>
<td>0.8</td>
<td>4.5</td>
<td>0.8</td>
<td>41.9</td>
<td>2.4</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>+85 n=9</td>
<td></td>
<td>mean 25.4</td>
<td>189.3</td>
<td>96.9</td>
<td>12.4</td>
<td>26.9</td>
<td>2185.9</td>
<td>17.5</td>
<td>79.7</td>
<td>58.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD 9.3</td>
<td>6.7</td>
<td>8.2</td>
<td>4.8</td>
<td>3.9</td>
<td>124.7</td>
<td>3.9</td>
<td>5.8</td>
<td>4.3</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>1,040</td>
<td>17.076</td>
<td>165.372</td>
<td>0.527</td>
<td>13.441</td>
<td>70.504</td>
<td>12.924</td>
<td>15.617</td>
<td>49.438</td>
</tr>
<tr>
<td>p&lt;</td>
<td></td>
<td>0.403</td>
<td>0.001</td>
<td>0.001</td>
<td>0.755</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>
The champions of four weight classes: - 63 kg, - 70 kg, - 78 kg and - 85 kg were significantly older than the upper limit of the 95 % confidence intervals for those populations. The champions of the four weight classes: - 57 kg, - 63 kg, - 70 kg and - 78 kg were significantly shorter than the lower limits of the 95 % confidence intervals of those classes, and the champion of the - 85 kg weight class was significantly taller than the upper limit of the 95 % confidence interval of the other competitors presented. In relation to body weight, in the - 63 kg weight category, the champion was heavier than the upper limit of the 95 % confidence interval of the competitors while in + 85 kg weight class, the champion weighed less than the lower limit of the 95 % confidence interval for this class. The time period of taekwon-do practice of the champion of the - 57 kg weight class was shorter while this time period for the champions of the weight classes of up to: 63 kg, 70 kg and 85 kg was longer in relation to the lower and the upper limits, respectively, with the 95 % confidence interval for these classes. The BMI of the champions of the weight classes: - 57 kg, - 63 kg and - 78 kg was higher while it was lower for the weight classes up to 85 kg and + 85 kg than respectively for the upper and lower limits of the 95 % confidence interval of the other competitors. The BMR of the champions representing the weight classes up to 63 kg, 70 kg, 78 kg and 85 kg was lower than the lower limit of the 95% confidence interval of the other competitors. The FAT value in the bodies of the champions - 57 kg and - 63 kg was higher while in the - 85 kg champion weight class, it was lower in relation to the upper and lower limits respectively of the 95 % confidence interval
Discussion

There are several methods to examine fat-free mass and total body water contents, and more precisely, among them is dual-energy X-ray absorptiometry - DXA. In our study, we used bioelectrical impedance analysis - BIA. Since Pineau and Frey [21] found significant differences, by approximately +/-2%, regarding fat-free mass and total body water present in the majority of the cases, we examined our participants after 24 hours of a consuming isocaloric mixed diet with drinking similar (in relation to body weight) volumes of isotonic water.

The taekwon-do athletes of all the weight classes who were included in the study were of similar age and they had been practicing taekwon-do for similar periods of time, which actually facilitated the analysis of the influence of the other variables being likely to have influence on the achieved sports results. However, the somatic variables, including BMR, differed in particular weight classes, which was shown by using analysis of variance. Those differences must be to a significant extent treated as derivatives of the division of the athletes significantly differentiating in weight into 6 weight classes and possibly of different organism susceptibility to the applied training practice, which mostly reduces the fat content and increases their FFM [22].

The analysis of the data, characteristic of the champions within the scope of the discussed variables of particular weight classes to which those elite athletes belonged, carried out on the basis of estimation of confidence intervals at the level of 95% shows that the champions of most weight classes were older and had been practicing taekwon-do longer, although there were few exceptions from this rule, especially in the terminal weight classes (Table 5). However, it needs to be pointed out that even in the terminal weight class of + 85 kg, both the age and time period of taekwon-do practice of the champions did not exceed the confidence intervals for those variables, while the champion in the lowest weight class of up to 57 kg, being of a similar age to the others in the same weight class, had been practicing taekwon-do for a significantly shorter period of time than his rivals. Coaching observations show that such situations are possible as older champions with a longer time period of practice and greater experience less frequently – even as few as 3 times a week in comparison to the athletes who are still developing their skills and abilities and work harder in order to become top tae-

Table 5. Limits of confidence intervals at the level of 95 % for the variables of the athletes representing particular weight classes

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>57 n=4</td>
<td>-95.00%</td>
<td>12.365</td>
<td>165.750</td>
<td>55.757</td>
<td>9.321↑ 19.225↑ 1418.186 7.102↑ 51.127↓ 37.45325↓</td>
<td></td>
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<tr>
<td>63 n=9</td>
<td>-95.00%</td>
<td>16.381↑ 168.144↑ 61.407↑ 6.173↑ 19.776↑ 1625.647↑ 7.619↑ 54.504 39.87929</td>
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<tr>
<td>70 n=15</td>
<td>-95.00%</td>
<td>20.488↑ 173.061↑ 67.677↑ 8.677↑ 21.216↑ 1703.761↑ 10.336 59.289 43.40103</td>
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<tr>
<td>78 n=10</td>
<td>-95.00%</td>
<td>20.423↑ 176.875↑ 74.058↑ 5.827↑ 22.428↑ 1624.024↑ 11.579 47.338 45.24725</td>
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<tr>
<td>85 n=9</td>
<td>-95.00%</td>
<td>20.144↑ 180.826↑ 82.689↑ 7.283↑ 24.360↑ 1929.863↑ 14.950 67.909↑ 49.68066↑</td>
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<tr>
<td>+85 n=8</td>
<td>-95.00%</td>
<td>18.039 182.928↑ 91.670↑ 7.998↑ 24.961↑ 1089.345↑ 14.304 75.920↓ 55.57508↓</td>
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<tr>
<td>90.50%</td>
<td></td>
<td>34.211↑ 194.572↑ 104.580↑ 16.583 30.389 2304.045↑ 21.121 85.255↓ 62.42492↓</td>
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</table>

† - p<0.05 – champions’ individual values which are higher than the upper limit of the 95% confidence interval
↓ - p<0.05 – champions’ individual values which are lower than the lower limit of the 95% confidence interval
The weight variable did not really differentiate the champions from the other practitioners of particular weight classes (although in two classes such differences were observed – Table 5), which is quite understandable and results from the used division of athletes into such classes, and was confirmed by the research results by Kazemi et al. [24] and Kazemi et al. [25]. Nevertheless, the height variable is an indicator which considerably distinguishes champions from their rivals in such a way that in lower weight classes, champions are shorter and in higher weight classes, they are taller (although in the + 85 kg weight class the only tendency is that champions are taller) than their rivals. An inversely proportionate dependence of athletes’ lower height and better sports results is also present in strength sports [26], although over the last few years, it has been noticed that top results are also achieved by tall athletes who can develop great power, which can be noticed in taekwon-do in the athletes who have longer lower limbs providing them with a better potential for generating greater power when performing kicks [24]. Heller et al. [18] also mention the significance of generating higher strength values and great power in taekwon-do athletes. It was also noticed that an increase in strength during the training process was possible without being accompanied by significant somatic changes [23]. Hence, it can be concluded that the shorter height of the champions of lower weight classes was determined by the use of greater strength or in the case of the champions of higher weight classes, by greater power generation, which might correspond to developing specific somatic changes [27,28]. Similarly, it was shown in strength sports that the significant factors determining achievement of the best possible results included high FFM value and shorter height [29].

Further knowledge about the relation between somatic variables and sports advancement can be obtained from the analysis of the BMI value and fat content (FAT) in the taekwon-do practitioners under study. Lower weight class champions’ BMI values were higher (in the -70 kg class, this was the only tendency present) than those of the rivals. However, it was a result of their having more fat tissue and not just having greater muscle mass. Those disadvantageous somatic adaptive changes are confirmed by the lower FFM and TBW values in the champion of the lowest weight class in relation to his rivals and the occurrence of this tendency in other lower weight-class champions. In heavier weight classes, the relations between the BMI and FFM were reverse, i.e. the champions displayed lower values of the first variable than their rivals while having lower fat content or displaying such a tendency. Hence, it needs to be acknowledged that BMI particularly is a variable which distinguishes champions from their rivals who do not have as many achievements, although Kazemi et al. [24,25] did not recognize this particular variable as a predicative factor in taekwon-do. In our study, the value arrangement of this variable in the case of the champions was rather atypical of particular weight classes. However, in the case of the other athletes of particular weight classes, BMI showed a linear increase along with an increase in body weight starting with the lower weight classes and ending with the heavier ones, similarly to the research conducted by Noh et al. [30].

The changes in FAT, FFM and TBW in our research showed different arrangement in the lower and higher weight-class champions in relation to their rivals and did not display much of an arranged tendency in the intermediate weight classes. For this reason, it needs to be acknowledged that these variables do not actually correspond significantly to the level of taekwon-do advancement and they do not distinguish champions from other taekwon-do practitioners, although Gao et al. [31] showed that elite taekwon-do athletes had less fat than the otherwise advanced athletes.

It is also worth noticing that analysis of BMR showed values lower in the champions than in their rivals or showed such a tendency in the lightest and heaviest weight classes which has actually been acknowledged in the literature on the subject reporting lower BMR and more economic functioning of a well-trained organism in which the influence of the parasympathetic nervous system on metabolism increases [32-34]. Hence, the BMR value should also be recognized as another physiological variable distinguishing taekwon-do ITF champions from the athletes of a lower advancement level. The conducted analyses indicate that comparing the analyzed variables in the champions against their opponents is worthwhile, and makes it possible to recognize the features characteristic of the elite taekwon-do practitioners; however, such analyses are ineffective when considering the variables in the champions against the whole group of athletes without differentiation between the weight classes.
Conclusions

1. The athletes representing different weight classes included in the study did not significantly differ in terms of their age or time period of taekwon-do practice. However, they differed in terms of their somatic variables, which may result from their being divided into weight classes or from their different susceptibility to the specific training practice applied.

2. The attempt to identify significant personal, somatic and metabolic features characteristic of the champions representing various weight classes against all the other athletes of the analyzed population is futile.

3. The analysis of personal, somatic and metabolic features of the champions representing particular weight classes against their opponents from the same weight class showed that age, time period of taekwon-do practice, height, BMI and BMR are variables which hold significance for such comparisons, although in lower weight classes, the tendency of those changes is different from the one in higher weight classes.

4. Specifying features characteristic of a champion is a complex analytical process as it should comprise examining as many variables corresponding to the achievement of the best possible results as possible. Hence, further research conducted in this manner is needed.

References


Author for correspondence:

Tomasz Gora,
E-mail: tomek_gora@op.pl
Phone number: +48 34 365 59 83
THE ROLE OF MOTIVATION IN AMATEUR BASKETBALL

Michal Tynski 1 ABDEF, Agnieszka Wojtowicz 1 ACDEF, Bartlomiej Dobroczynski 2 ACDEF

1 Department of Psychology, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Poland
2 Department of General Psychology, Faculty of Philosophy, Jagiellonian University in Krakow, Poland

Key words: motivation, amateur sport, basketball

Abstract

Aim. Motivation plays an important role in achieving success in sports, regardless of whether it is performed professionally or amateurly. Based on the level of external and intrinsic motivation, the effectiveness or quality of sports can be determined. Research indicates that there are differences in the type and level of motivation among persons who practice sport recreationally and professionally. For example, professional athletes have a higher level of identification and amotivation than people practicing sports recreationally. The aim of the study was to determine whether amateur league basketball players on teams occupying the top and lowest places on the league table differ in motivation level. In addition, efforts were made to identify other factors that may be related to the type and level of motivation in amateur basketball.

Basic procedures. The study consisted of 48 players of the Krakow basketball league called the Krakowski Nurt Basketu Amatorskiego (KNBA) [Eng. Krakow Amateur Basket Trend – transl. M.T.]. The players were men representing five teams participating in the 2015 competition (M̅ age = 28.40). In the study, we used the Polish version of the Sport Motivation Scale (SMS-6) measuring the level of intrinsic motivation, externally regulated motivation, identification, introjection and amotivation. We also used our own specially designed questionnaire, containing 15 additional questions related to previous experience with competitive sports, basketball experience and a description of current practice and the emotions associated with basketball. The questionnaire was anonymous.

Results. The conducted research showed that people playing on leading teams in the amateur basketball league had higher levels of introjection as well as all of the more autonomous types of motivation, especially integration and intrinsic motivation, than the players of the teams occupying the last places in the table. On the other hand, they did not differ significantly in the level of extrinsic motivation. It was also found that the players who had higher levels of intrinsic motivation, devoted more time to practicing basketball.

Conclusions. The games won, and hence the place occupied by the team in the table is connected with the self-motivation of a player. Participation in practice with team members has significant impact on the intrinsic motivation of an athlete and his/her level of integration with other team members. It can be stated that participation in practice not only improves physical fitness and technical abilities of a player, but has significant influence on his/her contact with the team.

Introduction

Initiating deliberations on achieving success in sport it is not possible to omit the issue of motivation, because due to it, a player begins his/her athletic development. However, not only in professional but also amateur sports, it is motivation that causes a person to achieve small and big goals, step-by-step. It seems obvious that motivation plays a key role in sports, mainly due to its influence on the final results, and maintaining it at a certain
level throughout the duration of the match or competition is one of the elements distinguishing the winners from the losers.

**Theory of self-determination**

One of the theories used to explain motivation in sports is the concept of self-determination [1]. It divides motivation into intrinsic and extrinsic, and additionally distinguishes amotivation, i.e. a condition in which a person does not need to perform objectives or tasks and does not take action. The whole process of motivation can be called a kind of ‘path or road’, starting with the level of amotivation, moving onto controllable motivation, thus external, and ending with intrinsic motivation, which is autonomous.

Intrinsic motivation is defined as motivation thanks to which actions that are being performed make a person feel contentment and satisfaction [2]. When a person is intrinsically motivated to perform tasks, they execute them automatically without external stimuli, additionally feeling satisfaction with the performance of these activities [3]. The first descriptions of this type of motivation appeared in studies on animal behaviour, which stated that they engage in playing and behaviours based on curiosity, even despite a lack of rewards or reinforcements [4]. In athletes, an example can be people continuing to practice a sport even though it does not bring them any financial gain, and can even sometimes expose them to health risks [5].

We can speak of extrinsic motivation when a person performs an action because of the outcome s/he wants to or can achieve. Deci and Ryan [6] distinguish four types, differing in levels of autonomy: external regulation, introjection, identification and integration. Two types of non-autonomous motivation are external regulation, controlled by external sources, such as cash prizes and introjection, occurring when a person performs an action with a sense of pressure in order to avoid guilt, punishment or anxiety. Much more autonomous are the other two types of extrinsic motivation, which are associated with the identification of a conscious choice of the objective important for the Self, and integration related to the satisfaction gained by achieving the aim alone. Studies indicate that a change in functioning occurs when the actions directed by factors external to the Self (non-autonomous) are replaced by actions directed by factors complying with the Self [7]. The less autonomous the motivation lying at the base of a given action is, the lesser the persistence in achieving the goal, the weaker the achieved results and the less responsibility is felt for the effects [8]. It is then harder to feel satisfied with the achieved results and even very high achievements may not improve one’s well-being and welfare [9]. However, greater autonomy of goals means greater readiness to act, greater certainty as to the ways of achieving the goal and greater determination in its achievement [10].

**Motivation, competition and sport**

High-performance sports (professional or amateur) are invariably connected with competition, which in concept, is mainly aimed at external motives. However, the relationships of competition with motivation are much more complex. Receiving positive reinforcement regarding competences combined with winning can increase the level of intrinsic motivation [11], and strong integration of the aim of an action with the Self, even in the event of failure, may prevent the reduction of intrinsic motivation [12]. It was also found that personal attitude and mood during the competition may affect the modification of intrinsic motivation [13]. Undermining competence, worsening the mood of a person, even if s/he wins the competition, can lower motivation. In other words, interpersonal stress can have negative impact on intrinsic motivation.

Numerous studies point to the existence of positive relationships of more autonomous motivation forms in sport, especially intrinsic motivation, which is one of the best predictors of long-term engagement in physical activity [14]. Apart from this, intrinsic motivation turns out to be a strong predictor of interest in sport and feeling satisfaction from its practice [15], as well as a harmonious passion for the sport. [16] The meta-analysis conducted by Cerasoli, Nicklin and Ford [17] showed that both based on the level of external and intrinsic motivation, sports effectiveness or its quality of performance can be determined. Gomez-Lopez and his colleagues [18] conducted a study among Spanish basketball players aged 16-18 years, in which they examined the relationship between the theory of achieving objectives and the theory of self-determination, which showed that with an increase of orientation towards the Self, there was an increase in the level of extrinsic motivation as well as amotivation. It was also found that the externally regulated motivation reduces task orientation. Information about the diversity of levels of autonomous motivation, depending on the type of sport, could also be found. For example, basketball players appear to have higher levels of intrinsic motivation than football players [19], and similar differences were observed in people practicing high-risk sports compared to individuals practicing low-risk sports [20].

Research also indicates that there are differences in the type and level of motivation among persons who practice sport recreationally and professionally. It has been observed that professional athletes have a higher level of identification and amotivation than those per-
forming sports recreationally [21, 22], and in amateur athletes, extrinsic motivation - introjection turns out to be positively related to the intention to continue practicing a particular discipline, but the motivation is negatively linked [23].

**Study aim**

The aim of the study was to determine whether amateur athletes of teams occupying the top and low places in the league table differ in the level of motivation. In addition, efforts were made to identify other factors that may be related to the type and level of motivation in amateur basketball.

The following hypotheses were put forward:

- The level of extrinsic motivation is higher in basketball players whose teams are in the first places on the KNBA amateur league tables than in athletes whose teams occupy places at the bottom of the table.
- The level of intrinsic motivation is higher in basketball players whose teams are in the first places on the KNBA amateur league tables than in athletes whose teams occupy places at the bottom of the table.
- Former players of the Polish Basketball Association (PZKOSZ) have higher levels of extrinsic motivation compared to amateur players.
- The higher the level of intrinsic motivation of the players, the more time they devote to practice per week.

**Research methodology**

**Study participants**

The study consisted of 48 players of the Krakow basketball league called the Krakowski Nurt Basketu Amatorskiego (KNBA) [Eng. Krakow Amateur Basket Trend – transl. M.T.). The players were men representing five teams participating in the 2015 competition (m_{25} = 28.40). The teams were selected based on their position in the table at the end of the season, with three teams occupying the top two places in the league, and the other two occupying the last places in the table. This choice was dictated by the desire to try to determine the relationships between the level as well as type of motivation and the sports scores in the amateur players.

**Tools**

In the study, we used the Polish version of the Sport Motivation Scale SMS-6 [24] based on Deci and Ryan’s theory of self-determination [8], consisting of 24 questions measuring the level of intrinsic motivation (e.g. „Because I feel great satisfaction when perfecting difficult training techniques”), integration (e.g. „Because performing sports is consistent with my principles of life”), introjection (e.g. „Because it is one of the best ways to develop and improve ourselves”), identification (e.g. „For material purposes and/or the social benefits of being an athlete”) and amotivation (e.g. „I do not know if I want to continue investing as much of my time and effort in sports anymore”). We also used our own, personally designed questionnaire containing 15 additional questions related to previous experience with competitive sports, basketball experience and a description of current practice and the emotions associated with basketball.

**Procedure**

Questionnaires were completed by the players after each team’s practice. They were completed anonymously, but noting to which team the player belonged. The time granted to fill out the questionnaire was tailored to the needs of the group.

**Statistical analyses**

Statistical calculations were performed using the STATISTICA 12 programme. In the analyses, the Student-t test, Pearson’s correlation analysis and analysis of variance with planned comparisons were used. The level of significance was \( \alpha = 0.05 \).

**Results**

The conducted analyzes showed that persons whose team occupied the top positions in the amateur basketball league had higher levels of introjection, identification, integration and intrinsic motivation than those on teams at low positions in the league (Table 1). However, the level of amotivation and external regulation was at a similar level in both groups.

It was also found that the more time a week the players devoted to the game of basketball, the higher their level of introjection (\( r=0.36; p=0.014 \)), identification (\( r=0.40; p=0.006 \)), integration (\( r=0.39; p=0.008 \)) and intrinsic motivation (\( r=0.59; p<0.001 \)). The more time a week the players devoted to playing basketball with their own team, the higher their level of intrinsic motivation (\( r=0.40; p=0.005 \), but also the higher the level of amotivation (\( r=0.31; p=0.031 \)). It was also found that the longer the experience in playing basketball, the higher the level of introjection (\( r=0.29; p=0.048 \)). In contrast, the
Table 1. Level of motivation depending on the occupied place in the league table

<table>
<thead>
<tr>
<th>Motivation</th>
<th>M_{WT}</th>
<th>M_{NT}</th>
<th>t_{st}</th>
<th>p</th>
<th>N_{WT}</th>
<th>N_{NT}</th>
<th>SD_{WT}</th>
<th>SD_{NT}</th>
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</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>11.00</td>
<td>9.89</td>
<td>0.718</td>
<td>0.476</td>
<td>30</td>
<td>18</td>
<td>5.84</td>
<td>3.83</td>
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<tr>
<td>Extrinsic regulation</td>
<td>11.57</td>
<td>12.56</td>
<td>-0.628</td>
<td>0.533</td>
<td>30</td>
<td>18</td>
<td>5.86</td>
<td>4.10</td>
</tr>
<tr>
<td>Introjection</td>
<td>21.13</td>
<td>18.00</td>
<td>2.369</td>
<td>0.022</td>
<td>30</td>
<td>18</td>
<td>4.27</td>
<td>4.70</td>
</tr>
<tr>
<td>Identification</td>
<td>19.27</td>
<td>15.50</td>
<td>3.749</td>
<td>0.022</td>
<td>30</td>
<td>18</td>
<td>3.68</td>
<td>2.77</td>
</tr>
<tr>
<td>Integration</td>
<td>21.93</td>
<td>16.39</td>
<td>4.865</td>
<td>0.001</td>
<td>30</td>
<td>18</td>
<td>3.55</td>
<td>4.24</td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>20.37</td>
<td>15.61</td>
<td>4.583</td>
<td>0.001</td>
<td>30</td>
<td>18</td>
<td>3.79</td>
<td>2.87</td>
</tr>
</tbody>
</table>

Abbreviations:
- WT – Teams occupying the leading places in the table
- NT – Teams occupying the last places in the table

Table 2. Level of motivation depending on the occupied place in the table and previous professional basketball experience

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Place in league table</th>
<th>Previous professional basketball experience</th>
<th>F_{(1,44)}</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>External regulation</td>
<td>High×Low</td>
<td>Yes×No</td>
<td>4.23</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Table 3. Level of motivation depending on occupied place in the table and passion for basketball

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Place in league table</th>
<th>Passion for basketball</th>
<th>F_{(1,44)}</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>High×Low</td>
<td>Yes×No</td>
<td>4.54</td>
<td>0.039</td>
</tr>
<tr>
<td>Integration</td>
<td>High×Low</td>
<td>Yes×No</td>
<td>13.78</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>High×Low</td>
<td>Yes×No</td>
<td>5.89</td>
<td>0.019</td>
</tr>
</tbody>
</table>

Figure 1. Level of externally regulated motivation depending on the occupied place in the league table and previous career in professional sport
The role of motivation in amateur basketball

**Figure 2.** Level of identification depending on the occupied place in the league table and passion for basketball

**Figure 3.** Level of integration depending on the occupied place in the league table and passion for basketball
more time players devoted to training sports other than basketball, the higher their level of introjection \( (r=0.29; p=0.047) \) and identification \( (r=0.38; p=0.009) \).

It was also found that two factors modify the differences in the level of motivation of the players of teams from the top and bottom of the table (Table 2 and Table 3). The conducted planned comparisons showed that people who played basketball professionally in previous years demonstrated higher extrinsic motivation if they occupied places at the bottom of the amateur league table than those occupying the top places \( (F_{1,44}=4.53; p=0.039) \) (Figure 1). It was also found that among people for whom basketball is a passion, the players whose teams occupied leading positions in the amateur league had a higher level of identification \( (F_{1,44}=23.86; p<0.001) \) (Figure 2), integration \( (F_{1,44}=46.35; p<0.001) \) (Figure 3) and intrinsic motivation \( (F_{1,44}=26.03; p<0.001) \) (Figure 4) than those whose team occupied the low table positions.

**Discussion**

The conducted research showed that people playing for teams in the leading positions in the amateur basketball league had higher levels of introjection and all of the more autonomous types of motivation, especially integration and intrinsic motivation. These results are consistent with the results of Ramos-Villagrasa, Garcia-Izquierdo and Navarro [25], who observed that the level of intrinsic motivation is one of the strongest predictors of efficiency during the middle and final stages of semi-professional basketball competitions.

It was also found that players who had higher levels of intrinsic motivation devoted more time to practicing basketball. This may suggest that higher levels of intrinsic motivation resulted in greater commitment to improve and develop one’s basketball skills. It was noted that the athletes for whom basketball was a passion had higher levels of intrinsic motivation if the team occupied a prominent place in the table. It can be argued that those players achieved coherence between their inner beliefs about the sport to which they sacrifice themselves, and the results they achieved thanks to that devotion, which in amateur basketball is quite important because not every player played in the professional leagues before, and for some, the peak of accomplishments and abilities is to achieve the best results in amateur basketball.

The study results did not confirm the hypothesis that the players on teams occupying leading places in the table have a higher level of extrinsic motivation. This may suggest that the level that has been achieved by them is satisfactory enough that external factors are not so big propellers for further work or sports development. But this does not change the fact that players whose teams occupied the lowest places in the table showed the need for motivation by external factors. This may be
important for coaches to control the motivation of players involved in amateur sports. For example, training that is more task-oriented can increase the level of extrinsic motivation.

An important fact is that the teams occupying top positions in the table won more matches than their opponents, which increases intrinsic motivation [26]. The level of identification was high, which may indicate that the players had a sense of influence on the victory and team development, because autonomous forms of motivation are linked with a sense of competence and a sense of connecting with the team [27], as well as the pro-social behaviour towards the team members [28].

Referring to the presented results, we can conclude that, similarly as in professional basketball, in amateur basketball too, the number of factors affecting the outcome of sports is important. First and foremost, amateur basketball differs from professional basketball due to the fact that the players and teams, in most cases, pay for themselves to have the opportunity to participate in the league and training. Most teams organize practices themselves or appoint a person for its management, and this is often not the person with coaching experience but simply the player with the longest experience in playing basketball. Hence, such factors as passion or previously being in a league clubs also directly affect and impact the team, its position in the league and the player him/herself, who showed a higher level of motivation. The consolidation of a team was testified by the number of joint practices, which is also a very important element of training in team sports, especially amateur in which to synchronize some tactical elements, the cooperation of many members of the team is needed and if they do not meet with each other regularly at practices, this decreases the chances to develop tactical assumptions and synchronize the team. It can be stated that a perfect amateur basketball team must have a coach, a few practices per week, planned short and long-term goals, and players who previously played in professional leagues as well as a high level of both intrinsic and extrinsic motivation. However, in light of current research and sports results, it can be said that the greater the chance for success of the basketball team, the more factors are measurable, because with increasing awareness of building such a team, the chances for achieving sporting success increase, which is also proof of the similarity to professional sports. Despite the limitations in access to research on amateur sports, lack of funds for its organization and the low level of sports infrastructure available to amateurs in Poland, basketball is developing very rapidly, which may indicate the development of the KNBA amateur league in which the research was conducted, and which currently has 680 players and has expanded over the editions from a few to the current 62 teams.

**Conclusions:**

- The won matches, and hence the places occupied by the team in the table is related to the intrinsic motivation of a competitor, i.e. the higher the level of intrinsic motivation of the players, the higher the team is ranked in the league table, and thus, is more successful.
- Participating in practices with one’s basketball team playing in the league has considerable impact on the intrinsic motivation of a player and his/her level of integration with other team members. It can be argued that participation in practice not only improves physical fitness and technical abilities of a player, but it has significant impact on his/her relationship with teammates and the bond - which results in effective communication on the court during learned moves and passes, which can only be achieved through participation in training which is often difficult to achieve in the amateur teams, primarily due to the limitations of time.
- Athletes playing in amateur leagues, who have experience from professional basketball leagues, show a higher level of extrinsic motivation even if their teams are low in the league table. It can be argued that the previous professionals, when assessing their competitive level, show a greater need to expand their skills in the case of weaker team results through greater participation in competitive sports, and therefore, they are more oriented on the sports outcome.

**References**


QUANTITATIVE AND QUALITATIVE ASSESSMENT OF DIET AND NUTRITIONAL STATUS IN ELITE PROFESSIONAL RACE-WALKERS DURING THE PREPARATORY PERIOD

Barbara Fraczek¹ ABCDEF, Maria Gacek¹ CDEF, Edward Mleczko² AG, Wanda Forczek³ AB, Waclaw Mirek² AB, Joanna Gradek² AB

¹ Faculty of Sports Medicine and Human Nutrition, Institute of Biomedical Sciences, Department of Physical Education and Sport, University of Physical Education in Krakow, Poland
² Faculty of Track and Field Sports, Department of Physical Education and Sport, University of Physical Education in Krakow, Poland
³ Faculty of Biomechanics, Sports Institute, Department of Physical Education and Sport, University of Physical Education in Krakow, Poland

Key words: diet, nutritional status, body composition, athletes, race-walking

Abstract

Aim. Evaluation of diet and nutritional status in an elite group of professional race-walkers during the preparatory period.

Basic procedures. The study was carried out in the spring of 2014 among 6 athletes who were the most advanced professional race walkers. Quantitative diet evaluation was based on diet monitoring with the use of the Wikt 2.0 programme. The level of implementation of the Swiss food pyramid for athletes was also assessed. Nutritional status was evaluated with the BIA method using the “Aken Srl” body analyser and “Bodygram” software.

Main findings. The participants’ mean daily intake included: 2,912.35 kcal, 122.48 g protein, 392.80 g carbohydrates and 102.85 g fats. The mean consumption of lipophilic vitamins was: 1,351.29 µg (A), 3.80 µg (D) and 13.41 mg (E). The supply of hydrophilic vitamins was: 1.84 mg (B1), 2.04 mg (B2), 2.34 mg (B6), 4.14 µg (B12), 27.91 mg (B3), 315.56 µg (B9), 78.74 mg (C). The mean amounts of consumed macroelements were: 888.37 mg (Ca), 1,799.82 mg (P), 372.21 mg (Mg), 4,644.41 mg (Na) and 3,692.46 mg (K), and of microelements: 14.37 mg Fe, 14.46 mg Zn, 1.42 mg Cu and 178.34 µg J. Average daily consumption of water and other sugar-free beverages was 3,090.93 L. Their body composition included: 65.78% of total body water, 10.12% of body fat, 88.88% of lean body mass and 51.93% of muscle mass. The mean BMI was 21.62 kg/m².

Conclusions. Both quantitative and qualitative mistakes were found in the diet of the elite group of professional race-walkers, such as: low supply of carbohydrates, some vitamins and mineral salts, as well as insufficient consumption of vegetables, fruit and dairy products.

Introduction

The condition for maintaining health potential and the optimization of athletes’ exercise capacity is a balanced diet, covering their increased demand for energy, protein, vitamin B, antioxidants, certain minerals and fluids [1-8]. Increased nutritional needs also apply to track and field athletes performing endurance-training disciplines, including race-walking. The decrease of exercise capacity in endurance disciplines is primarily due to exhaustion of...
energy reserves (muscle and liver glycogen resources), as well as fluid and electrolyte economy disorders [9, 10]. Planning nutrition in race-walking must take the specificity of the discipline into account, associated with the physiological and biochemical nature of the effort, including nutrition around the time of the effort, optimizing the effectiveness of training and accelerating post-exercise recovery. The challenge for athletes is also achieving optimal body mass and composition, further factors determining success in sport, also in endurance disciplines [3, 4].

Implementation of the demand for nutrients requires planning varied food rations, taking into account a variety of foods, as recommended for people with high physical activity. The developed dietary models aid rationalization of nutrition in athletes [11]; among them we may find the Swiss pyramid. The base of the pyramid is opened by sugar-free beverages, and the peak is closed by sweets, salty snacks and sweetened beverages between which the vegetables and fruit, whole grain cereal and legume, protein product and oil, fat and nut groups are placed, and are recommended for consumption in varying amounts and frequency [12, 13].

The aim of the study was the quantitative and qualitative assessment of the diet and nutritional status during the preparatory period of an elite group of athletes engaged in professional race-walking. We assessed the intake of energy and nutrients in light of the quantitative standards and consumption of groups of products in the light of quantitative and qualitative recommendations of the Swiss nutrition pyramid for athletes, and also the anthropometric indicators of nutritional status in the competitors. The presented material is a fragment of the research in the field of multidimensional diagnosis of athletes focused on optimization of the training process in selected disciplines of academic sports (with particular emphasis on track and field endurance competitions).

Material and methods

The study was conducted during the preparatory period in the spring of 2014 among 6 athletes engaged in professional race-walking. The group consisted of athletes from the following sports clubs: AZS AWF Krakow (5 people) and OTG Sokol Mielec (1 person), including: Rafał Sikora, Grzegorz Sudol, Lukasz Augustyn, Jakub Jelonek, Paul Gawronski and James Herba. The competitors achieved the highest level of sports. Four of them presented the international championship level (GS, JJ, LA, RS), one – the M-class level (PG) and one - the I-class level (JH). They were all Polish championship medalists, a few participated in the Olympics and world championships (GS, RS, JJ), and one was a European Championship medalist (GS). Their training experience was 12.67 years (SD 4.03; Me: 13; Min: 9; Max: 20), wherein for the individual players: 20 years (GS), 13 years (RS, JJ), 12 years (LA) and 9 years (HJ, GP). The athletes expressed their consent to use their data in the article.

Quantitative assessment of the athletes’ diet was performed on the basis of monitoring their diet from three (GS, RS), four (LA) and five (JJ, JH, PG) days. An analysis of the consumption of energy and essential nutrients, vitamins and minerals in the daily food rations (CRP) of the athletes was done using the Wikt 2.0 computer programme. The results were referred to the relevant standards (RDA, AI) for men aged 19-30 years with high physical activity (PAL = 2.0) from the Polish population [14] and quantitative recommendations for competitive athletes during vigorous exercise (at the lower limit of the accepted standards) [15]. Qualitative assessment of the competitors’ diet was conducted by analyzing the consumption of individual product groups in relation to the quantitative and qualitative recommendations of the Swiss nutrition pyramid for athletes [12, 13]. Measurement of anthropometric indicators of nutritional status in athletes was done using bioimpedance (BIA) with the “Akern Srl” body composition analyzer and the “Bodygram” computer programme. On this basis, we assessed: body fat, lean body mass, muscle mass, cell mass and water content. The results are presented in the language of descriptive statistics (M, SD, Me, Min, Max).

Results

In Table 1, we show the consumption of energy and basic nutrients of the respective players as well as the CRP of particular athletes and generally in the group compared to the accepted standards of nutrition. The average energy intake in the general CRP of the athletes was 2,912.35 kcal/24 hrs. The average food rations for the total number of athletes included: 122.48 g of protein, 392.80 g of carbohydrates and 102.85 g of fat. The share of macronutrients in the energy pool of the average CRP was successively 17.15%, 50.94% and 31.91%. About 10.75% of the energy was provided by sucrose. Among the fatty acids, the biggest percentage constituted of monounsaturated (12.73%) and saturated fatty acids (11.12% of energy) in the total CRP of athletes. The average intake of cholesterol in the CRP was 423.21 mg and fibre was 26 g/24 hrs.

The vitamin and mineral content in the CRP of individual athletes and the total group is shown in Table 2, and the level of implementation of the standards for them according to the physiological requirements with regard to accepted standards of nutrition is presented in Table 3. The average total food rations for all the competitors include lipophilic vitamins in the amount of 1,351.29 µg
## Table 1. Energy Intake and basic nutrients in the CRP of race-walkers compared to nutrition standards for young men (M 19-30 years) [14] and athletes [15]

| Nutrients            | RS       | GS       | LA       | JJ       | PG       | JH       | M        | SD        | Me        | Min      | Max      | M 19-30 years | Sport |
|----------------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|----------|----------|----------|----------------|-------|
| Energy kcal          | 3020.40  | 2363.00  | 4271.00  | 2691.30  | 2052.70  | 3075.70  | 2912.35  | 771.22   | 3048.05   | 2052.7   | 4271.0   | 3500    | 2600-4500      |       |
| g                    | 181.00   | 124.60   | 141.50   | 91.70    | 83.60    | 112.52   | 122.48   | 35.63    | 146.76    | 83.60    | 181.0    | -       | -               |       |
| g/kg mc              | 2.35     | 2.00     | 1.79     | 1.33     | 1.30     | 1.84     | 1.76     | 0.40     | 2.09      | 1.30     | 2.35     | 0.9     | 1.2-2.0        |       |
| Total carbohydrates % en | 41.90 | 48.70  | 57.30    | 60.30    | 47.40    | 50.06    | 50.94    | 6.75     | 45.98     | 41.90    | 60.30    | 50-70   | 55-75          |       |
| g                   | 338.70   | 312.80   | 615.50   | 432.20   | 253.30   | 404.32   | 392.80   | 126.54   | 371.51    | 255.30   | 615.50   | -       | -              |       |
| g/kg mc              | 4.40     | 5.00     | 7.79     | 6.26     | 3.95     | 6.62     | 5.67     | 1.46     | 5.51      | 3.95     | 7.79     | -       | 7-10           |       |
| Available carbohydrates g | 313.80 | 283.30  | 563.20   | 401.20   | 238.20   | 383.78   | 367.24   | 122.16   | 348.79    | 238.20   | 583.20   | -       | -              |       |
| g/kg mc              | 4.10     | 4.60     | 7.38     | 5.81     | 3.72     | 6.29     | 5.31     | 1.41     | 5.19      | 3.72     | 7.38     | -       | 5-10           |       |
| Saccharose % en      | 7.60     | 6.50     | 16.50    | 12.50    | 9.80     | 11.42    | 10.75    | 3.62     | 9.51      | 6.50     | 16.50    | <10    | -              |       |
| g                   | 24.90    | 29.70    | 32.30    | 32.20    | 15.10    | 20.84    | 26.00    | 7.09     | 22.87     | 15.10    | 33.20    | 25-40   | 30-40          |       |
| Fibre % en           | 34.10    | 30.20    | 29.40    | 26.10    | 36.30    | 35.40    | 31.91    | 3.98     | 34.75     | 26.10    | 36.30    | 20-35  | 15-30          |       |
| g                   | 114.30   | 79.30    | 139.80   | 79.30    | 84.40    | 120.00   | 102.85   | 25.45    | 117.15    | 79.30    | 139.80   | -       | -              |       |
| g/kg mc              | 1.50     | 1.30     | 1.77     | 1.15     | 1.31     | 1.96     | 1.49     | 0.31     | 1.73      | 1.15     | 1.96     | 0.7-1.3 | 0.7-1.5       |       |
| SFAs % en            | 31.30    | 30.20    | 29.40    | 26.10    | 36.30    | 35.40    | 31.91    | 3.98     | 34.75     | 26.10    | 36.30    | 20-35  | 15-30          |       |
| g                   | 114.30   | 79.30    | 139.80   | 79.30    | 84.40    | 120.00   | 102.85   | 25.45    | 117.15    | 79.30    | 139.80   | -       | -              |       |
| g/kg mc              | 1.50     | 1.30     | 1.77     | 1.15     | 1.31     | 1.96     | 1.49     | 0.31     | 1.73      | 1.15     | 1.96     | 0.7-1.3 | 0.7-1.5       |       |
| PUFAs g/kg mc        | 1.50     | 1.30     | 1.77     | 1.15     | 1.31     | 1.96     | 1.49     | 0.31     | 1.73      | 1.15     | 1.96     | 0.7-1.3 | 0.7-1.5       |       |
| Cholesterol mg       | 524.40   | 428.20   | 477.30   | 265.80   | 345.70   | 498.50   | 423.21   | 99.64    | 511.45    | 265.80   | 524.40   | <300   | -              |       |

SFA – saturated fatty acids, MUFAs – monounsaturated fatty acids, PUFAs – polyunsaturated fatty acids;
M – arithmetic mean, SD – standard deviation, Me – median, Min – minimum, Max – maximum
Table 2. Consumption of selected vitamin and mineral components in the CRP of race-walkers compared to nutrition standards for young men [14] athletes [15]

<table>
<thead>
<tr>
<th>Vitamins and mineral salts</th>
<th>Competitors</th>
<th>Total group</th>
<th>Noms</th>
</tr>
</thead>
<tbody>
<tr>
<td>A µg</td>
<td>RS</td>
<td>647.30</td>
<td>1122.80</td>
</tr>
<tr>
<td>D µg</td>
<td>GS</td>
<td>2.70</td>
<td>3.00</td>
</tr>
<tr>
<td>E* mg</td>
<td>LA</td>
<td>18.80</td>
<td>10.80</td>
</tr>
<tr>
<td>B1 mg</td>
<td>JJ</td>
<td>2.50</td>
<td>1.80</td>
</tr>
<tr>
<td>B2 mg</td>
<td>PG</td>
<td>2.60</td>
<td>2.20</td>
</tr>
<tr>
<td>B6 mg</td>
<td>M</td>
<td>3.70</td>
<td>2.80</td>
</tr>
<tr>
<td>B12 µg</td>
<td>SD</td>
<td>5.20</td>
<td>3.90</td>
</tr>
<tr>
<td>B3 mg</td>
<td>Me</td>
<td>50.30</td>
<td>28.30</td>
</tr>
<tr>
<td>B9 µg</td>
<td>Min</td>
<td>334.00</td>
<td>351.90</td>
</tr>
<tr>
<td>C mg</td>
<td>Max</td>
<td>128.60</td>
<td>52.90</td>
</tr>
<tr>
<td>Ca mg</td>
<td>M 19-30 years</td>
<td>841.80</td>
<td>1082.30</td>
</tr>
<tr>
<td>P mg</td>
<td>AI norm</td>
<td>2486.30</td>
<td>2026.20</td>
</tr>
<tr>
<td>Mg mg</td>
<td></td>
<td>456.30</td>
<td>365.80</td>
</tr>
<tr>
<td>Zn mg</td>
<td></td>
<td>17.90</td>
<td>15.10</td>
</tr>
<tr>
<td>Cu mg</td>
<td></td>
<td>1.40</td>
<td>1.40</td>
</tr>
<tr>
<td>J µg</td>
<td></td>
<td>255.60</td>
<td>118.30</td>
</tr>
<tr>
<td>Na* mg</td>
<td></td>
<td>6068.50</td>
<td>4326.60</td>
</tr>
<tr>
<td>K* mg</td>
<td></td>
<td>4700.30</td>
<td>3521.40</td>
</tr>
</tbody>
</table>

* – AI norm, unmarked components – RDA (norms for M 19-30 years, according to Jarosz)
M – arithmetic mean, SD – standard deviation, Me – median, Min – minimum, Max – maximum
<table>
<thead>
<tr>
<th>Components</th>
<th>Implementation of norms for M 19-30 years</th>
<th>Implementation of norms for athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RS</td>
<td>GS</td>
</tr>
<tr>
<td>A</td>
<td>71.92</td>
<td>125.75</td>
</tr>
<tr>
<td>D</td>
<td>16.00</td>
<td>200.00</td>
</tr>
<tr>
<td>E</td>
<td>25.33</td>
<td>18.00</td>
</tr>
<tr>
<td>B</td>
<td>198.00</td>
<td>108.00</td>
</tr>
<tr>
<td>C</td>
<td>84.18</td>
<td>108.23</td>
</tr>
<tr>
<td>P</td>
<td>289.45</td>
<td>259.38</td>
</tr>
<tr>
<td>Zn</td>
<td>110.07</td>
<td>98.46</td>
</tr>
<tr>
<td>Cu</td>
<td>160.73</td>
<td>127.27</td>
</tr>
<tr>
<td>Na</td>
<td>150.55</td>
<td>155.55</td>
</tr>
<tr>
<td>K*</td>
<td>100.00</td>
<td>74.92</td>
</tr>
</tbody>
</table>

* – AI norm, unmarked components – RDA (norms for M 19-30 years, according to Jarosz)
Table 4. Qualitative assessment of the diet of race-walkers based on the criteria of the Swiss nutrition pyramid for athletes

<table>
<thead>
<tr>
<th>Product groups</th>
<th>Recommended No. of portions (p)</th>
<th>Competitors</th>
<th>Total group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and other sugar-free beverages (L/24 hrs)</td>
<td>1-2 L + 0.4-0.8 L/h of training</td>
<td>RS 4825.00 GS 4950.00 LA 2750.00 JJ 2380.00 PG 1981.00 JH 1656.00 M 3090.93 SD 2240.82 Me 3240.50 Min 1656.00 Max 4950.00</td>
<td></td>
</tr>
<tr>
<td>Vegetables (N portions/24 hrs)</td>
<td>≥3.5-3.75 p</td>
<td>RS 0.75 GS 2.17 LA 1.61 JJ 1.25 PG 0.46 JH 1.20 M 1.00 SD 0.42 Me 0.97 Min 0.46 Max 2.17</td>
<td></td>
</tr>
<tr>
<td>Fruit (N portions/24 hrs)</td>
<td>≥2.5 p</td>
<td>RS 0.00 GS 1.00 LA 0.62 JJ 1.92 PG 0.87 JH 0.90 M 0.88 SD 0.62 Me 0.45 Min 0.00 Max 1.92</td>
<td></td>
</tr>
<tr>
<td>cereal, wholegrain and legume (N portions/24 hrs)</td>
<td>3.5-3.75 p + 1p/h of training</td>
<td>RS 4.50 GS 3.33 LA 3.43 JJ 4.12 PG 2.59 JH 3.60 M 3.59 SD 0.66 Me 4.05 Min 2.59 Max 4.50</td>
<td></td>
</tr>
<tr>
<td>Meat, fish and eggs (N portions/24 hrs)</td>
<td>1.25 p</td>
<td>RS 4.50 GS 2.33 LA 2.25 JJ 0.92 PG 2.08 JH 3.15 M 2.54 SD 1.19 Me 3.82 Min 0.92 Max 4.50</td>
<td></td>
</tr>
<tr>
<td>Milk and milk products (N portions/24 hrs)</td>
<td>3.75 p</td>
<td>RS 2.12 GS 1.17 LA 2.25 JJ 1.67 PG 0.67 JH 0.70 M 1.43 SD 0.69 Me 1.42 Min 0.67 Max 2.25</td>
<td></td>
</tr>
<tr>
<td>Oils, fats and nuts (N portions/24 hrs)</td>
<td>2.5 p + 1p/nut + 0.5 p/h of training</td>
<td>RS 2.75 GS 0.83 LA 2.00 JJ 3.00 PG 2.83 JH 2.70 M 2.35 SD 0.82 Me 2.72 Min 0.83 Max 3.00</td>
<td></td>
</tr>
<tr>
<td>Sweet and salty snacks, sweetened and alcoholic beverages (N portions/24 hrs)</td>
<td>limiting consumption</td>
<td>RS 0.37 GS 0.00 LA 0.00 JJ 2.00 PG 1.17 JH 3.20 M 1.27 SD 1.12 Me 1.78 Min 0.00 Max 3.20</td>
<td></td>
</tr>
</tbody>
</table>

M – arithmetic mean, SD – standard deviation, Me – median, Min – minimum, Max – maximum
### Table 5. Somatic indicators of nutritional status in race-walkers

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Competitors</th>
<th>Total group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RS</td>
<td>GS</td>
</tr>
<tr>
<td>Na/K ratio</td>
<td>0.90</td>
<td>1.00</td>
</tr>
<tr>
<td>Cell mass Kg</td>
<td>31.80</td>
<td>26.10</td>
</tr>
<tr>
<td>%</td>
<td>47.30</td>
<td>45.80</td>
</tr>
<tr>
<td>Total water L</td>
<td>49.20</td>
<td>41.70</td>
</tr>
<tr>
<td>%</td>
<td>63.60</td>
<td>65.40</td>
</tr>
<tr>
<td>Extracellular water L</td>
<td>18.00</td>
<td>16.10</td>
</tr>
<tr>
<td>%</td>
<td>36.70</td>
<td>38.70</td>
</tr>
<tr>
<td>Intercellular water L</td>
<td>31.20</td>
<td>25.60</td>
</tr>
<tr>
<td>%</td>
<td>63.30</td>
<td>61.30</td>
</tr>
<tr>
<td>Fat mass Kg</td>
<td>10.10</td>
<td>6.80</td>
</tr>
<tr>
<td>%</td>
<td>13.10</td>
<td>10.70</td>
</tr>
<tr>
<td>Body mass according to norms Kg</td>
<td>80.40</td>
<td>68.10</td>
</tr>
<tr>
<td>Actual mass Kg</td>
<td>77.00</td>
<td>63.00</td>
</tr>
<tr>
<td>Fat-free mass Kg</td>
<td>67.20</td>
<td>57.00</td>
</tr>
<tr>
<td>%</td>
<td>86.90</td>
<td>89.30</td>
</tr>
<tr>
<td>Muscle mass Kg</td>
<td>38.80</td>
<td>32.10</td>
</tr>
<tr>
<td>%</td>
<td>50.20</td>
<td>50.20</td>
</tr>
<tr>
<td>BMI kg/m²</td>
<td>21.60</td>
<td>21.10</td>
</tr>
</tbody>
</table>

M – arithmetic mean, SD – standard deviation, Me – median, Min – minimum, Max – maximum
(A), 3.80 µg (D) and 13.41 mg (E). The supply of hydrophilic vitamins stood at 1.84 mg (B1), 2.04 mg (B2), 2.34 mg (B6), 4.14 µg (B12), 27.91 mg (B3), 315.56 µg (B9) and 78.74 mg (C). The described supply of vitamins in relation to the standards proposed by Jarosz [2012] accounted for their larger implementation of vitamin B6 (180%), B3 (174.43%), B12 (172.50%), B2 (156.92%) and A (150.14%). Thus, there was a deficit in the supply of: folic acid (78.89%), vitamin C (87.49%) and particularly vitamin D (25.33% of the norm). Referring to the demonstrated supply of vitamins in the average total CRP for competitors to the norms of the increased demand for athletes showed their implementation only for vitamin B3 (116.64%). The supply of other vitamins did not realize the demand for high-performance athletes, which affected mainly vitamins E (13.41%), B6 (15.60%) and D3 (25.33% of the norm).

Among the mineral components, the average total number of the athletes’ food rations contained macro-elements in the amount of 888.37 mg (Ca), 1,799.82 mg (P), 372.21 mg (Mg), 4,644.41 mg (Na) and 3,692.46 mg (K). Among the micronutrients, the analyzed food rations contained, on average: 14.37 mg Fe, 14.46 mg Zn, 1.42 mg Cu and 178.34 µg J. The described consumption showed the oversupply of, in particular: Na (309.63%) and P (257.12% of the norm), and deficits in: Ca (88.37%) and K (78.56% of the norm) (relative to Jarosz’s norms, 2012). Referring to the demonstrated supply of mineral salts in the CRP to the general norms for competitors with increased demand for athletes showed their implementation only for P (143.98% of the norm). The supply of other minerals did not realize the demand for high-performance athletes, which affected mainly Ca (44.41%), Fe (57.48%), Zn (36.15%), Na (38.70%) and K (41.02% of the norm). Table 3 also contains the level of implementation of the norms in the food rations of individual athletes.

In Table 4, we present the results regarding the implementation of the quantitative and qualitative objectives of the Swiss pyramid for the nutrition of athletes in the group of athletes. It was shown that the average consumption of water and other sweetened beverages was 3,090.93 L per day. On average and per day, the competitors consumed: 1 serving of vegetables, 0.88 of fruit portions, 3.59 servings of cereals and/or legumes, 1.43 servings of milk and dairy products, 2.54 of other portions of proteins (from eggs, meat, fish), 2.35 servings of fats and/or nuts and 1.27 servings of sugary or salty snacks and sugary beverages.

In Table 5, we show the anthropometric indicators of nutritional status in race-walking competitors. Analysis of the average numbers for the total number of athletes showed that total water accounted for 65.78%, fat mass 10.12%, lean mass 88.88% and muscle mass 51.93% of body mass. The average body mass index (BMI) of the athletes was 21.62 kg/m². The diversity of these indicators for individual players is also presented in this table.

Discussion

The research showed the quantitative and qualitative dietary mistakes made in the group of elite professional race-walkers during the preparatory period. The found irregularities concerned the lack of balance in nutritional rations in terms of the content of some nutrients, not only in relation to the increased demand for athletes but also in relation to the standards for the young men of the Polish population. Also, quantitative and qualitative assessment of the athletes’ diet showed the incomplete implementation of the objectives of the Swiss nutrition pyramid for athletes, the model recommended for highly physically active people. The research on the nutritional methods was supplemented by the evaluation of anthropometric indicators of nutritional status in athletes.

The rational model of nutrition, based on a varied and balanced diet, promotes covering the physiologically increased demand for energy and building and regulating nutrients, including vitamins and minerals. It also ensures the prevention of dehydration, an important issue in sports nutrition [1, 2]. Therefore, it is one of the key factors contributing to success in sports [3, 4, 11].

One aspect of rational nutrition is realization of the demand for energy, which is especially high for professional athletes. Evaluation of the average energy supply in the studied group of elite athletes (2,912.35 ± 771.22 kcal) proved incomplete implementation of the standards, which for men with high physical activity (PAL: 2.0) and weighing about 70 kg (average weight riders) is about 3,500 kcal [14]. Improper balancing of nutritional rations in terms of energy supply is a factor disturbing energy balance, increasing the risk of nutritional disturbances and lowering the exercise capacity of athletes [1, 2]. Energy shortages have also been shown among other groups of endurance athletes, including Poznan recreational distance runners (deficit of 800 kcal/24 hrs) [16] and the Krakow middle- and long-distance runners (a deficit of about 400 calories) [17]. Energy deficiencies associated with a shortage of antioxidant vitamins were also described in a group of French endurance athletes [18]. Similar energy intake as in this study was found in an elite group of Kenyan distance runners [19] and higher (4,357.38 kcal/24 hrs) among members of the Polish national race-walking team (3,194.56 kcal/24 hrs) [20].

These studies also showed improper balancing of the share of certain nutrients in the energy pool of average energy rations for the elite group of race-walkers. The energy distribution of proteins, fats and carbohydrates
(17.15%; 31.91%; 50.94%) was similar to that recommended for the population (10-15%; 20-35%; 50-70%), but shifted towards a high share of fats and proteins at the expense of carbohydrates. Limited participation of carbohydrates in the energy pool of rations for the athletes was even more significant taking into account the recommendations for athletes (55-75% or 60-70% of energy) [5, 15]. According to the Polish recommendations for race-walkers: 12-13% of proteins, 25-27% of fats and 63-60% of carbohydrates [15]. A similar share of protein in the energy pool rations (12-15%), lower than that described in our study, was also suggested by other authors [5]. The evaluation of the average intake of essential nutrients must also be discussed regarding their supply per kg of the athletes’ body mass. The obtained data show that the supply of proteins and fats exceeded the recommended value for adults from the Polish population (respectively: 1.76 g vs. 0.9 g/kg and 1.49 g vs. 0.7-1.3 g/kg) [14]. It was contained, at the same time, in a wide range of recommendations for athletes (respectively: 1.2-2.0 g/kg bm and 0.7-1.5 g/kg bm) [1-5, 7, 15]. The described protein intake can be assessed as correct compared to most of the recommendations for endurance athletes, being within the range of 1.2-1.4 g/kg bm [5] to 1.2-1.7 g/kg bm [21] and 1.5-1.7 g/kg bm [1, 2]. The increased demand for protein in endurance disciplines is associated with increased synthesis of mitochondrial proteins, enzymes and amino acids used as an alternative source of energy [22, 23]. In turn, the carbohydrate intake (per kg of body mass) in the studied group of competitors was insufficient, which corresponded to their low participation in the pool of energy rations. The described average supply of carbohydrates (5.67 g/kg bm) did not execute the quantitative recommendations for endurance athletes, amounting to 6-10 g/kg bm [1, 3, 4, 7, 15, 24-26], and even 7-12 g/kg bm [5]. The deficit in carbohydrate intake described in the athletes required correction because their proper supply significantly affects the effectiveness of an effort and the pace of recovery after workouts in endurance disciplines [6, 10, 23, 24]. No balancing of rations in terms of the macronutrient content was also demonstrated in other groups of endurance athletes. The deficit in carbohydrate intake was found among marathon runners during the preparatory period (approx. 50% of energy) [27], in the Poznan group of recreational long-distance runners (approx. 53% of energy) [16], in the Krakow group of middle- and long-distance runners (approx. 53-54% of the energy) [17], in the group of Polish long-distance national team runners in the years 2004-2005 [28] and in another group of athletes training race-walking (approx. 49% of energy) [29]. The low intake of carbohydrates along with the diet is also described in a Canadian elite group of ultra-marathoners [30]. In turn, higher carbohydrate intake, in line with recommendations (about 64% of energy), was found in a group of top-class Ethiopian long-distance runners [31].

In a rational diet, the correct supply of vitamins and minerals is also essential for energy, repair and antioxidant processes, as well hemoglobin synthesis and bone mineralization [1, 2, 5, 32]. Our own research showed an unbalanced supply of certain vitamins and minerals, both in relation to the standards for young adult men from the Polish population [14], as well as in relation to the adopted quantitative recommendations for competitive athletes [15]. Assessment of the intake of vitamins compared to the Polish standards at the level of RDA (or AI for vitamin E) for men aged 19-30 years [14] proved the excessive supply of certain vitamins in the athletes’ average CRP, including A, E and B group (B1, B2, B3, B6, B12), along with a deficit in the supply of, among others: folic acid, vitamin C and the vitamin D (25.33% of the norm). Evaluation of the intake of vitamins in the average CRP of the total of competitors in relation to the increased standards for professional athletes proved shortages to a greater extent, which involved almost all the vitamins apart from B3, and mostly concerned vitamins E, B6, D and B2. Implementation of less than half the values of accepted standards also applied to vitamins B1 and C. Referencing the average supply of vitamins obtained in the group to the recommendation for race-walkers during the preparatory and starting period [15] confirmed significant deficiencies in vitamins A, B1, B2, B3 and C. Lack of balance in the nutritional rations in terms of the content of certain vitamins has been shown in other groups of endurance athletes. Deficits of vitamins (A, D, E, C, B9) were found in the nutrition rations of the Poznan long-distance runners [16]. Similar trends (deficits of vitamins B1, B2, B3, C and D) were found among the Krakow middle- and long-distance runners [17]. No balance in the nutritional rations in terms of supply of some of the vitamins is also described in another group of race-walkers. In relation to Jarosz’s standards [14], the excessive supply of vitamins A, E, B1, B2, B3, B6, B12, C and a deficit in supply of vitamin D were demonstrated [29].

Evaluation of the intake of minerals compared to the current Polish standards at the level of the RDA (or AI for Na and K) for men aged 19-30 years [14] proved over-supply of: P (257.12%) and Na (309.63% of the norm) and Fe, Zn and Cu, along with a deficit in the supply of: Ca and K, and Mg, to a lesser extent. Assessment of the intake of mineral salts in the average CRP of athletes related to the increased quantitative recommendations for competitive athletes has proved a larger scale of malnutrition, because deficits were shown related to almost all minerals, especially Ca, Zn and Na and K, with the exception of P. Referencing the results obtained for the
group regarding the average supply of minerals to the recommendation for race-walkers during the preparatory and starting period [15] confirmed significant deficiencies of Ca and Fe. No balance in the rations in terms of the levels of certain minerals was also not shown in other endurance athletes, including the group of Poznan recreational long-distance runners (Ca and K) [16] and the Krakow group of middle- and long-distance runners (Na, K, Ca, Mg, Fe) [17]. The lack of balance in the rations in terms of the supply of some of the minerals is also described in another group of athletes professionally training race-walking. In relation to Jarosz’s standards [14], an oversupply was demonstrated in: Na, P and Fe [29]. The low supply of vitamins and minerals found in our study and the others could have increased the risk of nutritional deficiencies in athletes, including those practicing race-walking.

Evaluation of the diets of elite race-walkers compared to the quantitative and qualitative recommendations of the Swiss nutrition pyramid for athletes showed limitation in scale of correct nutritional choices. The intake of water and other sugar-free beverages (average 3,090.93 L/24 hrs) are the only positively assessed elements. The irregularities mostly concerned: the low consumption of vegetables and fruits, milk and milk products and vegetable oils and nuts. Scarce, but to a lesser extent, was the intake of whole grain cereals and/or legumes. Excessive intake was, however, related to sweet and salty snacks, including sugary beverages. The reported trends favoured lowering the nutritional and health values of the nutritional rations. Irregularities in eating habits found in the study on elite race-walkers corresponded with the results of other studies among athletes. The research confirmed the insufficient frequency of consumption of certain recommended food groups, including fruits and vegetables, wholegrain cereals and dairy products as well as fish in different groups of athletes [28, 33-38]. The insufficient intake of fruit, vegetables and wholegrain cereal products found among the professional race-walkers corresponds with the quantitative dietary mistakes in different groups of athletes regarding the unbalanced supply of energy and carbohydrates [39, 40], some vitamins, including antioxidants [18, 40] and dietary fibres [40, 41]. The low frequency of consumption of dairy products increased the risk of calcium deficiencies, described in other groups of athletes performing various disciplines [40, 42-44]. Proper calcium intake in athletes is particularly important due to its involvement in regulating neuromuscular excitability and the acid-base balance of the system [5]. The magnesium deficiency also featured in athletes as a result of eating habit errors may also have negative impact on nerve and muscle excitability [45].

Interesting and of cognitive value is also discussion on the diversity of individual nutritional trends in elite professional race-walkers on the basis of analysis of the nutritional values in the CRP of individual athletes. In this regard, it was demonstrated that the average CRP of three players (initials: GS, JJ, PG) contained a lower, in 2 athletes (RS and JH) the proper, and in 1 of the athletes (LA) a greater value than the recommended amount of energy/24 hrs. The average CRP of 3 players (RS, GS, PG) showed a particularly low share of energy from carbohydrates (below 50%), including 1 player (RS) also below the lower limit of acceptable consumption levels for the Polish population, amounting to 45%. At the same time, a high share of energy from protein (over 20%) was reported in 2 athletes (RS, GS), and a high proportion of energy from fat (over 35%) in the following 2 participants (PG, JH). Proper energy distribution of macronutrients in the CRP was found in only 2 athletes (LA, JJ). At the same time, the average CRP of 3 players (initials: LA, JJ, JH) contained an increased amount of sucrose (over 10% of energy), including one athlete (LA) with a particularly high value (16.50% of energy). Proper intake of cholesterol (300 mg/24 hrs) has been found in only 1 athlete (JJ), the remaining 5 competitors’ cholesterol intake was excessive. Analysis of the nutritional value of CRP in the supply of macronutrients calculated per kg of body mass has proved that the nutrition rations of two athletes characterized by a high proportion of proteins in the energy pool, simultaneously contained ≥2 g protein/kg bm (RS, GS). The proper contents of total carbohydrates per kg body mass (in the range of 6-10 g/kg) was only noted in 3 athletes (LA, JJ, JH). Analysis of vitamins and minerals in the CRP of particular men with regard to standards for men aged 19-30 years demonstrated that there were vitamin D and folic acid deficits in all the study participants. In 4 athletes, we found a deficit of vitamin C (GS, LA, PG, JH). Deficiencies of other vitamins (A, E) occurred in individual athletes. In all the study participants, there was an excess of P and Na. The correct supply of Ca was found in 2 athletes, and the proper supply of Mg was also only found in 2 athletes (respectively: GS, LA, RS and JJ), and K in 1 athlete (RS). Analysis of the intake of vitamins and minerals in the particular men with regard to the accepted standards for athletes proved that the CRP of only 1 participant (RS) covered the demand for 4 components (vitamins: B12 and B3, and salts: P and J). At the same time, the CRP of the following 4 athletes (GS, LA, JJ, JH) implemented standards for 2 regulating components, and the food rations of 1 athlete did not meet the accepted quantitative standards for professional athletes.

Also, assessment of nutritional habits of individual men in relation to the quantitative and qualitative recommendations for athletes according to the Swiss pyramid model made it possible to determine the individual trends in eating behaviours of elite race-walkers. In this area, the proper intake of fluids (water and other sugar-free
beverages) was found in only 2 athletes (RS and GS). The largest, although insufficient, number of servings of vegetables (about 2/24 hrs) was found only in one athlete (GS). Sufficient intake of whole-grain cereal and/or legume seeds was demonstrated in only 2 athletes (RS and J). None of the athletes consumed a sufficient number of servings of milk or milk products and fruits. Different trends are described in the consumption of other protein products, which was excessive especially for one player (RS). The deficit in the intake of vegetable oils and nuts concerned 1 athlete (GS). The consumption of sweet and salty snacks as well as sugary beverages was limited in 3 of the 6 studied athletes (RS, GS, LA).

The function of a diet is nutritional status, determined by biochemical and anthropometric methods. Our own research included anthropometric measurements, among others, body composition using the method of bioimpedance. Average values of the analyzed indicators of body composition in the group were correct but indicators for individual players were varied, suggesting the planning and implementation of specific strategies for the normalization of body composition and body mass as some of the factors determining success in sports. It has been shown that correct body mass and body composition (decreased body fat while maintaining muscle mass) can support exercise potential of the body [46]. The importance of body composition for physical fitness was confirmed in research conducted among African runners [47]. The body composition of the race-walkers (low fat and high water content) was justified in the context of the use of triacylglycerol fat as an energy source in endurance efforts [48]. A similar level of indicators of body composition was also recorded in the other group of competitors practicing race-walking [29]. The positive effect of a balanced diet in improving somatic indicators of long-distance runners has been confirmed by the research conducted at the centre in Poznan [16].

The limited scale of implementing quantitative and qualitative recommendations for athletes recognized in the elite group of race-walkers during the preparatory period was a prerequisite to take individual and group educational and consultational action aimed at the rationalization of nutrition in order to optimize the nutritional status of the athletes and the achievement of sporting success during the starting period.

**Conclusions**

1. Quantitative assessment of the diet in a group of highly qualified professional race-walkers during the preparatory period showed incomplete balancing of daily nutritional rations in terms of the content of some nutrients, in particular: a small supply of carbohydrates as well as some vitamins (C, D and folic acid) and minerals (Ca, Mg, K). Lack of balance in the rations was described not only relative to the quantitative recommendations for competitive athletes, but also in relation to the current Polish standards for young adult men, indicating, however, a different scope and level of the reported deficits.

2. Qualitative assessment of diet in the group of highly qualified professional race-walkers during the preparatory period has shown the limited scale of rational dietary behaviors in light of the objectives of the Swiss nutrition pyramid for athletes. The irregularities were particularly related to inadequate intake of certain recommended products, including fruits and vegetables, wholegrain cereals and/or legumes as well as milk and milk products, and the excessive consumption of non-recommended products, including: sweet or salty snacks and sugary sodas.

3. Evaluation of anthropometric indicators of nutritional status in the group of highly qualified professional race-walkers during the preparatory period showed the correct average value of body mass and body composition, with an indication of inter-individual variability of the analyzed indicators, which formed the basis to take corrective action.

4. The results in terms of quantitative and qualitative assessment of nutrition and nutritional status of the elite group of professional race-walkers confirmed the validity of individualized planning and diet balancing, as well as developing appropriate nutritional strategies during the preparatory period.

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**References**

Quantitative and qualitative assessment of diet...


Author for correspondence:
Barbara Fraczek
Email: barbara.fraczek@awf.krakow.pl
Abstract

**Aim.** To examine changes in the rheological properties of the blood (blood count and elongation index) in patients with sciatica.

**Basic procedures.** The study group consisted of 10 men with sciatica - these patients were from Gabriel Narutowicz Krakow Specialist Municipal Hospital (preliminary study), aged 40-55 years. The control group consisted of blood donors from the Regional Blood Donor and Treatment Centre in Krakow. This group also included 10 men; the age of the donors corresponded to the study group. Blood was drawn from the men in a fasting state in the morning, in the amount of 3 ml from the ulnar vein and put into EDTA tubes. Morphological blood test - measurements were taken using the ABX MICROS 60 (USA) haematology analyzer. Erythrocyte deformability was tested using the LORCA analyzer (Laser-assisted Optical Rotational Cell Analyser, RR Mechatronics, The Netherlands). The results were obtained as the index of elongation and aggregation according to the Hardeman method (2001).

**Results.** Analyzing the average values of morphological and rheological indicators in men from the control and study group, there was a decrease in the value of: HGB [g/L], MCH [fmol], MCV [fL], MCHC [mmol/L], EI at the shear stress of 4.24-59.97 [Pa] and an increase in the value of EI at the shear stress of 0.58 [Pa].

**Conclusions.** The changes that occur when pressure is put on the L4, L5, S1 spinal nerves adversely affect the rheological changes of the blood in patients with sciatica, and are most likely caused by associated symptoms such as arthritis, fever or paresis of the lower extremity.

Introduction

Sciatica (ischialgia) is currently defined as a syndrome, most commonly caused by pressure or irritation of the sciatic nerve, which is accompanied by pain in the lumbosacral area of the spine, radiating to the hips, buttocks, along the rear and posterior part of the lower limb, sometimes even up to the foot. This pain is radicular and referred in nature [1]. Patients describe it as a pulling and stinging sensation; it usually occurs unilaterally and is accompanied by sensory disturbances (numbness and tingling); it constitutes 10% of all back pains [2]. It occurs most frequently due to direct pressure on the spinal nerve root caused by displacement of the nucleus pulposus of the intervertebral disc, an extradural tumor or inflammation [3]. The pain may radiate over the entire length of the sciatic nerve and this nerve is the longest and thickest nerve in the human body, the symptom range spreading over a large surface [4]. Referred pain is pain felt in a place other than the source of its origin, usually in specific areas on the body surface (Head’s zones). The nature of this pain is diffuse, and the precise determination of its borders is difficult; it is caused by irritation of the nerve fiber endings that innervate the spine and neighboring tissues [3].
Sciatica is a condition from which an estimated 13-40% of the population at different ages suffers from, and the annual incidence is 1-5% [5]. The probable causes of sciatica can include: pressure on the nerve root from a herniated disc, pressure from osteophytes, spinal stenosis, spondyloarthropathy, cancer of the spinal canal, muscular problems, disorders of the lymphatic and endocrine systems, stress or abscess surrounding the sciatic nerve [1, 6, 7]. Risk factors that predispose to the formation of sciatica include: cigarette smoking, being over 40, male sex, performing strenuous physical work and genetic factors [7, 8].

Hemorheology specializes in the issue of blood flow and deformation. Research in this field covers many aspects of whole blood, plasma and cellular components [9]. “Factors” affecting blood flow are hematocrit and plasma viscosity, the viscosity of whole blood, the ability of red blood cells to aggregate and deform [10]. Erythrocytes have the ability to deform at moderate and high flow speeds and to aggregate at a slow flow rate [5]. Blood flow affects the physical and physicochemical properties of the blood. To maintain proper body microcirculation, it is necessary for erythrocytes to be able to deform (their membranes) [11]. This phenomenon is very important because the red blood cells must change their shape so as to pass through the capillaries with a diameter of up to two times smaller than the diameter of the resting erythrocytes [12].

The aim of the study was to examine the changes in the rheological and morphological properties of blood in patients with sciatica.

**Study design**

The study group consisted of 10 men with sciatica - these patients were from Gabriel Narutowicz Krakow Municipal Specialist Hospital (preliminary study), and aged 40-55 years (not immobilized). The control group consisted of donors from the Regional Blood Donor and Treatment Centre in Krakow. This group also included 10 men; the age of the donors corresponded to the study group.

3 ml of blood were drawn from the vein inside the elbow from the participants on an empty stomach in the morning, into EDTA tubes. Blood samples were drawn by a qualified nurse under medical supervision, in accordance with the applicable standards of the Pathology of Locomotion Laboratory at the University School of Physical Education in Krakow, where rheological and morphological parameters of the blood were determined. The study was approved by the Bioethics Committee at the Regional Medical Chamber in Krakow.

Morphological blood test

Measurements were taken using the ABX MICROS 60 (USA) haematology analyzer. The determined parameters were:
1. Red blood cell count – RBC \( [10^{12}/L] \)
2. Hematocrit – Hct \([L/L]\) 
3. Haemoglobin – Hgb \([g/L]\) 
4. Mean corpuscular hemoglobin index – MCH \([\text{fmol}]\) 
5. Mean corpuscular volume index – MCV \([\text{fl}]\) 
6. Mean corpuscular hemoglobin concentration – MCHC \([\text{mmol/L}]\) 
7. White blood cell count – WBC \([10^9/L]\) 
8. Platelet count: PLT \([10^9/L]\)

**Statistical analysis**

The data are presented using mean values and standard deviation \((\text{x} \pm \text{SD})\). We used the t-Student test for independent samples. To determine the occurrence of relationships between selected blood parameters, we used Pearson’s linear correlation coefficient. We assumed the following level of significance \(\alpha = 0.05\) in the analyzes which were performed using Statistica 10 (StatSoft®, USA) and Excel 2013 (Microsoft®).

**Results**

Analyzing the average values of the morphological and rheological indicators in males from the control and study group, a decrease in the following values were noted: HGB \([g/L]\) by 9.49%, MCH \([\text{fmol}]\) by 16.23%, MCV \([\text{fl}]\) by 10.43%, MCHC \([\text{mmol/L}]\) by 1.18%, EL at the shear stress of 4.24 \([\text{Pa}]\) by 47.61%, EL at the shear stress of 8.23 \([\text{Pa}]\) by 43.75%, EL at the shear stress of 15.96 \([\text{Pa}]\) by 36.58%, EL at the shear stress of 31.04 \([\text{Pa}]\) by 33.33%, EL at the shear stress of 59.97 \([\text{Pa}]\) by 31.48%; and an increase in the value of EL at the shear stress of 0.58 \([\text{Pa}]\) by 57.69% (Tab. 1; Fig. 1-4).
Table 1. Average values ± standard deviation of morphological and rheological indicators of the blood in the control and study group

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Control group (n=10)</th>
<th>Study group (n=10)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC [10^12/L]</td>
<td>4.36±0.32</td>
<td>5.68±0.31</td>
<td>0.0877</td>
</tr>
<tr>
<td>Hct [L/L]</td>
<td>41.29±2.40</td>
<td>39.74±1.56</td>
<td>0.2159</td>
</tr>
<tr>
<td>Hgb [g/L]</td>
<td>15.17±1.07</td>
<td>13.54±0.47</td>
<td>0.0068</td>
</tr>
<tr>
<td>MCH [fmol]</td>
<td>34.62±1.60</td>
<td>29.00±1.77</td>
<td>0.0000</td>
</tr>
<tr>
<td>MCV [fL]</td>
<td>94.90±4.86</td>
<td>85.00±5.00</td>
<td>0.0028</td>
</tr>
<tr>
<td>MCHC [mmol/L]</td>
<td>36.49±1.17</td>
<td>34.06±0.41</td>
<td>0.0007</td>
</tr>
<tr>
<td>WBC [10^9/L]</td>
<td>5.68±1.04</td>
<td>5.92±0.92</td>
<td>0.6694</td>
</tr>
<tr>
<td>PLT [10^9/L]</td>
<td>198.10±31.79</td>
<td>204.40±30.62</td>
<td>0.7203</td>
</tr>
<tr>
<td>El at shear stress of 0.30 [Pa]</td>
<td>0.14±0.06</td>
<td>0.13±0.01</td>
<td>0.6574</td>
</tr>
<tr>
<td>El at shear stress of 0.58 [Pa]</td>
<td>0.11±0.04</td>
<td>0.25±0.03</td>
<td>0.0000</td>
</tr>
<tr>
<td>El at shear stress of 1.13 [Pa]</td>
<td>0.15±0.22</td>
<td>0.20±0.04</td>
<td>0.6021</td>
</tr>
<tr>
<td>El at shear stress of 2.19 [Pa]</td>
<td>0.12±0.03</td>
<td>0.20±0.25</td>
<td>0.3334</td>
</tr>
<tr>
<td>El at shear stress of 4.24 [Pa]</td>
<td>0.22±0.04</td>
<td>0.11±0.01</td>
<td>0.0001</td>
</tr>
<tr>
<td>El at shear stress of 8.23 [Pa]</td>
<td>0.30±0.10</td>
<td>0.18±0.02</td>
<td>0.0240</td>
</tr>
<tr>
<td>El at shear stress of 15.96 [Pa]</td>
<td>0.41±0.03</td>
<td>0.26±0.03</td>
<td>0.0000</td>
</tr>
<tr>
<td>El at shear stress of 31.04 [Pa]</td>
<td>0.48±0.02</td>
<td>0.32±0.04</td>
<td>0.0000</td>
</tr>
<tr>
<td>El at shear stress of 59.97 [Pa]</td>
<td>0.54±0.01</td>
<td>0.37±0.05</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Fig. 1. Chart presenting average HGB [g/L] values in the control and study group

Fig. 2. Chart presenting average MCV [fL] values in the control and study group

Fig. 3. Chart presenting average MCH [fmol] values in the control and study group

Fig. 4. Chart presenting average MCHC [mmol/L] values in the control and study group
Discussion

The aim of the research presented in this paper was to answer the question whether the changes occurring when pressure is put on the spinal nerves in patients with sciatica adversely affect the rheological properties of the blood.

In our own conducted studies, we noted a decrease in the values of: HGB [g/L], MCH [fmol], MCV [fL], MCHC [mmol/L], EI at the shear stress of 4.24-59.97 [Pa] and an increase in the value of EI at the shear stress of 0.58 [Pa].

Split et al. [14] conducted a study on 26 patients with sciatic lower back pain syndrome lasting from 3 weeks to 3 months. They analyzed the concentration of hemoglobin A1c in erythrocytes. Hemoglobin A1c, or glycated hemoglobin, is hemoglobin which is formed from attachment of non-enzymatic, stable molecules of glucose to the N-terminal amino group of the β-globin chain. In the subjects, an increase was noted in hemoglobin A1c exceeding the accepted norm in the red blood cells, and in more than half of them, the increase exceeded the value of 10%. The researchers explain that was due to, among others, the evolution of adrenalin and glucocorticoids by the adrenal glands occurring under the influence of pain that accompanies patients with this disease. Both of these hormones effect the increase in blood glucose level, and additionally, they increase plasma free fatty acids which leads to impairment of insulin action in the event of excessive concentration. The level of glucose in the blood depends on the glycosylation of hemoglobin. The authors suggest that hemoglobin A1c can determine the effectiveness of treatment [14, 15].

Kowal et al. [10] described hemorrhagic changes occurring in Waldenstrom's disease and multiple myeloma. According to the authors, the increase in plasma viscosity is attributed to the excessive concentration of monoclonal proteins. Rheological blood disorders are regulated by the body though reducing the synthesis of erythropoietin (EPO) and immunoglobulins. People with hypertension have increased blood viscosity, which is caused by impaired flexibility of erythrocytes and increased hematocrit. Increased blood viscosity due to increased plasma viscosity, increased erythrocyte aggregation and impaired erythrocyte deformability were observed in patients with acute ischemic strokes. There was no noted increase in blood viscosity in patients following episodes of ischemia or in patients with clinical silent ischemic foci, due to improved deformability of erythrocytes. It is believed that this is related to the mechanism of autoregulation [10, 16].

Kowal et al. [17] conducted a study, the purpose of which was to show what hemorrhagic changes occur in the blood when removing part of the plasma. Tests were performed on 3 patients, one person with myasthenia gravis, the other with multi-rot nerve inflammation. During the study, they determined hematocrit, plasma viscosity, relative blood viscosity at various shear rates. It was observed that the removal of portions of plasma from the blood lowered the plasma viscosity and caused a reduction in relative blood viscosity at low shear rates [16, 17].

Kowal et al. [17] conducted a study among 80 patients. The first group consisted of 20 patients without neurological disorders, where the average age was 63 years. The second group consisted of 30 patients with acute ischemic stroke, the average age of people was approx. 56 years. The third group consisted of the 30 people, the patients being six months after a stroke, and the average age was 67. The second and the third group were still under medical supervision, and additionally, some patients from both groups were diagnosed with comorbidities: diabetes, hypertension, myocardial infarction. The aim of the study was to compare rheological properties (plasma viscosity, deformability of erythrocytes, hematocrit, red blood cell aggregation, fibrinogen) in all of the groups. During the research it was found that in the first group, the viscosity of blood was higher compared to the other groups, but the viscosity of the plasma was lower. The increase of blood viscosity is influenced by hematocrit, plasma viscosity, red blood cell deformability and the aggregation of red blood cells. In all groups, there were no changes in hematocrit, thus in further analysis it can be excluded as a factor affecting blood viscosity. The differences related to the viscosity of blood and plasma can be explained by changes in the flexibility of erythrocytes and their aggregation. It is believed that the differences are due to the body triggering the mechanism of feedback in a patient with ischemic stroke, that works by changes taking place in the range of rheological parameters and reducing the viscosity of the whole blood. The human body itself can regulate changes in the rheological properties of the blood by e.g. decreasing plasma viscosity, but this mechanism is not precisely known to us [17].

In our study on sciatica, we observed a statistically significant decrease in hemoglobin by 9.49%, the average volume of red blood cells by 10.43%, the average mass of hemoglobin in the red blood cell by 16.23%, and the average concentration of hemoglobin in the red blood cells by 1.18 %. Also, we found a significant decrease in rheological blood indicators: EI at the shear stress of 4.24 [Pa] by 47.61%, EI at the shear stress of 8.23 [Pa] by 43.75%, EI at the shear stress of 15.96 [Pa] by 36.58%, EI at the shear stress of 31.04 [Pa] by 33.33% and EI at the shear stress of 59.97 [Pa] by 31.48%.
The observed changes in patients with sciatica are most likely caused by its associated symptoms such as lower extremity paralysis, arthritis, fever. Our study showed changes in the rheological properties of blood, but the detailed mechanisms are difficult to interpret. Research should be conducted among a larger group of subjects, broadening the study by whole blood viscosity, plasma viscosity, fibrinogen and the aggregation of red blood cells. Despite the fact that there are many studies on hemorheological changes in a variety of disorders, this study is, to our knowledge, the first to have been conducted among patients with sciatica.

Conclusions

The changes that occur when there is pressure on the L4, L5, S1 spinal nerves adversely affect the rheological changes of the blood in patients with sciatica, and are most likely due to associated symptoms such as arthritis, fever or paresis of the lower extremity.

References

[12] Harde

Author for correspondence:
Bartłomiej Ptaszek
E-mail: bartlomiejptaszek1007@gmail.com
A SCIENTIFIC EVENING WITH N.A. BERNSTEIN, A. EINSTEIN, S. HAWKING AND D.R. HOFSTADTER

Waclaw Petrynski

Katowice School of Economics
Katowice, Poland

Key words: motor control, physics, mathematics, system theory, consciousness

Abstract

In the presented paper, the author tries to place motor control within the general structure of contemporary science. By its nature, motor control is highly abstract and cannot be supported by empirical findings to such an extent as other sciences on physical culture. Accordingly, motor control may draw inspiration from reality, indeed, but explanation – from philosophy.

The author presents and justifies the conjecture that nowadays motor control may and should play the role of an engine, driving the development and progress in science as a whole. Over the course of several earlier centuries, such a function was played by physics. Its mathematical perspectives are very efficient in the non-living world, but not relevant to the description (and, all the more, explanation) of the phenomena and processes in motor control. Therefore, the spectacular and user-friendly empirically-mathematical methodologies cannot be effective in motor control. The latter has to find its own way of development, using the whole knowledge available to scientists and philosophers. The author compares the matter of motor control to that of – the apparently insignificant – issue of black body radiation, which at the break of the 19th and 20th century, initiated the development of quantum physics and showed a completely different way of thinking about physical reality. He takes on the tacit assumption that some general laws and rules of Nature are more easily discernible in physics, which deals with by far simpler matters than that of motor control. Nevertheless, in motor control and, all the more, in psychology, their – or, more exactly, their intellectual descendants’ – structure is much more complicated. Hence, the purely physical regularities – as well as their mathematical description – are not directly applicable in motor control, even if rooted in physics. In this respect, the motor control knowledge, analogous to that of quantum physics, still awaits its discoverers and explorers.

Introduction

Although the main guests of the virtual evening to which I would like to relate this time are Professors N.A. Bernstein, A. Einstein, S. Hawking and D.R. Hofstadter, let us start with the quotation from Professor M. Nadin, who said that “science was born together with the magical, and would continue to develop in this symbiosis” [1]. Therefore, in the work of a scientist, the childish fantasy, which underlies scientific intuition, is inevitable. Sometimes, the border between them is hardly discernible and hence, the (apparently) scientific notions of the “black box”, “sub-consciousness” and “self-organization” are in fact close relatives of fairy-tales.

Matured childish fantasy – free from constraints of reality, yet using a kind of logic and attired in a university gown – is termed “philosophy”. Just there the roots of any scientific novelty and progress reside. Hence,
a scientist cannot react allergically to hypotheses and conjectures, born in the free imagination and not firmly supported by “new, original experimental data”. In fact, only if such “moonshine conjectures” fall into specific, intellectual resonance with the observable reality, then they may initiate scientific, innovative reasoning leading to the production of more or less reliable theory. The latter constitutes the very salt of science.

From D.R. Hofstadter, let us take the question “how is it that animate beings can come out of inanimate matter” [2]. Such an event might be termed a biological “Big Bang”, forerunning the next one, may be even bigger – the explosive progress of elusive psychological, mental and intellectual nature, not liable to direct experimental research.

From A. Einstein, let us take the aphorism that “everything should be made as simple as possible; but not simpler”. This may be identified with N.A. Bernstein’s reduction of degrees of freedom [3] and, the intellectually equivalent, A. Clark’s “007 principle” (“to know only as much as you need to know to get the job done”) [4].

From S. Hawking, his view on the function of theory, which – in its essence – is consistent with Bernstein’s and Clark’s ideas. He claimed:

A good theory will describe a large range of phenomena on the basis of a few simple postulates and will make definite predictions that can be tested [5].

Here, a small comment is needed. In Hawking’s perspective one might clearly trace the imaptient “physical spirit”, closely related to observable reality. However, when the predictions cannot be practically tested — at the moment — it does not mean that the abstract theory is wrong. Already in 18th century, I. Kant stated that “general truths… must be independent of experience, – clear and certain by themselves” [6]. Practice and abstraction belong to two different spheres of human cognition, so it means merely that, at the moment, there is no resonance between abstract theory and real processes. But it is not that such a resonance is not possible at all. This is why a theory can neither be debunked nor empirically confirmed. Experiments may merely show whether it is applicable in a given field of reality or not.

A specific resonance between theory and reality, even in physics, is not obvious, clear or immediate. General theory of relativity had to wait four years for discovering the phenomena consistent with it; the idea of Higgs’ boson – half a century; Einstein’s gravitational waves – a full century. So, the “testability” of a theory (and especially immediate) cannot be regarded as an ultimate criterion of its quality.

Finally, let us take from N.A. Bernstein the description of consciousness, underlying each and every mental — and, consequently, scientific — activity of a human:

... for each human movement, whether complex or simple, full of deep meaning or feasible for any frog, consciousness obtains only information relevant to what is being managed by the leading level. This is how our consciousness is built. Its spotlight, as a rule, cannot illuminate more than one level at a time, although it is able to illuminate them successively [7, 8].

And the basic question being considered in this paper reads: To what extent motor control might and should contribute to progress in psychology, cognitive science and neuroscience? Although they are no doubt the most challenging disciplines for the whole of contemporary science.

1. Theory and its limitations

The reality consists of things, phenomena and processes, whereas science is “woven” of words, notions and theories. As M. Heller stated, “science sees the world through theories” [9]. It is just them that make up science’s raison d’être.

However, there is no direct and unambiguous relation, simply discoverable, between premises and theory. A. Einstein, while discussing his general theory of relativity, remarked:

... no collection of empirical facts however comprehensive can ever lead to the setting up of such complicated equations. A theory can be tested by experience, but there is no way from experience to the construction of a theory (my emphasis – WP) [10].

What is worth emphasizing, Einstein used the term “tested”, and not “confirmed.” Also, 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 [11].

As a result, basing on Bernstein’s description of consciousness, the essence of the theory might be graphically presented in the form of the “Street Lamp Analogy” (SLA), as in Fig. 1 [12].

The premises are obvious and — in everyday life — directly observable. The knowledge on life is accessible with sheer induction, basing on previous experience. However, the knowledge symbolized by the black ring is obtainable only by abduction and entailing deduction [12].

By the way: Fig. 1 clearly shows the concept underlying the “deep structure” of a theory, and expressed by B. Russell with the words: “the power of using abstraction is the essence of intellect, and with every increase in abstraction the intellectual triumphs of science are enhanced” [13].

In science, theories are not one-to-one, complete and universal representations of reality. W. Heisenberg stated
Figure 1. The street lamp analogy; theory and its “ordering power” [12]

that “every word or concept, clear as it may seem to be, has only a limited range of applicability” [14]. Hence, the higher the abstraction, the greater the field of applicability of a theory. However, such a field has its limits. M. Heller claimed that an inevitable element of each and every theory is specific self-limiting [9]. The remark by K. Lorenz on the tentative nature of every scientific theory is also very important. He said: “truth in science can be defined as the working hypothesis best suited to open the way to the next better one” [15]. Moreover, according to J. Cohen and I. Stewart, “A Theory of Everything would have the whole universe wrapped up. And that’s precisely what would make it useless” [16].

As a result, each and every theory has to be both limited in its scope of applicability and tentative in its nature. In fact, only such “initial conditions” enable the creation of a theory and underlies understanding its function in science.

2. From physics to motor control

Taking into account what has been said about the essence of a theory, let us start from the question posed by D.R. Hofstadter [2]. However, first, let us remember N. Bohr’s statement that “it is wrong to think that the task of physics is to find out how Nature is; physics concerns what we say about Nature” [17].

Here, it seems instructive to quote R. Penrose, who said:

There are two other words I do not understand – awareness and intelligence. Well, why am I talking about things when I do not know what they really mean? It is probably because I am a mathematician and mathematicians do not mind so much about that sort of thing. They do not need precise definitions of the things they are talking about, provided they can say something about the connections between them [18].

Accordingly, mathematics says nothing about “personalities” of the items, which it describes. This was expressed by A. Einstein in apparently frivolous form, who stated:

As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality [19].

For example, non-living, physical objects do not have their own personalities. Therefore, mathematics is highly efficient as a “language” of physics. However, in biology and, all the more, in motor science and in psychology, the personality, including memory and previous experiences of a given individual – no longer a sheer object! – plays a crucial function. This is why mathematics is hardly eligible for description (and, even more, explanation) of motor control issues.
Particularly, in motor control, which is much more complex than physics, we may only try to build a logically coherent model, which may mirror or represent the reality, more or less truly. Hence, a scientist can never be sure, whether it really represents reality, and – if so – to what extent. As a result, conjectures and hypotheses, though inevitable in science, make up a very “unstable ground” for reasoning. Paradoxically, it is this instability that makes any scientific, inventive reasoning possible.

Physical subjects are able to adapt themselves to external conditions. For example, a defined mass of air, while squeezed, changes its pressure and temperature. Previous remembrances and future expectations cannot influence its behaviour. It is completely indifferent to the past and future, so it is quite easily predictable and thus – mathematically describable. Hence, to physical, non-living subjects, one might assign the trait of stationary adaptability. The term “stationary” means “stable, insensitive to passage of time.”

A specific groups of physical atoms, using their passive adaptability, may join together and make a molecule of protein, underlying the phenomenon of life. It may adapt itself to current conditions.

An inseparable trait of life is multiplicability and, according to T. Gánti, mortality [20]. So, the best suited to the existing conditions, protein structures may transfer their traits to their similar descendant structures. Not optimally adapted ones must vanish. In such a way, the specific ability of living beings to adapt to future conditions, i.e., the passive purposefulness, surfaces. Here, a new element between stimulus and response appears (no longer a sheer reaction!): the information. To enable future changes, it has to be quite variable or even capricious, hence, it does not obey the “stiff and obvious” physical laws. This makes the whole system hardly describable mathematically.

Along with the development of the central nervous system – according to N.A. Bernstein it was “driven” by more and more challenging motor tasks in the environment – the mind was born. It was able to represent the external world and to extend the temporal axis of mental operations far beyond the limits marked by sensory experiences evoked by current stimuli. At that point consciousness, the ability to actively form one’s own behaviour and anticipation of its future consequences in the environment, arose. This makes the essence of the most advanced mental ability of a living being – active intentionality, sometimes addresses as “free will”.

However, even in the non-living world, mathematics cannot be fully reliable. It builds true representations of reality, indeed, but one ever knows whether all the relevant factors have been taken into account and thus – how mathematics works in relation to reality. This is why M. Heller wrote:

One may assume that the mathematical structures, used by us for modelling the world, are so different with their simplicity to richness of the real structure of the world that instead of similarity we should rather speak about a specific resonance between the structure of the world and the structure of its mathematical models invented by us [9].

In other words, the “translatability” of mathematical descriptions into representations of reality is of nonlinear nature, and cannot be fully performed (one-to-one mirroring). In this respect, the following statement by biologist J. Cohen and mathematician I. Stewart sounds very instructive:

By definition, mathematical statements are tautologies. Their conclusions are logical consequences of their hypotheses. The hypotheses already “contain” the information in the conclusions. The conclusions add nothing to what was implicitly known already. Mathematics tells you nothing new [16].

Accordingly, mathematics freely generates only various methods of thinking. Some of them may fall into resonance with reality. Then, mathematics transforms into calculations, deprived of fantasy but equipped with reliability, and thus gains the usefulness for non-mathematicians. Only in the form of calculations may mathematics display its usefulness in, say, technology, which exploits the findings of physics. The latter is the discipline dealing with non-living matter, where thinking-reality resonance is most easily discernible and thus – successfully applicable. Here, the application of virtual mathematical thinking patterns – usually reduced down to the level of calculations – to real physical processes is the easiest and sometimes almost obvious.

Let us analyse the mutual relations between physical adaptability, biological purposefulness and psychological intentionality in more detail. A single atom is able to adapt itself to external conditions: according to the energetic environment, an electron may circle this or that or ring). In this respect, the following statement by biolo-


tist G. B. S. F. K. D. W. (20) may circle this or that or ring). In this respect, the following statement by biologist G. B. S. F. K. D. W. (20)
between his/her fingers. The quantum world is available to the human mind only through the agency of mathematics. So, in a virtual world (in the case of quantum physics – of a different dimensionality than that accessible to our senses), one may imagine many phenomena and processes which do not exist in the real world, but nevertheless, such virtual representations enable the explanation of what goes on in reality. Can an electron like anything? And in this respect – was Feynman not crazy?

In fact, here we touch upon a pivotal problem in science. N. Bohr regarded:

> What is it that we human beings ultimately depend on? We depend on our words. Our task is to communicate experience and ideas to others. We must strive continually to extend the scope of our description, but in such a way that our messages do not thereby lose their objective or unambiguous character [17].

Accordingly, one might state that, thanks to biological diversity, *Homo* was born. But only word – the rich, diverse, full of fantasy, powerful “armed forces” of information – created *sapiens*. Bohr also remarked:

> We must be clear that when it comes to atoms, language can be used only as in poetry. The poet, too, is not nearly so concerned with describing facts as with creating images and establishing mental connections [22].

Let us listen to another Giant in physics, W. Heisenberg, who stated:

> The problems of language here are really serious. We wish to speak in some way about the structure of the atoms. But we cannot speak about atoms in ordinary language [14].

Essentially, the equivalent idea has been expressed by M.L. Latash, M.F. Levin, J.P. Scholz and G. Schöner, who wrote:

> ... the main goal of motor control research is to create a formal description, operating with exactly defined variables... Progress in motor control over the recent years has been slowed down by the lack of a broadly accepted and exactly defined set of notions that would be specific for typical problems of motor control; an adequate language for this area of research [23].

Let us be reminded of the already cited statement by N. Bohr about the task of physics and consider, whether Feynman spoke of an electron itself, or of its description? And if in the latter something is possible, what at first glance, while seen from observable and “tangible” reality, seems to be crazy, then is it – maybe – a distant loom of something possible in that portion of reality that at the moment is neither accessible to our senses or laboratory devices nor to our minds? Maybe, it is here possible to trace the “smell” of a resonance between reality and its description unknown to science, as described by Heller?

Maybe it is something unpredictable, qualitatively new, the properties of which are not derivable from the traits of its components?

The latter sentence includes, in fact, the definition of the emergent system effect [24, 25]. Its idea may be traced in the statement by Aristotle that “it is likely that unlikely things should happen.” Hence, if separate physical atoms join and make up a system – a molecule of protein – then it may be able to generate a system effect, which is the purposefulness. Such an imaginable event would be compared to the biological Big Bang, for which D.R. Hofstadter was looking.

By the way: this may be joined with what I have termed the “adjacent levels transcoding axiom” (ALT) [26]. It is essentially of nonlinear nature and – probably – mainly responsible for the unpredictable, qualitatively new, emergent system effect.

Therefore, mathematics “distills” merely the existing relations between the items which it describes, but says nothing about its essence. Such a limitation does not make a great hindrance for the development of physics or technology, but it makes mathematics almost completely irrelevant to the explanation of the phenomenon of life and – even more – of the mind. In short – mathematics is not an alpha and omega, as put by Galileo, but merely an alpha, as put by Bogdanov. The former said that “mathematics is the language in which God has written the universe,” the latter – that “…I perceive… mathematics… as an earlier developed, because of other reasons, branch of general science on organization.” [27, 28]. The main difference is that mathematics – unlike systems theory – cannot produce an emergent system effect.

In biology, a pivotal system effect is purposefulness. It is clearly directed towards the future and constitutes the very heart of the phenomenon of life.

Therefore, one may create a model in which biological life is rooted in physical adaptability, but nonlinear transformations inside the biological system have produced the qualitatively new ability: the purposefulness. In such an interpretation, the psychological intentionality, on one hand borders on biological purposefulness (and indirectly, on physical adaptability), and on the other – on miraculousness, children’s fairy-tales (Peter Pan, Alice in Wonderland, Harry Potter) or even divinity. And in science, also on charlatanry.

At this point, let us ponder what makes the most important difference between inanimate and animate matter. One might assume that the behaviour of animate matter is being controlled by the most primeval form of thinking, i.e., intelligence [26]. And the behaviour of inanimate matter is not. Nevertheless, what is being worked out in mind, has to manifest itself in the physical
environment. At this point, we come across the position of motor control in such a milieu. Here, the words by philosopher A. Wohl are highly instructive, who stated: “all that we dispose of, all what constitutes the resource of our culture, all the pieces of art, science and technology – all that results from motor activities” [29].

3. Basic thinking techniques: intelligence, instinct, intuition

Among the Giants in science, not only R. Feynman presented (apparently) wild ideas. In 1881, C. Darwin argued:

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 [30].

However, not only worms but also unicellular organisms exhibit goal-aimed behaviour, which might be termed “intelligent”. Already in 1906, H.S. Jennings defined “intelligence” as the “modification of behavior in accordance with experience… It is clear that we find beginnings of such adaptive changes of behavior even in the Protozoa” [31].

Similar conclusions have been formulated by E. Heron-Allen. In 1915, in the paper entitled “On beauty, design and purpose in the Foraminifera”, he presented the apparently sacrilegious idea:

I claim that every living organism living an independent existence of its own is endowed with the measure of intelligence requisite to its individual needs [32].

Still further went L. Cuénot, who in 1941 claimed that even a single cell disposes of a specific sort of intelligence [33, 34].

So, let us order the basic terminology and accept the following definitions:

- **Instinct** – in motor control: inborn (closed) or acquired (open), the well-established tendency to look for lacking information necessary for solving a given task in specific directions, where the probability of finding it is the greatest, or the propensity for choosing by intelligence the definite methods of developing responses likely to produce some desired results.

- **Intuition** – the potentiality of a living being for guessing the lacking information, necessary for employment of intelligence.

- **Intelligence** – in motor control: the potentiality of a living being for building a reliable motor response while having the whole necessary current information of proper modality or modalities, and using the logic suitable for that information [26].

Accordingly, if one assumes such a definition of intelligence and puts aside what might be termed “anthropomorphic attitude” concerning this term, then the assumption by Cuénot no longer seems extreme. To sum up, one might assume that particular thinking methodologies deal with:

- Instinct– experiences from the past;
- Intuition– expectations concerning the future;
- Intelligence – melting together past experiences with future expectations and producing a current, present motor operation.

4. Consciousness, non-consciousness and ignorance

The mental space, where the instinct, intuition and intelligence cooperate in full, is consciousness. In this respect, SLA [12] may also be illustrative in the depiction of mutual relations between attention, consciousness, unconsciousness and ignorance (Fig. 2).

Attention enables reduction of Bernstein’s degrees of freedom, of various modalities [3, 7, 8] according to Clark’s “007 principle” [4]: to know only as much as to efficiently perform a given motor operation. Therefore, the attention “illuminates” the consciousness, i.e., that part of knowledge (stored in the memory), where the intellect starts its activity in order to solve a given task.

It is worth noting that the regions consciousness, unconsciousness and ignorance are not homogenous. As a result, the borders between them are also not sharp and strictly defined, but constitute rather fuzzy zones. Between consciousness and unconsciousness lies what might be termed “half-active consciousness” [35]. For example, in the ring of ignorance bordering directly on unconsciousness, resides the potentially easily graspable knowledge.

Interesting considerations and reflections on consciousness and activity of the mind have been presented by physicist L. Mlodinow [36]. However, surprisingly, he defined neither the term “consciousness”, nor – consequently – “unconsciousness”. So, while considering the already cited description of consciousness by N.A. Bernstein, let us formulate the following definition:

- **Consciousness** – a dynamically changing component of a quasi-static multimodal knowledge of an individual, activated at a given moment by perception guided by attention, aimed at dealing with the task at hand [37].

Accordingly, unconscious is what remains beyond this limit. There are two kinds of knowledge, which remain beyond the region illuminated by Bernstein’s spotlight:

- That existing somewhere in the field of the Known, potentially accessible but not activated at the moment; let us term it **unconsciousness**.
- That in the region of the Unknown, including the knowledge not accessible at all; let us term it **ignorance**.

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Antropomotoryka
5. Movement and mind: paleokinetic and neokinetic creatures

A crucial factor in movement management development is predictability. It was very illustratively described by Bernstein:

It is interesting to note that the reflex loop in primitive animals… works quite differently from how it functions in us. Consider a worm that crawls to an obstacle or a snail that reaches the tip of a grass blade. When there are complications of this kind, these animals start rather animated, aimless searching movements in all directions. In the more highly developed neokinetic animals, movements follow sensations; that is, movements are directed and controlled by sensations. In the lower animals the opposite is true; sensations are served and provided by movements [7, 8].

Further progress in information processing in living creatures has been expressively described by S. Agnew, who remarked: “Human development has two stages: in the first we think about things; in the second we begin to think about thinking”.

Nevertheless, only movement may be regarded as a “looking glass” allowing to mirroring what happens in mind [38]. Moreover, apart from the already quoted statement by A. Wohl [29], psychologist J. Kalat also stated:

A great brain without muscles would be like a computer without a monitor, printer or other output. No matter how powerful the internal processing, it would be useless. Nevertheless, most psychology texts ignore movement (my emphasis – WP) and journals have few articles about it [39].

Thus, the usually not highly valued movement – often reduced by “genuine scientists” to simple push-ups and knee bends – may play a similar part in psychology such as the black body radiation phenomenon in physics.

Basing on these quotations, one might formulate two conclusions:
1. The only way to understand what happens in the human psyche is through observation of motor behaviour of an individual. On that basis, a scientist may formulate conjectures and hypotheses, build a theory, strengthen its internal structure with logic and check its applicability and reliability.
2. The only way to explain real motor behaviour of an individual is understanding the virtual mental processes in the human mind.

So, as it was stated by N. Bohr, “everything we call real is made of things that cannot be regarded as real.” By the way: essentially, the same idea can be found in the Exodus (3:14), yet expressed in a much more concise form: “I am that I am”.

The consequences of this for motor control as a scientific discipline are by far greater than one might learn at first glance. It is “woven” of such highly abstract knowledge that any experimental support is hardly possible here. No matter how reluctant the “genuine scientists” are to admit it.

In such a situation, the notion of what might be termed “active non-consciousness” may be put into a “junk room”. As a non-defined item, but nevertheless used to produce knowledge which is labelled “scientific”, it is
in fact harmful to science. It violates the basic principle of scientific determinism that each effect has its cause. Hence, it merely enlarges the “cemetery of facts”. This term has been coined by R. Thom [40] and denotes knowledge processed according to commonly accepted scientific methodologies, which, however, cannot contribute to the explanation of the processes that underlie them.

6. The “consciousness tower” in humans

The metaphor of SLA [12] turned out to be effective in the depiction of the power of theory (Fig. 1) and the essence of consciousness (Fig. 2). Unfortunately – because, according to A. Einstein, “everything should be made as simple as possible, but not simpler” – the graph showing the whole structure of human consciousness, while seen from the ML perspective, has to be inevitably by far more complex. Nevertheless, let us try to adopt the general idea presented in Fig. 2 to the illustration of the “anatomy” of consciousness in humans, and the information processing resulting from it. In other words, let us try to build the “consciousness tower” (Fig. 3), basing on the seminal concept by N.A. Bernstein (brain skyscraper) [3, 7, 8] and the concept of the modalities ladder (ML) [26], resulting from Bernstein’s findings.

Both the ML and the “consciousness tower” consist of five levels: symbolic E, verbal D, visual C, haptic B and proprioceptive A. Fig. 3 clearly illustrates Bernstein’s principle of lower level development [26]. The region of consciousness accessible to the D-level code is marked in light grey. It includes not only the circle under the D-level “lamp”, but also the outer ring under the C-level “lamp”. The latter represents the knowledge accessible to the C-level only in the presence of the D-level. For example, understanding of traffic signs has to be shaped at the “clumsy” verbal D-level, but on the road, “in the heat of the battle”, it has to function at the “swift” visual C-level.

Moreover, all the “circles of knowledge” make one coherent system, and intra- and inter-level communication – the latter of nonlinear nature – runs both down-up and up-down. The “Burning Giraffe” by S. Dali belongs to the outer ring of C-level knowledge, but it cannot be born without the D-level and indirectly, E-level inspiration. One might state that a brilliant scientist is able to project their E-level mental constructs onto the multimodal sphere of intellect, and a brilliant artist – onto the multimodal sphere of emotions. They both have to be able to overcome the barrier of translatability between particular levels of the consciousness tower to a much greater extent – sometimes even bordering on madness.

![Figure 3. The consciousness tower. The letters denote Bernstein’s brain skyscraper’s “floors”, equivalent to the modalities ladder rungs](image)
– than a “man on the street”. This may be illustrated with the aphorism by H. Miyazaki that “reality is for people who lack imagination.”

It also shows the adjacent levels transcending axiom (ALT) [26]. For example, the verbal D-level does not see the B-level haptic stimuli and all the more, the A-level proprioceptive ones. This is why it is not possible to verbally explain (D-level) how to keep balance while cycling (B-level). On the other hand, while processing the, say, D-level information, it is not necessary “to tow” the B-level or even A-level information “belonging” to a given task, which in such a situation would simply make up an intellectual ballast.

The consciousness tower may be regarded as a specific “gearbox” enabling the use of the most efficient and, at the same, “cheapest” (in mental and physical terms) information processing modality, which enables successful solving of a given motor task. This makes it possible to unveil another face of Bernstein’s process concerning reduction of freedom degrees. Its idea is borrowed from theoretical mechanics, but while “shifted” towards higher rungs of the ML, it turns out to also be effective at higher levels of abstraction. In this case, the physical principles, easily mathematically describable with theoretical mechanics, may be regarded as a “loom” of more general regularities, accessible only via virtual, mental operations.

It is not commonly known that the mathematical knowledge of the probably greatest mind of the 20th century, A. Einstein, was sometimes questioned. H. Steinhaus quoted the words of the outstanding mathematician H. Minkowski saying that “the mathematical education of this young physicist (A. Einstein – WP) is not very high, what I am able all the daringly to assess, because in one’s time in Zurich he received it from me” [41]. Mathematical knowledge of Minkowski evokes no doubts, so one’s time in Zurich he received it from me.

In sport, the phenomenon of “choking” is commonly known [42]. This may be illustrated by the words of ski jumper A. Malysz, who stated:

“I have to switch off thinking… Before each jump, I wonder what should be improved. In team contests, I focused my attention on preventing a delay in the take-off. As a result, I skied too passively and did not take-off dynamically enough – admits the World Cup holder [43].

Therefore, information processing at the D-level did not improve, but impair the motor operations for which the natural “chief” was the C-level. This is – maybe – a distant, observable loom of the much more general principle, which might be assigned to information processing in humans. Would Einstein have been able to produce the general theory of relativity if he “dove” deeper into mathematics and, consequently, perceived the physical issues less profoundly? Would mathematics be merely an intellectual ballast for him in such a situation? Or did Einstein’s mathematical and physical knowledge, joined with brilliant inventiveness, match the “007 principle” perfectly, and only because of this, while coming across a scientific problem challenging enough, enabled creation of one of the most precious products of human mind in 20th century? As the last mathematicians, who mastered mathematics as a whole, we may refer to H. Poincaré and D. Hilbert. Why did not they – or even, say, H. Minkowski – create the general theory of relativity?

Therefore, to invent the general theory of relativity, Einstein had to find specific balance between mathematic formalism and the elusive beauty of his ideas. So, he placed one foot in sober logics, and the other – in an apparently “moonshine” poetry. Another Giant in physics, P. Dirac, argued: “It seems that if one is working from the point of view of getting beauty in one’s equations, and if one has really a sound insight, one is on a sure line of progress.” Moreover, it is the poetic beauty that plays the part of a “leading edge”, and the sound insight, entailing it – that of merely a “working tool”.

The beginning of the 20th century was a blissful moment in the history of science, when the current problems, great minds and specific intellectual limitations met each other, overcame a definite “critical mass” and exploded as a certain “Big Bang” in science. However, basing only on “new, original, experimental data”, without ascending to the level of poetry – often disregarded by “genuine scientists” – would not be able to generate such brilliant products, e.g., the general theory of relativity.

While coming back to motor phenomena, the existence of the lower, “cheaper” (in intellectual terms) levels of the consciousness tower may – paradoxically – enhance the potentialities of the higher ones [44, 45]. Therefore, not only do the higher levels influence the activity of the lower ones, but similar phenomenon may be also observed in the opposite direction. It seems worth noting, too, that this conclusion has been drawn based on Bernstein’s brain skyscraper, invented to explain the movements’ construction system in humans.

7. “Subliminal” and “non-conscious” processes

The term “subliminal stimulus” seems to be analogous to physical tunnelling. The threshold – as in quantum physics – is higher than the stimulus energy, indeed,
but nevertheless, the “subliminal stimulus” miraculously influences further events!

Unfortunately, the “quantum way of thinking” is not applicable in our Newtonian reality. In fact, in motor control, the terms “subliminal stimulus” or “subliminal information” are oxymora. The raison d’être for any threshold is to eliminate the items which do not fulfill specific criteria (energy level, modality, etc.). So, if something may be termed “subliminal” [36], then it has to be eliminated and cannot influence any further events. Let us remark that even the cellular membrane, “one of the greatest inventions of evolution” – as M.L. Latash described it [46] – is made of a system of such thresholds, dynamically cooperating with each other. Just this underlies, at the very basis, the phenomenon of life.

A similar oxymoron is the term “non-conscious process”. As already stated, the physical things dispose of adaptability, biological organisms – of purposefulness, and the psychological individuals – of intentionality. Especially the latter, clearly directed towards the future, is not possible without consciousness.

In this context, the words by naturalist F.W. Jones sound highly symptomatic, who remarked that “whoever wins to a great scientific truth will find a poet before him in the quest” [47]. The same idea in its essence was expressed by S. Kowalik [48]. In this context, the following words from L. Carroll’s poem “The Hunting of the Snark” are highly instructive:

To the horror of all who were present that day
He uprose in full evening dress,
And with senseless grimaces he endeavoured to say
What his tongue could no longer express [49].

For a motor control specialist, who logically analyses those “moonshine” verses from the perspective of the sober ML and the “consciousness tower,” it is important that in the human mind, information encoded in one modality may be not “translatable” into another one. In other words, the C-level “visual consciousness” may not be fully translatable into the D-level “verbal consciousness” (Fig. 3). The “senseless grimaces” (C-level) should communicate information which cannot be expressed verbally (D-level), yet is somehow understandable at that level. This makes the basis of the adjacent level’s transcoding axiom [26]. Therefore, in the presence of the D-level, the C-level circle of knowledge is much more extensive than in the situation, which there was no D-level at all (Fig. 3).

In humans – and some animals –, deterministic cause-effect chains are “driven” by psychological intentionality. It may work at various ML rungs (C, D and E), though at C-level, it may resemble biological purposefulness from which it has probably germinated. However, both purposefulness and intentionality are based on cause-effect logic. Thus, the MM perspective enables elimination of violation of cause-effect logic and putting the terms “subliminal stimulus” and “unconscious information processing” into the junk room.

By the way: here one may quote the statement by N. Bohr: “How wonderful that we have met with a paradox. Now we have some hope of making progress” [50]. In this case, the paradox consists in violating the logic of the cause-effect principle, indeed, but also in addressing the description of this phenomenon as “scientific”. Moreover, Bohr’s remark unveils a much greater function of sense of humour in science – i.e., the sensitivity to paradoxes – than the “genuine scientists” would be prone to admit. Not without cause philosopher W. James stated that “Common sense and a sense of humor are the same thing, moving at different speeds. A sense of humor is just common sense, dancing” [51].

The formulation “unconscious activity” violates the basic principle of determinism that each result has to have a cause. Hence, a consistent chain of events, the latter resulting from the former, dies, but it miraculously rises from the dead later and acts as if there were no break in it! In this paper, I propose another process. The chain of events does not die, but it divies toward lower levels of the ML, where its processing goes on, and then it resurfaces. Is my idea right? I do not know. I would only like to say that I do not like the notions of “subliminal stimulus”, “unconscious processing”, “self-organization”, etc. – which, according to K. Lorenz and W. Heisenberg, are of tentative nature – so I tried to build such a model of my own representation of the external world, where such notions are superfluous. In other words, in my image of reality they were paradoxes, which I strove to eliminate. Having some hope of making progress…

For example, let us remember the already cited statement by A. Einstein:

As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality [19].

A “genuine scientist” deprived of a sense of humour, would describe the idea underlying such a formulation in a thick book. Its great thickness – which violates the “007 principle” – would for sure impair the “graspability” of this idea. The humour-packaged formulation by Einstein makes it both easily graspable and full of profound, scientific content. In short, in intellectual terms, it is not a slippery, difficult to grasp fish, but a user-friendly, effective fishing pole.

The quoted statement by A. Einstein may be confronted with the equally concise remark by mathematician R. Thom, who said: “Well, mathematicians envy each other, but as far as hatred is concerned – they leave it for physicists” [40].
The intellectual content of the apparently frivolous statement by Thom is in fact inversely proportional to its conciseness. For the worshippers of mathematics, highly irritating is the fact that only some of intellectual fishing poles, produced by them, are suitable for catching the physical fishes. The other ones may be, then categorized as "pure nonsense". So, if such a "zone of hatred" exists (this is no doubt an overstatement) between mathematics and physics, then the analogous "zones of not realizable expectations" may be discerned between, say, physics and biology, or biology and motor control. In this respect, the views by N. Bohr are highly instructive, stating "that, if there is to be order in nature, the laws of physics cannot be broken… On the other hand, he stuck to the view that biology is a topic different from physics in principle as well as in practice" [17].

By the way: let us be reminded of H. Minkowski's poor opinion of Einstein's mathematical knowledge. If so, Einstein's esteem to mathematics was probably proportional to his knowledge. Maybe this limited trust made the precise application of the "007 principle" possible and consequently, the invention of the general theory of relativity. If mathematics were placed high on the altar of science, any manipulation of it would have been categorized as sacrilege, so a genuine worshipper of mathematics would be not able to do it! Paradoxically, while seen from such a perspective, Einstein's brilliant achievement might be perceived as… the victory of his mind over the then existing science! Here, let us be reminded of the already cited words by K. Lorenz that "truth in science can be defined as the working hypothesis best suited to open the way to the next better one." [15]. Accordingly, no matter how paradoxically the words about victory of the mind over science may sound, just such phenomena underlie great leaps in quality of the human image of the world. In physics, this might be exemplified by the achievements of M. Planck, A. Einstein, W. Heisenberg, "crazy" R. Feynman and many, many others.

Unfortunately, a "genuine scientist", coming across a paradox, would rather kick it into the long grass, if existing, the commonly accepted methodologies are not able to successfully deal with it. In short, the activities of a "genuine scientist" are rather determined by their methodologies and not by the problems, which need to be solved. And motor control needs not only new scientific "working methodologies," but – first of all – new philosophical ways of thinking. This is probably why in contemporary motor control the "genuine scientists" are nearly completely inefficient.

Let us analyse information processing in humans [26]. In reactive mode, the first link in the cause-effect chain is sensitivity (transducer), which after reception of a stimulus produces a sensory input. Then comes perception (detector), which joins the sensory input with some information specific to it and retrieved from one’s own memory. Next comes attention (input filter), which assesses the information. Still later comes motivation (input zero-one switch and amplifier) which passes the information on to the intellect (or not) and the intellect itself (processor) works out a response.

The set of multimodal thresholds makes up a nonlinear system of filters. A-level threshold "distills" the A-level information, which later comes across the B-level filter, and so on. The lower level "filters" have to be inevitably more "permeable" to information than the higher ones; otherwise, the latter would have nothing to do. Moreover, the assessment of information by attention is not a "zero-one phenomenon". Between full rejection and full acceptance, there is a field of intermediate assessments. Hence, near the rejection zone, which may be termed the "Cheshire Cat’s grin zone," where the information is reduced to zero and, while achieving that value, it changes its modality [52]. Therefore, to be born in the target modality, it has to die in the source modality. Just the latter constitutes the Cheshire Cat’s grin zone, i.e., the modality transformation zone, much more complex than simple "half-activeness" [35]. As a matter of fact, the idea of such a zone – borrowed from L. Carroll’s "Alice’s Adventures in Wonderland" [49] – bases on a similar way of thinking such as that underlying mathematical differential calculus; L. Carroll was not only a poet, but also a mathematician and logician. Hence, to enter the "assessment zone", the information identified by perception has to overcome a threshold specific to attention – hence, it cannot be termed "subliminal" – but may be assessed as being of nearly zero importance and "obscured" by other, more significant information.

Let us analyse the Cheshire Cat phenomenon in more detail. While changing speed, one may analyse the consecutive speed increments, smaller and smaller, approaching zero while the time intervals also approach zero. At the end of such a process – when the speed increments and time intervals become infinitesimally small, next to zero – one gets pure changeability, the tendency to speed change, i.e., the acceleration. However, let us remember the statement by J. Cohen and I. Stewart about mathematics and tautologies. One might compare speed changes to the Cheshire Cat, and its grin – to acceleration. The latter exists somehow in speed changes, so it is nothing new, and the mathematical procedure merely unveils it, or "distils" it in its pure form. On the other hand, as L. Cuénot stated, "there is nothing living in a cell apart from the cell itself." Hence, life is something qualitatively new that cannot result from sheer tautology of mathematical-like nature.

The information at various rungs of the ML are of different modalities, so the particular thresholds at each of them are not only different, but not even comparable. It
is not possible to say whether something is more warm (B-level) or more green (C-level). Hence, the B-level threshold is not "visible" to the C-level. Nevertheless, it exists and functions.

Let us illustrate the C-level processing with the following situation. During a penalty kick, when the ball flies at a speed of about 30 m/s, and the goal is 7.32 m wide and 2.44 m high, the goalkeeper has to his/her disposal about 0.3 s for:

- identifying the direction of the ball flight,
- inventing what to do to defend the goal,
- performing all the necessary motor operations.

In such a short time, execution of all these operations is not possible. However, sometimes a goalkeeper realizes the (apparently) impossible task and defends the goal. How?

S/he has to accurately anticipate the shot direction and prepare the necessary motor operations in advance. Then s/he only has to execute an action planned in advance, basing on anticipation. What makes the basis for such anticipation? When one asks a goalkeeper, s/he answers that s/he…does not know. In fact, it may be a short gaze of the player, his/her body configuration, foot placement direction – in short, the C-level signals. Only C-level processing may be swift enough to make the whole operation effective, so the information processing has to be made exclusively at that level. An important conclusion is that at C-level, probably the most advanced thinking methodology "germinates", i.e., anticipation.

The B-level information may be exemplified with the situation in which somebody suddenly and unexpectedly is pricked with a pin. S/he performs a rapid movement away from the source of pain before s/he realizes, what namely happened. Hence, at the "swift" B-level, stimulus is received, the movement pattern is prepared and the physical response is executed before it is even identified at the "clumsy" D-level. It seems worth noting that such an identification would be contradictory to Bernstein’s degrees of freedom reduction, because it is not possible to adjust the motor operation to such an extent that it would become inefficient.

While using the commonly accepted terminology, both these situations would be probably termed "subliminal", "unconscious" or "instinctive". While seen from the ML perspective, the two former terms cannot be termed "scientific". On the other hand, the latter includes conscious, active, yet extremely shortened information processing – hence very swift – basing on previous experiences, both of phylogenetic and ontogenetic nature.

8. Conclusion: Motor control and black body radiation

Let us be reminded of one more aphorism by A. Einstein that "the whole of science is nothing more than a refinement of everyday thinking" [53]. By the way: this might be perceived as a close "cousin" of the theory of recapitulation (biogenetic law) by E. Haeckel [54].

Therefore, it is possible to apply the consciousness tower (Fig. 3) to build a specific, systemic hierarchy of scientific disciplines involved in the description and explanation of human motor behaviour. At the A-level, directly bordering on physical reality, anatomy and biomechanics may be located. At B-level – physiology. The C-level might be associated with neurophysiology, D-level – with motor control, and E-level – with psychology at a lower sub-level and philosophy (and poetry) at a higher one.

Incidentally: here one may determine the difference between philosophy and poetry. Both are detached from reality, but philosophy is mainly focused on logic, whereas poetry – on aesthetics. In the development of science, the latter constitutes a much more significant criterion of usefulness of a given portion of knowledge than one might admit at first glance. For example, in many cases, in physics, just striving for beauty and symmetry of equations led to great leaps in this discipline of science. Therefore, the already cited statement by F.W. Jones about scientists and poets is in fact not merely a frivolous "mental gewgaw", but includes a profound, fruitful idea.

It seems worth noting that poetry is not regarded as being a very serious human mental activity. It often borders on madness. Therefore, just the poet, being perceived as a "great child", may express a seemingly crazy – yet, in fact, valuable – idea, which cannot be invented by deadly serious, sober, logical, methodological "genuine scientists," deprived of a sense of humour.

In this context, one may show another important attribute of the system, i.e., its flexibility. J. Morawski wrote:

…the borders between particular layers are absolutely relative. Their demarcation depends on the goal of researches, experiments results and a scientist’s practice. By division into system layers, the boundaries between them are to be seen not in a morphological sense, but in some categorical caesurae [24].

One might add that not only “borders between particular layers”, but also arrangement of those layers has to be adjusted to the main goal of a given system.

Motor control describes the production of physically observable movements, indeed, but nevertheless, its relations to reality are so distant that the experimental research in this discipline may play a merely auxiliary
part. On the other hand, it borders on general psychology, which may be completely detached from any physically observable phenomena and/or processes. Still higher – philosophy, by definition detached from observable reality. Nevertheless, while applying such a model, one may learn that the only way to understanding highly elusive psychology is lead through motor control. Its one end is rooted in the original Aristotelian peripatetic axiom “nihil est in intellectu quod non prius in sensu” (“nothing is in intellect that was not first in senses”) [55], whereas the other one may be associated with its 17th century extension by G.W. von Leibniz, who supplemented the idea by Aristotle with the words: “excipe: nisi ipse intellectus” (“except the understanding itself”) [56].

The relationship of psychology with motor control may be compared to that of mathematics and calculations. Mathematics is full of even more “moonshine” fantasy, able to ignore any really existing constraints, and thus, it is highly inventive. However, to gain the attribute of usefulness it has to be reduced to the level of sober, even trivial calculations. Similarly, if one compares psychology to “head in a cloud”, then the motor control plays the part of “feet on the ground”. In short, without psychology, motor control would be mindless. But without motor control, psychology would be blind.

Unfortunately, motor control is nowadays – all over the world – categorized as a sport or discipline of physical education, i.e., the funny baby-science based on push-ups and knee bends.

However, motor control issues, often even disregarded by “genuine scientists”, may play a similar part as the issue of black body radiation in physics. According to W. Heisenberg, the history of quantum physics has been initiated by a phenomenon of black body radiation, which “did not belong to the central parts of atomic physics” [14]. However, it was just an irritating paradox, which inspired M. Planck to invent the notion of quantum. Its idea was a highly “moonshine” concept, not derivable from “new, original, experimental data”; all the more, its essence was contradictory to the Newtonian rules, regarded as being unshakeable. Therefore, the black body radiation was observable in Newtonian metrics, indeed, but the explainable only in quantum dimensionality. Contrary to Heisenberg’s statement, it did not matter that it was not a component of the “central part” of atomic physics; as a paradox, it had to be explained. As a result, just this apparently marginal phenomenon gave rise to invention of the whole of quantum physics.

Similarly, the observable human motor operations (motor control) open the perspective on the vast space of complex mechanisms underlying them, not experimentally researchable, but accessible only by speculations and interpretations (psychology). So, one cannot exclude that in development of the whole science in the 21st century, it is motor control that will play the similar part as the black body radiation in physics. Already existing, commonly accepted scientific methodologies of research into it – especially the empirical ones – turned out to be hardly effective. Fortunately enough, motor control is already strong enough to make any attempt at brushing it under the carpet unsuccessful. It has already passed its intellectual “point of no return” and the only way of its development leads ahead, towards new methodologies and innovative, original, not yet known ways of thinking about structure of human motor behaviour. To be effective, the context of such thinking has to include the whole cultural heritage of humanity, including not only science, but also, e.g., philosophy or poetry. The “genuine scientists” are sticking to their commonly accepted methodologies (e.g. “new, original, experimental data”), whereas motor control needs qualitatively new problem solving tactics and ways of thinking. Therefore, it seems hardly possible that the “genuine scientists” will be able to generate any significant progress in motor control.

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Author for correspondence:
Waclaw Petrynski
E-mail: waclaw.petrynski@interia.pl