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 Kraków since 1989, and from 2010, in cooperation with the University School of Physical Education in Wrocław. The journal has received academic patronage from the Rehabilitation, Physical Education and Social Integration Committee of the Polish Academy of Sciences and can be found in the IC Journal Master List international indexing database. Since 2014, the journal is published in the original electronic version in English. On subscribers’ request, the journal may be issued in English and Polish in book format.

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

Aim

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

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

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

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

Requirements for submission

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

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

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

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

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

• The volume of empirical work including the summary, figures and tables should not exceed 22 pages, and the reviews – 30 pages standard A4 size (up to 1,800 characters including spaces per page);
Texts should be prepared using only Microsoft Office Word text editor, pages should be numbered, font: Times New Roman; size: 12 points; spacing: 1.5; justified text; title written in bold typeface; centred.

Tables and figures labelled using Arabic numerals and headers, explanations and descriptions of illustrations below the figures and the results above the tables should be placed on separate pages in the English and Polish versions. Headers, explanations and descriptions below the figures and above the tables should be in English and Polish. Example:

Table 1., Fig. 1., Objasnienia, Chlpecy

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

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

Abstract and key words (English and Polish versions on separate pages – if article is meant for publication in both English and Polish) 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 Oxford Referencing System. According to it, referencing material from the source in the body of the text should end in the bibliographic item number in square brackets, e.g. [1]. In the case that reference is made to the authors, the reference is placed immediately after the author’s surname (without first name initial) (e.g.: “According to Aronson et al. [23] this study is ...”).

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

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

Monograph by no more than six authors:


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


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


Monograph publisher (collaborative work)


Chapter in the monograph (collaborative work)


Conference reports (papers)


Monographs published in electronic version


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


Articles published in journal supplements


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


Articles in journals published in electronic version, with digital DOI


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


Important information for authors of articles submitted for publication

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


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

Illustrative material

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

Example:

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Me</th>
<th>SD</th>
<th>Me</th>
<th>SD</th>
<th>d</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>A</td>
<td>21.5</td>
<td>3.2</td>
<td>22.0</td>
<td>1.5</td>
<td>–0.5</td>
<td>p=0.567</td>
</tr>
<tr>
<td>Body height [cm]</td>
<td>A</td>
<td>176.2</td>
<td>3.3</td>
<td>178.0</td>
<td>4.1</td>
<td>–1.8</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>A</td>
<td>68.3</td>
<td>2.7</td>
<td>79.4</td>
<td>3.5</td>
<td>–11.1</td>
<td>p=0.005</td>
</tr>
<tr>
<td>BMI [kg/m²]</td>
<td>A</td>
<td>22.3</td>
<td>2.2</td>
<td>25.7</td>
<td>2.8</td>
<td>–3.4</td>
<td>p=0.006</td>
</tr>
</tbody>
</table>

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

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

**Regulations for reviewing:**

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

  - [http://bbn.uksw.edu.pl/node/76](http://bbn.uksw.edu.pl/node/76)

**Appropriate Procedures of Reviewing in the Sciences:**

- **Veracity in Scientific Research and Respect for Intellectual Property:**

**Ethical Principles of a Scientific Researcher:**


**Regulations regarding eligibility for printing:**

- Articles not prepared in accordance with the requirements of the “Article publication requirements” will be returned to the author for improvement. The publisher reserves the right to remove linguistic defects or apply abbreviations.
- The publisher reserves the right to adjust or condense the text, make improvements related to terminology standardization.
- The publisher decides whether the article will be released for publication based on the reviewers’ opinions and the responses of the authors or lead author to the reviewers’ comments.
- After translated, proofread and edited, the article is sent to the author(s) for approval. The publisher sets a one-week deadline for submission of further modifications by the author.
- Before publication, the author responsible for correspondence with the publishing office will receive the article by e-mail (in PDF format), edited in accordance with the journal’s style template, to obtain consent for its publication. At this stage of publishing, only minor, final modifications may be made. Delay in re-submission/consent may cause the article to be moved to the next issue.

**Concluding remarks**

- **Publication of articles in Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES) is free of charge.**
- The author responsible for correspondence concerning the article receives a free PDF file with the issue of the quarterly journal, in which his/her paper is published.
- **Subscription** to issues of the journal published in book format can be ordered for a fee at: joanna.stepien@awf.krakow.pl.
- **Distribution and sales** of current and archival issues of “Antropomotoryka. Journal of Kinesiology and Exercise Science” can be found at:
  - Department of Academic Research and International Relations at the University of Physical Education in Address: al. Jana Pawła II 78, 31-571 Kraków, Tel./Fax: 48 12 683 1224; Tel.: +48 12 683 1278.
  - Krakow Physical Culture Bookshop. Address: al. Jana Pawła II 78, 31-571 Kraków, Tel./Fax: 48 12 681 36 22.
EDITOR-IN-CHIEF’S FOREWORD
Edward Mleczko
We begin the latest issue of Antropomotoryka with the “inverted u” hypothesis

SECTION — FUNDAMENTAL AND APPLIED KINESIOLOGY
Waclaw Petryński
A scientific evening with N.A. Bernstein, R.M. Yerkes, J.D. Dodson and D.O. Hebb
Vadzuk Stepan, Ulianutska Nataliia, Indyka Svitlana, Andriychuk Olga, Yakobson Olena
Peculiarities of Visual Functions and their Restoration in Teenagers with Emmetropic Refraction after Work on Computers

SECTION — SPORT SCIENCES
Robert Rokowski, Robert Staszkiewicz, Marcin Maciejczyk, Zbigniew Szymula, Michail Michailov,
Jadwiga Szymura, Magdalena Wiecek, Tomasz Regwelski
Body build, strength and endurance performance in elite sport and alpine climbers – a pilot study
Jacek Polechoński, Rajmund Tomik, Michał Rozpara, Mirosław Jurczak, Michał Tobor
Evaluating the Intensity of the 10-Minute Snatch Test During a Hardstyle Kettlebell Polish Championship

SECTION — EXERCISE SCIENCES
Henryk Duda, Mateusz Kaczor
Influence of transfer of creative information on the performance of football players
Tadeusz Ambroży, Katarzyna Sterkowicz-Przybycień, Stanisław Sterkowicz, Andrzej Kędra, Dawid Mucha,
Mariusz Ożimek, Dariusz Mucha
Differentiation of physical fitness in polish elite sports ju-jitsu athletes physical fitness in elite ju-jitsu athletes
Hanna Żukowska, Mirosława Szark-Eckardt
Changes in the level of fitness and physical development in children from first-grade swimming classed compared to peers

SECTION — VARIA
Bartłomiej Ptaszek, Aneta Teleglów, Jakub Marchewka
Impact of whole body cryotherapy on the blood plasma viscosity and fibrinogen concentration in women with rheumatoid arthritis
It should be said at the very beginning that the idea of introducing the curvilinear, U-shaped dependence between the strength of excitation and the quality of movement performance was initiated by our constant contributor – the one to continuously arrange for our journal to mention the scientific merits of people who, after years of oblivion, become duly recognized once again, often with the rights of being the precursors in a given topic, rights which had been wrongly attributed to others. Reading the guest-list of those invited to the discussion at the evening meeting, published by the author of the publication in the title A scientific evening with N.A. Bernstein, R.M. Yerkes, J.D. Dodson and D.O. Hebb, one can expect that its content will provide interesting information on the phenomenon of movement under the influence of a specific mental state. The identification of the names of potential interlocutors indicates that the following figures may be attributed with: being the discoverers of the phenomenon (R.M. Yearkes and Dodson), the inventor of the inverted U-model (D.O. Hebb), as well as the avant-garde in neurophysiological research in the field of motor control and motor learning, especially in the field of central nervous system motion control (Nikolay Aleksandrowicz Bernstein). The name of the author of the publication should be included in the list of outstanding scientists participating in the meeting. The fact that he is competent to participate in the debate on the inverted U may be proved by the content of his monograph Motor Control in Humans. A System-Theoretical Approach. Its contribution to the achievements of science was put very aptly in a laconic statement by the pre-eminent expert in the field of human motor functions, prof. T.D. Lee, in the passage of the review (cited in the preamble to the main part of the dissertation): “It pulls together a diverse literature via a systems approach, and connects many heretofore areas that previously existed in their own vacuums.”

As follows from the above introduction, this time the discussion is about to revolve around the matter of an interesting phenomenon discovered a long time ago. The concept of curvilinear dependence between the animal shock caused by electricity of different voltage and the speed of learning simple skills had interested researchers at the beginning of the last century. For the first time, such a phenomenon was described by Robert M. Yerkes and John D. Dodson in a publication published more than a century ago: Yerkes, R.M., Dodson, J.D.: The relation of strength of stimulus to rapidity of habit-formation. Journal of Comparative Neurology and Psychology, 1908; 18: 459-482. It contains the results of experiments carried out on mice. The applied procedure of conditioning the behaviour of an animal under the influence of electric shock gave the reason to find a curvilinear relation between its level and the speed of learning and the evident existence of an optimal level of stimulation, only for a difficult task. The studies of that time, for an easy task, showed the existence of a different, practically linear relationship. This concept of dependence was not yet assigned the shape of an inverted U. Connecting it with the so-called Yerkes-Dowson law is unjustified. The concept of a curvilinear, u-shaped dependence was introduced to psychology by Donald Olding Hebb (“the father of neuropsychology and neural networks”) half a century after the discovery of the dependence made by two scientists from Harvard Psychological Laboratory. He managed this by generalizing a series of tests carried out with various methods (not only on animals), the purpose of which was to verify the validity of the Yerkes-Dowson hypothesis [Diamond, D.M., Campbell, A.M., Park, C.R., Halonen, J., Zoladz, P.R.: The temporal dynamics model of emotional memory processing: a synthesis on the neurobiological basis of stress-induced amnesia, flashbulb and traumatic memories, and the Yerkes-Dowson law. Neural Plasticity, 2007]. According to the Canadian scientist, there were grounds to describe in the form of an “inverted U” the curvilinear relationship between physiological stimulation and the performance of both easy and difficult tasks. He published such a concept in his extremely popular book [Hebb, D.O.: The Organization of Behavior: A Neuropsychological Theory. Wiley and Sons, New York, 1949], which was also published in Poland [Hebb, D.O.: Podręcznik psychologii, 1973. Warsaw, PWN.]. The theory proposed by Hebb can be reduced to two basic statements:

- As physiological excitation (regulated by the reticular formation) increases, it becomes easier to perform a given activity, but only to a certain level. Later, there is only a decline in efficiency, leading to a complete disintegration of behaviour in an extreme situation.
- For difficult tasks, the optimal level of excitation is lower than for easy tasks.
The Yerkes and Dodson law concerning the U-shaped dependence so formulated by D.O. Hebb did not stand the test of time. Both in behavioural research and in particular in neurology, in cognitive, social and personality psychology, far-reaching supplements and modifications have been made. In some statements, it is sometimes believed that there is not enough evidence to confirm its existence [e.g. Teigen, K.H.: Ye- rkes-Dodson: A Law for all Seasons. Theory & Psychology, 1994; 4 (4): 525-547]. Other opinions are also numerous [Hancock, P.A., Ganey, H.C. N: From the Inverted-U to the Extended-U: The Evolution of a Theory of Psychology. Journal of Human Performance in Extreme Environments, 2003; 7 (1): 4-11] that suggest that the inverted U law is an "over-simplistic and fundamentally flawed proposition."


The article discusses precisely this classic curvilinear dependence. However, it does not run along the tracks designated by modern psychologists and computer scientists, or neurologists. It as if turns back the clock by several decades. For what purpose does the author of the article do that? Well, he comments on his mission in the field of science in the following way:

I feel like Foraminifera by E. Heron-Allen, which select only separate, in itself useless grains of sand – yet of specific parameters – to build a single, coherent, useful test around their unicellular organisms. It should be emphasized that in science there are plenty of separate scientific “grains of sand”, i.e., theories, effective only in a limited field of reality. The problem – probably the greatest challenge to the whole contemporary science – is not to produce new ones, but to rationally modify (if possible) the already existing concepts and to build a user’s friendly, internally coherent and efficient compilation, a peculiar “protecting test”, possibly extensive, around the scientifically ordered body of human knowledge.

In the on-going discussion on the viability and usefulness of the Yerkes-Dodson law (especially in competitive sport), the author of the publication tries to focus the attention on solving the following problems:

Author focuses his analyses on two factors determining the efficiency of a motor operation: the cognitive factor (depth of information processing) and temporal factor (speed of information processing). Stress, of multimodal nature, may either stimulate, or deteriorate the efficiency of a motor operation just being performed. One of the possible descriptions of the structure of a motor operation bases on the theory invented by N.A. Bern-stein (Brain Skyscraper - BS). Its continuation enabled creation of two other scientific models, the Modalities’ Ladder (ML) and the Movements’ Management Matrix (MMM). They make a specific perspective enabling joining the theories concerning stress-efficiency relation.

I am not going to comment on the author’s recapitulation, nor express my opinion on the results of the discussion. I leave this task to the readers who, I hope, will not limit themselves only to this issue’s opening article.

The next publication, Peculiarities in visual functions and their restoration in teenagers with emmetropic refrac- tion after work on computers and the method of its reduction by the Ukrainian researchers from the scientific centers of Tarnopol (State Medical University) and Luck (Lesya Ukrainka Eastern European National University) presents medical and rehabilitation aspects of sight of young people who use stationary and portable computers. Until recently, attention has been paid to the negative impact of viewing television programs and working on the computer by children and teenagers in the context of pedagogical problems or problems with achieving the objectives of physical education and pro-health lifestyle. The report of the interdisciplinary Ukrainian team contains interesting material from empirical research conducted on Ukrainian children and teenagers to determine the effects of long-term use of stationary and portable computers firstly on the manifestation of the computer vision syndrome (CVS), and secondly, of the application of an original programme of regenerative exercises entitled “Protecting and restoring eyesight” (the programme contains special exercises for eyes, upper limbs and neck with elements of breathing exercises) on emmen- tropy indicators.

The presented research results are confirmed by American observations, in which it was found that up to 90% of computer users experienced various types of ailments directly related to working on the computer for long periods of time [Thomson, W.D.: Eye problems and visual display terminals – the facts and the fallacies. Ophthalmic Physiol Opt 1998;18:111-119], and the risk of their occurrence increased especially in people who spent more than 4 hours a day looking at the monitor screen [Rossignol A.M., Morse E.P., Summers V.M.,

The proven, positive impact of the original recovery programme, although difficult to explain based on known biological and physiological patterns, should be implemented in practice. The value of the application results of the experiment is confirmed by the results of the study by Dain et al. [Dain S.J., McCarthy A.K., Chan-Ling T.: Symptoms in VDU operators. Am J Optom Physiol Opt 1988; 65:162-167], in which it was clearly shown that optimization and ergonomics of the workplace as well as frequent breaks significantly reduce the occurrence of CVS (63.4% vs. 25.2%). In addition, the National Institute of Occupational Safety and Health found that frequent short breaks significantly reduce CVS discomfort compared to the now historical two 15-minute breaks - breakfast and afternoon breaks [Sellers, D.: 25 Steps to Safe Computing. Peachpit Press, Berkeley, CA 1995].

It seems that the results of the experiment with suggesting a programme of regenerative exercises under the name “Protecting and restoring eyesight” encourage proposing the use of similar relaxation and regeneration methods to people working on computers, as well as to athletes practicing sports competitions in which the eye remains under stress for a long time, such as: computer games, chess, shooting, bridge. The validity of this hypothesis can be proved by the experience of trainers from Krakow who successfully use the functional condition training (awarded with the Minister of Sports’s prize) with the young Polish chess grandmasters and champions.

In the “Sport Sciences” section there are two works: Body build, strength and endurance performance in elite sport and alpine climbers - a pilot study and Evaluating the Intensity of the 10-Minute Snatch Test during a Hard-style Kettlebell Polish Championship which present the results of research which can be used to develop a model of a champion in the following competitions: rock and mountain climbing, and a competition little-known in Poland called kettlebell (KB). Currently, kettlebell is included in the sport competition which consists in raising ball weights with a handle that resemble cannonballs, in a given time, in accordance with sport regulations. They are called kettlebells in English, and giria in Russian. Although lifting kettlebell (giria) has a long history (especially in Russia), it is only from the 1960s that it develops as a standard sport called kettlebell lifting (or giriewoj sport). On the other hand, mountain climbing in the form of sport has had the status of an Olympic competition only since 2016. It has been included in the Olympic programme of the Tokyo Olympiad, which will take place in 2020. The competition will be organized in the so-called combined formula, which means that competitors must compete in each of the three previously separate disciplines: speed climbing, lead climbing and bouldering. In addition to this Olympic competition, amateur climbing is also practiced in various mountaineering, rock climbing and cave climbing competitions.

Since it has not been long that the disciplines mentioned above have had an official status, the specificity of practicing them and the conditioning of sports results in both of them have not been the subject of broader scientific research. Both articles contain exceptionally valuable material derived from physiological, biomechanical, anthropometric and fitness tests of people who practice kettlebell lifting, as well as rock climbing and high-mountain climbing in Poland. Undoubtedly, they should be considered an important contribution to the newly created sports championship model in both mentioned sports.

In the “Exercise Sciences” section one can find three works that have tackled the following problems:

- modernizing the teaching of football by introducing to the training of young footballers a “creative method with a didactic creative instruction, based on a conscious analysis of the action” [Influence of transfer of creative information on the performance of football players],
- the scientific basis for shaping and evaluating the physical fitness of Polish athletes practicing ju-jitsu on the master level [Differentiation of physical fitness in Polish elite sports ju-jitsu athletes physical fitness in elite ju-jitsu athletes] and swimming in a sports school [Changes in the level of fitness and physical development in children from first-grade swimming classed compared to peers].

The presentation of the articles published in the 79th issue of Antropomotoryka ends with a brief description of the publication Impact of the whole body on the blood plasma viscosity and fibrinogen concentration in women with rheumatoid arthritis found in the “Varia” section. The article addresses the problem of the effectiveness of using cryotherapy in the treatment of rheumatoid arthritis (RA) disease. As we know, the condition concerns mainly small and medium joints. As the name suggests, it is an inflammatory disease of the connective tissue. In the course of its chronic course, destruction, contractures, deformation and impaired function of affected
joints occur. It most often leads to premature and progressive disability. In 90% of cases the erythrocyte sedimentation rate, called Biernacki reaction, is increased. In addition, about 80% of patients have so-called “anaemia of chronic disease” (the presence of microcytes - blood cells of abnormally small size, with a haemoglobin concentration usually greater than 9g / dl). Another common abnormality observed in the blood test is the elevated concentration of the coagulation factor – fibrinogen – in blood plasma [Lawrence, J.S.: Rheumatism in populations. London: Heinemann; 1997]. The medical organization of doctors, health professionals and scientists (American College of Rheumatology) lists the following additional diagnostic criteria that complement the study of the rheumatoid factor: joint erosion confirmed by X-ray, symmetrical arthritis, morning stiffness lasting at least one hour, arthritis of the hands, inflammation affecting three or more joints, and the presence of rheumatoid nodules.

Based on current knowledge, it should be assumed that there is no cure for rheumatoid arthritis [Zimmermann-Gór ska, I.: Choroby reumatyczne. Podręcznik dla studentów medycyny. PZW L, Warsaw 1993]. The basic treatment consists of administering various ineffective medicines, such as: acetylsalicylic acid and non-steroidal anti-inflammatory drugs (NSAIDs). In addition to all available methods of pharmacological treatment, the use of rehabilitation treatments is also recommended. One of the methods is cryotherapy – either systemic or local. As with any type of treatment, systemic cryotherapy has its advantages and disadvantages. The available literature informs us that 20% of patients were forced to cancel their treatments due to unwanted side effects. In the case of local cryotherapy, there is no systemic action and adverse reactions are minimized.

The experiment described in the article entitled Impact of whole body cryotherapy on the blood plasma viscosity and fibrinogen concentration in women with rheumatoid arthritis concerned the evaluation of the effectiveness of treatment of women with rheumatoid arthritis after cryotherapy on the basis of the variability of coagulation factor – fibrinogen – in blood plasma, one of the primary markers of the disease [Rośniak-Bą k, K., Łobos, M.: “Przydatność kliniczna i diagnostyczna oznaczeń D-dimeru w różnych stanach chorobowych.” Folia Medica Lodzienia, 2016; 43 (1): 69-91]. It seems that even though the conducted experiment did not result in any statistically significant differences in the level of the disease marker either before or after the treatments, no far-reaching conclusions should be drawn from this observation. The results of other studies that used cryotherapy for the treatment of rheumatoid arthritis [e.g. Atarowska, M., Sobieska, M., Samborski, W., Oczechowska, S., Michałowska, A., Wiktorowicz, K., Ponikowska, I.: The influence of total body cryotherapy on acute phase protein level in patients with rheumatoid arthritis (Wpływ kierapii ogólnoustrojowej na stężenie białek ostrej fazy u chorych z reumatoidalnym zapaleniem stawów). Borgis – Medycyna Rodzinna 2004; 3: 127-130] may be an incentive to undertake further such experiments.

I presume that the longer than usual editorial may be an incentive for a thorough reading of the 79th issue of Antropomotoryka, and, at the same time, for ordering the next issue, already in the process of preparation for print. Dear readers, I would like to wish myself and the whole staff that such a hypothesis turn out to be valid, and want to express my deepest respect.

Edward Mleczko
Editor-in-Chief
Abstract

Author compares various models of relation between stress and efficiency of a motor operation, described with the Inverted-U Principle (IUP), Multidimensional Theory of Anxiety (MTA) and Catastrophe Model of Anxiety (CMA). He presents the “classical” theory, invented by R.M. Yerkes and J.D. Dodson in 1908, and modified significantly by D.O. Hebb in 1955. The latter is commonly known as the Inverted-U Principle (IUP).

Author focuses his analyses on two factors determining the efficiency of a motor operation: cognitive factor (depth of information processing) and temporal factor (speed of information processing). Stress, of multimodal nature, may either stimulate, or deteriorate the efficiency of a motor operation just being performed.

One of the possible descriptions of the structure of a motor operation bases on the theory invented by N.A. Bernstein (Brain Skyscraper – BS). Its continuation enabled creation of two other scientific models, the Modalities’ Ladder (ML) and the Movements’ Management Matrix (MMM). They make a specific perspective enabling joining the theories concerning stress-efficiency relation. This perspective unveils two mechanisms of efficiency deterioration: hypervigilance and hypovigilance, and, consequently, their different products: mistake, proper execution, choking and collapse.

Finally, author remarks that the already long known theories may still include great resources of scientific explainability, and that the main task of science is not absolutely true mirroring of reality, but creation of its simplified models. They should be comprehensible enough to be useful in practice. This concerns also the issues of rather complex relation between stress and efficiency in a motor operation.

Introduction

In opinion about my book „Motor Control in Humans. A System-Theoretical Approach” [1], Professor T.D. Lee, wrote: „It pulls together a diverse literature via a systems approach, and connects many heretofore areas that previously existed in their own vacuums.” In fact, all the papers from the cycle „A scientific evening…” [2, 3, 4, 5, 6] follow just this way of thinking. To some extent, I feel like Foraminifera by E. Heron-Allen, which select only separate, in itself useless grains of sand – yet of specific parameters – to build a single, coherent, useful test around their unicellular organisms [7]. It should be emphasized that in science there are plenty of separate scientific “grains of sand”, i.e., theories, effective only in a limited field of reality. The problem – probably the greatest challenge to the whole contemporary science – is not to produce new ones, but to rationally modify (if
possible) the already existing concepts and to build a user’s friendly, internally coherent and efficient compilation, a peculiar “protecting test”, possibly extensive, around the scientifically ordered body of human knowledge.

In this respect, science comes across a specific menace. Each theory is a simplification and may be useful only in a limited area of reality [5]. If a scientist discovers a phenomenon or process not coherent with the existing theory, s/he often triumphantly heralded this theory as being “irrelevant” and “outdated”. However, sometimes a small modification – “cheap” in intellectual terms – may make it useful again, not rarely in much broader region of reality. Unfortunately, on scientific vanity fair refuting the “outdated” theory and inventing a new one – not necessary better, yet usually by far more complicated – enables signing it with his/her name, whereas modification of the already existing one is by far less praiseworthy.

In fact, in science we have to do with the situation similar to that of Foraminifera. There exist already many theories, hypotheses, and conjectures, which exist “in their own vacuums.” Therefore, the main problem is not to invent new ones, but to bridge the gaps between the already existing mental representations of external world and to build a simple, coherent, rational structure encompassing great body of knowledge, corresponding to possibly extensive portion of reality. Apart from other things, the latter methodology seems to be much “cheaper” and promising – in mental and economic terms – than the former. Therefore, let us try to bridge the gaps between the Inverted-U Principle (IUP) by R.M. Yerkes and J.D. Dodson [8], Multidimensional Theory of Anxiety (MTA) by R. Martens, R. Vealey and D. Burton [9], and the Catastrophe Model of Anxiety (CMA) by J. Hardy and L. Fazey [10]. As a specific “common denominator” for them, let us take the concepts by N.A. Bernstein [11, 12, 13].

The Inverted-U Principle

It is worth noting that the original finding by R.M. Yerkes and J.D. Dodson of 1908 [8] has been creatively modified in 1955 by D.O. Hebb [14]. Just this version, termed “Inverted-U Principle” (IUP), is commonly known in science. It is often criticized as being outdated [15, 16, 17]; nevertheless, its simplicity makes it still popular and useful.

The Hebbian version of IUP is shown in Fig. 1. Additionally, in this figure has been shown the phenomenon of attention narrowing (with bold solid line), as by D. Kahneman [18].

While analysing changes in quality of a performance along with stress increasing, one may learn that at first the quality increases. This is shown with the left, constructive “stimulation leg” in Fig. 1. However, while overcoming the optimal level, the quality decreases along with stress increasing. This is shown with the right, destructive “anxiety leg” in Fig. 1.

In the various commonly acknowledged versions of IUP the vertical axis does not evoke any doubts. It shows the efficiency of a performance, i.e., a “unidi-

![Figure 1. Stress-efficiency relation, the Inverted-U Principle [14]. The left „stimulation leg” has been marked with dotted line, the right „anxiety leg” – with broken line, and the attention narrowing as by Kahneman [18] – with bold solid line.](image-url)
Motor performance from the Movements’ Management Matrix perspective

Each mental operation may manifest itself only with a motor action. Philosopher A. Wohl maintained, “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” [19]. Hence, the psychological processes may be traced only by observation of motor behaviour and artefacts resulting from it.

In the model of MMM, a motor operation entails the chain of the following, consecutive processes (in parentheses field of science and technological analogy):

1. Sensitivity – sensory organs (physiology, “sensor”);
2. Perception – mind (psychology, “transducer”);
3. Attention – mind (psychology, “preliminary filter”);
4. Motivation – mind (psychology, “on-off switch and preliminary amplifier”);
5. Intellect – mind; instinct, intuition, intelligence (psychology, “processor”);
6. Foresight – mind (psychology, “final filter”);
7. Decision – mind (psychology, “on-off switch and final amplifier”);
8. Skills – mind (psychology, “controller”);
9. Efferent copies – mind (psychology, “recorder”);
10. Action – muscles (physiology, “actuator”) [1].

The connection between physiological sensitivity and psychological perception may be well illustrated with the statement of I.N. Stewart: “The main problem is that the brain doesn’t just passively take a photograph of what is out there; it provides automatic understanding of what eye is seeing” [20].

This needs a small comment. A “photograph” may be assigned to physiological brain, but “understanding” – to psychological mind. However, in this quotation the word “automatic” means that the processes of “seeing” and “understanding”, are inseparably connected with each other. In fact, both they make a single, coherent, physiologically-psychological process.

Such a chain of events may take place at five levels of information processing, with the following modalities (in parentheses types of motor operations and mechanisms of movements’ management corresponding to them):

A – proprioceptive (reflex, “feeling-in-hand”);
B – contactceptive (automatism, technique);
C – teleceptive (habit, tactics);
D – verbal (performance, strategy);
E – symbolic (no specific motor operation, politics) [1].

The idea of such an arrangement of the modalities has been borrowed from N.A. Bernstein [11, 12, 13]. The hierarchy of the “floors” of the central nervous system, along with information processing potentialities specific to each of them, he termed “Brain Skyscraper” (BS) [12, 13]. However, while distilling from the whole extensive body of the BS merely the issues of information processing, one may build the mental structure termed Modalities’ Ladder (ML). It is firmly rooted in the original Bernstein’s concept, indeed, but, for the sake of simplicity, it ignores evolutionary and neurophysiological factors and focuses only on modalities of information processing [1]. Accordingly, the particular “rungs” of ML are tightly connected with respective “floors” of BS, though not identical with them.

The events succession and the ML are coherent (yet not homogenous) systems, and not merely sums of separate components. While assuming that the presented chain of events may take place at each “rung” of the ML – providing for information processing potentialities of a given “rung” – then it may make a basis for construction of the Movements’ Management Matrix (MMM). The chain of successive events may be arranged horizontally, and the consecutive modalities, i.e., the ML – vertically. The MMM has been described in detail in [1].

The lower level, the simpler information processing potentialities. Hence, at A-level the links from “Perception” through “Action” are practically reduced to “Cheshire Cat’s grin” [21], so at that level one observes nearly direct stimulus-action coupling. As a result, the motor operation seems like a physical reaction rather, and not a psychologically-physiological motor response. In short, the higher level, the more profound, more sophisticated – and, consequently, more time consuming – information processing.

In the context of IUP, in the motor operation events’ chain especially significant seem to be attention and motivation. The former includes evaluation of information at all the levels of ML with emotions: arousal at A-level, excitement at B-level, impression at C-level, affect at D-level, and attitude at E-level [1]. Therefore, in the MMM model emotions are in fact a “condensed rational experience” of both evolutionary and individual’s origin. Their main advantage is the speed, but the necessary price, which has to be paid for this, is the precision. However, because the assessment of the same event may differ at various ML levels, the next link – motivation – is necessary. It reduces the evaluations from all levels to a “common denominator” and makes an “on-off switch”. Additionally, it works as a “preliminary amplifier” which determines the persistence of further processes and – indirectly – their efficiency [1].
The common product of attention and motivation may be termed “stress”. In short, just the motivation’s “preliminary amplifier” – inseparably connected with the attention and its main “working tool”, i.e., the emotions – defines the level of stress as presented in Fig. 1.

While looking at Fig. 1, one might discern two “faces” of stress. Its “left leg”, from low to optimal level is – generally – of constructive nature, i.e., efficiency rises along with stress increasing; this may be termed “stimulation”. On the other hand, the “right leg”, from optimum to high level, is of destructive nature, i.e., efficiency decreases along with stress increasing; this may be termed “anxiety.”

The Inverted-U Principle and the Movements’ Management Matrix

While looking at Fig. 1, one may learn that it shows the interplay of purely psychological factors. No matter, whether the resulting motor operation is of poor or high quality, the working organs (“actuators”) are the same. The difference is in the head, and not in the muscles.

In their book „Figments of Reality”, mathematician I. Stewart and biologist J. Cohen argued:

Mind is not immaterial transcendence: it is the response of an evolving brain to the need to survive in a complex environment. And with evolution of culture, that environment has become self-modifying and self-referential, and human mind done the same [22].

The same general idea of tight connection between physiological brain and psychological mind, highly “Darwinist” in its core, underlain the theory by N.A. Bernstein [11, 12, 13]. Unfortunately, because of language barrier, his achievements are not widely known in detail in the English-speaking world (though the latter heading was published in English). Nevertheless, Bernstein became “fashionable” and has been commonly acknowledged as a classic, though his ideas are not fully understood by now; this seems to be the worst possible fate for a scientist.

Bernstein’s concept of five-level movements’ construction system (BS) was founded on the assumption that in the course of evolution there were some „leaps” in information processing potentialities in living creatures. The „evolving brain” was forced to develop new potentialities – and modalities of information processing – along with increase of quality of newly developed sense organs. At both highest levels – D and E one – information processing has been released from direct connection with the sensory stimuli, hence the mind became “self-modifying and self-referential.” Basing on neurophysiological data, Bernstein distinguished five levels of the BS [12, 13]. This concept underlies also the structure of its “younger sister”, the ML [1].

General idea – in fact, of systemic nature – was that when an information processing modality at a given level reaches its „high end”, the only possibility to exceed such a threshold is to produce a new, more sophisticated – and, at the same time, more general – modality. In short, when the extensive, quantitative expansion reaches its limit, the intensive, qualitative transformation becomes necessary. This makes the difference between the bare development and the fruitful progress. Such a phenomenon might be traced in the evolutionary enhancement of the BS [12, 13] and, consequently, of both the ML and MMM [1].

Accordingly, it seems obvious that the more sophisticated information processing is needed, the higher “rung” of the ML has to be engaged. Therefore, the higher region of the inverted-U efficiency (Fig. 1), the higher “rung” of the ML.

While taking such an assumption, it is possible to build a model, which “melts together” the IUP and the ML. This might be presented as in Fig. 2.

The diagram coordinates are “Stress” and “Efficiency of a motor operation”. At the “left end” of the Fig. 2, the stress, induced by motivation, is too low to evoke any action (“I don’t like”). On the other hand, at the “right end” too high stress makes such a motor operation – even a simple reflex – infeasible (“I can’t!”); this phenomenon may be identified with the “stupor.” In both these cases, a motor operation will not be executed because of psychological reasons.

Accordingly, the most interesting processes take place between both these extremes. Each of the ML “rungs” has its “own” motor operation, which it performs best, better – sometimes much better – than the other ones, no matter, lower or higher. Accordingly, the simpler such an operation, the lower ML “rung” has to be engaged. The result is that the simpler operation, the less complicated information processing modality, and the more extensive stress range, where its efficient accomplishment is possible (Fig. 2).

It is worth noting that the lower levels – A, B, and C – have their “own” sensory organs (proprioceptive, contactceptive, and teleceptive, respectively). On the other hand, the higher ones, D and E, are not directly joined with any sense organs. Consequently, their connections with any current environmental stimuli – if any – may be only indirect. This results with a crucial potentiality, which dramatically transforms the information processing at those levels: their “time axis” – unlike at lower ones – may be extended far into past and future (theoretically – into eternity), what makes a basis for long-reaching anticipation.

For the sake of simplicity, let us term the A, B and C levels “sensory levels”, and the D and E ones – “mental levels”. In fact, it is not a dichotomic division, because
Figure 2. The Inverted-U Principle and the Modalities’ Ladder. It is should be reminded that the E-level does not control any real operation [11, 12, 13].

Figure 3. The Multidimensional Theory of Anxiety, the Inverted-U Principle and the Modalities’ Ladder.
also “sensory levels” need mental activities, whereas activation of “mental levels” may be evoked either by current sensory experiences, i.e., stimuli, or by purely mental anticipation (“self-reference”).

**The Inverted-U Principle and the Multimodal Theory of Anxiety**

According to Multidimensional Theory of Anxiety (MTA) by R. Martens, R. Vealey and D. Burton [9], the phenomenon of anxiety may be divided into two sub-categories: somatic and cognitive one. In such a division, the old, Cartesian partition into “res extensa” and “res cogitans” is clearly visible; one might state – *nihil sub Sole novum*. However, joining the original MTA with the ML, firmly rooted in the Bernstein’s BS, enables much more detailed analysis.

The “sensory levels” are directly joined with the current extrinsic stimuli, which act “here and now”. They may be associated with the somatic anxiety. For example, if somebody sees (C-level) a great puddle to be jumped over, s/he feels a somatic anxiety, even without expressing it with the D-level verbal code. On the other hand, if somebody imagines a difficult exam while sitting in comfortable conditions – warm, cozy room, with a cup of coffee in hand, and listening to Bach’s music – where there is no any direct endangerment, s/he may feel anxiety of purely cognitive nature, resulting from anticipation. Both the “somatic anxiety” and “cognitive anxiety”, while seen from the ML perspective, may be presented as in Fig. 3.

Let us remember that according to MMM model, the chain of events underlying a motor operation may take place at each “rung” of the ML. Accordingly, the somatic anxiety (and somatic stimulation as well) may be of proprioceptive (A-level), contactceptive (B-level), or teleceptive (C-level) nature. Each of these “rungs” disposes of its own, specific potentialities, which determine both the depth and speed of information processing.

The cognitive anxiety may result from either “common reason” (D-level), or “fantastic imagination” (E-level). The former may be associated with fear, concerning specific, clearly defined threat, whereas the latter – with apprehension about indeterminate, vague danger.

**Inverted-U Principle and the Catastrophe Model of Anxiety**

The Catastrophe Model of Anxiety (CMA) by J. Hardy and L. Fazey [10] differs significantly from both original IUP (Fig. 1) and MTA (Fig. 3). Two latter deal with the analysis of the phenomenon of stress (or even anxiety) as such, whereas the former describes it in the context of a specific motor task just being performed. A closer examination of the issues under consideration needs redefinition of the vertical axis of the diagram shown in Fig. 1. It shall symbolize no longer a unidimensional, ephemeral efficiency, with upper end “well”, and lower end “poor”. In fact, the two main factors determining the efficacy and efficiency of a motor performance, are depth and speed of information processing. Only their proper combination – and the certain place on vertical axis, corresponding to it – may be termed “well.”

In this respect, one has to do with a specific trade-off: the more depth, the less speed, and vice versa. This unveils another face of the “constructiveness” of IUP’s “stimulation leg”. The problem is not to achieve the more sophisticated – and, unavoidably, more time consuming – information processing, but the optimal combination of its depth and speed (Fig. 4).

In 1983, I. Janis, P. Defares and P. Grossman discovered a phenomenon, which they termed “hypervigilance” [25-27]. R. Schmidt described it as a raised level of stress that produces ineffective decisions and, consequently, is harmful to the operation just being performed. While joining this with the IUP, it is possible to create a diagram like in Fig. 4.

The “two-dimensionality” of the vertical axis of the diagram needs a closer definition of the inverted-U curve. In such a model, it should be regarded as a representation of possible intensity of a product of both attention and motivation. The word “possible” means that along with stress increasing the attention may “climb up” the inverted-U curve, towards the region of hypervigilance. In short, in the presented model the “hypervigilance space” encompasses the whole field under the inverted-U curve, and not only the line that marks its upper limit. Moreover, such a “climbing up” is being driven by emotions, which may be “harnessed” by reason and/or skilfulness of an individual who performs a given operation. Consequently, despite of stress level, the efficiency may well remain on the optimal level.

Too cautious thinking – unnecessary “climbing up” the inverted-U curve – may cause the hypervigilance and thus be harmful for a motor operation. This may be exemplified by the following statement of outstanding ski jumper A. Małysz. In 2007, his results in Kuusamo were astonishingly poor. While analysing them, he stated: *I have to switch-off thinking* [23]. The mechanism of “chooking under pressure” R. Schmidt and C. Wrisberg described as follows:

For skilled athletes, automatic processing usually produces their best performance. However, in high-pressure situations these athletes are sometimes guilty of “thinking too much” and trying to control their movements in conscious fashion (i.e., using controlled processing) [24].
Therefore, while seen from the BS and ML perspective, hypervigilance "switches off" the patterns of sub-operati-ons residing in the region of "background" of the BS, i.e., those working efficiently without attention focusing. Accordingly, the individual who performs a given motor operation has to direct his/her precious attention towards those sub-operations, which in fact are able to work without attention engagement.

On the other hand, as a popular adage has it, "haste makes waste." Therefore, while paraphrasing the poem by J.W. Riley, "only the best combination of speed and depth of information processing is good enough."

While analysing Fig. 4, one may learn that overcoming the hypervigilance stress level on "stimulation leg" may increase the depth of information, indeed, but at the same time it slows down the execution of the motor operation and thus may ruin not only its efficiency, but also its efficacy. As a result, "simpler modality" does not mean "poorer modality." Symptomatically, collapse makes the final part of the stress-efficiency relation, hence there is no "aftercollapse" part of the bell-like inverted-U curve.

In this respect, one might create a hypothesis analogous to A. Jost's law [28], which might be termed "back to the roots." In the initial, cognitive phase of the process of motor operation pattern creation (according to P. Fitts) first comes a E-level general concept, then specific D-level plan, C-level movement's image, B-level muscle synergies' set and A-level particular muscle contractions' sequence [1]. One might imagine that in the case of serious difficulties in a motor operation execution, an individual turns back to the older, more primeval (and higher) modality of information processing. In terms of motor control, it means that s/he analyses probably his operation at too high -- and, consequently, too "clumsy" -- "rung" of ML, may be at verbal D-level, though the optimum one is the C- or even B-level. Moreover, s/he tries to discover a new task solution, and no to use the already known one.

The B-level information processing might be identified with what is sometimes -- rather oddly -- termed "muscle memory" [29]. The ML philosophy enables elimination of this notion. The only task of muscles is to produce strength and speed, whereas memory is a system aimed at information processing located in mind. The lowest levels of this system use the proprioceptive and contact-ceptive modality, what might be identified with the notion of a "muscle memory." Therefore, the latter is no longer a separate phenomenon, but an inherent component of a system. In the MMM model, it may be identified with the "feeling-in-hand" and technique. As a result, the weird term "muscle memory" becomes superfluous.
Slightly differently may work a mechanism of performance deterioration on the right, “anxiety leg” (Fig. 4). When the stress level exceeds the panic threshold, then ability to perform a just being executed motor operation deteriorates dramatically and immediately. Such a phenomenon might be termed “collapse” and – roughly – associated with psychological stupor.

As already mentioned, the excessive hypervigilance may be “harnessed” by reason. Thus, the attribute termed in common language “poise” or “calmness” enables efficient execution of a given motor operation even in the region of possible hypervigilance. A brilliant example of such calmness was the landing of the “Airbus A320” on Hudson River on 15th January 2009, performed by Captain C. “Sully” Sullenberger and first officer J. Skiles [30]. While compared with Fig. 4, one might locate the stress level somewhere near the collapse threshold, and not of choking threshold. The great merit of both pilots was that they were able to suppress the hypervigilance and not to enter the region of panic. Chapeaux bas!

By the way: The motor operation failure because of too high stress may be identified with the “catastrophe”, as by Fazey and Hardy. However, I propose to use the word “collapse” instead of it. The term “catastrophe” is fashionable, indeed, because it is rooted in mathematical theory of catastrophes by R. Thom. Consequently, here one may feel a charming and fascinating smell of the “Queen of Sciences”, allegedly “omnipotent”. Nevertheless, in fact, mathematics is a discipline like any other one and its scope of applicability is limited. As it A. Einstein remarked, “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” [31]. In this respect the statements of other scientists, who well know mathematics and its limitations, sound highly instructively. Mathematician and physicist J. von Neumann stated that “In mathematics you don’t understand things; you just get used to them.” As it mathematician R. Penrose remarked, mathematics is “interested” only in relations between items which it describes, but not in their nature or even “personalities” [32]. Consequently, mathematics works very well in physics; physical bodies do not have their own “personalities” and simply obey the physical laws. However, in biology and, all the more, in psychology (and motor control as well), such “personalities” are active and strongly influence both the relations between the items being analysed, and the effects of the processes in which they participate. Therefore, in motor control the pure and quite stiff relations of mathematical nature, without taking into account the “personalities” of the items being described, are by far less useful (if any) than in physics. In this context, downright ominously sounds the apparently joking statement by economist R. Heilbroner, who remarked: “Mathematics has given economics rigor, but alas, also mortis”. This may – even more – pertain to psychology and motor control. In those areas of science the systems theory – deprived of mathematical formalism, but not of mathematical-like discipline of thinking – seems to be much more promising, whereas mathematics – simply perilous, however paradoxically it may sound. Mathematical formalism causes a specific “petrification” of the mental structures, which it describes. Therefore, it fixes also those “degrees of freedom” which in psychology and motor control have to remain flexible. In short, using mathematics in motor control is like employing a screwdriver when a computer is necessary.

While looking attentively at Fig. 4, one may discover another problem. If to right of the “optimal efficiency stress level” lies the field of hypervigilance, then – analogously – the region to the left of this line should be termed “hypovigilance”. Why it is not so harmful to the just being performed motor operation as the hypervigilance?

The answer may be found in Bernstein’s theory. In any motor operation only the main level (“master”) needs attention focusing, whereas lower ones (“slaves”) work “in the background”, i.e., without attention engagement. Symptomatically, the background should not be identified with “sub-consciousness”. The latter term not without reason I wrote in inverted commas; in this case I would like to mark my distance and scepticism towards this notion. The background may be regarded not as a mysterious and undefined, sub-conscious “mental hole”, more or less “black”, deprived of a clear organisation, but as a resource of many previously developed mental patterns of sub-operations, which may be executed automatically.

By the way: For coining the term “sub-consciousness” often S. Freud is being credited. Nonetheless, he himself wrote:

I should also like to hear you admit that our designations – unconscious, fore-conscious, and conscious are much less likely to arouse prejudice, and are easier to justify than others that have been used or suggested – such as sub-conscious, inter-conscious, between-conscious etc. [33].

Nonetheless, as a popular adage has it, nothing is as simple as it seems at first glance. Sometimes, while driving back home and having something to do in the city, a driver goes “automatically” along the “usual” way, and not along the planned route. However, s/he controls the course of driving in a skilled manner. Why?

Something like that happens when a given motor operation is being controlled from the level lower than necessary. In the described situation, the driving should have been controlled with the D-level motor program.
and not with a set of C-level motor scenarios – a series of images, fixed in memory – which may be located somewhere on the border between C- and D-level. Such a phenomenon may be termed “mistake”. It should be emphasized that the lower levels work faster (sometimes much faster) than the higher ones, therefore the mechanism of a mistake – as described in this paper – makes a rationale for the popular adage “haste makes waste.” This may happen when the background motor operation patterns are “educated” enough to be able to work effectively neither with attention focusing, nor control of a main level.

By the way. Such a phenomenon may be observed also in animals. Old, good, experienced horse is able to bring a cart home with sleeping or drunken carter on it.

To sum up, while examining the Fig. 4, one may learn that to the left of the choking threshold lies “zone of mistake”. Between choking and collapse thresholds – zone of proper execution of a given motor operation, provided that the performer is able to avoid (or to suppress) the hypervigilance. Finally, to the right of collapse threshold – panic and complete blockade of a motor operation.

Accordingly, it is possible to discern three main kinds of motor malfunctions: mistake, resulting from hypovigilance; choking, resulting from hypervigilance; and collapse, resulting from panic.

While seen from the perspective of attention, the whole field under the inverted-U curve may be divided into five vertical zones (Fig. 5): sleeping attention, dozing attention, optimal attention, raised attention and overstimulated attention. The situation of “attentionless” driving along the way “as usual” may be located somewhere on the border between sleeping and dozing attention zones.

It is obvious that the shape and dimensions of the inverted-U curve depend on individual’s psyche, whereas the relative positions of particular attention zones – on both curve shape and task specificity.

Incidentally, transition from overstimulated to sleeping attention is a normal process aimed at lowering the mental costs of a given motor operation, and especially at saving the precious and limited resources of attention. The situation, when in the process of perfecting an operation the attention reaches the state of dozing, or even sleeping, is in daily language termed “routine.” Such a situation occurs when a given sub-operation reaches the level of automation enabling it to work as a “background.” This lowers the mental costs of performing a given motor operation, indeed, but at the same time makes it resistive to any changes, including learning.

The analysis of information processing organisation in humans, while seen from the MMM perspective, may lead to another, apparently paradoxical hypothesis. If the whole MMM makes a coherent, yet not uniform, system, then the general laws may manifest themselves not only in processes entailing easily observable, motor operations, but also in purely mental activities. As it mathematician H. Minkowski – A. Einstein’s teacher of mathematics – stated, Einstein’s knowledge of mathematics was not perfect [5]. Hence, one might assume that just this “shortcoming” prevented the greatest genius in physics in 20th century from mental hypervigilance. Accordingly, he was able to direct his precious attention only towards

![Figure 5. States of attention in relation to stress level](image-url)
most significant and relevant mathematical constructs underlying his theories, and not to “scan” vast regions of mathematics useless for his considerations. Such a phenomenon A. Clark termed “007 Principle” (“Know only as much as you need to know to get the job done”) [34]. This is consistent with much older sentence by philosopher and psychologist W. James “the essence of genius is to know what to overlook.” Therefore, in science the problem is not to know more than other scientists do, but to possess the right knowledge, applicable to the problem just being considered. In addition, at the right time.

On the other hand, in daily life the “attention dissipation” – resulted from the phenomenon of a “mental hypervigilance”, and evoking a “sensory hypovigilance” – makes the greatest danger during phone talking while driving, no matter, with a hand-free phone or not.

To sum up, the old – yet by far not obsolete – Inverted-U Principle may contain still much greater load of scientific “explainability” than it may seem at first glance.

Conclusion

Writer and futurist A. Toffler stated – very aptly – that:

One of the most highly developed skills in contemporary Western civilization is dissection: the split-up of problems into their smallest possible components. We are good at it. So good, we often forget to put the pieces back together again [35].

In fact, such a methodology is highly dangerous to science. If one dismounts a system, then its most precious product – the qualitatively new, unpredictable system effect [36] – is being killed. From the separate piles of chemical elements, which together make a biological cell, one cannot learn how and why the cell lives.

Therefore, the presented paper goes in precisely opposite direction then that described by Toffler. It is aimed at finding a “common denominator” for three theories concerning the relation between stress and motor performance efficiency (IUP, MTA, and CMA), and including it into one coherent system. It seems that the following conclusions may be driven from the presented analyses.

1. The Bernstein’s perspective may facilitate joining the various concepts (IUP, MTA, and CMA) and thus make the general understanding of the phenomenon of anxiety (and stimulation as well) simpler, yet precise enough for practical purposes.

2. The already existing theories, often regarded (openly or tacitly) as being outdated, may include great reserves of scientific “explainability”. Hence, for a scientist it often pays off to go back to the roots instead of searching for new concepts, though the latter is no doubt by far more “fashionable.” This concerns the IUP, MTA, and CMA. All they may be harmoniously joined with BS, ML and MMM.

3. The Bernstein’s theory, though invented in 1947 – hence, already 70 years old – still includes high resources of such “explainability”. As each and every theory, it cannot be universal, indeed. However, before we put it in the scientific discard pile, there is yet much to be “squeezed” from it. In this respect, important is that because of language barrier the ideas by Bernstein (most of them have been published only in Russian) are not as commonly and profoundly known in scientific society, as they deserve it.

And, finally, the important “take-home-message”. According to Nobel laureate, physicist N. Bohr, “it is wrong to think that the task of physics is to find out how Nature is; physics concerns what we say about Nature.” Consequently, even in physics – which deals with matter much simpler than that of biology, psychology and motor control – it is necessary to build simplified representations of reality, i.e., theories and models. Also in motor control, we are not able to create an absolutely truthful image of reality, but merely its simplified representation. For example, the issue of relation between stress and efficiency of a motor performance seems to be by far too multifaceted and complicated to be grasped scientifically as a whole. To build any understanding, it is then necessary to create a specific theory. J. Cohen and I. Stewart very aptly argued, “A theory is a kind of code that transforms complicated messages from nature into much simpler ones” [37].

Therefore, the problem with the “outdated” (or even “irrelevant”) IUP is not whether it truly explains mental mechanisms underlying motor operations in humans, but whether it is – and, if so, to what extent – useful in practice, i.e., may be applied successfully on a specific region of reality. In this respect instructively sound the words by another Nobel Prize winner, biologist K. Lorenz, who stated, “Truth in science can be defined as the working hypothesis best suited to open the way to the next better one.” To deserve the noble title “scientific”, also this paper should be regarded as a “working hypothesis”, and not as the attempt at ultimate solution of the issues under consideration. On scientific vanity fair, it would be tantalising, indeed, but in fact, the considerations presented in this paper may merely make a “springboard” for scientists who will look for “the next, better ones.” For example, it cannot be excluded that in a given individual each modality has its ”own” inverted-U curve. Consequently, it is still long way to understanding the stress-efficiency relations.
References

[30] Petryński W: Miracle on the Hudson as seen from scientist’s perspective. How captain Sully was able to land after failure of both engines in Airbus? [in Polish]. Gazeta Wyborcza. 2017, 01 May.
PECULIARITIES IN VISUAL FUNCTIONS AND THEIR RESTORATION IN TEENAGERS WITH EMMETROPIC REFRACTION AFTER WORK ON COMPUTERS AND THE METHOD OF ITS REDUCTION

Stepan Vadzuk 1ADE, Nataliia Ulianytska 2BCDE, Svitlana Indyka3DE, Olga Andriychuk 4E, Olena Yakobson 5CDE

1 Department of Physiology. State Medical University named after Horbachevsky. Ternopil. Freedom Square 1. The Ukraine
2 Department of Human Health and Physical Therapy. Lesya Ukrainka Eastern European National University. Lutsk Hrushevskoho Avenue. 2b (building E)
3 Department of Physical Education Theory. Fitness and Recreation. Faculty of Physical Education and Sports. Lesya Ukrainka Eastern European National University. Lutsk. Vynnychenka Street 30/118 (building B)
4 Department of Physical Education and Sports. Lesya Ukrainka Eastern European National University. Hrushevskoho Avenue. 2b (building E). Lutsk.
5 Department of Human Health and Physical Therapy. Lesya Ukrainka Eastern European National University. Faculty of Physical Education. Sport and Health. Hrushevskoho Avenue. 2b (building E)

Key words: impact of computers, teenagers, visual acuity, contrast sensitivity, restoration programmes

Abstract

Introduction. Modern IT penetration leads to the usage of information devices, especially PCs. In the teaching and learning process. Nowadays, according to expert research in the Ukraine, more than 9.5 million people are PC users (in fact, one in five people), but half of them are children and teenagers. As a result, the changes in functional activity of different organs and systems are produced, however, work with video-display terminals exerts the most influence on the visual analyser.

Aim. To study the visual acuity and contrast sensitivity in senior pupils while working in front of a computer monitor. and to recommend the effective way of its correction, if any parameters’ disorders are determined.

Material and methods. Sixty, healthy 14-16-year-old senior pupils (120 eyes) with emmetropic reaction were examined. These schoolchildren did not present any ophthalmic, somatic or mental disorders. Visual acuity, its threshold limit values and contrast sensation were studied using special techniques. The investigation consisted of three stages. At the first stage, the effect of one-hour, uninterrupted computer work on visual functions was studied. Their state after 15-minute passive rest was determined at the second stage. The author’s programme “Eyesight Preservation and Restoration”, including special exercises for the eyes, upper limb girdle and neck, with the elements of breath-holding, followed by the determination of the parameters in question, was used at the third stage [1].
Results. A decrease in visual acuity by 7.4% after one-hour constant visual strain on the computer monitor was found. The fact performing restoration exercises for fifteen minutes after one-hour visual strain increased visual acuity by 7.2% is quite conspicuous. It is worth pointing out that contrast sensitivity increases to 36.1 ± 1.42% and 36.08 ± 1.65%, respectively, in the right eye and the left eye after a one-hour visual workload. This indicates a contrast sensitivity decrease in the eyes and the reduction of successful implementation of visual work under changes in brightness.

Conclusions. Indices of visual functions, such as visual acuity and contrast sensitivity change under the impact of working on the PC, however, the 15-minute set of restoration exercises brings them closer to baseline levels.

Introduction

Nowadays, computers are widely used all over the world and have significant popularity. Right before, those devices could only be found at research institutions, universities and at the workplace, but now, many of them are at homes and the number of modern technology owners is growing. Work using a computer display is characterized by heavy visual strain on the visual analyser, and for this very reason, such professional activity is considered to be visually strenuous. Visual strain and visual working capacity are closely connected with the state of the accommodative convergent system [2]. The intensive computerization process creates many medical and social problems. Up to 40-60% of people suffer from computer eye syndrome [3-5].

The problems regard especially young people with refractive disorders due to using video-display terminals (VDT). The number of individuals is increasing every year, while we may also note the emergence of late acquired myopia in computer users [5-7].

Attention was drawn to the investigation of computer impact on eyesight in recent years in the Ukraine [2,8], but the impact of the computer monitor on visual functions in senior pupils has not been yet determined. Some studies have suggested the necessity of the ergonomic workplace organization for a computer user that would provide visual comfort [4]. But meeting these requirements would not improve much due to the fact that the changes in the functional state of the visual analyser under the impact of operating a PC would still remain [9]. Modern programmes and finding new drug-free physiological recommendations for a set of restoration exercises require further improvement. The implementation of such exercises will reduce the negative affect of the computer technology and protect eyesight.

The aim of our work is to study visual acuity and contrast sensitivity in senior pupils while working in front of a computer monitor, and when disorders are determined, to offer a method for their effective correction.

Method of the study

60 healthy 14-16 year-old senior pupils (120 eyes) with emmetropic refraction but without ophthalmic, physical or mental deviations were examined. The study group consisted of 20 males and 40 females. Significant differences between visual functional indexes in the males and females were not found. These indexes belongs to the same population. This conclusion was very important. Otherwise, it would be necessary to carry out data analysis for the males and females separately.

The conditions of the study met hygiene requirements [9] and counted changes of higher nervous activity by academic school day. All schoolchildren had worked on 17-inche LCD screens (screen resolution 1280x1024). The examined pupil was offered to sit down face-to-PC screen so that the eyes were at the middle level of the test field. The test was carried out under standard lighting conditions. Uninterrupted computer work took one hour. A screen picture differs from a natural one: a screen image is a blink, light-absorbing and more contrastless [5].

So, visual strain in this study met to the following requirements:

- subject's load did not include significant mental activity; (їх корекція – ок)
- programme authoring did not require any special training in computer technique.

After the given requirements, of the participant was asked to read a scientific text (14 pt. font size, “Word” text editor – as visual strain [10,11].

The visual acuity, its threshold limit values and contrast sensitivity were determined by special computer techniques [12,13].

The visual acuity and contrast sensitivity were determined monocularly, starting with the right eye. The head was in a straight position. The second eye was closed with an opaque shield. Visual acuity was determined by means of Landolt’s rings, the dimensions of which were determined with regard to the proportion of symbols from Sivtseva-Golovin’s table. The contrast of symbols with the background screen constituted 100%. The black
symbols were shown against the white background. The examination was conducted from a distance of 4 m. The presence or absence of the complaints in the examined pupils served as the criterion for selecting the initial number of optotypes for the study.

Thus, when there were no complaints of decreased visual acuity, the table with Landolt’s rings was shown on the monitor screen, the dimensions of which fitted the visual acuity of 1.0. The table with Landolt’s rings, the dimensions of which corresponded to the data of subjective vizometry under contrast at 100%, was displayed. The contrast of the symbols and the background were reduced each time by 10.0%, and along with this, the orientation of Landolt’s rings was changed on the screen due to the law of software random distribution that eliminated undesired formation of a consistent image of maximum contrast optotypes.

The data were clarified by the increase in contrast to 0.2–0.8 % with each step. The range of possible contrast measurement was 100-0.8%. The examination was conducted at three stages. During the first stage, the impact of one-hour computer operation on the visual functions was studied. The visual acuity and contrast sensitivity after one-hour of computer work and a 15-minute break (closing eyes or shifting eyes away from the monitor) were determined at the second stage.

The third stage included the study of the investigational visual functions after work on the computer and a set of restoration exercises with the elements of breathing exercises.

The results were processed on the PC with the aid of the Statistica 6.0 (Statsoft. USA) application package. The digital data were processed concerning statistical analysis according to the Ukrainian State DSTU 3008-95 standard. After implementing the requirements, the results were given as average number (M), standard error of the mean (m), relative error and checking the null hypothesis and The Student’s t-test for independent variables [14]. Analysis of the given data was provided in normal distribution of results within groups or subgroups. If data distribution deviated from the norm (according to the Lilliefors test), the Wilcoxon-Mann-Whitney U-test for nonparametric criterion was applied.

Results of the study

It can be stated that the visual acuity of the pupils with emmetropic retraction decreased by 7.4% from baseline after their visual workload and constituted 1.20 ± 0.07 and 119 ± 0.07 in the right and left eye, respectively. It was found out that the 15-minute restitution did not significantly effect that index (Table 1).

It is worth mentioning that the performance of restoration exercises for fifteen minutes after the one-hour visual strain increased visual acuity by 7.2%, which reached values closer to baseline and was: right eye – 1.29 ± 0.09, left eye – 1.28 ± 0.08.

The contrast sensitivity at baseline (Table 2) was 28.30 ± 1.31% in the right eye and 28.34 ± 1.28% in the left one.

Table 1. Visual acuity before and one-hour after visual computer workload, after 15-minutes of rest and following the set of restoration exercises (c.u.).

<table>
<thead>
<tr>
<th>Indices of visual acuity</th>
<th>OD (right eye)</th>
<th>OS (left eye)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before visual strain</td>
<td>1.30±0.03 *</td>
<td>1.29±0.06 *</td>
</tr>
<tr>
<td>After visual strain</td>
<td>1.20±0.07 b</td>
<td>1.19±0.07 b</td>
</tr>
<tr>
<td>After 15-minutes of rest</td>
<td>1.23±0.08</td>
<td>1.22±0.06</td>
</tr>
<tr>
<td>After the set of exercises</td>
<td>1.29±0.09</td>
<td>1.28±0.08</td>
</tr>
</tbody>
</table>

Note: * – the probability of data before the visual strain (P<0.05), b – the probability of data after the visual strain (P>0.05).

Table 2. Contrast sensitivity before and after one-hour of computer visual strain, after 15-minutes of rest and following the set of the restoration exercises (%).

<table>
<thead>
<tr>
<th>Indices of contrast sensitivity</th>
<th>OD (right eye)</th>
<th>OS (left eye)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before visual strain</td>
<td>28.30±1.31</td>
<td>28.34±1.28</td>
</tr>
<tr>
<td>After visual strain</td>
<td>36.10±1.42 a</td>
<td>36.08±1.65 a</td>
</tr>
<tr>
<td>After 15-minutes of rest</td>
<td>35.10±1.52 a</td>
<td>35.20±1.64 a</td>
</tr>
<tr>
<td>After the set of exercises</td>
<td>31.50±1.42 a</td>
<td>31.70±1.42 a</td>
</tr>
</tbody>
</table>

Note: a – the probability of data before the visual strain (P<0.05), a – the probability of data after the visual strain (P<0.05)
The increase in the contrast index to 36.1 ± 1.42 % and 36.08 ± 1.65 %, respectively, in the right and left eye after one-hour of visual strain should be noted. This proves the decrease in contrast sensitivity of the eyes and the reduction of successful implementation of visual work under the changes in brightness. This is in agreement with the scientists’ findings that prolonged and repeated contact with displays impact the ability of the visual system to contrasting eyesight [15,16].

The unreliable results were achieved after the 15-minute rest. Thus, the contrast sensitivity was 35.1 ± 1.52% in the right eye and 35.2 ± 1.64% in the left one, which was close to the data obtained after 1-hour of visual strain. The determined indices show significant improvement of the contrast sensitivity after the set of restoration exercises, the duration of which was 15 minutes. This proves their effectiveness and expediency for reducing sensory fatigue as the index of contrast sensitivity decreased and amounted to 31.5 ± 1.42% in the right eye and 31.7 ± 1.42% in the left one.

Conclusions and discussion

Our results coincide with the findings of some scholars, who outline the positive correlation between the duration of work on a personal computer and the decrease in visual acuity [15-17].

Normal visual perception of the world requires not only high acuity but full spatial-frequency channels of contrast sensitivity. These channels provide high frequency filtering which inform us about the details of an object: low ones, without which the perception of a complete image is impossible even when distinguishing small and medium details, and medium ones which set the preconditions for high-quality analysis of object contours. Thus, the study of visual contrast sensitivity at all frequencies gives full and good knowledge about the possibilities of the perception of visual information. The determination of contrast sensitivity can be used for initial diagnosis of visual system diseases in all cases, and for establishing pathophysiological approaches to improve visual functions. Contrast sensitivity is physiologically a more delicate function and does not always correlate with visual acuity [18-21]. It is believed that the changes in contrast sensitivity are early manifested, which provides better information about the functional state of the visual analyzer compared to visual acuity.

Our study points out that the exercises, which are followed by a set of breathing exercises, are the most effective rehabilitation means for improving visual acuity and contrast sensitivity. So, possible increase in the supply of the brain with blood and oxygen results in the functional restoration of neurons in the visual centres and with them, in the indices of acuity and contrast sensitivity [22].

Thus, 1-hour computer visual workload caused a decrease in visual acuity by 7% in the teenagers. The index of contrast sensitivity increased: 36.1 ± 1.42% and (36.08 ± 1.65%, in the right and left eye, respectively, under the impact of 1-hour computer work. This indicates a disorder in visual function. The 15-minute passive rest did not significantly change the index. The performance of the restoration exercises brought the visual functions closer to baseline.

The study provides deep insight into the current understanding of visual analyzer functioning in senior pupils with emmetropic refraction, who experience strains working on a computer. The obtained findings demonstrate the positive dynamics in functional indices of the “Eyesight Preservation and Restoration” programme developed by the author. Thus, the programme can be recommended both for autonomous work on a computer and for educational institutions in the restoration of visual functions and the prevention of visual disorders.

References

Peculiarities in visual functions and their restoration in...
BODY BUILD, STRENGTH AND ENDURANCE PERFORMANCE IN ELITE SPORT AND ALPINE CLIMBERS – A PILOT STUDY

Robert Rokowski¹, Robert Staszkiewicz², Marcin Maciejczyk³, Zbigniew Szygula⁴, Michail Michailov⁵, Jadwiga Szymura⁶, Magdalena Wiecek³, Tomasz Regwelski²

¹ Department of Alpinism and Tourism, Faculty of Tourism and Recreation, University of Physical Education, Krakow, Poland
² Department of Biomechanics, Faculty of Physical Education and Sports, University of Physical Education, Krakow, Poland
³ Department of Physiology and Biochemistry, Faculty of Physical Education and Sports, University of Physical Education, Krakow, Poland
⁴ Department of Sports Medicine and Human Nutrition, Faculty of Physical Education and Sports, University of Physical Education, Krakow, Poland
⁵ Department Theory and Methodology of Sports Training, National Sports Academy, Sofia, Bulgaria
⁶ Department of Clinical Rehabilitation, University of Physical Education, Krakow, Poland

Keys word: biomechanics, oxygen uptake, anaerobic threshold, body fat

Abstract

Aim. The aim of the study was to compare the main indicators characterizing body build, including the strength and endurance potential of elite mountain and rock climbers.

Methods: The study comprised of high-class male athletes, performing rock and mountain climbing. It involved anthropometric, biomechanical (maximal grip strength in two hand positions and maximal absolute muscle strength of the forearms and arms) and physiological (maximal oxygen uptake [VO2max], second ventilatory threshold [VT2] measured in laboratory conditions and physiological responses during climbing on an indoor climbing wall) measurements.

Results: The absolute and relative strength was higher in rock than mountain climbers. Mountain and rock climbers were characterized by high aerobic performance (VO2max: 64 ml/kg/min), but differed in the exercise intensity at VT2 (80.6%VO2max in mountain climbers and 70.3%VO2max in rock climbers). The duration of the effort performed on the climbing wall was shorter in the mountaineers than the sports climbers.

Conclusion: The mountain climbers have higher body mass and BMI compared to rock climbers. The mountain climbers are characterized by a lower level of upper limb muscle strength than rock climbers. The mountaineers have better endurance performance compared to the rock climbers.
Introduction

Climbing is typically associated with mountaineering. However today, there are many climbing disciplines, among which rock climbing and alpine mountaineering should be primarily mentioned. The differences between these types of climbing mainly arise from, inter alia, different material-spatial surfaces and climatic conditions. Climbing disciplines are differentiated by their degree of risk. It is different when overcoming a difficult technical path to an 8K peak, and different on a totally secure outdoor climbing path or an indoor climbing wall.

Sport success in the high mountains is a result of many factors i.e. suitable body build of the climber. During climbing, the main resistance is body mass, and therefore, the competitors are forced to minimize (optimize) its level. Previous studies [1,2] showed that, for example, rock climbers should be characterized by low body mass and body mass index (BMI) as well as low body fat (BF). Unfortunately, there are few studies devoted to the somatic build of alpine climbers [3,4]. It can be stated that alpine climbers have similar body height as sports climbers, while differences are related to body mass and body fat levels. Previous studies have also proved the more mesomorphic physique of alpine mountaineers [3,4].

According to Twight and Martin [5], as well as House and Johnstone [6], in the wider notion of mountain climbing, muscular strength and endurance are of prior importance since the climbing time can range from a few to several hours. The mentioned authors also emphasized the importance of aerobic performance and technical skills as well as psychological predisposition. In addition, the higher above sea level the competition takes place, the physiological adaptation to function in an environment of low atmospheric pressure is significant and is decisive in the success [7-9].

Previous studies [10,11] have shown that appropriately high muscle strength and endurance in sports climbers is of critical importance for the outcome of rock climbing. Due to the fact that motor activity in rock climbing and technical mountaineering are similar, it may be presumed that alpine climbers need to be better prepared physically the more technically difficult the path. It should be noted that the difficulties of technical mountaineering derive from objective dangers, hypoxia factors, uncomfortable belaying and extremely difficult climbing movements (e.g. the line of Divine Providence on Mt. Blanc or Non Siesta on Grande Jorasse). The technical difficulty of climbing is directly linked with the size of grips on the rocky path. Their size is not an obstacle only for climbers with an appropriate stable grip force of considerable value [12]. Other studies [13,14] indicated the level of upper limb muscle strength as a key to achieving excellent sport results in climbing.

Our research hypothesis stated that due to different types of climbing, body build, strength and muscular endurance differentiate rock climbers and alpine mountaineers. The aim of the study was to compare the main indicators characterizing body build, including the strength and endurance potential of elite mountain and rock climbers. In principle, the performed measurements are to serve as a contribution to further research, particularly with respect to alpine mountaineers. So far, their comprehensive, biomechanical-physiological profile has not been created.

Material and methods

Participants

The study design and procedures were approved by the Commission of Bioethics at the Regional Medical Chamber. Each participant submitted written consent to take part in the study and was acquainted with the procedures, apparatus and aim of the study.

The study was comprised of high-class male athletes, performing rock climbing (RoC) or mountain climbing (MoC).

In the RoC group (n=3), the athletes tackled wall difficulties from the so-called red point (RP) style, measured on the “French” 8c/9a scale, while climbing rock lines from the so-called on-sight (OS) style, measured on the same 7c+/8b scale. The average age of the men in this group was 27 years, with average 17-year competitive experience.

The second group (MoC) was comprised of two climbers (n=2), who enthusiastically practice mountain climbing and are active mountaineering instructors, members of the Polish Mountaineering Association. The average age in this group was 36 years, the average experience 20 years. The documented sporting achievements of this group’s representatives were tackling the following: 8b-8b+ (RP) and 7b+/7c+ (OS). Representatives of the MoC group had such mountain achievements under their belts as difficult and fast climbs, among others, in the Alps, both in summer and winter. Due to the small number of participants, the results are presented as a pilot study, and the results were analysed as a case study.

Anthropometric measurements

Prior to laboratory tests, we carried out basic somatic measurements. Body height (BH) was measured using a Martin-type anthropometer to the nearest 0.1 cm, body mass (BM) and body fat (BF) were assessed using the Tanita InterScan scale (Japan). Measurements of body mass and body composition were performed in similar conditions each time. The subjects were in a fasting
state, properly hydrated, their feet and electrodes were cleaned and degreased, and the day before the measurements, no intense physical effort was performed. Two weight-height indicators: body mass index (BMI) and the Rohrer index (RI) were also calculated for each subject.

**Biomechanical measurements**

In a laboratory, the performed tests aimed at characterizing the functional status of selected upper limb muscles. In the case of strength performance, they were:

- **a)** Measurements of maximal grip strength in two-hand positions (F1max and F2max). In the first case, we used the typical dynamometric grip (handgrip), wherein resistance of the distal part of the dynamometer fell on the central phalanges. In the second, only the nail phalanges of four fingers (not the thumb) were actively used, while the forearm was in pronation (crimp). Grip strength measurements were performed at a prototypical, specially prepared station. The measurement line included: strength sensors (Hottinger U9B/2kN type, Germany), a tensometric bridge (M-100 type, Poland), analogue-digital card (14 Bit AD/DA) and a computer as a recorder. The most important element of the measuring line was the strength sensor, meeting the requirements under the international ISO 6789 standards, which enforce minimizing the measurement error of force transducers to a maximum of 1% of the actual value. The manner of positioning the hand for the study is illustrated in Fig. 1.

- **b)** Measurements of maximal absolute muscle strength of the forearms and arms (F3max) in a special test with the use of a so-called “grip-board” with 2-cm wide wooden slats. The subjects, using only the nail phalanges of one hand, hung on the slat and tried to lift their body. The value of the traversed resistance force was read from a dynamometer permanently fixed to the ground and rigidly connected to the climbing harness worn on the hips. The length of the various elements in the measurement line was chosen so that the measurement took place in conditions of isometric work of the involved muscles. All strength variables are presented in this study as absolute and relative values, i.e. per kilogram of body mass (respectively: [N] and [N/kg]).

Additionally, two further laboratory tests were conducted in order to assess upper limb muscle strength; both were performed until refusal (t60%Fmax, t7/3). The first

---

**Figure 1.** Hand placement at the station for measurement of maximal grip strength (F1max – Fig.1A, F2max – Fig. 1B)
involved maintaining climbing grip strength in the previously described special test, the value of which was equal to 60%Fmax. In the second test, we used the same grip, and the test consisted of performing and maintaining maximal arm and forearm muscle tension for 7 sec, followed by 3-second full muscle relaxation, and then, another maximal contraction for the duration of 7 sec. The number of such cycles was counted and their total duration time was measured.

Physiological measurements

Physiological tests of the athletes took place twice: in a laboratory, we tested their aerobic performance using the direct method (test with a gradually increased load). A week later, in conditions typical for this discipline, testing was performed on an indoor climbing wall during exercise to extreme exhaustion.

a) Laboratory test

In order to measure the maximal oxygen uptake (VO2max) and determine the second ventilatory threshold (VT2), we used a test with a gradually increased load, carried out until extreme exhaustion of the participant. The test was performed on a Saturn 250/100R (Germany) treadmill and began with a 4-minute warm-up performed at a speed of 9 km/h and treadmill inclination angle of 1°. Then, every 2 minutes, the running speed was increased (1 km/h) until it was impossible for the subject to continue the effort (extreme exhaustion). At this time, using the Medikro 919 (Finland) ergospirometer, oxygen consumption (VO2), carbon dioxide output (VCO2), pulmonary ventilation (VE), the percentage of carbon dioxide in the exhaled air (%FECO2), respiratory exchange ratio (RER) and the respiratory equivalent for carbon dioxide (VE/VCO2) were measured. Heart rate (HR) was measured with the Polar-Accurex Plus (Finland) heart rate monitor. In order to determine lactate concentration in the blood plasma before and 3 minutes after the test, arterialized blood was collected from the fingertip.

The following criteria for VO2max determination were adopted [15]:
- VO2 plateau (set oxygen uptake despite the increase in running speed),
- heart rate close to maximum values typical for age of subject,
- RER towards the end of the test higher than 1.1,
- lactate concentration above 8 mmol/L after completion of the test.

Based on the dynamics of changes in respiratory system rates, VT2 was determined and the following criteria were adopted [16, 17]:
- non-linear VE increase (second deflection),
- inflection of VE versus VCO2,
- decrease in %FECO2 after attaining maximal value,
- increase in VE/VCO2 after attaining minimum value.

b) Test on indoor climbing wall

In order to evaluate the body’s physiological response while wall-climbing, we carried out two tests until extreme exhaustion (refusal). In the first one, climbers traversed with a predetermined rhythm on a climbing route consisting solely of smaller grips (SG), and in the second, with larger climbing grips (LG). Both trials were separated by an hour break. During the test, we measured the duration of the tested effort and oxygen uptake using a portable ergospirometer (MES, Poland), and heart rate using a heart rate monitor (AccurexPlus, Polar, Finland). In addition, prior to the test and 3 minutes after its completion, the concentration of lactate in the arterialized blood plasma taken from the fingertip (LactatPAP) was determined.

To determine the concentration of lactate, 300 µl of blood was collected into test tubes that contained K2EDTA and sodium fluoride to block glycolysis. The blood was kept on ice no longer than 20 minutes and was centrifuged at RCF 14300×g for 3 minutes in the MPW55 centrifuge. A total of 10 µl of plasma was collected immediately after the blood was centrifuged, and the concentration of lactate was determined by applying the Lactate PAP enzymatic test (BioMerieux, France). Absorbance was measured at 505 nm with a UV/Vis Evolution 201 ThermoScientific spectrophotometer (USA).

Results

Body build

Rock climbers were characterized by lower body mass and greater body height compared to the mountain climbers. For this reason, the value of BMI among the

<table>
<thead>
<tr>
<th>Climb</th>
<th>BH [cm]</th>
<th>BM [kg]</th>
<th>BMI [kg/m²]</th>
<th>RI [g/cm³]</th>
<th>BF [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoC</td>
<td>174.0</td>
<td>66.1</td>
<td>21.9</td>
<td>1.31</td>
<td>5.90</td>
</tr>
<tr>
<td>RoC</td>
<td>176.3</td>
<td>64.4</td>
<td>20.7</td>
<td>1.18</td>
<td>6.55</td>
</tr>
</tbody>
</table>

MoC: mountain climbers, RoC: rock climbers, BH: body height, BMI: body mass index, RI: Rohrer index, BF: body fat
mountaineers was, on average, higher than in the rock climbers. For representatives of both groups, a similar percentage of body fat was noted.

The recorded values of the Rohrer index indicate that alpine climbers may be characterized by a more athletic type of physique as opposed to the rock climbers who seem to be characterized by a leptosomatic build. In Tab. 1, we have presented the basic indicators of somatic build in the tested climbers.

Biomechanical indicators

In Fig. 2, we have presented the results of the strength variable measurements in the mountaineers and rock climbers in absolute terms. On the other hand, Fig. 3 illustrates these variables in relative terms. In the case of $F_{1\text{max}}$, $F_{2\text{max}}$ and $F_{3\text{max}}$, higher values were noted in the RoC group. This observation is also confirmed by the values of the calculated arithmetic means. The maxi-
mal strength of the dynamometric grip (handgrip) in the rock climber group was, on average, 712 N, and for the special grip (crimp), 411 N; however, in the "grip-board" test, 564 N (for the MoC group, the average values of these variables were, respectively: 692 N, 383 N and 454 N). As it can be seen, the significantly large difference was variable in F3max (approx. 20%), in the other cases, the differences ranged from 3 to 7%.

Calculation of quotients regarding the absolute values and mass of the athletes confirmed the strength dominance of the rock climbers, in relative terms as well (Fig. 3). In the case of the dynamometric grip (F1rel), the difference in favour of the RoC representatives averaged above 5%, while in the special grip (F2rel), it was approx. 15%, and in the slab test (F2rel), it totalled more than 20%.

The last element of biomechanical measurements was assessment of the potential muscle endurance in the climbers. As mentioned, the conducted tests were continuous (t60%Fmax) and intermittent (t 7/3) in nature, and were performed until refusal. The results obtained in the RoC and MoC groups were almost identical. The time period of maintaining grip strength at a level equalling 60% of the maximum level was slightly longer than 80 s. On the other hand, in the intermittent test, the mountaineers and rock climbers achieved an average of 20 full cycles consisting of a 7-second maximal effort and a 3-second interval.

**Physiological indicators**

**a) Laboratory test**

Subjects from both groups were characterized by a high level of aerobic performance: the relative values of maximal minute oxygen uptake were on average: 64.7 and 64 ml/kg/min (mountain and rock climbers, respectively). The second ventilatory threshold was exceeded by the mountaineers at the average work intensity of 80.6%VO2max, while in the rock climbers, the VT2 was noted at a lower intensity: 70.3%VO2max (Tab. 2). After the test, we noted a higher (by 25%) average blood lactate concentration in the MoC group than in the rock climbers.

**b) Test on indoor climbing wall**

The duration of the effort to extreme exhaustion of the subject was shorter in the mountaineers than the sports climbers. In the case of overcoming the difficulties of the wall with larger grips, they performed the exercise an average of 26 seconds faster than the sports climbers. This difference increased during climbing on the smaller grips and amounted to an average of 65 seconds (Tab. 3).

In the test using the larger grips, the work intensity in both groups of climbers was similar. At the same time, in the case of walking the climbing line consisting of

<table>
<thead>
<tr>
<th>Climbers</th>
<th>VO2max (min-max)</th>
<th>VO2VT2 (min-max)</th>
<th>%VO2max</th>
<th>HRmax (min-max)</th>
<th>La</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoC</td>
<td>64.7 (62.6-66.9)</td>
<td>52.2 (48.5-55.9)</td>
<td>80.6</td>
<td>197 (197-198)</td>
<td>19</td>
</tr>
<tr>
<td>RoC</td>
<td>64.0 (60.6-67.4)</td>
<td>45.0 (41.2-48.9)</td>
<td>70.3</td>
<td>192 (184-200)</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Table 2. Average level of physiological indicators of climbers measured in the graded test

<table>
<thead>
<tr>
<th>Climbers</th>
<th>SG</th>
<th>LG</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>[s]</td>
<td>[s]</td>
</tr>
<tr>
<td>VO2 (%)</td>
<td>[mL/kg/min]</td>
<td>[mL/kg/min]</td>
</tr>
<tr>
<td>HR (%)</td>
<td>[bpm]</td>
<td>[bpm]</td>
</tr>
<tr>
<td>La</td>
<td>[mmol/L]</td>
<td>[mmol/L]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Climbers</th>
<th>SG</th>
<th>LG</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>[s]</td>
<td>[s]</td>
</tr>
<tr>
<td>VO2 (%)</td>
<td>[mL/kg/min]</td>
<td>[mL/kg/min]</td>
</tr>
<tr>
<td>HR (%)</td>
<td>[bpm]</td>
<td>[bpm]</td>
</tr>
<tr>
<td>La</td>
<td>[mmol/L]</td>
<td>[mmol/L]</td>
</tr>
</tbody>
</table>

MoC: mountain climbers, RoC: rock climbers, VO2: oxygen uptake, VT2: second ventilatory threshold, HR: heart rate, La: lactate concentration

<table>
<thead>
<tr>
<th>Climbers</th>
<th>SG</th>
<th>LG</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>[s]</td>
<td>[s]</td>
</tr>
<tr>
<td>VO2 (%)</td>
<td>[mL/kg/min]</td>
<td>[mL/kg/min]</td>
</tr>
<tr>
<td>HR (%)</td>
<td>[bpm]</td>
<td>[bpm]</td>
</tr>
<tr>
<td>La</td>
<td>[mmol/L]</td>
<td>[mmol/L]</td>
</tr>
</tbody>
</table>

MoC: mountain climbers, RoC: rock climbers, SG: small grips, LG: large grips, VO2: oxygen uptake, VT2: second ventilatory threshold, HR: heart rate, La: lactate concentration; t: duration of the test
smaller grips, the intensity of the work noted among the representatives of the mountaineer group was lower than in the group of rock climbers.

**Discussion**

The study results indicate that the alpine climbers are characterized by average body height and low mass. The observation of lowered body mass can be explained by e.g. the influence of regular training, which also seems to be suggested by the results of other studies [3,4]. The results of the study by Ozimek et al. [12] showed that rock climbers should be endowed with above-average levels of relative muscle strength (per 1 kg of body mass). However, it may be assumed that the results obtained in the mountaineers are not so much conditioned by its level. Therefore, the radical reduction (optimization) of mass is not a prerequisite for success, as in the case of rock climbers. In the latter, BMI is sometimes smaller than 20 (own calculations based on morphological parameters of the competitors on the official IFSC website).

The importance of strength preparation for the achievements of climbers is also postulated by other authors [10,11]. It seems, however, that at an advanced level of climbing, special strength takes on more importance, including the strength of the muscles that determine effective gripping of small rock formations while climbing (finger, forearm and arm muscle strength). This is probably why, for both rock and mountain climbers, we noted from 20 to 40% higher relative and absolute strength values in the dynamometer grip, and in the special and forearm and arm test (F1, F2, F3) compared to the same tests carried out among students [18].

The comparison of strength indicators in representatives of rock and mountain climbing is slightly different. In this case, the individuality of the various specializations becomes visible — it is the mountaineers who are distinguished by lower levels of upper limb muscle strength, especially in relative terms. This observation is probably due to the fact that the training needed in sports climbers regards increasing muscle strength while maintaining the lowest possible body mass. Research in world-class climbers [1,13] confirms our observation. On the other hand, in the realities of alpine mountaineering, increasing strength seems to be necessary only to a certain degree of competence, above which other characteristics seem to take on critical significance (e.g. psychological, physiological, biochemical).

Comparison of biomechanical indicators of the muscle strength in rock and mountain climbers showed a similar level in this regard. Both in the continuous \((t_{max})\) and intermittent \((t_{3:6})\) tests performed until refusal, the results in the RoC and MoC groups were almost identical. For the first variable, time of maintaining grip strength at 60% of the maximum level was slightly longer than 80 seconds. However, in the intermittent test, we noted an average of 20 cycles of maximal muscle tension and muscular relaxation for the mountaineers and rock climbers. Nonetheless, it should be emphasized that these kinds of tests, carried out in a biomechanical laboratory, evaluate muscle strength in relative terms, i.e. in respect to individually listed maximum force values. This means that rock climbers had to develop and maintain a higher strength value by about a few percent. This observation is not without significance because the duration of muscle work depends, among others, on the size of the developed strength [18]. The above-described image of strength and endurance capacity did not change when the tests were specially carried out on the slat and climbing wall. They also indicate the advantage of the rock climbers over the mountaineers. It should be noted, however, that the longer the duration of exercise, the smaller the advantage of the rock climbers.

Consequently, it becomes clear why the special endurance test carried out with small grips was dominated by the rock climbers when considering the earlier-mentioned relationship of muscle strength and endurance as well as the need to have a sufficiently high level of strength when overcoming technically difficult climbing passages. On the other hand, in the test same in kind but carried out using larger grips, the differences in favour of the rock climbers were significantly lower. It should be noted that in the intermittent endurance test, the results of climbers from both groups were similar.

Analysis of the results allowed to conclude that what particularly distinguishes mountain climbers is a high level of endurance, in which an important role is played by aerobic metabolism. In this study, aerobic performance was evaluated by measuring \(V_{O2}\text{max}\) and \(V_{T2}\). The \(V_{T2}\) has important functional implications because it is a demarcation of the work rate above which metabolic acidosis accelerates the stimulation to breathing, and exercise endurance is reduced [19]. In the conducted graded test, there was a similar reported level of \(V_{O2}\text{max}\) in both characterized groups of climbers. At the same time, the second ventilatory threshold occurred in the alpine climbers at a higher intensity, indicating a higher level of endurance. The \(V_{O2}\text{max}\) results of the mountain and sport climbers are higher than the data presented in other studies [7] in which \(V_{O2}\text{max}\) was reported to be 59.5 mL/kg/min. Simultaneously, the measured level of this indicator was not as high as that recorded in representatives of typical endurance sports (e.g. long-distance runners and cyclists). This was probably due to the fact that the effort in the high mountains is intermittent. Thus, a sufficiently high level of aerobic performance among mountaineers seems to be necessary, since only effi-
cient mechanisms of oxygen supply determine the pace and effectiveness of recovery in the intervals between successive efforts.

Rock climbers and mountaineers were characterized by similar values of VO2max but differed in work intensity at which they surpassed VT2 and in the concentration of lactate after completion of the test. The main energy systems required during indoor rock climbing are aerobic and anaerobic alactic systems. Furthermore, the contribution of these energy systems does not depend on the training status, route difficulty or upper body aerobic and anaerobic performance of the climbers [20]. The observed differences in the level of VT2 and La between the mountaineers and rock climbers may, therefore, arise from different energy substrates of the performed efforts. The mountaineers must rather be characterized by good strength abilities and a high tolerance for acidification, while rock climbers should be characterized by superior strength abilities (aerobic performance) which are necessary for efficient phosphagen recovery and proper alactic anaerobic exercise capacity.

Limitation of the study

The conducted comparative analysis of selected morphological, biomechanical and physiological indicators in elite mountain and sports climbers does not exhaust the topic of developing their comprehensive, biomechanical-physiological profile. This issue, in the opinion of the authors, was hardly signalled, and the only way to deal with it is to increase the number of participants and the scope of measurements, especially in the field of physiology and biochemistry. The reason for such an approach regards the results of this study, and also, such important aspects of mountain climbing indicated in the literature as hypoxic hypoxia tolerance or thermal stress, the efficiency of oxidative processes in the mitochondria. It also seems necessary to develop tests and measurement equipment specific for climbers which would reflect the nature of the muscle work in biomechanical terms.

Conclusions

Analysis of the research results led to the conclusion that mountain climbers have higher body mass and BMI compared to rock climbers. The recorded values of the variables also indicate that the MoC group is characterized by a lower level of upper limb muscle strength. The mountaineer group had better endurance compared to the rock climbers. The results also suggest that the applied typical biomechanical research tools do not allow to determine the differences in the profile of elite mountaineers and rock climbers: the biomechanical image of the functional state in the muscles of elite climbers from both groups was similar. The differences between the MoC and RoC groups become visible in the level of the physiological variables.

Conflict of interests

The author authors declare that they have no competing interests.

References

Body build, strength and endurance performance in elite sport...


Author for correspondence:

Robert Rokowski
E-mail: robert.rokowski@awf.krakow.pl
EVALUATING THE INTENSITY OF THE
10-MINUTE SNATCH TEST
DURING A HARDSTYLE KETTLEBELL
POLISH CHAMPIONSHIP

Jacek Polechoński 1 ABCDEFG, Rajmund Tomik 1 AC,
Michał Rozpara 1 CD, Mirosław Jurczak 2 B, Michał Tobor 3 B

1 Department of Tourism and Pro-Health Physical Activity, The Jerzy Kukuczka Academy of
Physical Education, Katowice, Poland,
2 Kettlebell Foundation, Bielsk Podlaski, Poland
3 Department of Dance Theatre in Bytom, The Ludwik Solski National Academy of Theatre
Arts, Kraków, Poland

Key words: kettlebell, snatch test, physical effort, Hardstyle

Abstract

Aim. Over the last few years, an increasing number of people have started training with kettlebells (KBs) all over the world. Unfortunately, there is very little scientific data on the effect of training with KBs, and essentially, no research has been done on the various kettlebell sports which are dynamically developing. The main aim of this paper was to analyse the intensity of physical effort during the 10-minute Snatch Test (10-min ST) at the HardStyle Kettlebell Polish Championship (HSKPC). Our research also included an analysis of the contestants' body composition on the day of competition.

Basic procedures. Ten male contestants and five female contestants were examined. Physical effort intensity was measured using Polar Team2 Pro. Body composition was evaluated with Tanita SC-330 immediately before the beginning of the competitions. The mean values of the analysed parameters in the study contestants were compared with the best male and female contestants of the Championship.

Results. Heart rate during intensive exertion for the 10 min ST was at a consistently high level (80-89% HRmax) or very high level (90-100% HRmax). Such a high HR was maintained for 98% of the exercise performance, and the mean relative energy expenditure was 14.4 METs among the women and 15.5 METs among the men. Analysis of body composition showed that participants of the HSKPC were characterized by an athletic build.

Conclusions. Even though the contestants lift relatively heavy loads during the 10 min ST (men 24 or 28 kg, women 16 kg), the effort can be described as an endurance test. Considering all the competitions taking place during the HSKPC and the results of the participants, it can be stated that these competitions are unusually demanding and require versatile physical fitness, as well as strength, endurance and coordination.

Introduction

The kettlebell, a weight which resembles a cannonball with a handle, has a growing group of supporters throughout the world. Most exercises with KBs are based on integrated, multi-faceted, dynamic movements requiring acceleration, braking and body stability. They are especially appreciated by functional trainers [1–4]. Some enthusiasts even encourage the use of KBs in physical therapy [5]. It has also been reported that training with KBs can relieve neck, shoulder and lower back pain [6].
Even though exercising with KBs has been long in Russia, and later in the former Soviet Union, it has only recently become popular. Undoubtedly, Pavel Tsatsouline, who propagated Hardstyle training, created StrongFirst and is the author of several books about exercises with KBs [7–10], was responsible for the dissemination of its popularity. However, his publications are rather methodological guides and not typical scientific reports.

During the last few years, some scientific studies have been conducted on working out with KBs and its influence on a person’s physical fitness. There are some reports about the impact of KBs on power and strength [6, 11–14], cardio-vascular performance [6, 15–18] as well as some biomechanical parameters [19–22]. According to Beardsley and Contreras [23], scientific literature on KBs is limited and therefore, there is a need to continue research on the use of this type of equipment and specifically, related exercises, in order to best implement them in training.

An overview of the previously mentioned literature shows that there are several studies regarding exercises with KBs. To date, kettlebell sport has not been researched. Many associations and sport federations exist throughout the world with various forms of competitions. They organize national competitions, European Championships and even the World Cup.

As already mentioned, thanks to P. Tsatsouline, the HardStyle method and StrongFirst training have become very popular among people working out with KBs. Put simply, these methods emphasize strength building by very precise movements to ensure safety and proper technique as well as combining muscles tension with biomechanical breathing. As in functional training, which is currently very popular, proper positioning and spine stability are focused on while exercising. The most popular exercises with KBs using HardStyle include: deadlift, swing, squat, clean, press and the Turkish get-up (TGU).

For persons training with KBs, one of the most frequently performed exercises is the snatch [8].

A few years ago, as a result of popularity of the HardStyle training method and the establishment of well-structured StrongFirst clubs certified by P. Tsatsouline in Poland, a cycle of HardStyle Kettlebell competitions for amateurs and professionals was organized. It is notable that these nation-wide competitions are probably unique on a world-wide scale.

The main aim of this study was to determine the level of effort during the 10-min Snatch Test competitions of professional competitors during the HardStyle Kettlebell Polish Championship (HSKPC). This research also includes an analysis of competitors’ body composition on the day of competition. Furthermore, characteristics of the HSKPC competition as well as the original way of classifying the participating competitors are given.

The authors of this paper regard that this information can be inspiration for those who train using the HardStyle method to organize similar sport events on national and international levels.

**Materials and Methods**

**Participants**

The research was carried out during the 3rd HardStyle Kettlebell Polish Championship which was held on August 27, 2016 in Bielsk Podlaski, Poland. The study included 10 of 13 male competitors and 5 of 6 female participants in the professional category who completed all aspects of the competition. When the participants expressed their willingness to take part in the study, they were equipped with a pulse monitoring apparatus. The age range of the women was 24.0-33.0 years (27.8±3.8 years) and for the men 22.0-36.0 years (27.3±4.4 years). Calculated on the basis of the classical formula 220-age maximum pulse (HR\textsubscript{max}) 192.0±4.0 bpm (187.0-196.0 bpm) and 193.0±4.0 bpm (184.0-198.0 bpm) was noted for the men and women participants, respectively.

**The organization of the competition, characteristics of the competition and final classification**

The men’s professional group competed in five events during the III HSKPC: the Military Press – raising the KB with one hand from a rack position, Pistol – squatting on one leg with a KB, Pull Up - with a KB attached to the waist, Turkish Get Up - getting up from lying on the back while holding a KB to a standing position, holding the KB over the head and returning to a lying position, 10-minute Snatch Test (10 min ST). The first four are for strength and involve one repetition with maximum weight (three trials). However, the 10 min ST is an endurance competition with repetitious lifting of kettlebells (20, 24 kg or heavier) with one hand over the head for 10 min. At any moment during the 10 min, the participant can set aside the KB or change hands. Women start in four events – omitting the pull ups and use 12 or 16 kg KBs for the 10 min ST.

In the HSKPC, there are no weight categories. Classification of participants in the individual and final events is based on allometric scales which are appropriately applied in weight lifting sports [24–27].

The allometric scale is calculated according to the following formula:

\[
AS = S \times M^{-2/3}
\]

where:

- AS – allometric scale,
- S – weight lifted [kg],
- M – body mass of contestant [kg].
For the 10 min ST (multiple lifts), the number of lifts performed to determine the indicator was also taken into consideration and multiplied by the AS value. The final result of the HSKPC contestants comprised the results from all competitions.

**Measures**

The exercise intensity during the last 10-min Snatch Test was measured with Polar Team2 Pro (POLAR) which telemetrically monitored the heart rates of several individuals simultaneously while they exercised. A program which analysed the obtained data was included. With the Polar Team2 Pro, the exercise intensity is based on heart rate while exercising (ExHR) as well as information about the maximum value measured or estimated in each person (HRmax). With this information, it is possible to record how long the performance lasted in a specific intensity area. Data about heart rate during exercise is also used to estimate energy expenditure.

The following parameters characterizing exercise intensity and the accompanying energy expenditure were recorded for the studied participants: minimum heart rate during 10 min ST (ExHRmin), average heart rate during the 10-min ST (ExHRave), maximum heart rate during the 10-min ST (ExHRmax), time in zone 50-59% HRmax (ZT1), time in zone 60-69% HRmax (ZT2), time in zone 70-79% HRmax (ZT3), time in zone 80-89% HRmax (ZT4), time in zone 90-100% HRmax (ZT5), absolute energy expenditure during the 10-min ST – amount of physical activity (AEE), relative energy expenditure during the 10-min ST – exercise intensity (REE).

Body height was measured with the RADWAG 100/200 OW altimeter. Body mass and composition were determined with the Tanita SC-330 analyser before the competitions started. The equipment was adjusted for typical body build. The following body parameters were measured and estimated: body mass (BM), body mass index (BMI), visceral fat indicator (VFI), fat rate (FR), fat free mass (FFM) and muscle mass (MM).

For all the analysed variables, the arithmetic mean (Mean) and standard deviation (SD) as well as their minimal (Min) and maximum (Max) values were calculated using Statistica 12.0 StatSoft, Inc. The mean values of the analysed parameters in all the studied subjects were compared with the best participants of the championship.

**Results**

The analysed minimal (ExHRmin), average (ExHRave) and maximum (ExHRmax) heart rates which were recorded while exercising during the competition’s 10-minute

---

**Table 1. Intensity characteristics of the 10-minute Snatch Test**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Participants</th>
<th>Women n=5</th>
<th>Men n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Min-Max</td>
<td>Mean±SD</td>
</tr>
<tr>
<td>ExHRmin [bmp]</td>
<td>All</td>
<td>127.0±25.0</td>
<td>95.0-161.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>139.0</td>
<td>–</td>
</tr>
<tr>
<td>ExHRave [bmp]</td>
<td>All</td>
<td>176.0±9.0</td>
<td>164.0-189.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>189.0</td>
<td>–</td>
</tr>
<tr>
<td>ExHRmax [bmp]</td>
<td>All</td>
<td>184.0±9.0</td>
<td>171.0-197.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>197.0</td>
<td>–</td>
</tr>
<tr>
<td>TZ1 [s]</td>
<td>All</td>
<td>1.4±2.2</td>
<td>0.0-5.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>0.0</td>
<td>–</td>
</tr>
<tr>
<td>TZ2 [s]</td>
<td>All</td>
<td>3.8±3.6</td>
<td>0.0-8.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>0.0</td>
<td>–</td>
</tr>
<tr>
<td>TZ3 [s]</td>
<td>All</td>
<td>8.2±5.8</td>
<td>0.0-16.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>9.0</td>
<td>–</td>
</tr>
<tr>
<td>TZ4 [s]</td>
<td>All</td>
<td>231.0±265.2</td>
<td>13.0-548.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>14.0</td>
<td>–</td>
</tr>
<tr>
<td>TZ5 [s]</td>
<td>All</td>
<td>355.0±273.3</td>
<td>32.0-587.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>576.0</td>
<td>–</td>
</tr>
</tbody>
</table>

Legend:

ExHRmin – minimum heart rate during 10-minute ST, ExHRave – average heart rate during 10-minute ST, ExHRmax – maximum heart rate during 10-minute ST, ZT – time in zone 50-59% HRmax, ZT1 – time in zone 60-69% HRmax, ZT2 – time in zone 70-79% HRmax, ZT3 – time in zone 80-89% HRmax, ZT4 – time in zone 90-100% HRmax.
Snatch Test indicate the significance of its intensity. The values of the ExHR\textsubscript{ave} and ExHR\textsubscript{max} variables observed in the best participants were found to be in the upper limit of the variability of these parameters for all of the men and women (Tab. 1).

The evaluation of the length of physical effort in specific intensity zones showed that during the 10-min ST, high (TZ\textsubscript{4}) and very high (TZ\textsubscript{5}) intensity dominated. This was especially evident in both winners of this competition, who with little effort, obtained medium (70-79\% HR\textsubscript{max}) and high (80-89\% HR\textsubscript{max}) intensity with a distinct advantage of maximum intensity effort (90-100\% HR\textsubscript{max}) (Tab. 1, Fig. 1).

Based on heart rates registered during the physical exertion of the 10-min Snatch Test, the absolute and relative caloric costs of the competition were determined. This required significant absolute energy expenditure (AEE) which averaged 170.2±21.3 kcal in women and 228.3±24 kcal in men. The high relative energy expenditure (REE) was, respectively, 14.4±1.8 METs and 15.5±1.4 METs, and indicates the significant physical exertion during the 10-min ST. Those who finished first in the competition had the highest or almost the highest REE. The male winners of the 10-min ST expended the greatest amount of energy in absolute terms (Tab. 2).

The study of the HardStyle Kettlebell competition contestants found participants with an athletic build (BMI=24.7±2.7 kg/m\textsuperscript{2} for women and BMI=27.0±2.0 kg/m\textsuperscript{2} for men) to have a typical amount of fat cells for the general population, 28.4±2.5\% for women and 17.4±1.5\% for men. The studied athletes had low visceral fat indicators (VFI) and significant muscle mass (FFM and MM). The best female contestant was the shortest and at the same time the lightest, while the best male contestant was one of the tallest and heaviest (Tab. 3).
Evaluating the Intensity of the 10-Minute Snatch Test...

Discussion

The main aim of the study was to evaluate the intensity of physical effort during the 10-minute Snatch Test of professional athletes at the HSKPC. The mean REE during the 10-min ST was 14.4 METs for women, and 15.5 METs for men. The profile of intensity for the best female contestant was 16.6 METs, and for the best male contestant, 16.4 METs. Considering the fact that the HR of athletes was 80-90% HR_{max} or 90-100% HR_{max} for almost the entire time of the physical effort (97.8%) it can be stated that the physical effort was intense or very intense. It should be emphasized that the ExHR for the best female contestant was 90-100% HR_{max} for more than 96% of the duration of the exercise. Maintaining such a high HR during the 10-minute Snatch Test shows not only great physical intensity but also great endurance.

To help understand the exercise intensity during the 10-min ST, it can be compared to other forms of physical activity. For example, bike riding at a speed of more than 32.2 km/h correlates to 15.8 METs. Running 17.7 km/h (1 km – 3:24 min) involves an exercise intensity of 16.0 METs [28].

Schnettler et al. [18] carried out research similar to ours on 10 volunteers (women and men) aged 29-46 years old, experienced with kettlebell training. They examined the HR response, and EE during the standard 20-minute snatch workout using 12, 15 or 20 kg KBs, depending on the sex, body mass, level of physical fitness and experience. They found an ExHR_{ave} of 164±15 bpm, which equated to 93.0±4.5% of maximum HR. However, the EE of the subjects was on the level of 13.6±3.1 kcal/min.

The intensity of physical effort while exercising with KBs was also evaluated by Farrar et al. [15] and Husley et al. [16]. They determined the HR and EE during swings but not during snatches. Farrar et al. [15] studied a group of 10 men who performed two-handed swings for 12 min with 16 kg KBs. Although all subjects were recreationally active, only 1 had previous experience exercising with KBs. Their ExHR_{ave} was 165±13 bpm, which was 87.0 ± 6.0% of HR_{max}. In the studies conducted by Husley et al. [16] 13 individuals were studied (11 men and 2 women), 19-27 years old. The subjects were moderately trained but had no experience exercising with KBs. The research procedure included 10-min swing with 16 kg KB (men) or 8 kg KB (women). During this exercise the ExHR_{ave} was 180±12 bpm, which was 89.0±5.3% HR_{max}. With respect to %HR_{max} it turns out that training based on swings can be almost as intensive as the intensity of the snatches. In accordance to the guidelines of the American College of Sports Medicine (ACSM) exercising with KBs can be classified as a "hard" or "very hard" exercise [17].

Table 3. The biometric parameters of participants (athletes)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Participants</th>
<th>Women n=5</th>
<th>Men n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Min-Max</td>
<td>Mean±SD</td>
</tr>
<tr>
<td>BH [cm]</td>
<td>All</td>
<td>170.2±6.6</td>
<td>160.0-178.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>160.0</td>
<td>–</td>
</tr>
<tr>
<td>BM [kg]</td>
<td>All</td>
<td>71.5±8.1</td>
<td>61.9-80.2</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>61.9</td>
<td>–</td>
</tr>
<tr>
<td>BMI [kg/m2]</td>
<td>All</td>
<td>24.7±2.7</td>
<td>21.6-27.8</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>24.2</td>
<td>–</td>
</tr>
<tr>
<td>VFI [1-12 units]</td>
<td>All</td>
<td>2.6±0.5</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>2.0</td>
<td>–</td>
</tr>
<tr>
<td>FR [%]</td>
<td>All</td>
<td>28.4±2.5</td>
<td>26.3-31.7</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>26.3</td>
<td>–</td>
</tr>
<tr>
<td>FFM [kg]</td>
<td>All</td>
<td>51.0±4.3</td>
<td>45.6-55.7</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>45.6</td>
<td>–</td>
</tr>
<tr>
<td>MM [kg]</td>
<td>All</td>
<td>48.5±4.1</td>
<td>43.3-52.9</td>
</tr>
<tr>
<td></td>
<td>First place</td>
<td>43.3</td>
<td>–</td>
</tr>
</tbody>
</table>

Legend:

BH – body height, BM – body mass, BMI – body mass index, VFI – visceral fat indicator, FR – fat rate, FFM – fat free mass, MM – muscle mass
Since the physical exercise occurring during snatch- es or swings is intense, it can be assumed that this type of exercise should have positive impact on aero- bic capacity. However, this is not entirely clear from the few studies performed to date. Beltz et al. [29] found a significant improvement of VO\textsubscript{max} in an experimental group after 8 weeks of training with KBs compared to a control group. However, this was not confirmed by Jay et al. [6] in their similar 8-week research. Even though the length of both experiments was the same, the length and frequency of the training differed. The subjects under the direction of Jay et al. [6] exercised 3 times per week for 15-20 minutes. Those under the supervision of Beltz et al. [29] exercised 2 times per week for 30-45 minutes. Differences also involved training exercise, physical fitness, the selection of exercises, etc. Eckert and Snarr [30] feel that in spite of contradicting results of exercising with KBs, they can elicit a cardiovascular and metabolic response sufficient for improvements in aerobic performance. To improve the circulatory system, experts from the ACSM recommend exercises of moderate (64-76% HR\textsubscript{max}, 46-65% VO\textsubscript{2max}) or vigorous intensity (76-96% HR\textsubscript{max}, 64-91% VO\textsubscript{2max}), lasting at least 10 min [31]. The cardiovascular responses to kettlebell routines included in this study would all be classified as at least of moderate- or vigorous-intensity.

In order to better interpret the nature of physical ef- fort and the intensity of exercise during the 10-minute Snatch Test during the Polish Championship, it is worth looking at the contestants’ results. Women started with 16 kg weights and performed 208 repetitions. The best did 239 repetitions. The men used 24 kg KBs and had a mean of 184 repetitions. The best result, based on the A5 scale, was obtained by the only man who used 28 kg KBs, with 210 repetitions. The results of research indicate not only high performance but also a significant level of strength. For the average person, only lifting such KBs above the head once can be challenging.

Confirmation of the influence of exercises with KBs on the functional strength of subjects can also be seen in their mean results in other competitions (men – m, women – w): Military Press (45.7±6.4 kg – m, 21.0±4.2 kg – w), Pistol (48.8±11.1 kg – m, 25.0±7.8 kg – w), Pull Up (53.2±14.4 kg – m), Turkish Get Up (60.0±10.2 kg – m, 34.0±4.0 kg – w). The best and female athlete in a given competition had the following results: Military Press (56 kg – m, 26 kg – w), Pistol (68 kg – m, 36 kg – w), Pull Up (80 kg – m), Turkish Get Up (80 kg – m, 38 kg – w). The performance of diverse and difficult exercises with heavy weights can reflect a high level of overall fitness in terms of strength and endurance as well as joint stability and mobility, and coordination. This suggestion, however, needs to be verified and can be done with appropriate motor testing among Hardstyle contestants training with KBs.

At the moment, there are few studies dealing with the improving influence of training with KBs on muscle strength [30]. Manocchia et al. [13] showed that a 10-week training period with KBs (two times per week) can significantly improve barbell bench press and clean and jerk results. These researchers suggested that KBs may be an effective alternative tool to improve performance in weightlifting and powerlifting. Jay et al. [6] found that after an 8-week period of training with KBs (3 times/wk for 15-20 min), which included the deadlift, two-handed and one-handed swing; the subjects had significantly in- creased strength of the trunk extensors. Otto et al. [14] showed that training with KBs 2 times/wk for 6 weeks makes it possible to obtain significantly better results for the back squat, vertical jump and power clean performance. Exercising with KBs significantly affects not only strength but also power. One can risk saying that training with KBs can have a greater effect on power compared to strength because typically, kettlebell exercises (swings, cleans, snatches, push-presses, high-pulls) are performed in a ballistic manner in which the stretch-shortening cycle is elicited due to the rapid concentric movement immediately following the eccentric counter movement [19, 21].

Apart from high performance and physical fitness, contestants training with the Hardstyle method must also have certain volitional traits which can influence their endurance while lifting the weights. Most important is resistance to pain. With repeated lifts of heavy weights, there is often relatively deep damage to the skin of the palms.

While weighing the contestants on the day of the Polish Championship, their body composition was also evaluated. Even though this was not the main aim of our study, it can contain important information for future e.g. comparison of contestants in other sport disciplines or individuals not training with KBs professionally. Furthermore, the results present the body composition of athletes training with the Hardstyle method during competitions. Some of the body composition parameters of the contestants can be applied to the population norm. For this, normative data from the instruction manual of the measuring equipment was used (http://tanita.eu/help-guides/products-manuals, available: 17.02.2017). Using body fat ranges developed on the basis of research car- ried out by [32] and the visceral fat indicator VFI, it can be stated that both female and male athletes were within the norm. However, their BMI was relatively high, with the mean for women being on the norm border, while for men, it was exceeded. This indicates the athletic body build of those professionally training KB HardStyle. It is worth noting that the best male and female contestants had FR and VFI less than the mean of all the participants. Interestingly, the best female contestant was the short-
est (10.2 cm shorter than the mean height) and weighed the least (9.6 kg less than the mean). Nonetheless, the best male participant was one of the tallest (2.8 cm taller than the mean) and only one other contestant weighed more than him (10.6 kg above the mean). This may indicate that short, light female contestants are predisposed to finishing near the top in the final classification of Hardstyle competitions, while a better predisposition was found in tall, well-built men with little fat tissue. This thesis is confirmed by the fact that both individuals won first place in the HSKPC.

Training with KBs is becoming more and more popular throughout the world, and at the same time, reports are not extensive, meaning that many areas of research can be investigated in the future. This is justified since there are reports stating that training with KBs is very promising and can improve overall physical fitness. Further research should include comparison of KB training with traditional equipment and methods of developing strength, power and endurance. It would also seem interesting to evaluate the metabolic effects of various KBs exercises (swings, cleans, snatches, jerks, etc.) in comparison to other typical physical exercises such as running various distances, biking, cross country skiing, etc. One must not overlook safety factors while exercising. Repetitive and long-term weightlifting requires appropriate precautionary measures and proper technique.

For the development of the kettlebell sport, it would be worth studying the sportspersons who train its various forms. Valuable information could be obtained by conducting measurements at sport events with additional factors such as stress and motivations which do not occur during training. Carrying out such research, however, is problematic and not always possible. It can only be done with permission from the contestant and the organizer of the sporting event. The measuring equipment can not hamper the execution of movement nor interfere with participation in competitions.

Conclusions

To summarize, it can be stated that the intensity of physical effort during the 10-minute Snatch Test at the sport event is high or very high. Even though the participants lift relatively heavy weights, the physical effort is of endurance nature.

Taking all the competitions during the Hardstyle Kettlebell Polish Championship into consideration, it can be stated that the competitions are unusually challenging and the contestants must be geneologically very fit, having the appropriate strength and endurance. Individuals competing in this form of rivalry should have an athletic body build with relatively little fat tissue.

References


Author for correspondence:

Jacek Polechoński,
Phone number: +48 32 207 51 10,
E-mail: j.polechonski@awf.katowice.pl
INFLUENCE OF CREATIVE INFORMATION TRANSFER ON THE PERFORMANCE OF FOOTBALL PLAYERS

Henryk Duda 1 ABCDEFG Mateusz Kaczor 1 ABCDF

1 Faculty of Sports and Recreational Games, Sports Institute, University of Physical Education, Krakow

Key words: football, creativity, information

Abstract

Study aim. The increasing level of sporting achievements is the reason for seeking new and different solutions in various areas of the training process. Therefore, it is aimed at enriching training content with new methods, forms or introducing more effective organization of training classes. It should be assumed that the way to improve training effectiveness consists in combining developmental activities: motor skills, special motor abilities and mental abilities [1, 2]. Among these athletic qualities, considerable reserves are recognized in the teaching-learning of special motor activities and tactics in which athlete's mental abilities are utilized. Hence, by looking for new ways to optimize the training process for players, attention is drawn to a problem that until recently, was unpopular in sports learning, the relevance of which is systematically increasing, i.e. the need for intellectualization of the training process.

Basic procedures. Demonstrating the influence of conscious analysis of a movement task among football players on their performance and on the basis of the importance of thought processes for the efficient performance of movement tasks determining directions for creative teaching of the sports game as an effective way of teaching technical and tactical activities.

The test group comprises football players in three age categories:
• Youngsters (U-12)
• Juniors (U-16)
• Seniors

In the research process, the creative method is applied to creative exercises [3, 2] based on the conscious analysis of the motor activity.

Results. The analysis of the research results shows that creative teaching learners achieve better results in movement performance.

Conclusions. 1. Efficacy of motor activity requires understanding of causal relationships. 2. Mentalization of the training process increases the effectiveness of the players' movement.

Introduction

The increasing level of sports achievements is the reason for searching for new solutions at various levels of the training process. Therefore, we strive to enrich the training content with new methods, forms or to introduce more effective organization of training activities. It should be assumed that the way to improve the effectiveness of training is to combine activities developing: motor skills, special movement skills and mental abilities [1]. Among these characteristics of athletes, significant reserves are seen in teaching-learning special movement activities and tactical actions, utilizing the mental abilities of athletes. Therefore, looking for new ways to optimize the training process of players, attention is paid to the until recently unpopular issue in learning sports games – the
Antropomotoryka

importance of which is systematically increasing – i.e. the need for intellectualization of the training process, which develops a player's creativity in a unique way [4]. It requires the involvement of awareness and independent, creative thinking of the players in the process of teaching them. Adoption of such a direction in organized player training seems to be a necessity, because a sports game - as a multi-entity operation, is a dependent competition, the essence of which is to resolve conflicts of player rivalry to one's advantage via any deliberate and purposeful actions [1]. Efficient operation during the game requires optimal functioning of the central nervous system, which plays a fundamental role in the transition from reflexive behaviours to conscious (conceptual) actions [5]. It should be borne in mind that the finalization of an external (manipulative) activity – the manifestation of motion is the end product which is preceded by an internal action – is the basis for external action. Thus, the player, wanting to efficiently perform actions in changing game situations, must have the ability to predict the consequences of events (anticipation), i.e. the possibility, occurrence or non-existence of a favourable or unfavourable situation in the future. Effective prediction of events significantly depends on knowledge resources regarding the ways of acting in different game situations.

The further mental process in the player's effective operation is the ability to quickly perceive events and recognize them accurately. This process is called perception and concerns "active reception, analysis and interpretation of sensory phenomena in which currently incoming information is processed on the basis of knowledge about the surrounding world recorded in one's memory" [6-p90]. The player's specialist knowledge combined with the experience acquired during competitions, leads to the improvement of specific perception, enabling effective action in dynamic, constantly changing game situations. According to Naglak [7], without knowledge (information about the action), a player is deprived of "materials" needed for thought processing. Perception is manifested in rapid adoption, processing and evaluation of information relevant to the course of the game via sensory organs, especially sight and hearing [8]. The perception of the situation is based on thinking, the mental activities concerning understanding, prediction, assessment and reasoning.

The player, being in dynamic game situations, strives to achieve the intended goal via the performance of conscious actions by making decisions. The player makes his/her decisions based on the information coming from the game infield in terms of the purpose of the action, experienced emotions, which means that decisions can be both effective or ineffective, neutralizing the favourable state of the game [7]. If, during the game, the player consciously solves the tasks in accordance with the knowl-
An attempt was made to demonstrate how mental impact affects the performance of a motor activity. Correlations were sought for creative transfer, which in the assumptions of the research objectives, was done to determine the influence of thought processes on the efficiency of movement activities of players at various levels of training (children, adolescents, adults). In hypothetical deliberations, it is believed that better recognition of the mental sphere can significantly increase the effectiveness of player preparation in organized training.

**Study aim**

The research issue refers to intellectualization of the training process in sports games. These issues in the theory of training are quite widely known, but in practice, they are treated as a "slogan". In present training, the mental sphere is still underestimated in the player control process.

The aim of the study is to show the influence of conscious analysis of a motor task among footballers on the efficiency of their performance, and on the basis of the importance of thought processes in the efficient performance of movement tasks, setting directions for creative teaching in sports games as an effective way of teaching technical and tactical activities. These research problems are innovative because demonstrating the importance of thought processes for efficient operation and the indication of directions of control and shaping these processes in specialized creative exercises may not only modify the current concept of teaching methodology in sports games, but also significantly improve the process of training players in sports and pro-health aspects.

Taking this into account in the research procedure, the following research questions were posed:

1. Does the process of mental control have a positive effect on a player’s performance?
2. Is training experience decisive in the effectiveness regarding the reception of creative instruction?
3. What parameters should be included in the methodology of shaping creativity for sports games?

**Research hypotheses:**

1. The conscious participation of a player in movement activity increases the effectiveness of carrying out the objective of the game.
2. The development of creativity in sports game players requires specific selection of measures taking analysis of the situational character of an action into account.

**Study material and methods**

The study group comprised randomly selected football players from three age categories:

- Youngsters – 1st county league (32 individuals)
- Juniors – Inter-Voivodeship league (32 individuals)
- Seniors – 4th and 3rd league (32 individuals)

A total of 96 football players were examined in so-called continuous research, which was conducted in 2012–2017. In the organized selection (homogeneous groups in movement action skills), they were divided into an experimental and control group (50% of individuals in a given age category).

In the research process, the creative method along with didactic creative instructions were used in the perfor-
mance of movement actions [3, 10], based on their conscious analysis. The makings of greatest importance for a future championship regard the ability to score points. The player’s attitude towards scoring points makes him/her active (mobile), so s/he is constantly looking for opportunities to achieve the objective of the game. In turn, the biggest difficulty in achieving the game objective is to obtain points (goals, baskets) [1]. Taking this into account, the selection of the task in the implementation of the research objectives concerned the nature of the movement activity and the goal of the game, hence, the choice of action included the objective of the offence game – goal scoring.

In the research, the so-called test of creative activities – movement test was used, which included supporting activities (not subject to evaluation): ball reception, slalom sprint and the main action (subject to evaluation), i.e. the effectiveness of kicking the ball into the goal in the presence of the goalkeeper (scoring a goal). Relevance of the test used is \( r = 0.89 \) [10]. This value, according to Brzeziński’s assumptions [11], meets the requirements for experimental research.

The test was carried out in the penalty area of the football field (Fig. 1), where the participating players performed the action in a designated sector at a 45 degree angle, the peak of which is at the midpoint of the goal.

In this sector, the following were designated:

- the area of goalkeeper’s action in which s/he moves along the bisector of the angle from the goal line towards the corner of the goal area (section length: 6 m); at this height, the goalkeeper assumes a passive defensive position (RH, right hand – to the side, LH, left hand – covering the face) – for actions on the left side of the goalpost;
- the area of action of the tested player, who is in the designated sector, in the zone between 8-7 m (distance from the end line of the goalkeeper’s sector); in movement activities, s/he has to perform an effective kick towards the goal.

When the striking player passes the starting line in his/her sector, the goalkeeper was able to perform only one intervention: a defensive exit with passive defensive position (Fig. 1). In defensive actions (goalkeeper-striker), there was no direct contact. The strictly defined intervention of the goalkeeper in repeated attempts fulfilled the condition of "identical event" [10]. The test participant (the striker), exceeding the starting line of his/her sector of activity, was to achieve the objective, i.e. score a goal. This activity was rated as positive (scored goal) or negative (no goal scored) [12]. Earlier, the striker during a specified part of the test, in reception of the ball, introduces it into the action sector. These activities are not evaluated, they are only so-called activities adaptive to operation.

The tests were carried out twice. The first, so-called control test, was carried out without creative instructions improving operation. It was performed on randomly selected players. The second test was repeated among the same individuals after 3 days. As a result of organized selection (based on rankings from the first examination), the participants were divided into groups: E – experimental and C – control. The study was based on the implementation of an identical motor task as in the first study. However, in group E, the test was preceded by creative instructions to improve the operation (but without feedback).

The instruction – “observe the goalkeeper – strike effectively”, was based on effective action directives (detailed explanation before the given “queue of kicks” included: evaluation of the situation (positioning the goalkeeper, analysis of his/her movement), the moment and way of striking the ball (distance from the goal, angle of attack, strength of impact, technique of impact)).

These activities were aimed at activating the mental sphere of the player in this activity. In the research activities, confirmation of the fact that mentalization and activation of the mental sphere in action took place, is the value of the differentiation of results obtained in two homogeneous groups (E and C) in the first and second tests. To compare the obtained results, basic statistical calculations were performed: standard deviation, arithmetic mean, and the Student’s \( t \)-test will determine the significance level of differences [13]. Verifying the hypotheses, a significance level of \( p < 0.05 \) was assumed.

**Study results**

Undertaking research in the assessment of the didactic effect of creative instruction on the efficiency of movement activity among the tested players, an attempt was made to answer the question: does the transfer of creative information favourably affect the efficiency of movement? In order to answer the question posed, in the experimental procedure, the evaluation of the players’ performance was subjected to research analysis, the performance of which required not only skills in motor activities but, above all, conscious analysis for the performance of a movement task. According to Szewczuk [14], Panfila [12] and Duda [15], such a psychophysical state is readiness to act effectively when carrying out a specific type of task, with the possibility of adapting to changing conditions. Taking this into account in the selection of actions in the research procedure, it was necessary to perform such a task that would require not only great emotional engagement (goal scoring), but above all, a high level of thought advancement (creative activity). Such an assumption results from the operational goal of educating a player [4], which assumes that effec-
Influence of creative information transfer... 

tive action in achieving the objective of the game requires not only appropriate movement skills but also an optimal emotional attitude (willingness to perform exercise) and, above all, conscious motor control (internal action) [1]. Therefore, for research purposes, this was based on the performance of a task, which concerned carrying out the highest objective in offensive operation, i.e. scoring goals [12]. These activities took the requirements for creative action into account, i.e.: solving the movement task, maximally similar circumstances to playing conditions and a practical directive on the effectiveness of the task - but with the option of choosing decisions on how to act. In order to successfully perform the entrusted tasks in the experimental study, the player had to assume a creative attitude in action. Also, the specific objective of the task (scoring a goal) was the motivational factor (willingness for self-evaluation) in achieving the highest aim of the game in offensive action.

Thus, the experimental task in the study required a creative attitude, because its participants, based on effective guidelines in action, independently influenced the course of implementing the set goal. Analysing the results of research within the aspects of intellectual control of the players' physical activities, the rational values of the effectiveness of goal strikes were performed in the first attempt of the experiment (so-called habitual action) - the 1st examination.

These activities were conducted in two experimental and control groups for players in three age categories: youngsters, juniors and seniors (Table 1-3).

The selection of players for three categories was aimed at determining the impact of creative information, assessing the level of mental control depending on age, experience in action and the level of habitual movement development in the player's action. In the research assumptions, analysis of the players' activities not only determines the level of transfer of creative instructions to smooth action of the player, but it additionally determines the degree of a player's vulnerability to intellectual control.

Analysing the first test conducted in three training groups of football players' (youngsters, juniors, seniors), it should be noted that in the spontaneous, so-called "habitual" action in selected groups, no significant changes were found in activity. The obtained values do not show differentiation on a statistical level (Tab. 1-3). For research purposes, such a state is advantageous, as it indicates regularities in the selection of random and targeted samples for the groups studied in the conducted experiment [16].

Interesting research results can be noticed during the second examination (Tab. 1-3). Analysis of data shows that the impact of creative instruction transfer is significant (has statistically significant value) and occurs in three training categories. This fact confirms not only the significance of mentalization in the player's process of action but also indicates that this process is carried out at every stage of training.

Significant relationships can be observed when analysing the results obtained for the first and second tests in the studied groups. In the detailed analysis of this process, it can be noticed that for the youngster category, there is a low level of established motor behaviours [17]. It seems that the youngest of the surveyed groups were willing to analyse the situation (the highest goal rate). In the junior and senior categories, these values were slightly smaller (the 1st test), and also in the second study, it can be seen that the score rate in the juniors and seniors was slightly lower than in the youngster group. This statement is surprising, because it may indicate that professional training weakens the effectiveness of movement. However, in deeper analysis of the achieved

Table 1. Differentiation values in the creative test of the player's activities for the first level of research – the "youngster" category

<table>
<thead>
<tr>
<th></th>
<th>Examination I</th>
<th></th>
<th>Examination II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group</td>
<td>Experimental group</td>
<td>Control group</td>
<td>Experimental group</td>
</tr>
<tr>
<td>Arithmetic mean</td>
<td>2.250</td>
<td>2.333</td>
<td>2.667</td>
<td>3.500</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.965</td>
<td>0.888</td>
<td>0.622</td>
<td>1.087</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>42.903</td>
<td>38.041</td>
<td>22.603</td>
<td>31.060</td>
</tr>
<tr>
<td>Significance of differences between groups</td>
<td>0.828</td>
<td></td>
<td>0.033*</td>
<td></td>
</tr>
<tr>
<td>Level of significance between examination I and II in the given group</td>
<td>0.096</td>
<td>0.000***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
experimental effects, it seems that we are dealing with the process of shaping a physical habit, closed off when not using a creative training method, which together with the training experience (older groups: especially the senior group, where the lowest values for the second exam were also obtained), can be solidified. This process is unfavourable for sports games [1], as it can consolidate the mechanical ways of performing actions. The obtained effect in the experimental study is consistent with the studies by Basiaga-Pasternak [18] and Birch et al. [17], who confirm that in children, due to the lack of formation of motor habits, there are large reserves for the transfer of perception.

According to the goals of experimental research, we can also see interesting results in the second study, in which creative instruction was used in the experimental group (Table 1–3). The analysis of data shows that in the three studied groups: youngsters, juniors, seniors (children, adolescents, adults), a characteristic pattern was observed in the experiment. Statistically significant differences were obtained for experimental groups. This fact indicates that there is a high level of transfer for creative instruction that measurably translates into the effectiveness of performing a task in the action of a football player. It seems that such a state results from the essence of sports games, in which the situational nature of a game requires conceptual action (perception, analysis, decision) [1]. Also within the concept of experimental research, the essence of creative information transfer was sought. It seems that the state of mental stimulation seems to be most important in this aspect [4], where it has been proven that in motivation to act in the game, a creative attitude can have significant impact on a player’s effectiveness. Also, the transfer of knowledge about the operation – which was characterized by the applied experimental activities – could significantly affect more
Influence of creative information transfer... effective performance of tasks in the player's operation for the experimental group. In this aspect, Superlak [19], Duda et al. [2] and Duda and Brzyski [20] may confirm this status, verifying the importance of knowledge in the smooth performance of a player in sports games. Taking the results above into account, it can be stated with great certainty that mental processes are of great importance in the actions performed during a sports game. However, in order to fully carry out the objectives of research, which may significantly confirm the importance of thought processes in effective multi-entity operation (the level of creative information transfer), comparison of the test results in the control and experimental groups was conducted for the first and second tests.

From analysis of data contained in Tab. 1-3, it can be seen that similar values were obtained in all study groups. In the control groups, a low increase in the effectiveness of activities was noted, while in experimental groups (for all age categories), a significant increase was obtained - statistical significance was at a high level. These regularities underline the significant importance of mentalization in the processes of sports game operation. These results are consistent with earlier studies among volleyball players [19], handball players [21] and footballers [21]. These facts clearly confirm that mentalization in the process of training for sports games is significant, hence, taking into account its importance, it should particularly be considered in the training process, not only for older players but also the youngest who have a high-level knowledge acquisition about the game. These activities undertaken for effective training should include not only creative training measures [4], but they should also shape the player’s reflexivity in practice (analysis, alternative decision-making, self-assessment) [15].

The obtained research results emphasize the essence of sports games, which are of tendentious actions in nature [9]. Indeed, multi-entity type activities must be carried out deliberately. Research observations also confirm the didactic appropriateness that should apply to learning the game. This regularity indicates that if the game is to be learnt effectively, one should first learn when and how to act, and then what motor skills to use for these purposes [1]. Considering the fact that the intellectualization of the teaching process in sports games regarding the everyday training of a player is treated as a “slogan” [7, 12, 15], the research carried out, confirming the importance of mentalization in training, strengthens the essence of this issue, appointing the direction of effective activities in the process of teaching sports games.

Conclusions:
1. The effectiveness of movement activity requires understanding of cause-and-effect relationships.
2. Mentalization of the training process increases the effectiveness of players’ movement activity.
3. Mental processes in movement activities should be developed and shaped at all stages of a football player’s education.
4. Due to the equivalent nature of action in team sports games, reserves in the sphere of players’ mental disposition should already be sought out from an early age.

References:
[12] Panfil R: Prakseologia gier sportowych, Studia i Monografie. AWF Wrocław, 2006; 82.

**Author for correspondence:**

Henryk Duda
E-mail: hendud@wp.pl
DIFFERENTIATION OF PHYSICAL FITNESS IN POLISH ELITE SPORTS JU-JITSU ATHLETES

Physical Fitness in Elite Ju-Jitsu Athletes

Tadeusz Ambroży 1 ABCDEFG, Katarzyna Sterkowicz-Przybycień 2 ACDEFG, Stanisław Sterkowicz 1 ACDEFG, Andrzej Kędra 3 ABDEFG, Dawid Mucha 4 ACDE, Mariusz Ozimek 5 EFG, Dariusz Mucha 6 ABDEFG

1 Department of Theory of Sport and Kinesiology, Institute of Sport Sciences, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Poland
2 Department of Gymnastics and Dance, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Poland
3 Doctoral Studies, University of Physical Education in Krakow, Poland
4 Institute of humanities, social sciences and tourism, Podhale State College of Applied Sciences in Nowy Targ, Poland
5 Department of Track and Field Sports, Institute of Sport, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Poland
6 Department of the Biological Renovation and the Correction of Defects of Attitudes, Institute of Biomedical Sciences, University of Physical Education in Krakow, Poland

Key words: cluster, combat, Ju-jitsu, competition, physical fitness, condition, norm, test

Abstract

Aim. Ju-jitsu athletes are expected to reach competitive readiness adequate for the demands of tournaments. Apart from technical expertise, one of the aspects of readiness is general and special preparation. This is critical to the athlete's level of achievement since it helps him or her cope with the training load as it is linked to mental preparation and ensures that the athlete uses technical and tactical variants more accurately during a fight. The cognitive aim of this study is to characterize fitness preparation of top athletes from the Polish Ju-jitsu Association. The practical aim is to identify talented athletes who can become members of national teams participating in international tournaments.

Basic procedures The study evaluated 29 national Ju-jitsu team members in the preparation period (pre-competition mesocycle), who expressed their interest and consent to participate in the experiment. 13 of these athletes were listed in the Ju-jitsu International Federation ranking, including 3 medalists in the World Championship in Wrocław, Poland (2016). 13 tests of general physical fitness were performed by means of selected tests from the Eurofit test battery, the ICSPFT tests and additional strength tests. 8 special physical fitness tests were also used. The results were described using cluster analysis and comparison of fitness profiles.

Results and main findings. The differences between three clusters in general physical fitness were noticeable in the performance of pull-ups (1 < 2 and 2 > 3 clusters), the Cooper test (1 < 2 and 1 > 3 clusters), the shuttle-run test (1 > 2 and 2 < 3 clusters),
Conclusions The studied athletes were characterized by high differences in fitness-related readiness level. Their profiles in 3 clusters show that some athletes in the national level group match top athletes at the international competitive level in these terms. Analysis of individual profiles allows for effective diagnosis and classification while revealing strengths and weaknesses in the fitness preparation of Ju-jitsu athletes. Therefore, it should be used for testing and monitoring modifications over the training cycles. Knowledge of the structure and the data on baseline physical fitness and special fitness in elite athletes may be useful for the development of individual training programmes for Ju-jitsu athletes.

Introduction

Ju-jitsu as a martial art emerged from two famous schools: Daito-ryu (12th century) and Takenouchi-ryu (16th century). The Kito—ryu and Tenshin-Shinjo-ryu schools in the Edo/Tokugawa era (1603-1868) paved the way for the evolution of the Randori practice, used later in Kodokan Judo (1882). In those days, Kodokan Judo was considered a modification of Ju-jitsu [1]. This martial art of a Japanese samurai, used to capture enemies or eliminate them, gave rise to such sports as Judo [2], Brazilian Ju-jitsu [3] and sport Ju-jitsu that includes the four forms of sport competition: duo demonstration, duo show, Ne waza and the fighting system of the Ju-jitsu International Federation [4]. Our study intends to characterize the adequate level of fitness-related readiness of top contestants who participate in fighting tournaments. Therefore, we found it indispensable to present a brief description of this combat sport convention, including three phases and taking up to 3 minutes or even longer (Fig.1).

As results from the analysis of the fighting regulations specified by the Ju-Jitsu International Federation, the fighting system is characterized by intensive bouts

![Figure 1. Schematic diagram of Ju-jitsu fighting](image-url)
of exercise separated by short periods of rest (Ju-jitsu International Federation www.jjif.org). After the Hajime! verbal command, the fight starts at the first phase in a standing position. The contestants perform punches and kicks (both single and combinations) in order to score points that give them the advantage over an opponent. The points can be scored in both attack and counterattack. The second phase starts at the moment the athlete holds the opponent. Punches and kicks are forbidden during this phase (except for the initial hold). In this phase, opponents strive to perform efficient throws on the square fighting area with dimensions of 8 x 8 m. The thrower must start performing the throw while on the fighting area. The receiver can fall on the external safety area (2 m in width) if it is secure for the athlete. If the opponents are kneeling on both knees or one of them is sitting or lying on the mat, the fight is continued in the third phase.

The athletes can move to other phases of the fight but they have to be active in all the parts. If, in the first phase, the athlete only moves towards the opponent without performing any technique or the activity is insecure for himself/herself, s/he are punished by Shido technical penalty and the fight is continued from the first phase. After completion of the fight, the referee announces the winner (point advantage). The Hajime! command is used to begin the fight and resume it after the Matte! command. The referee announces Matte! to stop the fight in the following cases: if in the first or the third phases one or both athletes are completely outside the fighting area; if, in the third phase, both contestants are completely outside the fighting area; to announce the penalty for one or both contestants; if one or both contestants are injured or taken ill; if one of the contestants is unable to signal submission by him/herself; during a strangulation or a lock; if the Osae-komi pin time is expired; if, in the second or the third phase, the contact is lost between the contestants and they do not continue the fight in the first phase. The referee uses the Sono mama! command to temporarily stop the fighters to give one or both contestants a warning for being passive or announce penalty points for one or both contestants. After the Sono mama! command, the athletes remain in the same position as they were the moment the fight was stopped. The fight is resumed by the referee announcing the Yoshii! command.

Points during the fight have to be scored by the majority of indications by at least two of three referees. If three referees indicate various scores, the intermediate score prevails. If one of the referees did not see the action, the lower of the two remaining scores prevails. In the first phase, points can be scored for punches, strikes and kicks (unblocked punches, strikes or kicks \(Ippon = 2\) points), partially blocked punches, strikes or kicks \(Wazaari = 1\) point). In the second phase, the points can be given for throws, take-downs (transition actions), locks and strangulations (if the contestant cannot tap out by him/herself to signal submission and the referee has to stop the fight by announcing the Matte! command \(Ippon = 2\) points), strangulations and locks with tapping \(Ippon = 2\) points), a perfect throw or take-down \(Ippon = 2\) points), an imperfect throw or imperfect take-down \(Wazaari = 1\) point). During the third phase, the points can be given for efficient holds, locks and strangulations (strangulations and locks with tapping the mat twice; if the contestant cannot tap the mat twice by him/herself and the referee has to stop the fight by announcing Matte! \(Ippon = 3\) points), efficient hold announced by Osae-komi! lasting 15 seconds \(Ippon = 2\) points), and lasting 10 seconds \(Wazaari = 1\) point). The lightly forbidden acts during the fight are punished by Shido and the opponent is given Wazaari. The forbidden acts are punished by Chui (the opponent scores 2 Wazaari). In the case of two forbidden acts, the fight is lost by announcing the Hansoku-make! command. The contestant can win the match before the end of fighting time if s/he scores at least one Ippon in each of the three phases of the fight. This is announced as a Full Ippon. In this case, the loser scores 0 points and the winner gets 50 points or, the number of points s/he has already achieved if the number is higher than 50 points. After the time has expired, the contestant who scored the most points is announced the winner. If the competitors scored equal number of points after this time, the contestant with at least one Ippon or more in different parts of the fight wins the match. If, after the standard time, the score and number of techniques that scored Ippon is equal, an additional 2-minute round is announced until the fight is settled. A 1-minute break is used between the additional rounds. Therefore, this situation can be repeated. The scores, Ippons and penalties from the initial round are transferred to the additional round (Ju-jitsu International Federation www.jjif.org).

Based on observation and analysis of fights during Junior Ju-jitsu World Championships (Bucharest 2013), it was found that the most frequent hand techniques used in the first phase include punches \(gyaku-tsuki\), \(hai-to-uchi\) and \(uraken-uchi\), whereas the kicks were: \(yoko-geri\), \(mawashi-geri\) and \(mae geri\). In the second phase of the fight, hand techniques were most frequent (i.e. \(morote gari\) and \(seoi nage\)) and foot and leg techniques (i.e. \(osoto gari\), \(osoto otoshi\), \(uchi gari\)) rather than hip techniques (i.e. \(goshi guruma\), \(harai goshi\), whereas in the third phase, more frequent techniques included pinning compared to joint locking and choking techniques [5]. This comparison and previous analyses revealing correctness of the fight [6, 7] show that the first part of the match in the Ju-jitsu fighting system is similar to Ka-
rate, whereas the second and the third phases are more alike a Judo fight [8, 9].

In the opinion of instructors, the greatest effect on the model of athlete readiness is from technical and tactical (31.3%) and physical preparation (including body build and physical fitness, 28.4%). Lower contribution is from theoretical (25.5%) and psychological (14.8%) preparation. According to experts, on average, 5 years is needed to achieve a black belt [10]. Undoubtedly, Ju-jitsu athletes are expected to reach the readiness adequate for the demands of tournaments. Apart from technical expertise, one of the aspects of readiness is general and special preparation. This is critical for the athlete’s level of achievement since it helps him or her cope with the training load as it is linked to mental preparation and ensures that the athlete uses technical and tactical variants more accurately during a fight (both during competitions or training sessions).

The feedback between training and tournaments is provided by periodical and ecological (performed in the athlete’s natural environment) physical fitness testing [11]. Seeking the relationships between the level of fitness preparation and athletes’ achievements using cluster analysis has been successful in such combat sports as Karate [12], Judo [9] and Ju-jitsu [8, 13]. The following hypotheses will be verified based on the examinations planned in this study:

H1. The specific physical fitness that is needed for competition is developed over many years of Ju-jitsu training.

H2. The level of sports achievement is likely to be linked with the profile of fitness preparation.

H3. Some athletes who compete at lower levels are characterized by a fitness level similar to those competing at higher competitive levels.

The cognitive aim of this study is to characterize fitness preparation of top athletes from the Polish Ju-Jitsu Association. The practical aim is to identify talented athletes who can become members of national teams participating in international tournaments.

Material and Method

The study evaluated 29 national ju-jitsu team members in the preparation period (pre-competition mesocycle), who expressed their interest and consent to participate in the experiment. 13 athletes were listed in the Ju-Jitsu International Federation’s ranking (www.jjif.org), including 3 world medal winners in the World Championships in Wroclaw, Poland (2016). This research project was approved by the Research Bioethics Commission (Regional Medical Chamber in Kraków, Poland, No. 42/KBL/OIL/2015). The age and sports experience of study participants was $23.41 \pm 1.92$ years and $5.1 \pm 1.39$ years, respectively. They performed training sessions from 6 to 10 times a week, each session taking from 1.5 to 2 hours. Furthermore, apart from the above data derived from a standardized sports interview, the respondents claimed that they preferred only throws during the fight. They were included in a group of hand techniques (seoi nage, tai otoshi, soto makikomi, su-kui nage, daoshi), throwing from a lying position (tani otoshi, ura nage, tawara gaeshi, kani basami), hip techniques (o goshi, goshi guruma) and foot and leg techniques (uchi mata, osoto gari, ouchi gari, kouchi gari, kosoto gari, de ashi barai).

The study participants competed in five weight categories, i.e. up to 69 kg (n=5), up to 77 kg (n=6), up to 85 kg (n=8), up to 94 kg (n=7) and over 94 kg (n=3). Mean body height of the participants was $181.03 \pm 4.72$ cm, with the body mass of $83.57 \pm 10.71$ kg. Body height was measured using the Martin-type anthropometer. Body mass was measured by means of the Beurer glass diagnostic scale, type BG17, max. 150 kg, d=100 g (Beurer GmbH Germany, limited edition 2010).

Fitness testing

Comprehensive physical fitness was tested using selected components of the Eurofit test battery. The first day of tests: maximal static strength (in kgf) of dominant hand (HGSmax) was evaluated using a handgrip dynamometer (USSR); explosive strength: standing long jump (SLJump in cm), body trunk strength: dynamic sit-ups (Sit-ups in reps), speed: shuttle run (shuttle run in sec) and plate tapping (time of 25 cycles performed in sec), flexibility: sit and reach test (S-RT in cm), overall balance: the flamingo balance test (number of falls [n]) [14]. The second day of tests: the ICSPFT test: relative strength of hands and shoulders: pull-ups on a bar (number of pull-ups)[15], the Cooper test: continuous run for 12 minutes (in m)[16] and additional strength tests1 (the third day of tests):

- bench press with weight equal to the mass of the individual performing the exercise (BP expressed by the number of repetitions);
- conventional barbell squat with the load equal to body mass (CS expressed by the number of repetitions).

---

1 These tests were implemented as additional since weight categories are used in combat sports and the success is often determined by the relative strength i.e. the ratio of the absolute strength to body mass. We used the bench press and squat not as tests but as lifts used in powerlifting. Our examinations were performed not based on the measurement of 1RM but on the number of repetitions with the load equal to the participant’s body mass.
Aerobic capacity was measured using the graded aerobic endurance test [17]. The test evaluated VO2max (ml/kg/min) and the level of the second ventilatory threshold (VT2). The test was performed using a mechanical treadmill (Saturn 250/100R, h/p/Cosmos, Germany). The exercise started with a 4-minute warm-up performed at the speed of 8 km·h⁻¹, and the treadmill inclination angle of 1°. Next, the running speed was increased by 1.0 km/h every 2 minutes. If the heart rate (bpm) reached the maximal value, the running speed was maintained and the load was increased (every minute) by the change in the angle of treadmill inclination by 1°. The test was continued until the athlete refused to continue work due to extreme fatigue. Heart rate (HRmax) during the test was measured by the Polar sport tester (S-610i, Polar, Finland).

During the following week, special fitness tests were also performed (the fourth day of testing) according to the procedures of the SPFT test batteries used in Karate [18, 19], Judo [20, 21] and Ju-jitsu [22]. They included [22]: (1) Hip turning speed test. In the hip turning speed (frequency) test, each athlete had a belt attached over the right hip and, using the fighting position, turned hips to the left. This movement caused tension of the belt held by the coach standing behind the athlete (control) and the participant returned the hip. After the Hajime! (Forward!) command, the participant performed 30 hip turns (the number of belt tension instances was counted). The results were expressed in seconds; (2). Punch speed test. The speed (frequency) of punches was evaluated from the fighting position. Each participant performed a combination composed of two fist punches: left straight punch to the head (Oji seiken jodan tsuki) and right straight punch to the body trunk (Gyaku seiken chudan tsuki), without changing the distance. The targets which the participant performed 30 such combinations (60 punches in total) were held by the other person at a constant height. The time to perform 30 complete combinations of punches was recorded (s); (3). The flexibility test was performed using Mawashi-geri kicks (cm) and the flexibility index = maximum range of kick/body height (cm/cm) was computed. In the flexibility test, the maximal reach (feet kick height) was measured for the roundabout kick (Jodan mawashi geri). Five measurements were performed for the dominant limb and the maximal result was recorded (cm); (4). Rapid kick test. The speed (flexibility) of kicks was evaluated by participants performing 30 Jodan mawashi geri kicks (high roundabout kicks) with the front of the leg towards the target held by the coach. Time measured after the last kick was recorded at the moment of lowering the leg by the study participant to the ground (s); (5) Agility test. During the agility test, the participant followed a zig-zag-shaped route, moving forward on one leg and maintaining the knee of the lifted leg at waist height. Each study participant repeated the 5 m distance 6 times with each 5 m section followed by the change in the movement direction by ca. 180°. Time of covering the distance (s) was recorded; (6). Evasive action test. In the evasive action test, study participants started from the fighting position while moving backwards between the lines at the distance of 8 m from each other. The loop-shaped track between the lines was covered 6 times. Time to perform the test was measured in seconds; (7) Push-ups. They were done with one hand clapping at one second (maximum repetitions – n) [22]; 8. Special Judo Fitness Test (SIFT) [19, 23]. Briefly, the SIFT is divided into three periods (A=15 s; B and C=30 s) at 10 s intervals. During each period, the athlete (tori) being evaluated throws two partners (uke A and B, with distance from each other of 6 m) as many times as possible using the ippon-seoi-nage technique. Both uke A and B should be of similar height and weight as the tori. Heart rate is measured immediately after and one minute following the test. The test has also been presented in visual form [Special Judo, 2015]. This study evaluated the Index in SIFT:

The SIFT index is calculated as follows:

\[ \text{SIFT Index} = \frac{\text{Final HR (bpm)} + \text{HR1 min (bpm)}}{\text{Throws (N)}} \]  \tag{1}

where:

- Final HR – heart rate recorded immediately after the test.
- HR1 min – heart rate obtained 1 minute after test.
- Throws – number of throws completed during the test.

Response to the exercise was recorded by means of a heart rate monitor S-610i (Polar, Finland).

Statistics

Means (X) and standard deviations (SD) were computed after verification of normality of distribution of variables. Structure of physical fitness among top male Ju-jitsu competitors was described using cluster analysis (Ward’s method, Euclidean distance). The input data were individual measurement of qualitative variables obtained during examinations of 29 athletes: Competitive level (I – international, n=13; N – national, n=16) and quantitative variables, such as age, training experience, body height and mass, results obtained during 13 general fitness tests and 8 special fitness tests. The standardized skewness and standardized kurtosis were used to determine whether the sample came from normal distribution. Values of these statistics outside the range of -2 to +2 indicate a significant deviation from normality. 1/Y transformation was used for the flexibility test in order for the distribution of this variable to be closer to
normal distribution. The results were presented as tabular data (means, SD, min-max values). Before cluster analysis, individual results of measurements in fitness tests were standardized to 0, 1 based on the data collected in the entire group of study participants. Next, the division into three clusters was made and their profiles were developed. The coefficient of profile similarity was used for the comparison by applying the formula [24]:

$$r_{ps} = 2*(S/T - 0.50)$$  \hspace{1cm} \text{eq. 2}

where:

$S$ – sum of corresponding profile segments which exhibit similar slope. $T$ – total number of profile segments making up a profile.

In the interpretation of the results, performance of test tasks was interpreted as worse if they took longer, more falls were recorded during the Flamingo balance test and the value of the 1/Flexibility Index and SJFT Index were higher. Statgraphics Centurion v.17 software was employed for all descriptive statistics.

Results

The test results and the effect of grouping athletes in three clusters were illustrated in Fig. 2 and Tab. 1.

Differences in the thirteen tests of comprehensive physical fitness were pronounced in six of them: pull-ups (1<2 and 2>3 clusters, No. 3), Cooper test (1<2 and 1>3 clusters, No. 5), shuttle-run test (1>2 and 2<3 clusters, No. 7), sit-and-reach test (2<3, 2<1 clusters, No. 9), maximal hand-grip-strength test (1>3 clusters, No. 10), Flamingo balance test (1-3 and 2-3 clusters, No. 11). Of the eight special physical fitness tests, substantial differences were observed for speed punches (1>2 clusters, No.15), 1/Flexibility Index (1>3 cluster, No. 16), evasive actions (1<3, 2<3 clusters, No. 19), push-ups (1>2 and 1>3 clusters, No. 20).

Cluster 1 (n=10, left side of the dendrogram, see Fig. 2) contains 6 athletes from group I, including two finalists of the 2016 World Championship (No. 7 and 8) and 4 athletes from group N. First relationships were observed between the athletes from group I (1 and 7), and I and N (9 and 28, 4 and 23, 6 and 27). Compared to the two remaining clusters, these participants (cluster 1), were characterized by the best level of results in pull-ups (Index No. 5), HGSmax (Index No.10), HRmax (Index No.13), Rapid kicks (Index No.17), Evasive actions (No. 19) and Push-ups (No. 20). They also demonstrated the worst quality of performing the shuttle-run test (No. 7), 1/Flexibility Index (No. 16) speed punches (No. 15), and Agility tests (No. 18).

Cluster 2 (n=10) was comprised of 4 athletes from group I (including bronze medal winner in the 2016 World Championships, No. 10) and 6 athletes from group N. The first links were found between the characteristics of the representatives of group I illustrated on the dendrogram (see Fig.) (No. 11 and 13, group N) (No. 15 and 20, 16 and 22) and groups I and N (bronze medal winner (No.10 and No. 19, respectively). The fitness profile of
Table 1. Results of testing athletes included in Polish national team training

<table>
<thead>
<tr>
<th>Index/Variable</th>
<th>Cluster 1 (n=10)</th>
<th>Cluster 2 (n=10)</th>
<th>Cluster 3 (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\bar{x})</td>
<td>SD</td>
<td>Min- Max</td>
</tr>
<tr>
<td>1. BP (reps)</td>
<td>7.50</td>
<td>3.03</td>
<td>3-12</td>
</tr>
<tr>
<td>2. CS (reps)</td>
<td>22.10</td>
<td>2.23</td>
<td>19-27</td>
</tr>
<tr>
<td>5. Cooper (m)</td>
<td>3004</td>
<td>145.24</td>
<td>2800-3210</td>
</tr>
<tr>
<td>7. SLR (s)</td>
<td>12.82</td>
<td>0.52</td>
<td>11.45-13.17</td>
</tr>
<tr>
<td>8. PT (25 cycle in sec)</td>
<td>12.64</td>
<td>0.79</td>
<td>11.71-14.20</td>
</tr>
<tr>
<td>9. S-RT (cm)</td>
<td>17.40</td>
<td>4.79</td>
<td>11-25</td>
</tr>
<tr>
<td>10. HGSmax (kgf)</td>
<td>53.80</td>
<td>4.98</td>
<td>46-60</td>
</tr>
<tr>
<td>11. Flamingo (n)</td>
<td>5.4</td>
<td>1.84</td>
<td>3-9</td>
</tr>
<tr>
<td>12. VO2max (ml/kg/min)</td>
<td>52.31</td>
<td>3.858</td>
<td>48.08-58.67</td>
</tr>
<tr>
<td>13. HRmax (bpm)</td>
<td>188.4</td>
<td>4.719</td>
<td>181-197</td>
</tr>
<tr>
<td>14. Hipt (s)</td>
<td>12.16</td>
<td>0.82</td>
<td>11.03-13.76</td>
</tr>
<tr>
<td>15. Punches (s)</td>
<td>12.54</td>
<td>0.8429</td>
<td>11.29-13.80</td>
</tr>
<tr>
<td>16. Flexibility Ind</td>
<td>1.05</td>
<td>0.05</td>
<td>0.97-1.12</td>
</tr>
<tr>
<td>17. Kicks (s)</td>
<td>19.02</td>
<td>0.77</td>
<td>17.09-20.56</td>
</tr>
<tr>
<td>18. Agility (s)</td>
<td>16.59</td>
<td>1.202</td>
<td>14.8-18.3</td>
</tr>
<tr>
<td>19. Agility (s)</td>
<td>42.3</td>
<td>0.6346</td>
<td>41.32-43.24</td>
</tr>
<tr>
<td>21. SJFT Index</td>
<td>14.6</td>
<td>1.179</td>
<td>12.39-16.41</td>
</tr>
</tbody>
</table>
study participants is characterized by the best results in the shuttle-run test (Index 7), the plate tapping test (Index 8), hip turns (Index 14), speed punches (Index 15), similarly to the high level of performance in the evasive actions test as in cluster 1 (Index No. 19). The poorest results concerned performing the following tests: Sit-and-reach (No. 9), Flamingo balance (No. 11), HRmax (No. 13), Rapid Kicks (No. 17).

Cluster 3 (n=9, right side of the dendrogram, see Fig. 2) contains characteristics of 3 athletes from group I and 6 from group N, with the first connections occurring between fitness profiles of athletes from class I (No. 12 and 29) and N (No. 14 and 18, 21 and 24) (Fig.2). In this profile, the best results were found for: the bench press test (Index No.1), plate taping (No. 8), Sit-and reach test (No. 9), Flamingo balance test (No. 9), hip turns (No.14), 1/Flexibility Index (No. 16), push-ups (No. 20), SJFT Index (No. 21). The worst results compared to other clusters were recorded for the classic squat (No. 2), pull-ups (No.3), sit-ups (No. 4), the Cooper test (No. 5), HGSMAX (No. 10), VO2max (No.12), Rapid kicks (No. 17) and Evasive actions (No. 19).

Fig. 2 illustrates similarities and differences between profiles. Comparison of the configuration of fitness profiles between three clusters demonstrated a very low level of similarity (cluster 1 vs. cluster 2 rps = -0.52; cluster 1 vs. cluster 3 rps = -0.24; cluster 2 vs. cluster 3 rps = -0.32).

Discussion

The major achievement of this study was demonstrating the internal differentiation in physical fitness of top Ju-jitsu athletes. We found that the athletes who competed at an international competitive level (group I) occurred in all three clusters. Their fraction, however, decreased in consecutive clusters. World championship medal winners were found in the cluster 1 (two) and cluster 2 (one athlete) with not only athletes from group I, but also those competing at a national competitive level (group N), who had similar fitness profiles. These athletes from group N who were present in clusters 1, 2 and 3 met the fitness-related criterion of inclusion into the national team.
Examination of muscle strength in Judo, which is a sport representing an important component in terms of techniques used in Ju-jitsu, demonstrated that many years of training leads to the development of a specific topology of muscle groups responsible for performing specialized movements i.e. using techniques during a fight [25]. Our previous study [7, 26] showed that preparation of Ju-jitsu athletes requires substantial work of the arms, shoulder girdle and the back. The best results in strength tests connected with overcoming body mass were achieved by athletes located in cluster 3 (bench press) and cluster 1 (classic squat). This organization of the results may point to a dominant role of the upper limb strength in the high level of achievement in the sport of Ju-jitsu since most elite athletes were found in clusters 1 and 2. This tendency may be an indicator for the method of preparation of athletes over the last several years. This finding is also reflected by the results of upper limb strength tests (pull-ups), with the best results obtained by athletes in cluster 2. Dynamic changes in body position and arm flexion that are often observed in Ju-jitsu matches, using two planes of movement, can be categorized as plyometric training, characterized by the work that extends muscle fibres (eccentric work) and a dynamic phase of contraction (concentric work) [27]. The best results in the explosive strength tests of athletes can be observed in the cluster 1. Integration of various exercises of explosive character of the movement into the training process may lead to improvement in speed at the initial phase of the movement in a technical action during a fight and the dynamics of the upper and lower limb movement [28]. Our own study demonstrated the critical importance of upper and lower limb and the trunk explosive strength in the physical fitness of Ju-jitsu athletes since the best results in the standing long jump and push-ups with one hand clapping and the abdominal muscle strength test were achieved by elite athletes who were present in cluster 1.

Blais et al. [29] emphasized that strength training oriented via the choice of adequate exercises in the training programme should mimic the movements performed by contestants on the mat. Furthermore, training stimuli should match the temporal profile of the fight and the required muscle strength. Meeting these assumptions should be reflected in the SJFT results. It is worth noting that the most popular [6, 7] throws i.e. morote seoi nage and ippon seoi nage are numbered as hand throws termed Te Waza [2]. Despite this classification, it is most likely that lower limb involvement in the throw performed by the athlete is substantial [30]. This type of throw belongs to physical lever-type throwing techniques applied with the variable arm (fulcrum from uke’s waist to his knees) in the biomechanical classification [31]. Therefore, better results in strength tests (relative and explosive strength) of the lower limbs were observed in the Ju-jitsu athletes in cluster 1. The athletes with higher level of muscle strength can be more efficient during performing a technical task through maintaining greater movement economy, since this leads to the increase in endurance of the athlete during a specific exercise [32, 33]. It is worth noting that the best results in the endurance tests (the Cooper test and the VO_{2max} level) also occurred in the athletes grouped in cluster 1.

In mixed fights, such as Ju-jitsu matches, where the fight can be performed in vertical (the first and the second phase) and horizontal position (the third phase), characterization of exercise intensity is varied since breaks are also used between the work bouts. However, fitness level differentiates between athletes and some results point to the advantage of the elite athletes while others concern the non-elite athletes. Other factors, such as age, training experience, competitive experience [7], and even the level of competitive readiness on a specific day, can have an effect on variation of the fitness level. It is also worth highlighting that success in a sport fight is determined not only by better physical preparation. Important factors are also technical and tactical preparation (ability to distribute exercise over the fight, control over the fight time, control over the point advantage, knowledge about the opponent) and good luck (advantageous drawing of fights or scoring a point in the last second of the fight that settles the results).

The physiological characterization of the threshold values in the process of sport training control allows to find and use the individual (optimal) intensity of the loads that lead to the desired responses in the human body, and consequently, to the improvements in aerobic capacity [34]. In training practice, threshold loads are useful to determine intensity of individual training sessions, with the main goal being improvement in the indices at the level of the second ventilatory threshold [35].

The level of aerobic capacity in the studied athletes was 51.36 ± 3.79 ml·kg⁻¹·min⁻¹. In similar sports, the mean level of maximal oxygen uptake was 40.8 ml·kg⁻¹·min⁻¹ (Judoists) [36], 53.8 ml·kg⁻¹·min⁻¹ (Judoists) [37], 63.8±4.8 ml·kg⁻¹·min⁻¹ (boxers) [34], 50.3±5.3 ml·kg⁻¹·min⁻¹ (boxers) [38], 44.13 ml·kg⁻¹·min⁻¹ (kick-boxers) [39] and 58.4 ml·kg⁻¹·min⁻¹ (MMA) [35]. This comparison shows that aerobic capacity in the Ju-jitsu athletes in our study is at an average level compared to other combat sport athletes, with the only significantly higher VO_{2max} levels obtained by MMA athletes. Body build of outstanding Ju-jitsu athletes (with the dominant component being mesomorphy) can be a moderating factor in the susceptibility to training oriented towards the development of aerobic capacity. General somatotype of Polish high level Ju-jitsu players is 2.3-6.1-2.1, which reflects a balanced mesomorph type. In this group, how-
ever, endomorphic mesomorph was dominant (14 of 30 participants), whereas 7 individuals were classified as balanced mesomorph type and 9 as mesomorphic-ectomorph [40]. The meso-ecto and mesomorphic groups, but not endo- group, showed improvements in aerobic capacity following aerobic training [41].

Comparison of the results of other general fitness tests with athletes from other combat sports leads to the conclusion that the athletes did not differ in their fitness level from kick-boxers [42]. Differences were found in the flexibility test to the advantage of Ju-jitsu athletes, but in static strength and endurance, to the advantage of the kick-boxers.

Interesting findings were presented in our earliest study on Ju-jitsu instructors [26]. In the general motor fitness profile (ICSPFT), the best score (73.2 points) was found for body trunk strength (abdominal muscles), with the average of untrained young men =50 and SD =10 pts. Our Ju-jitsu group demonstrated good performance in flexibility (stand-and-reach test, 63.7 points), strength of the hands and shoulders (pull-ups, 63.0 points), and the static strength (HGSmax, 68.5 points). They show worse results in running (the 1,000-metre endurance run, the 4 x 10-m run, and the 50-m run) and explosive strength of the legs, i.e. standing long jump. During the 50-m run, male Ju-jitsu athletes scored only 40.9 points, compared to the average of untrained young men =50 and SD =10 pts. Our Ju-jitsu group demonstrated good performance in the standing long jump (0.592), 1,000-m run (0.780) and shuttle run (agility, r=-0.44), the number of pull-ups (hand and shoulder strength, r=0.50) and the flexibility tests (r=0.41) [26]. Furthermore, the structure of physical fitness based on the ICSPFT test batteries and the number of ippon seoi nage throws were subjected to factor analysis with VARIMAX rotation. Three factors were found to explain 76% of common variance. The greatest weights/loadings in the first factor (49.9%), where the number of ippon seoi nage throws (0.731) was contained, were found for the results of the 50-m run test (-0.812), pull-ups (0.804), standing long jump (0.592), 1,000-m run (0.780) and the flexibility test (0.727). In the second factor (14.4%), the results of the shuttle run test (0.720) and body trunk strength (0.924) could be found, whereas the third factor contained HGSmax (11.9%) [10]. This analysis revealed that strength, speed and endurance supported by the anatomic aptitude of flexibility are conducive to performing a series of ippon seoi nage throws, with their group performance evaluated as good (4pts) [21].

Coaches of each sport would like to have tools for quick and reliable evaluation of athletes. Although the fight is the best test to evaluate the effectiveness of the training process, it is difficult to standardize this type of intermittent exercise. Therefore, additional special fitness tests have been used in combat sports. Their content reflects not only the temporal structure of the fight but also technical and tactical activities typical of a specific sport. The special Ju-jitsu fitness test battery contains Karate and Judo components which are also present in hapkido. Individual level of performance in special fitness tests was examined by two English instructors, outstanding members of the European Hapkido Alliance Demonstration Team. Motor effects of black belt testing were close to the values recorded in Ju-jitsu and Kyokushin Karate instructors, distinguished by 20% advantage in performance of speed punches. Compared to the red belt, advantageous differences for the black belt concerned performance of speed punches, hip turns, rapid kicks and the number of throws [44]. The special fitness test battery turned out to be especially needed during professional preparation of Ju-jitsu coaches who performed the test and were experienced in this respect [22], as well as to control the training effects in athletes from the national Ju-jitsu team [8, 13]. Since no standards have been developed for athletes in this sport, we compared study participants to the normative values created for Karate [19] and Judo athletes [21]. The classification grades were specified based on the performance of male Karate fighters (n=219) and male Judo athletes (n=141). This evaluation is expressed on a five-degree scale: 1 – Very poor, 2 – Poor, 3 – Regular, 4 – Good, 5 – Excellent. Table 2 presents results for experienced male Ju-jitsu athletes.

This study revealed not only pronounced differences between clusters but also between the three medalists, with performance in individual tests ranging from 1 (flexibility index, agility, SJFT Index) to 5 (push-ups). Mean performance in the whole group was similar to previous studies [13], especially in hip turning speed, speed punches (heavyweights, but not in lightweight competitors), flexibility index, rapid kicks (lightweights but not in heavyweights), push-ups and SJFT Index (heavyweights, but not in lightweights). The differences between these two series of examinations are likely to result from the choice of material since in the present examinations, we did not examine the athletes from the heaviest weight categories. In general, the group of athletes in the present study achieved worse assessment than coaches in the tests of hip turning speed, (3 vs. 4 pts), speed punches (2 vs. 4 pts), rapid kicks (3 vs. 4 pts) and better scores concerning the flexibility index (2 vs. 1 pt), agility (2 vs. 1 pt), push-ups (4 vs. 3 pt).
Table 2. The evaluation of control exercise performance by 3 leading competitors, the best and worst different individual performances in the whole group, and averaged results of different male groups

<table>
<thead>
<tr>
<th>Evaluation (pts)</th>
<th>Hip turning speed</th>
<th>Speed punches</th>
<th>Flexibility index</th>
<th>Rapid kicks</th>
<th>Agility</th>
<th>Evasion actions</th>
<th>Push-ups</th>
<th>SJFT Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>This study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp. 1. (23)</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Comp. 2. (20)</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Comp. 3. (20)</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Cluster 1 (20)</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Cluster 2 (23)</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Cluster 3 (20)</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Total group mean (21)</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Total group best (33)</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Total group worst (14)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sterkowicz-Przybycień, Ambroży 2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavyweights (22)</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Lightweights (22)</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sterkowicz-Przybycień 2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coaches (21)</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Comp. – Competitor

and SJFT Index (2 vs. 1 pt). The best performance in the special Ju-jitsu fitness test battery ranged from 3 (agility) to 5 (flexibility index and push-ups), whereas the worst performance was assessed from 1 to 2 pts. Although variation between groups was connected with individual performance of the tests, the total scores ranged from 14 pts (the worst performances of different study participants) to 33 pts (of the best performances in different people).

The results of our study demonstrated differences between group fitness profiles presented in three clusters (Table 1, Fig. 2) and were converted into point scores (Table 2). With five 20-percent ranges used for construction of the tables of normative values, we found that: comparison of cluster 1 shows that 60% of Ju-jitsu athletes are much worse than Karatekas in the number of repeated combinations (speed punches), 20% in rapid kicks, and 80% - in agility, only 20% - in push-ups and 60% - in the special judo fitness test (index). It should be emphasized that the SJFT test provides comprehensive information about the capacity required during the fight [45]: the alactic energy system showed higher (F = 20.9; p < 0.001; power = 1.0) contribution (57.1 ± 11.3 kJ; 28.2 ± 2.9%) and lactic (58.9 ± 12.1 kJ; 29.5 ± 6.2%) energy systems (p < 0.001 for both comparisons). Therefore, coaches evaluate mainly their athletes’ anaerobic alactic system, which can be considered to be the most dominant system contributing to the efficiency of actions (techniques) performed in the match [45]. The number of throws in the test is more related to anaerobic capacity (Wingate test results), whereas the number of throws performed in segment C and the index in SJFT are more related to aerobic capacity (Treadmill test results) [20]. In Ju-jitsu athletes, eight weeks of circuit training with 4 units per week aimed to develop strength and endurance caused an increase in the number of throws but it failed to increase the point scores (1 pt). Furthermore, it substantially reduced the index in SJFT, consequently leading to higher assessments (from 1 pt to 3 pts) [46]. The SJFT duration is 95 seconds and it can be expected that in the second part of the Ju-jitsu fight, aerobic contribution will be dominant. The SJFT test has been used in both scientific experiments and in empirical studies used to control training effects in women and men who practice Judo. Elimination of the Uke resistance led to a higher number of throws (in the form of tandoku-renchu) and...
reduced the index and HR [9]. After a review of the relevant literature, we recommended taking into account and documenting all four components of the SJFT rather than merely index values [23]. The SJFT’s adaptations to Sambo [47], wrestling [48] and kickboxing [49] are also available.

Conclusion

The studied athletes were characterized by high differences in fitness-related readiness level. Their profiles in three clusters show that some athletes from the national level group match top athletes at the international competitive level in these terms. The athletes from group I, whose fitness profiles led to the presence of the athletes in cluster 3, are likely to present a higher level of other aspects of readiness for participation in Ju-jitsu tournaments by compensating deficiencies in the level of fitness preparation.

Practical implications

Analysis of individual profiles allows for effective diagnosis and classification while revealing strengths and weaknesses of fitness preparation in Ju-jitsu athletes. Therefore, it should be used for testing and monitoring modifications over the training cycles. Knowledge of the structure and the data on baseline physical fitness and special fitness in elite athletes may be useful for the development of individual training programmes for Ju-jitsu athletes. In order to improve anaerobic capacity, it is recommended to use brief and intensive bouts of exercise and longer rests between sets of exercises using the repetitive methods. Aerobic motor abilities can be developed using the principles of endurance training (e.g. circuit or interval training).

Acknowledgements: This scientific work was funded by the Ministry of Science and Higher Education from the 2015-2018 programme “The Development of Academic Sport”; project No. N RSA3 01753.

Glossary

Cluster analysis. A technique used to differentiate subgroups within a single collection of information about a group, people or objects [50].

Combat. An activity which involves defeating an opponent in a stylized way which has similarities to war of battle [50].

Competition. A contest in which a winner is selected from among two or more participants. In sport competition it is socially regulated and is generally direct [50].

Ju-jutsu. General term for systems of combat using empty-handed or short-weapon techniques against unarmed or armed opponents [51].

Norm. The set point, reference point or system goal in a control system. An empirically-established standard. Sometimes the norm refers to the normal or average value [50].

Physical fitness. The ability of a person to function efficiently, to enjoy, to subject oneself to leisure, to be healthy, to resist hypokinetic disease and to cope with emergency situations. The health related components of physical fitness include body composition, cardiovascular fitness, flexibility, muscular endurance and strength. Skill related components include agility, balance, co-ordination, power, reaction time, and speed [50].

Test. An examination designed to reveal the relative standing of an individual in a group (e.g. with respect to achievement or fitness) [50].

References


Author for correspondence:

Mucha Dariusz
E-mail: nauka.autograf@gmail.com,
Phone No. 0048601482162
Changes in the Level of Fitness and Physical Development in Children from First-grade Swimming Classes Compared to Peers

Hanna Żukowska ¹ ABCDEFG, Mirosława Szark-Eckardt ¹ ABCDFG

¹ Department of Physical Culture, Health and Tourism, Kazimierz Wielki University in Bydgoszcz, Poland

Key words: sports class, swimming, physical fitness, International Physical Fitness Test, physical development, training children, non-training children

Abstract

Aim. Determining the values of changes in fitness and physical development of children from first-grade “swimming classes”¹ compared to general classes.

Material and methods. The study included two groups of children attending the first grade – the first were children “training swimming”² (including 26 boys and 23 girls), the second – non-training children (including 26 boys and 23 girls). Children admitted to the first swimming class underwent the program of “classes with an extended physical education program for children gifted with motor abilities”, in which apart from the physical education classes resulting from core curriculum, they also attended systematic swimming lessons – four hours a week. In both groups, selected International physical fitness test trials were conducted in September and June. The results were focused on the following aspects: results obtained by boys and girls which constitute sexual dimorphism, determination of differences and their direction between groups and gender in the first and second test.

Results. In the group of children “training” swimming, there were no statistically significant differences in physical development. In the “non-training”³ group, statistically significant differences in body height were found – only in the first test (b-120.30, g-117.86) and body mass both in the first (b-24.57; g-21.22) and second test (b-26.80, vs. g-22.83). In the assessment of physical fitness in the group of children subjected to systematic swimming classes, differences between boys and girls were found in the following: standing long-jump (only in the first test; b-151.65, g-134.96); hand strength measurement (only in the first test; b-23.5 test, g-19.36); bent arm hang both in the first (b-13.40, g-7.70) and second test (b-14.46, g-6.31); forward bend only in the first test (b-5, g-1.34); 4x10m run both in the first (b-14.54, g-15.23) and second test (b-13.66, g-15.11). However, in the control group: standing long-jump (also only in the first test; b-107.78; g-95.88); hand strength measurement in both the first (b-18, 95, g-12.26) and second test (b -12.09, g-12.77); bent arm hang (only in the first test; b-8.21, g-3.02); forward bend (b-2.43, g-1.30), as well as in the second test (b-3.30, g-2.19).

¹ The authors used the term “swimming class” – resulting from the functioning of such terminology at school, taking into consideration that these are classes with extended programmes of Physical Education for children gifted in motor abilities.

² In the work, the term children “training swimming” was used in order to more easily distinguish those who were selected (as a result of selection) for the first grade swimming class from those accepted to general classes. However, the authors consider the fact that this group of children, going to the first swimming class, undergo systematic swimming education (pre-selection).

³ The term “non-training” children was used in the work to identify children from general classes.
**Conclusions.** In both groups, for both boys and girls, statistically significant changes in physical development were observed, which is a normal sign of growth, but only in the group of girls was there a statistically significant increase in the BMI index. When assessing the impact of increased physical activity of children attending swimming-profiled classes, it can be concluded that in the boys’ group, this positively influenced the results obtained in such attempts as: bent arm hang and sit ups from supine position. On the other hand, among girls: this was positively affected only in sit ups from supine position trial. In the group of girls, it was also noticed that although the “training” individuals obtained a significantly better result in the bent arm hang in the first test, in the second one, they achieved a weaker result, while the non-training girls achieved statistically significantly better results in the second rather than the first test. Conducting a proper pre-selection for swimming should be based on existing scientific premises. Achieving “sports championship” is not only the result of proper work during practice, but to a large extent, properly conducted pre-selection and selection at all stages of swimming training so that candidates and swimmers can fully utilize their psycho-physical abilities and swimming training.

**Introduction**

Planning training for children and youth in competitive sport requires taking all actions (including recruitment to sport, ‘stageization’, skillful adjustment of training to the laws of biological development), which should be subordinated to the general premises resulting from “uniform treatment of the whole process” [1, p. 24]. Achieving sports championship requires “meeting certain conditions in the field of: somatic build, energy and regulatory functions of the system, properties of the psyche, profile and level of physical fitness, technical and tactical skills (…). Some of these factors are to a large extent genetically determined (…)” [1, p.51]. Therefore, the search for candidates concerning relevant sports disciplines that meet the above expectations becomes an important aspect. The selection of candidates as future champions and the selection for swimming, alike any discipline, can be natural, intuitive or directed [1, 2, 3]. Thus, what should the guiding principle be and on the basis of which features should future swimming champions among the many willing candidates be determined? According to Bulagowa and Woroncowa, the basis for forecasting swimming skills is the stability of those traits that “do not succumb to the influence of training and are largely determined by hereditary factors (…)” [4, p. 39]. On the basis of many years and long-term research, the authors have identified the following factors characterized by greatest stability: skeletal dimensions, mobility index in the ankle joint and the results of swimming medium and long distances [4]. Sozański (1999) also states that at the beginning, healthy children and those interested in sport should be distinguished, and only then is it time to recognize “specific talents and properties desirable in a given discipline” [1, p. 50]. These are such elements as: health condition, consent of a parent or guardian and willingness to participate in classes or great commitment - these were the most frequently used and often the only forms of selection and choice in swimming at various stages of training [5]. Children admitted to “first-grade swimming classes” should start their adventure with sport from general (versatile) training. The task of the first stage is: to arouse interest in the sport of swimming sport, to recognize the abilities specific for sport in water, to equip with as many skills needed in water, to increase aerobic capacity of the body, and to increase the mobility of the articular-ligament apparatus [6].

On the basis of a literature review, the authors undertook analysis of the recruitment procedure for swimming classes in Bydgoszcz and assessed whether the admitted candidates differed significantly from children at the same age from general classes, and whether the basic tasks of the comprehensive stage (increased number of physical activities) had impact on increasing the fitness level of candidates for future swimming champions after one year of classes.

**Research questions**

1. **What kind of selection for swimming classes is implemented in Bydgoszcz?**
2. **Are there differences in the level of somatic development and physical fitness between children admitted to swimming and general classes resulting from the selection process?**
3. **Does increased physical activity, realization of tasks at the comprehensive stage, favourably affect the physical fitness of swimmer candidates?**

**Hypotheses**

1. Children are accepted to swimming classes on the basis of their state of health, the consent of their parents (guardians) and fitness tests.
2. Children admitted to swimming classes subjected to the selection process (fitness tests) are characterized by better physical fitness during the first test.
3. After a year of comprehensive training (including an increased number of hours of systematic swimming lessons), these children will achieve better results in the assessment of physical fitness than those from general classes.
Changes in the level of fitness and physical development...

Material and Methods

Document analysis was used to assess the type of selection for swimming classes in Bydgoszcz. Requirements regarding the recruitment process available to candidates were analysed.

The study involved two groups of children from first-grade classes – the first: children training swimming (including 26 boys and 23 girls), the second: non-training children (including 26 boys and 23 girls). Physical development, based on height, body mass and BMI, was assessed in both groups. Somatic development of the children was determined on the basis of anthropometric measurements in accordance with the applicable rules. The following were examined: body height (basis – vertex) – measurement using anthropometer, and body mass. For the measurements, subjects stood in so-called anthropometric position (standing position, free upright, upper limbs hanging freely along the trunk, hands straightened, lower limbs straightened and joined, slightly stride position). Body mass was assessed by weighing the participants on a medical scale in a standing position [7, 8]. The obtained results of height and body mass measurements were used to determine the Quetelet II i.e. relative body mass – BMI (Body Mass Index) [7].

The BMI was calculated according to the formula: 

$$\text{BMI} = \frac{\text{body mass (kg)}}{\text{body height (m}^2)$$

In order to assess physical fitness, selected International Physical Fitness Test tests were carried out:

- standing long jump,
- hand strength measurement,
- relative strength measurement – bent arm hang,
- shuttle run 4 x 10-m,
- sit ups from supine position in 30 s,
- forward bend.

The study was carried out at two dates, at the beginning of the 2016/2017 school year (September) and at the end of the 2016/2017 school year (June). All tests were carried out in accordance with the applicable procedure [9].

The examined children attended schools with similar sports infrastructure (swimming pool, large and small gymnasiuems, outside pitch). The swimming-class children attended compulsory sports classes at the swimming pool 4 x 45 minutes per week.

The obtained BMI score was compared to the results achieved by Woynarowska [10] and contained in the table below, which defines the norm of body mass, its deficiency, overweightness or obesity.

In order to present the obtained results, figures were made, and statistically significant differences were marked with an arrow (✓).

While analysing the results, focus was placed on three aspects – the assessment of sexual dimorphism among training and not training children in the first and second test. Furthermore, are there any statistically significant differences, and what is the direction in the assessment of physical fitness in the group of training and non-training children in the first and second tests? And are there statistically significant differences and what is the direction between training and non-training boys and girls in the first and second tests? The collected material was subjected to statistical analysis using STATISTICA PL by StatSoft [11]. The Mann-Whitney U test was used to assess the significance of differences (the variances between boys and girls in the first and second tests in the group of children attending the swimming class and control group), and to assess the differences between the first and second tests in the group of boys and girls attending the swimming class and mass class, using the Wilcoxon signed-rank Z- and T-tests (the differences between the first and second tests in boys and girls in the group of children attending the swimming class and control group).

Results

In the area of Bydgoszcz, children are accepted to swimming classes on the basis of their state of health, consent of their parents/guardians, swimming skills tests (degree of acquaintance with water), and in the case of some, physical fitness tests are additionally carried out.

The results of our own research regarding the level of physical development and fitness are presented below in the form of figures (1-14), and the arrow (✓) indicates statistically significant differences between studied the groups. Figures 1-4 present the results of the assessment of differences between boys and girls in physical development and fitness resulting from sexual dimorphism regarding the first and second study in the

### Table 1. BMI for boys aged 7-18

<table>
<thead>
<tr>
<th>age years</th>
<th>underweight</th>
<th>normal</th>
<th>overweight</th>
<th>obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>&lt; 13.5</td>
<td>13.6 - 17.8</td>
<td>&gt; 17.9</td>
<td>&gt; 20.4</td>
</tr>
<tr>
<td>8</td>
<td>&lt; 13.7</td>
<td>13.8 - 18.8</td>
<td>&gt; 18.9</td>
<td>&gt; 22.2</td>
</tr>
</tbody>
</table>

(source: Woynarowska [19])
group of children training and non-training swimming; in the next two (5-6), body mass norm, deficiency, overweightness or obesity with regard to sex in both groups are shown; Figures 7-10 – comparison of the results of somatic development assessments and physical fitness of training boys and girls, as well as boys and girls not training during the first (September) and second (June) test; in the last four figures (11-14) – differences in somatic development and physical fitness between the training and non-training children were presented.

On the basis of statistical analysis concerning the difference in sex distributions in the groups of children from the
swimming and control classes, no differences were found. Statistically significant correlations are marked on the graphy using arrows ( ).

In comparable groups of training and non-training children, no differences in gender distribution were found. In the group of children training swimming, there were no statistically significant differences in physical development (body height, body mass, BMI) between boys and girls both during the first (body height: b-122.79, g-124.70, body mass: b-23.51; g-24.56, BMI: b-15.57; g-15.76), as in the second test (body height: b-125.35, g-127.28; body mass: b-25.21, g-26.66, BMI: b-15.78, g-16.72) (Fig. 1). In the non-training group, there were statistically significant differences between boys and girls in body height - only in the first study were the boys much taller than the girls (b-120.30; g-117.86) and body mass both in the first (b-24.57, g-21.22) and second test (b-26.80, g-22.83), the boys turned out to be heavier (Fig. 2).

In the assessment of physical fitness among the group of training children, sexual dimorphism was found in: standing long-jump (only in the first test: b-151.65, g-134.96); hand strength measurements (only in the first test: b-23.5, g-19.36); Bent arm hang in the first (b-13.40; g-7.70) and second test (b-14.46; g-6.31); forward bend (only in the first test: b-5, g-1.34); 4x10m shuttle run (both the first: b-14.54, g-15.23 and second test: b-13.66; g-15.11) (Fig. 3). While in the control group: standing long-jump (also only in the first test: b-104.78, g-95.88); measurement of hand strength (both in the first: b-18, 95, g-12.26 and in the second test: b-12.09, g-12.77); bent arm hang (only in the first test: b-8.21, g-3.02); forward bend (both in the first: b-2.43; g-1.30 and second test: b-3.30; g-2.19) (Fig. 4).

Based on the standards for the BMI index according to Woynarowska [10], it was found that both boys and girls from both groups were characterized by normal body fatness. In the assessment of obesity, among the group of children training swimming, the majority of children admitted to the swimming class had normal body mass (92% boys and 83% girls), no one was overweight or obese, and at the end of the school year (June), 85% boys and only 57% of girls displayed normal body mass. In the second test, the percentage of overweight children increased - 8% boys and 26% girls (Fig. 5). Among non-training children, in the first test, 87% of boys and 85% of girls were of normal mass, 13% of boys were obese and 15% of the girls were underweight. During the second test (June), the percentage of children with normal body mass decreased among boys and girls, the percentage of overweight boys increased by 9%, and in girls, the number of underweight girls increased by 19% (Fig. 6).

Comparing the results, the physical development (body height and mass, BMI) scores obtained by the subjects in the first (September) and second (June) test, we found statistically significant changes in physical development among both groups for boys and girls (increase in height and body mass) (Fig. 7 and 8). Only in both training and non-training girls was there a statistically significant increase in BMI found during the second test (training girls - 15.76; 16.72, non-training girls - 15.08; 15.26) (Fig. 7 and 8).

When assessing the level of motor skills between the first and the second test, the positive effect of swimming training on the majority of the assessed trials was noticed. Both boys and girls training swimming improved their performance in five out of six trials, and in three, statistically significant differences were noted. Boys and girls significantly improved their results in the following tests - hand strength measurement (boys: test I-23.5, test II-28.88, girls: test I-19.36, test II-27.17), sit up from supine position in 30 s (boys: test I-14.04, test II-19.81, girls: test I-11.26, test II-19.95), boys – 4x10 m shuttle run (test I-14.54, test II-13.66), girls – forward bend (test I-1.35, test II-3.26). A statistically significant reduction was observed for both groups in the explosive strength of the lower limbs (standing long jump) (boys: test I-151.65, test II-127.54; girls: test I-134.96, test II-119.35) (Fig. 8). The non-training boys improved their results in three trials, including one which was statistically significant - hand strength measurement (test I-18.96, test II-27.09), girls – in five, including two significant ones - standing long-jump (test I-95.88, test II-107.5) and bent arm hang (test I-3.02, test II-4.96). Among those non-training, the children obtained weaker results in the second test: boys in two attempts assessing muscle strength – bent arm hang (test I-8.21, test II-4.66) and sit ups from supine position in 30 s (test I-12.26, test II-10.09), in the assessment of agility (test I: -2.43, test II: -3.3) they achieved weaker results, but the difference was not statistically significant; girls in the assessment of abdominal muscle strength (test I-1.77, test II-10.31), however, this difference was not statistically significant (Fig. 10).

Figure 11 presents a comparison of the results of body height and mass, BMI and the results obtained in individual International physical fitness test trials by boys who were accepted into swimming classes and boys starting their studies in mass classes. On the basis of analysis of results, no statistically significant differences in physical development were found, while in the assessment of physical fitness, boys who started studies in the sports class obtained significantly better results in only three attempts – standing long-jump (swimming class-151.65; mass class-107.78), forward bend (swimming class:-5, mass class:-2.43) and the 4x10 m shuttle run (swimming class-14.54, mass class-16.14). In the other trials, differences were not statistically significant (Fig. 11). In the second test (June), the results of the physical devel-
Figure 3. Differences in results obtained during International physical fitness test attempts for boys and girls training swimming in the first (September) and second (June) test

(♀) – statistically significant difference – p < .05; I – first test (September), II – second test (June)

Figure 4. Differences in results obtained during International physical fitness test attempts for boys and girls not training swimming in the first (September) and second (June) test

(♀) – statistically significant difference – p < .05; I – first test (September), II – second test (June)
Figure 5. Underweight, normal, overweight and obese body mass norms in children training swimming in the first and second test. 
I – first test (September), II – second test (June).

Figure 6. Underweight, normal, overweight and obese body mass norms in children not training swimming in the first and second test. 
I – first test (September), II – second test (June).
Figure 7. Comparison of results regarding somatic development in girls and boys training swimming in the first (September) and second (June) test

(✓) – statistically significant difference – p < .05; I – first test (September), II – second test (June)

Figure 8. Comparison of the results regarding physical fitness in boys and girls training swimming in the first (September) and second (June) test

(✓) – statistically significant difference – p < .05; I – first test (September), II – second test (June)
Changes in the level of fitness and physical development...
opment assessment were still similar (Fig. 11), while in fitness assessment, the swimmers obtained significantly better results in five of the six trials – standing long-jump (swimming class-127.54; mass class-110.26), forward bend (swimming class: 5.12, mass class: -3.3), bent arm hang (swimming class-14.47, mass class-4.66), sit up from supine position (swimming class-19.81, mass class-10.09) and the 4x10 m shuttle run (swimming class-13.66, mass class-15.55) (Fig. 12). Girls from swimming classes were at the beginning (September) significantly taller and heavier than their peers from mass classes (body height: training girls-124.7, non-training girls-117.87, body mass: training girls-24.56; girls non-training – 21.22, BMI: training girls – 15.76, non-training girls-15.08) (Fig. 13). This trend was maintained throughout the year and in the second test (June), they still outnumbered the height and mass of non-training girls (body height: training girls-127.28, non-training girls-121.65, body mass: training girls-26.66, non-training girls-22.85, BMI: training girls-16.73, non-training girls-15.26) (Fig. 13). In the assessment of physical fitness at the beginning of the school year, the girls from swimming classes achieved better results in the assessment of lower limb dynamic strength (swimming class-134.96, mass class-95.88), hand strength (swimming class-19.36, mass class -12.27) and shoulder girdle strength (swimming class-7.71, mass class-3.02). In the remaining trials, the differences were not statistically significant (Fig. 13). In the second test during the first two attempts, the swimmers were still better regarding dynamic strength of the lower limbs (swimming class-119.35, mass class-107.5), hand strength (swimming class-27.17, mass class-12.77), while in the second attempt concerning the assessment of shoulder girdle strength, the results evened out, i.e. for the participants from the swimming class, the results for this trial decreased (6.32), while in non-training girls, they increased (4.96) (Fig. 14). After a year of practice, the training girls achieved statistically significantly better results in sit ups from supine position compared to the non-training girls (swimming class-19.95, mass class-10.31) (Fig. 14).

Discussion

Swimming belongs to so-called early sports [1, 4, 12-14], which means that the initial training of swimmers starts already in first grade [12-14]. Selection for the swimming class is based on the results obtained during entrance exams. In literature on the subject, the main prospective parameters defining a child’s abilities are length features (body height, length of trunk and limbs) [1, 4, 12, 14]. In reference to the above premises, the selection of the tested “swimmers” seems to be incorrect, since the children were accepted to the “swimming class” on the basis of swimming fitness tests and physical fitness on land. However, the condition was met that healthy and the most efficient children were accepted from among the candidates, perhaps the future champion hidden among them.

In the assessment, differences between boys admitted to the “swimming class” and the control group are small, while among girls, swimmers turned out to be significantly taller than their peers. Different results were obtained by Pietrusik, the examined seven-year-olds obtained opposite values, the girls from the control group and the boys from the swimming group turned out to be taller and heavier in both tests [15]. There are only a few studies regarding the comprehensive stage, most often the assessment or comparison of body build and physical fitness between the training and non-training groups of swimming concern older children [14, 16, 17, 18, 19, 20].

In the assessment of physical fitness, between the first and the second test, statistically significant differences were found in four trials among the training boys - three positive and one negative, while only one positive and two negative were found among the non-training boys. In training girls, positive changes were also observed in three trials and one negative, as in boys, while in non-training girls, only two positive changes were found. In similar studies conducted among first-graders, the author noted a statistically significant difference in all trials evaluating physical fitness [21]. In studies conducted among older children, a similar direction of changes was also noted [15, 17, 19].

All systematic physical activity is conducive to proper development, and the universal benefits of sports for children are widely known and often emphasized in scientific research. Movement is a factor having wide-ranging impact on the body. Swimming is also included in this general trend, where based on the review of literature and the authors’ research, it was found that the positive effect of increased motor activity on motor fitness is already visible at the first-grade level.

Verifying the assumed hypotheses, not all have been completely confirmed. In the assessment of physical fitness, candidates from the swimming class obtained statistically significantly better results in the assessment of somatic development and in three attempts to assess physical fitness (standing long jump, hand strength measurement, bent arm hang). In two, they obtained better results but were not statistically significant (forward bend, 4x10 m run). In one, the results were weakest – sit ups from supine position. The boys achieved statistically significantly better results in only two trials (bent arm hang, forward bend). In the assessment of physical development, they turned out to be taller and lighter, but the differences were not statistically significant.
Changes in the level of fitness and physical development...

Figure 11. Comparison of results regarding somatic development and physical fitness assessment in boys training and not training swimming in the first (September) test

(✓) – statistically significant difference – p < .05

Figure 12. Comparison of results regarding somatic development and physical fitness assessment in boys training and not training swimming in the second (June) test

(✓) – statistically significant difference – p < .05
Figure 13. Comparison of results regarding somatic development and physical fitness assessment in girls training and not training swimming in the first (September) test
(✓) – statistically significant difference – p < .05

Figure 14. Comparison of results regarding somatic development and physical fitness assessment in girls training and not training swimming in the second (June) test
(✓) – statistically significant difference – p < .05
In the second study, the female swimmers turned out to be better in all trials assessing physical fitness, including three which are statistically significant (standing long-jump, hand strength measurement, and sits from supine position). In the final results, what seems interesting is the decrease in distance regarding the assessment of functional strength, between groups and among the girls training swimming, there was a decrease in this strength (statistically non-significant), while among those not training, there was a statistically significant increase in this strength. When assessing boys, a positive effect of increased physical activity was found, boys training swimming obtained better results of physical fitness assessment in all the assessed trials (standing long-jump, bent arm hang, forward bend, sit ups from supine position, 4x10 m run), and five of them were statistically significant (standing long jump, bent arm hang, forward bend, sit ups from supine position, 4x10 m run).

Conclusions

- Fitness tests are not a reliable tool for selection in swimming, however, good physical fitness and lack of fear of water may be a good start to pre-selection.
- In both groups of boys and girls there were statistically significant changes in physical development (height and body mass), which is a normal sign of growth, but only in the group of training and non-training girls was there a statistically significant increase in BMI.
- In the assessment of physical fitness, between the first (September) and second (June) test, statistically significant differences were found in four trials among the training boys – three positive (hand strength measurement, sit ups from supine position in 30 s, 4x10 m run) and one negative (standing long jump), while among the non-training boys, there was only one positive difference (hand strength measurement) and two negative ones (bent arm hang and sit up from supine position in 30 s). In the training girls, positive changes were also observed in three trials; similarly to boys, in two tests (hand strength measurement, sit ups from supine position within 30 s) and in the forward trunk bend, and one negative, as in the boys, for the standing long-jump, while in the non-training girls, only two positive changes were found (standing long-jump, pull-ups with bent arms).
- Statistically significant differences in physical development between training and non-training children were only found in the group of girls – in both tests the training girls turned out to be taller and heavier than the non-training females, and in the second test, they had a higher BMI index.
- In the assessment of functional strength, there was a noticeable decrease in the distance between the assessed groups of girls. Among the females training swimming, there was a decrease in this strength (statistically insignificant), while among those non-training, there was a statistically significant increase in this strength.
- In assessing the explosive strength of the lower limbs (standing long jump), the training children achieved significantly weaker results in the second test, while the non-training children achieved better results in the second one test than in the first one; non-training girls achieved statistically better results.
- In the assessment of shoulder girdle strength (bent arm hang), the training boys obtained better results in the second measurement than in the first one, while the girls achieved weaker outcomes – these results were not statistically significant. However, in the group of non-training children, the opposite occurred. The boys in the second test achieved weaker results than in the first one, the girls were better and in both groups, the results were statistically significant.
- When assessing the increased amount of physical activity and its impact on physical fitness, it can be stated that in the boys' group, it positively influenced the strength tests (bent arm hang and sit ups from supine position) – only in the second attempt did the boys training swimming obtain better results. In the remaining attempts, there were no statistically significant differences for both the first and the second test. However, among girls, the positive effect of increased physical activity was found only in the test evaluating abdominal muscle strength (sit ups from supine position).
- Conducting proper pre-selection for swimming should be based on existing scientific premises, however, among the children admitted on the basis of good health, willingness and good physical fitness, a future “swimming champion” candidate may be hidden.
- Achieving “sports championship” level is not only the result of proper work at practices, but to a large extent, the properly conducted pre-selection and selection at all stages of swimming training so that candidates and swimmers can fully utilize their psycho-physical abilities and swimming training.
References


Author for correspondence:

Hanna Żukowska
E-mail: zukowska@ukw.edu.pl
Phone number: 508-282-585
IMPACT OF WHOLE BODY CRYOTHERAPY ON THE BLOOD PLASMA VISCOSITY AND FIBRINOGEN CONCENTRATION IN WOMEN WITH RHEUMATOID ARTHRITIS

Bartłomiej Ptaszek 1,2,3 ABDEF, Aneta Teleélów 4 ABDEF, Jakub Marchewka 3,5 CE

Abstract

Aim: The aim of this study was to assess the effects of whole body cryotherapy on the plasma viscosity and fibrinogen concentration in women with rheumatoid arthritis.

Basic procedures: The study groups consisted of 10 women with rheumatoid arthritis, aged 57.2 ± 9.4, who underwent systemic cryotherapy treatments (3 min treatment time, -120°C chamber temperature, 10 treatment sessions, 5 times a week). Their average body height was 165.5 ± 4.6 cm, weight 68.5 ± 4.9 kg and BMI 24.8 ± 2.2 kg/m². In order to analyse plasma parameters, venous blood samples were drawn from the participants of the study twice. The first study was held on the day of beginning treatments and the second test was conducted after a series of 10 treatments. The viscosity of the blood plasma was determined in the viscometer (type D-52159 Roetgen, Myrenne Co., Germany). Determination of plasma fibrinogen was performed using the Bio-Ksel, Chrom – 7 camera.

Results: Analysing the average values of plasma viscosity and fibrinogen in women with rheumatoid arthritis before and after whole body cryotherapy, no statistically significant differences were found.

Conclusions: Regular usage of cryotherapy treatments (whole body cryotherapy) not affect the levels of fibrinogen and plasma viscosity in women with rheumatoid arthritis.

Introduction

Rheumatoid arthritis (RA) is a chronic, autoimmune, systemic connective tissue disease whose etiology is not fully understood, that leads to progressive joint damage, disability, deterioration in quality of life, and shortened life expectancy. Even mild inflammation may result in irreversible damage and permanent disability. RA is more frequently observed in women and elderly people [1]. The consequences of ongoing RA are pain, impaired...
physical function, and fatigue, which cause limitations in physical functioning and work disabilities, and finally adversely affect the health-related quality of life [2]. 50% of the risk for development of rheumatoid arthritis is attributable to genetic factors. Smoking is the main environmental risk. In industrialised countries, rheumatoid arthritis affects 0.5–1.0% of adults, with 5–50 per 100 000 new cases annually [3]. Although the prospects for most patients are now favourable, many still do not respond to current therapies. Accordingly, new therapies are urgently required.

In an arthritic joint, the temperature increases [4, 5]. Local cryotherapy e.g. with cold packs, is widely used to alleviate pain in inflammatory diseases, injuries and overuse symptoms [6]. Whole-body cryotherapy (WBC) is currently used to alleviate inflammation and pain in arthritis and osteoarthritis, and for pain relief in fibromyalgia. WBC has been found useful in neurological diseases in reducing spasticity, as a method of kinesitherapy in rheumatic diseases and multiple sclerosis, and for its sedative effect in psoriasis and neurodermatitis [7, 8, 9].

The usage of systemic cryotherapy is one of the ways to reduce pain threshold or cause its abolition. WBC creates favourable conditions to improve cardiovascular health, can help to decrease skeletal muscle tension, reduce the size of edema, increase muscle strength, improve metabolism, and well-being, accelerate regenerative processes and repair and improve mobility in treated joints. The use of systemic cryotherapy is a way of increase the threshold of pain perception or its endurance [10, 11, 12].

Morphological and biochemical research carried out after application of cryotherapy is indicative of an increase in levels of haemoglobin, leucocytes and blood platelets compared to baseline values. There is also an increase in serum concentrations of epinephrine, norepinephrine, acetylcholinesterase, cortisol, and a reduction of inflammatory parameters such as ESR (erythrocyte sedimentation rate), Waaler-Rose reaction and seromucoid [13, 14].

The aim of this study was to assess the effects of whole body cryotherapy on the plasma viscosity and fibrinogen concentration in women with rheumatoid arthritis.

**Study design**

The study group consisted of 10 women with rheumatoid arthritis (RA type II - classification criteria RA according to American College of Rheumatology (ACR) and European League Against Rheumatism (EULAR) - 2010) – patients of the Malopolska Cryotherapy Centre in Krakow (preliminary research – without calculation), aged 57.2 ± 9.4, who underwent systemic cryotherapy treatments (3 min treatment time, -120°C chamber temperature, 10 treatment sessions, 5 times a week). Their average body height was 165.5 ± 4.6 cm, weight 68.5 ± 4.9 kg and BMI 24.8 ± 2.2 kg/m². Illness duration 6 - 41 years. Most of the respondents were also treated with Methotrexate and NSAID (nonsteroidal anti-inflammatory drugs). Additionally, the subjects were screened for the following exclusion criteria: diabetes mellitus, use of β-blockers or anxiety medication, and consumption of more than four cups of coffee each day or more than two alcoholic drinks each day. In order to analyse plasma parameters, venous blood samples were drawn from the study participants twice. The first study was held on the day of beginning treatments and the second test was conducted after a series of 10 treatments. Methodology was the same as in previous studies [15]. The parameters obtained in the cryo-chamber:

- aerial temperature: -60°C
- chamber temperature: -120°C

The time of a single treatment for the group of males was 1.5 min (1st treatment), 3 min (2nd-10th treatment) - 10 treatment sessions, 5 times a week. 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 applicable standards of the Pathology of Locomotion Laboratory at the University School of Physical Education in Krakow, where plasma parameters were determined. The study was approved by the Bioethics Committee at the Regional Medical Chamber in Krakow.

**Measurement of plasma viscosity**

After centrifugation of cellular blood components, the obtained 0.5 ml of plasma was put into the measurement capillary of the viscometer. The viscosity of the blood plasma was determined in the viscometer (type D-52159 Roetgen, Myrenne Co., Germany).

**Determination of plasma fibrinogen**

50 µl of plasma was used for the study. Determination was performed using the Bio-Ksel, Chrom – 7 camera.

**Statistical analysis**

Continuous variables are presented as mean ± standard deviation (SD) or median and interquartile range, depending on the normality of distribution. The normality of distribution was tested using the Shapiro-Wilk test. To assess changes between the beginning and after cryotherapy, we used the t-test for dependent samples or the Wilcoxon signed-rank test. Calculations were performed using the Statistica 12 (StatSoft®, USA) software. All p-values were two-tailed, statistical significance was defined as p≤0.05.
Results

Analysing the average values of plasma viscosity and fibrinogen in women with rheumatoid arthritis before and after whole body cryotherapy, no statistically significant differences were found: fibrinogen – increase 4.62% and plasma viscosity – increase 2.88%. (Tab. 1).

Table 1. Mean values ± standard deviations of the plasma viscosity and fibrinogen at the beginning of the study and after 10 whole-body cryotherapy sessions in rheumatoid arthritis patients. N = 10 subjects.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>After cryotherapy</th>
<th>p</th>
<th>change %</th>
<th>normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrinogen - FIBR [g/L]</td>
<td>3.25 ± 0.86</td>
<td>3.40 ± 1.03</td>
<td>0.373</td>
<td>4.62</td>
<td>1.50 – 4.00</td>
</tr>
<tr>
<td>Plasma viscosity [mPa x s]</td>
<td>1.04 ± 0.07</td>
<td>1.07 ± 0.08</td>
<td>0.110</td>
<td>2.88</td>
<td>1.12 – 1.27 (reported at 37°C)</td>
</tr>
</tbody>
</table>

Discussion

The research presented in this paper is intended to show changes in the plasma viscosity and levels of fibrinogen in women with rheumatoid arthritis who underwent a series of 10 systemic cryotherapy treatments at -120°C. A review of literature indicates a lack of detailed data on the effects of systemic cryotherapy on rheological properties of the blood in patients with RA.

In our research, analysing the average values of plasma viscosity and fibrinogen, no statistically significant differences were found in the women undergoing cryotherapy treatments in relation to the measurements made on the day of beginning the cryotherapy treatment.

The results of the research carried out so far (very little) are difficult to interpret or compare because of differences in their research protocols. Lubkowska and Szygula [16] showed that the number of cryotherapy sessions (3 min at -130°C) has significant impact on changes in morphological indices [16].

After a few days of stimulation by cryogenic temperatures, an increase in the level of haemoglobin, platelet count and creatinine concentration as well as severity of glycaemia was observed [16, 17]. Some reports indicate a decrease in erythrocytes [18, 19, 20, 21, 22] and an increase in leukocyte number [23, 24], while others declare no changes in the number of erythrocytes and/or white blood cells, most likely due to the low number of sessions [17, 18, 20, 21, 25].

The aim of study by Lange et al. was to compare the effect of whole-body cryotherapy in the criostream on pain reduction, disease activity and pro-inflammatory cytokines (tumor necrosis factor-TNF-α and interleukin-IL-1), and improvement in functional scores. There was a significant reduction in TNF-α and IL-1 [26].

Among the patients with Rheumatoid Arthritis, the progress of disease and impact of treatment on pain is usually the subject of evaluation. The study conducted by Istrati et al. [27] showed the effect of cryotherapy on changes in fibrinolytic activity of patients with rheumatoid arthritis. After applying ten cryotherapy treatments, they noticed that the t-PA (tissue plasminogen activator) parameter decreased, and PAP complexes (plasmin-α2-antiplasmin) were increased in the serum. All patients experienced an improvement in mood and a decrease in pain intensity [27]. The research carried out by Braun et al. [28] involved 48 patients with RA. They used cryotherapy treatments twice a day. The researchers observed a reduction in pain after the application of treatments [28].

Zagrobela et al. [29] described WBC effect on selected hemodynamic indices. (63 patients with rheumatoid arthritis - 14 days, once daily - cooling the body for two-minute periods in cryogenic chamber with temperatures ranging from -110 degrees C to -160 degrees C) It was demonstrated that after a single session in the cryogenic chamber, after 7 and 14 days the level of ACTH, cortisol and beta-endorphins in blood serum rises. The level of TSH, T4, T3, GH and 6-keto-PGF1 alpha+, however, remains unchanged. The cryogenic chamber treatment does not affect the heart rate, arterial blood pressure nor the value of the left ventricle fractional shortening index and its ejection, neither does it cause of arrhythmias and ischemic changes of the heart [29].

The interaction of coagulation factors with the perivascular environment affects the development of disease in ways that extend beyond their traditional roles in the acute hemostatic cascade. Key molecular players of the coagulation cascade like tissue factor, thrombin, and fibrinogen are epidemiologically and mechanistically linked with diseases with an inflammatory component. In particular, a proinflammatory role for fibrinogen has been reported in vascular wall disease, stroke, brain trauma, multiple sclerosis, Alzheimer's disease, rheumatoid arthritis, colitis, lung and kidney fibrosis, and several types of cancer. Genetic and pharmacologic studies have unraveled pivotal roles for fibrinogen in determining the extent of local or systemic inflammation. As cellular and molecular mechanisms for fibrinogen functions in tissues are identified, the
role of fibrinogen is evolving from a marker of vascular rapture to a multi-faceted signaling molecule with a wide spectrum of functions that can tip the balance between hemostasis and thrombosis, coagulation and fibrosis, protection from infection and extensive inflammation, and eventually life and death [30].

Increase in erythrocyte aggregation (EA) is pathognomonic for rheumatoid arthritis, and its estimation through erythrocyte sedimentation rate (ESR) is part of DAS 28-4 activity diagnosis, with low correlation with aggregation and that does not discriminate the contribution of cell factors that increase aggregation. Plasma factors, lgs and Fb increased aggregation, since rigidity index is altered, this reduces the process efficiency regarding aggregation. Patients with active RA present an increased EA, with values modifications associated with the activity index DAS 28-4, thus becoming an RA activity indicator [31].

Plasma viscosity is determined by water-content and macromolecular components. Plasma is a highly concentrated protein solution, therefore weak protein–protein interactions can play a role that is not characterized by electrophoresis. The effect of a protein on plasma viscosity depends on its molecular weight and structure. The less spheroid shape, the higher molecular weight, the higher aggregating capacity, and the higher temperature or pH sensitivity a protein has, the higher plasma viscosity results. Plasma is a Newtonian fluid, its viscosity does not depend on flow characteristics, therefore it is simple to measure, especially in capillary viscosimeters. In rheumatoid arthritis, its sensitivity and specificity are better than that of ESR or C-reactive protein. Plasma fibrinogen concentration and plasma viscosity are elevated in unstable angina pectoris and stroke and their higher values are associated with higher rate of major adverse clinical events. Elevation of plasma viscosity correlates to the progression of coronary and peripheral artery diseases. [32]

Blood rheology was studied in 130 consecutive RA outpatients. All rheological variables were significantly elevated in the RA patients compared with the controls. Painful joint count (PJC), morning stiffness (MS) and radiographic changes (RC) correlated significantly with plasma viscosity (PV), CRP, ESR and fibrinogen concentration (FC). RA patients with EAD (extra-articular disease) had higher PV, CBV (corrected blood viscosity) at 92/s and ESR than the RA patients without EAD. Differences in profiles of viscosity variables between subgroups of EAD in RA patients were observed. [33]

Cryotherapy used as an adjuvant therapy and applied using standardized and optimized protocols could help to spare corticosteroid and NSAID (nonsteroidal anti-inflammatory drugs) doses in these patients, and subsequently, decrease cardiovascular, infectious or gastrointestinal morbidity and mortality. This treatment option may be of special interest in an increasing number of patients with NSAID and/or corticosteroid contraindications (cardiovascular diseases, diabetes, kidney deficiency, and so on) [34].

In summary, these studies have reported that exposure to cold in the form of whole body cryotherapy not affect the levels of fibrinogen and plasma viscosity in women with rheumatoid arthritis. However, these studies require expansion to become acquainted with the body’s response under these conditions. Despite many studies on laboratory parameters changes in a variety of disorders, this study, as we know, is the first to have been conducted in patients with rheumatoid arthritis.

Conclusions

Regular usage of cryotherapy treatments (whole body cryotherapy) not affect the levels of fibrinogen and plasma viscosity in women with rheumatoid arthritis.

References

Impact of whole body cryotherapy on the blood plasma...


Address for correspondence:
Bartłomiej Ptaszek
e-mail: bartlomiej.ptaszek@awf.krakow.pl