REGULATIONS FOR ARTICLE PUBLICATION

Description and profile of the journal

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

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 (anthropomotomics) 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 anthropomorphic research achievements (Varia).

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

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

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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);
Regulations for article publication

• Texts should be prepared using only Microsoft Office Word text editor, pages should be numbered, font: Times New Roman; size: 12 points; spacing: 1.5; justified text; title written in bold typeface; centred.

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

Example:
Tabela 1., Ryc. 1., Obaśnienia, Chłopcy
Table 1., Fig. 1., Commentary, Boys

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Monograph by no more than six authors:
College of General Practitioners; 2005.

Monograph by more than six authors After the sixth author,
the following abbreviation is placed: et al.
et al: The genetic basis of human cancer. New York:

Articles in journals. Standard, list only six authors,
above six – abbreviated: et al.
monograph]. Sydney, NSW: University of New South
Wales Press; 2005 [cited 2009 Nov 10]. Available from:
NetLibrary.

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In view of the fact that since 2014 onwards, the quarterly
journal will be published in the original electronic version
in English, please translate into English: titles of articles in
the bibliographic listing published in a language other than English,
providing the language of the original in square brackets after
the English title. The title of the journal must remain in full
version or in functioning abbreviated form. Example:
nisms, symptoms and after-effects of delayed muscle
soreness (DOMS) [in Polish]. Med Sportiva, 2002, 4,
189-201.

Articles published in electronic version, without
DOI (digital object identifier). Enter the URL (Uniform Re-
source Locator) – journal website
nisms, symptoms and after-effects of delayed muscle
soreness (DOMS) [in Polish]. Med Sportiva, 2002, 4,
189-201.

Articles published in electronic version, with
digital DOI
nisms, symptoms and after-effects of delayed muscle
soreness (DOMS) [in Polish]. Med Sportiva, 2002, 4,
189-201.

Articles in journals published in electronic version,
found in the PubMed database.
[12] Jaskólska A, Bogucka, Świstak R, Jaskólski A: Mecha-
nisms, symptoms and after-effects of delayed muscle
soreness (DOMS) [in Polish]. Med Sportiva, 2002, 4,
189-201.

Example:


Illustrative material

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

Example:

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

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

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• 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:


Veracity in Scientific Research and Respect for Intellectual Property:
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• The publisher reserves the right to adjust or condense the text, make improvements related to terminology standardization.
• The publisher decides whether the article will be released for publication based on the reviewers’ opinions and the responses of the authors or lead author to the reviewers’ comments.
• After translated, proofread and edited, the article is sent to the author(s) for approval. The publisher sets a one-week deadline for submission of further modifications by the author.
• Before publication, the author responsible for correspondence with the publishing office will receive the article by e-mail (in PDF format), edited in accordance with the journal’s style template, to obtain consent for its publication. At this stage of publishing, only minor, final modifications may be made. Delay in re-submission/consent may cause the article to be moved to the next issue.

Concluding remarks

• Publication of articles in Antropomotoryka. Journal of Kinesiology and Exercise Sciences (JKES) is free of charge.
• The author responsible for correspondence concerning the article receives a free PDF file with the issue of the quarterly journal, in which his/her paper is published.
• Abstracts and full texts in English and Polish are posted on the following websites: http://www.antropomotoryka.pl/ and http://970.indexcopernicus.com/.
• Subscription to issues of the journal published in book format can be ordered for a fee at: joanna.stepien@awf.krakow.pl.
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EDITOR-IN-CHIEF’S FOREWORD

SECTION – FUNDAMENTAL AND APPLIED KINESIOLOGY

Wacław Petryński
Efficiency in physics, biology, and motor control; lessons from the cheshire cat .................................................. 11

SECTION – SPORT SCIENCES

Anna Tyka, Tomasz Palka, Wanda Plich, Agata Cebula, Marek Strzala, Anna Biel, Przemysław Pajor, Aleksander Tyka
Effects of exercise training and creatine malate supplementation on ventilatory threshold and anaerobic working capacity in long-distance runners ................................................................. 21

Dominika Kolbiarz, Aneta Teleglów, Anna Ścisłowska-Czarnecka, Jakub Marchewka, Jacek Gładzik, Krzysztof Żaba, Katarzyna Filar-Mierzwa
Changes in morphological-rheological blood properties of Hutnik Club football players .............................................. 29

Agnieszka Zagórska, Katarzyna Kulig, Maciej Pawłowski
Selection of the appropriate lubricant and adjuvant for massage therapy ................................................................. 37

Michał Żak, Janusz Jaworski, Grzegorz Lech
Evaluation of the usefulness of cluster analysis in the identification of motor ability structure in leading polish badminton players from different age categories .................................................. 43

Henryk Duda
Application of life kinetik in the process of teaching technical activities to young football players .............................. 51

SECTION – EXERCISE SCIENCES

Friedrich Kugler, Beata Sikorska-Krzyżosiak
Selected aspects of sport and recreational activity of students in Thuringia ............................................................. 63
EDITOR-IN-CHIEF’S FOREWORD

HOW TO ACHIEVE GOOD HEALTH AND BEAT SPORTS RECORDS?

The summer holiday is drawing near in Poland. Vacation should help replenish strength for the new year’s tasks – theoretically, at least. For athletes and coaches, the summer holiday is a time of intensive work. Regardless of where, the summer holiday becomes relaxation for some, and for others, the most important period of summarising the effects of various treatments aimed at achieving the best possible physical shape. We can then admire it at sporting events; we also show, and not only on the pages of our journal, the best way to achieve health through an active lifestyle.

Despite the development of scientific knowledge, it is still difficult to solve the (seemingly simple) problems: how to achieve record-breaking results in sports and good health at the same time? Some of these problems are addressed in the works published in the 71st issue of our journal.

The article “Efficiency in physics, biology, and motor control: Lessons from the Cheshire Cat,” the opening one to a series of seven articles, contains the authorial attempt to falsify Galileo’s statement that “mathematics is the language with which God has written the universe” while taking into account the extremely complex issue of biological and psychological processes of men in action. The article also points to the correct conception of the choice of mode of scientific cognition. The reference point for the author of the publication is the thought contained in the quoted motto taken from A.A. Bogdanov: “the quantitative relations I perceive as a specific kind of structural ones, and mathematics itself – as an Earlier developed, because of other Reasons, branch of the general science he organization”.

Three articles contain valuable results of research focused on the problem of supporting the training process of athletes engaging in competitive sports. The review publication “Selection of the appropriate lubricant and adjuvant for massage therapy” indicated for the first time (not only in our magazine) the role of available and legal pharmacological substances in supporting wellness of athletes using body massage. Next, the authors of “Effects of exercise training and creatine malate supplementation on ventilatory threshold and anaerobic working capacity in long-distance runner” demonstrate the effectiveness of supplementation of training process of athletes practicing long-distance running with a legal pharmacological agent – tri-creatine malate. The documented empirical research presented in the article “Application of in the process of teaching technical activities to young football players” shows that the use of a particular method of methodical proceeding called Life Kinetic can be regarded as an effective form of support in teaching football.

So far, the effect of physical effort on the rheological processes of blood is poorly documented in research. The problem is addressed in the article “Changes in morphological rheological blood properties of Hutnik Club football” that discusses the results of tests conducted on a group of football players. A similarly unrecognised problem in the selection of athletes for competitive badminton is determining the characteristics of the master model. The authors of the article “Evaluation of the usefulness of cluster analysis in the identification of motor ability structure in leading Polish badminton players from different age categories” offered their own way to solve the problem with the use of statistical methods for clusters.

In accordance with the mission of our journal we include an article created as a German-Polish cooperation: “Selected aspects of sport and recreational activity of students in Thuringia”. It includes a very interesting mode of testing the directional objectives of physical education, i.e. of the efficiency of preparing children and young people to care for their own body through the use of various forms of physical activity.

I wish our readers a wonderful summer holiday. I would also like to assure them that the well-deserved rest for the editorial staff has been postponed. We shall not rest until the next, 72nd edition of the Krakow-Wroclaw Antropomotoryka. Journal of Kinesiology and Exercise Sciences is ready to be published.

Editor-in-Chief
Edward Mleczko
EFFICIENCY IN PHYSICS, BIOLOGY, AND MOTOR CONTROL; LESSONS FROM THE CHESHIRE CAT

Wacław Petryński

Keywords: kinesiology, system, energy, efficiency

Abstract

Galileo’s statement that “mathematics is the language with which God has written the universe” concerns only the outer, “tangible” layer of our world. So, mathematics makes up the language of physics, which is indifferent to future events. Biology involves purposefulness, and psychology, which makes up the core of the motor control – intentionality. As a result, mathematics hardly lends itself to description of the biological and – all the more – the psychological phenomena.

The systemic structure of living organisms, being formed in the course of evolution, justifies the assumption that it has already made all the mistakes possible. So, the systemic perspective on the motor control phenomena and processes shall turn out to be relevant to their scientific description. The paper is aimed at creation of a coherent description of physiological and psychological aspects of energy and efficiency, rooted in the physical nature of those phenomena.

Motto:
The quantitative relations I perceive as a specific kind of structural ones, and mathematics itself – as an earlier developed, because of other reasons, branch of general science on organization.

A.A. Bogdanov
[transl. W. Petryński]

Introduction

Alluding to the idea expressed in this motto, one might state – what is obviously trivial – that only ordered knowledge deserves the noble title of science. In physics, the basic mechanism bringing order to knowledge specific for this discipline is mathematics. However, physics deals with quite simple stimulus-reaction couplings, which are fairly predictable and quite easily describable mathematically, even if in statistical or probabilistic terms. Einstein argued:

What we call physics comprises that group of natural sciences which base their concepts on measurements, and whose concepts and propositions lend themselves to mathematical formulations [1].

However, in his office at Princeton, there was an inscription:

Not everything that can be counted counts, and not everything that counts can be counted.

Consequently, in our world there have to exist phenomena and processes, concepts which do not “lend themselves to mathematical formulation”. Biologist Cohen and mathematician Stewart wrote:

Physics deals with invented, simplified world. This is how it derives its strength, this is why it works so well. (...) Sciences like biology are less fortunate (my emphasis – WP) [2].

What is significant, in physics the stimulus-reaction couplings have no goal: they simply exist. Physicist
and philosopher Heller described the relations between mathematics and the real world in more detail:

One may assume that the mathematical structures, used by us for modelling the world, so much diverge with their simplicity from richness of the real structure of the world that instead of similarity we should rather speak about a specific resonance between the structure of the world and the structure of its mathematical models invented by us. The structures designed by us somehow fall into resonance with the structure of the world so that, despite of drastic simplification, they inform us about specific features of the world [3].

One should still add one word: “sometimes”. However, in biology the respective cause-effect chain is longer [4] and consists of stimulus, information and response. No longer a sheer reaction! The information has to be identified and processed. Moreover, it is specific to both the whole species and to a given individual as well. Hence, it blasts out the “stiff” mathematical formalism. Here one might discern a specific trade-off: we lose obvious mathematical beauty and simplicity, but gain purposefulness, somewhat directed towards the future and quite freely seeking its own way. Even the cellular membrane – being one of the greatest “inventions” of evolution [5] – somehow “knows” what substance may or should be introduced into the cell, and what has to be pumped out. For scientists, it is crucial that in this field the possible “resonance” between mathematics and reality is not so easily observable and obvious as it is in physics. If it exists at all.

Microbiologist Kunicki-Goldfinger claimed:

A living organism is a hierarchic, multilevel, cybernetic system. Additionally, it is provided with a program which is transferred from one generation to the next one. The program is being modified in the course of evolution. Because of using experience, the system is able not only to react to extrinsic and intrinsic stimuli, but to limited anticipation of future events as well [6; transl. W. Petryński].

Still, the situation looks more complicated in psychology. The cause-effect chain consists of three links, like in biology, but the effect of their systemic cooperation is not passive purposefulness, but active inventiveness, controlled by an individual. In this field, simple physical methodology, based on mathematics, turns out to be almost completely ineffective. Thus, the statement by Galileo that “mathematics is the language in which God has written the world” may be regarded as being true only in the non-living world.

The information in biology and psychology bears ambiguity, uncertainty and probability to a much greater extent than that in quantum physics. Hence, the possible psychological theory, as a highly abstract mental construction, is inevitably much more distal to the “tangible” reality than that in physics. As a consequence, in psychology intellectual considerations, inferring and interpretations are much more significant than experimental results. This is why evolutionary biologist Dawkins argued that “careful inference can be more reliable than actual observation, however strongly our intuition protests at admitting it” [7]. Hence, in biology and all the more, in psychology, the purity and correctness of reasoning is much more significant because the possible experimental results cannot be directly – if at all – related to the theory. Nevertheless, some natural, versatile regularities are much more easily discernible in “tangible” physics than in “elusive” psychology.

In the latter, mathematics loses its descriptive and explanatory power. For example, let us try to mathematically model the emotional structure underlying Hamlet’s famous question “To be, or not to be...”?

The motor control may be regarded as a specific bridge linking physics and psychology. It is worth noticing that the only manifestation of any mental process in a living being is movement. Accordingly, each and every conduct is inevitably motor behavior – even if only the jaws and tongue (in humans) or tail (in cats) are mobile. So, when looked at from such a perspective, motor control would be mindless without psychology; however, without motor control psychology would be blind.

Incidentally. Paradoxically enough, the first psychological laboratory established by psychologist Wundt in 1879 in Leipzig [8] was no doubt a great scientific achievement. However, along with exhausting the “explanatory power” of experimental methods in psychology, they have more and more ... a ballast for psychology! The concrete nature – here the ambiguity of the English term “concrete” sounds very symptomatic – the experimental data makes them close to the “tangible” reality. However, the psychological theories may be produced only at a very high level of abstraction, by its nature much more flexible than the concrete and obvious experimental data. Hence, they result from “careful inference” rather, and not from “actual observation”. According to Einstein:

It seems that human reason first has to independently construct the forms, before we can detect them in things (...) cognition cannot blossom from sheer empirics, but from the comparison of what is imagined, with what is observed [9].

Also mathematician Thom (Fields Medal laureate) stated:

Since 17th century modern science is possible only as much, as the theoretical progress overtakes the experi-

\[\text{1 Translated by “Executive Intelligence Review”.}\]

\[\text{2 There is no Nobel Prize in mathematics; the Fields Medal is considered as being the mathematical equivalent of the Nobel Prize.}\]
Efficiency in physics, biology, and motor control; the lessons from Cheshire Cat

Great achievements we owe no more to discovery of new facts, but they appear rather as new ways of thinking or interpretations of already known facts [10; transl. W. Petryński].

Consequently, empirical methodology makes theoretical analyzes close to observable reality, whereas psychological theories inevitably have to be distal to it.

Order bringing structure in biology and psychology: the system

Also in physics and technology, the full of fantasy, “ruffled” mathematics is hardly useful. To become the attribute of immediate applicability, it has to be reduced to the level of sober, slightly boring (luckily enough, computers do not feel any boredom) algorithmic calculations. However, the latter cannot effectively “fall into resonance” with biological and psychological issues. Accordingly, it seems reasonable to follow the footsteps of Nature and to use what it has developed over the course of many centuries: the system.

At the break of the 1910s and 1920s, physician and philosopher Bogdanov [11], whose words make up the motto of this paper, founded science on systems and termed it “tektology”. Nearly half a century later, biologist von Bertalanffy developed the general theory of systems [12]. Probably the most advanced systemic concept of biological structure of the human central nervous system – and, as a consequence, the structure of information processing – has been developed by founder of “physiology of activity”, neurophysiologist and polymath Bernstein [13, 14, 15, 16].

Bernstein derived his theory – termed “brain skyscraper” – from solid evolutionary and physiological data. Unfortunately, it is rather complicated and its understanding requires some mental effort. So, here one comes across a similar problem as that with mathematics and calculations. To become useful, Bernstein’s theory should be simplified and reduced to purely informational structure; let us term it “modalities’ ladder”.

The comparison of the brain skyscraper and modalities’ ladder is shown in Tab. 1.

The column “Motor potentiality” includes the type of motor operation (reflex, automatism, habit and performance) and mechanisms of movement management (strength control, technique, tactics, strategy and politics). The column “Modalities’ ladder” includes the type of internal model of a motor operation (coupling, template, scenario, program and idea), kind of information processing code (proprioception, contactception, teleception, words and symbols), and common language description of respective ability (“feeling-in-hand”, movement harmony, “measure-by-eye”, common reason and fantasy).

Bernstein’s theory might be, toutes proportions gardées compared to mathematics, and the modalities’ ladder – to calculations.

The mathematical comparison makes a metaphor rather than an analogy. According to Heller, “the notions, while already born, multiply and mutate quicker than the biological species” [17]. One might assume that in the

<table>
<thead>
<tr>
<th>Brain skyscraper</th>
<th>Motor potentiality</th>
<th>Modalities’ ladder</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Unrealistic topological motor representations</td>
<td>No motor operation, politics</td>
</tr>
<tr>
<td>D</td>
<td>Realistic geometrical motor representations</td>
<td>Performance, strategy</td>
</tr>
<tr>
<td>C2</td>
<td>Net of muscle synergies, working organs, “fine motoricity”</td>
<td>Habit, tactics, dexterity</td>
</tr>
<tr>
<td>C1</td>
<td>Net of muscle synergies, whole body, “gross motoricity”</td>
<td>Habit, tactics, agility</td>
</tr>
<tr>
<td>B</td>
<td>Two-muscle synergies</td>
<td>Automatism, technique</td>
</tr>
<tr>
<td>A</td>
<td>Single-muscle contraction</td>
<td>Reflex, strength control</td>
</tr>
</tbody>
</table>

Table 1. Bernstein’s brain skyscraper and the modalities’ ladder
course of evolution the “shadows of notions” might have arisen at C-level (in early reptiles), along with development of teleceptors and brain structures able to process the teleceptive stimuli, but in reality, they ripened only at D-level. Accordingly, the processes connected with them gained such a “buzzing diversity” that they have fallen more outside the frames of mathematical description.

The data in Tab. 1 show only what is happening in living beings, and especially in humans; only Homo sapiens developed all the five “floors” of the brain skyscraper (and, consequently, the complete modalities’ ladder). However, life somehow sprouted from the physical world, hence there must be some bridge linking inanimate and animate matter [18]. Let us try to trace such a possible bridge.

Before further considerations, let us remember the scene from “Alice’s adventures in Wonderland”. It is worth mentioning that Carroll was a mathematician and logician, and his masterpiece, commonly classified as a fairy-tale, may be also regarded as a mathematical treatise. The scene to be remembered is that when Alice talks to the Cheshire Cat, who vanishes – starting from tail – and at the very end, it is merely his grin that remains [19]. Here arises the question: is the elusive grin alone a part of the real Cat, or not?

By the way: The Cheshire Cat is a mathematical creature. It exemplifies the situation, when something real approaches zero, but then it does not vanish, but transforms into something qualitatively different. As its physical counterpart, another famous cat may be regarded, that of E. Schrödinger [20]. It is at the same time, dead and alive. In psychology, analogous phenomenon of qualitative transformation can be traced to Aristotle’s Peripatetic axiom (“Nihil est in intellectu quod non sit in sensu” – “Nothing is in the intellect that was not first in the senses”), and its supplement by Leibniz: “… excipe: nisi ipse intellectus.” (… except for the mind itself”). Aristotle’s statement may be compared to the Cheshire Cat (idea evoked by sensory experiences), whereas in Leibniz’s supplement – to its grin (idea detached from sensory experiences). Moreover, while seen from another viewpoint (Fig. 1), one might regard the sensory experiences as the “grin” of reality.

In fact, it is the crucial question in differential calculus and systems theory. The problem is, what is the difference between “to be zero” and “to be reduced to zero”? An analogous situation one comes across in daily life: while driving a car, when do the speed increments transform into qualitatively new acceleration? To become acceleration, the increments have to be reduced to zero, indeed, but they somehow retain some relation to their “native” speed. Exactly like the grin of Cheshire Cat.

Here it should be emphasized that quantitative changes give rise to a given quantity of qualitative transformation. In other words, while the changes are being reduced to zero, they transform into the tendency. Here we come across a specific trade-off: we gain knowledge about characteristics of changes, but lose information about specific values of what is being changed.

In physics, such phenomena are quite easily observable sensorily, measurable experimentally and describable mathematically. If we compare them to the Cheshire Cat – with his tail proudly sticking towards sky – then it seems instructive to look for his grin on the particular “rungs” of the modalities’ ladder. In fact, the modalities’ ladder merely comprises an “empty scaffolding” for information processing in humans. Its “treads”, while assembled together, make not a sum but a system. Probably the most elusive and miraculous potentiality of the system is its ability to produce a qualitatively new, unpredictable system effect. In short, one might say that in arithmetic $2 + 2 = 4$, whereas in a system two and two equals four and unpredictable, emergent system effect.

The properties of the system have been concisely described by the Nobel laureate, biologist Jacob, who stated:

*Is it possible to make predictions at one level on the basis of what is known at a simpler one? The properties of a system can be explained by the properties of its components. They cannot be deduced from them [21, 22].*

As biologist Cuénot stated, “there is nothing living in a cell apart from the cell itself”; so, in biological systems, the system effect is the life (for dust thou art and unto dust shalt thou return; Genesis, 3:19). Moreover, this formulation is fully coherent with the life criteria by Gánti [4].

**The Cheshire Cat’s grin in the modalities’ ladder**

In biology and psychology, the problem of reduction to zero – leading to a modality change – is more complicated. The modalities specific to particular “rungs” of the ladder (Tab. 1) are of multifaceted nature, and reduction concerns only selected components. Just this makes – roughly – the essence of nonlinearity, probably responsible, at least to a great extent, for the emergent system effect [23].

Incidentally: Although I have adopted the assumption that mathematics is not eligible for biological analyses, yet the mathematical thinking discipline and some mathematical thinking patterns – not so “stiff” as strict mathematical formalism – may turn out to be useful in building the intellectual image of the real world. According to Cohen and Stewart, “a theory is a kind of code that transforms complicated messages from nature into much simpler ones” [2].
Efficiency in physics, biology, and motor control; the lessons from Cheshire Cat

Let us assume that the term "rationality" denotes the coherence of the mental world representation with reality. If in fantasy (topological E-level) irrationality gets reduced to zero, then its "grin" at D-level is common reason.

If in common reason (geometrical D-level) the temporal frames of information processing get limited to "here and now", and mainly visual data are being used, then its "grin" at C-level is what might be termed as "measure-by-eye".

If "measure-by-eye" (kinematical C-level) is transformed into particular muscle synergies, then its "grin" at B-level is movement harmony.

Finally, if movement harmony (kinetical B-level) is transformed into particular muscle contractions, then its "grin" is strength control (dynamical A-level), which might be termed as "feeling-in-hand".

The relation of information for different characteristics had become the point of interest of scientists even before the concept of the modalities’ ladder was even invented. Already in 1688, W. Molyneux put forward the problem whether a man who has been born blind and who has learnt to distinguish and name a globe and a cube by touch, would be able to distinguish and name these objects simply by sight, once he had been enabled to see [24].

Here, one has to do with B-level touch, C-level sight and D-level naming. However, let us focus on the C-level. In fact, the essential factor is not the physiological eye, but the psychological ability to analyze one’s own movements in the space of “three-and-fraction” dimensionality (three spatial dimensions and small part of time axis). To create the necessary “map” of such a spatial and temporal environment, vision is most suitable, indeed, but not absolutely necessary. For example, blind persons have to build such a “map” without using their eyes [25]. Moreover, while regaining sight, such a person has to arduously learn how to “translate” particular codes into each other and to join haptic and visual information. In short, information processing potentiality specific to particular “rungs” of the modalities’ ladder depend on mental abilities, and not on sensory organ properties. By the way: seen from the modalities’ ladder perspective, association of visual data with “here and now” spatial and temporal frames of information processing is characteristic just for the C-level and makes its “systemic identity”.

Summing up, when considered from the modalities’ ladder perspective, the whole information processing in humans – from the underlying simple patellar reflex to the creation of Higgs’ boson concept – makes one coherent, yet not uniform, system.

Energy and efficiency from a systemic perspective

While analyzing physical descriptions of the observable reality, the first obstacle is the mathematical language being commonly used in this discipline. As Goethe stated, “mathematicians are like Frenchmen: whatever you say to them they translate into their own language, and forthwith it is something entirely different”. This is without doubt a joke (and a very intelligent one), but nevertheless, even if hardly or not at all describable mathematically, the biological and psychological processes cannot violate physical laws. Consequently, one might try to trace the atavistic, physical roots in sophisticated psychological phenomena and apply the easily discernible physical logical “stencils” to biological and psychological ones.

Before further analyzes, let us assume that the reality is too complicated to be grasped intellectually as a whole. So, to understand it at all (to any extent), its simplified mental representations, i.e., theories, have to be created. They are not obvious and unambiguous representations of reality. Schmidt argued:

Since laws are the product of human creativity, different laws can be formulated by two different individuals who are examining the same observations. Laws do not automatically spring forth from the facts [26].

Accordingly, the reality may be compared to a multidimensional shape, whereas the law, theory, or even the science discipline – to a two-dimensional shadow (Fig. 1). It is worth noticing that all the shadows come from the same body; none of them is more or less true.

Figure 1. Complex reality and its simplified representations (theories): three-dimensional body and its two-dimensional shadows.
than any other one; but nevertheless, each of them differs from the other.

Thus, firstly, let us translate two important physical terms: energy and power into common language. In physics energy is — not very strictly, but for our purposes precisely enough — the ability to perform work. The power is the rate of doing work. In mathematical terms, the power is a first time derivative of energy, whereas the energy is the integral of power over time; just this is “the mathematicians’ language” as by Goethe. Let us try to express this in common language and — while looking from the modalities’ ladder perspective — to trace the grin of Cheshire Cat in respective terms (and notions) embedded in motor control and psychology.

The meaning of energy in common language does not differ greatly from that in physics, but is much more extensive. It may denote not only the physical but also the mental ability to perform specific work. Just this may make up a narrow intellectual “footbridge” linking the worlds of physics and those of biology and psychology.

The term efficiency (along with the adjective “physical”) is commonly used in physiology and sport sciences. It may be defined as follows:

*Physical efficiency* — conditioned by physiological processes, rate of energy transformation in a living organism, measure of which is a momentary power which given organism is able to develop [27].

However, while seen from the modalities’ ladder perspective, itseems instructive to look at this more carefully. As mathematician Sokal and physicist Bricmont remarked, “it’s a good idea to know, what one is talking about” [28]. So, let us define the terms “energy” and “efficiency” as follows:

**Energy** — the current potentiality of a living organism for using a given psychomotor ability to perform work of specific modality.

**Efficiency** — a measure of immediate availability of a given ability, needed to solve the actual task, at the highest intensity possible.

It is worth noticing that efficiency depends on the living organism’s abilities and the task specificity as well.

In both of the proposed definitions, the term “modality” has been used. It means that in biology and psychology — unlike in physics — the terms “energy” and “efficiency” have various characteristics, specific to the modality ladder “rungs”.

Although the term “psychomotor” has been used in both definitions, one should take into account that at various “rungs” of the modalities ladder, the relative shares of “psycho-” and “motor” are different. At D and E levels, the motor component is reduced to zero and vividly resembles the Cheshire Cat’s grin.

The current efficiency may differ in intensity according to current task demands. Of importance is the maximum efficiency a living being is able to develop. Because of fatigue — physiological “fuse” protecting an organism against overloading — the maximum efficiency may be developed only for a short or even very short period.

The kinds of energy and efficiency specific to environment and particular “rungs” of the modalities’ ladder are shown in Table 2.

### Table 2. Physical energy and power; biological and psychological energy and efficiency

<table>
<thead>
<tr>
<th>MOTOR CONTROL LEVEL</th>
<th>PSYCHO-MOTOR ABILITY</th>
<th>PSYCHOSOMATIC ENERGY</th>
<th>PSYCHOSOMATIC MAXIMUM EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>Creativity</td>
<td>Ability to use mental</td>
<td>Current potentiality for maximal usage of the available resources of mental creativity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fantasy</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Expertise</td>
<td>Ability to use mental</td>
<td>Current potentiality for maximal usage of the available resources of mental expertise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>expertise</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Agility (C1)/ Dexterity (C2)</td>
<td>Ability to use somatic agility/dexterity</td>
<td>Current potentiality for maximal usage of the available resources of somatic agility/dexterity</td>
</tr>
<tr>
<td>B</td>
<td>Speed</td>
<td>Ability to use somatic</td>
<td>Current potentiality for maximal usage of the available resources of somatic speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>speed</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Strength</td>
<td>Ability to use somatic</td>
<td>Current potentiality for maximal usage of the available resources of somatic strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td>strength</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PHYSICS QUANTITY</th>
<th>PHYSICAL ENERGY</th>
<th>PHYSICAL MAXIMUM POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical environment</td>
<td>Force</td>
<td>Ability to use physical force</td>
</tr>
</tbody>
</table>
In Tab. 2, one can discern the three clearly different areas; prevailing are:

- Physics, environment (bold small caps),
- Physiology, body, joined with environment by agency of sensory organs (bold letters),
- Psychology, mind, wholly encompassing mental processes, detached from direct relation to physical environment (bold italics).

At first glance, one might identify physiology with the Cartesian res extensa, and psychology – with res cogitans [29]. This would be a great mistake. The process of psychological thinking also takes place at “physiological” levels A, B and C, even in humans. For example, nearly all processes underlying car driving might be placed at C, B, and A levels; they do not need D-level verbal representations of respective operations. Moreover, in Tab. 2, one might trace some relations to the theory of training [30], e.g., the various kinds of mental-motor endurance.

The processes at D and E levels may concern reality, indeed, but they are not necessary. However, extending temporal frames beyond the limits marked by potentialities of sensory organs (timing) was possible only after complete detachment of the mental analyzes from current sensory stimuli. Hence, the D and E levels gained the ability to “live their own lives”, independently of environmental influences. As a result, only at those levels was it possible to create the concepts of, say, ether or phlogiston – nowadays regarded as obviously false – but also quantum theory, general relativity theory or Higgs’ boson concept.

From Tab. 2, one might infer that if a Cheshire Cat dwells at a given level, then his grin resides at a lower level. Accordingly, D-level expertise may be regarded as a “grin” of E-level creativity; C-level agility/dexterity – as a “grin” of D-level expertise, etc. Here one might develop an analogous “litany” as in the case of Tab. 1.

However, in living organisms, the notion of efficiency is much more complex than that of energy. The latter depends on an individual’s abilities, whereas the former – on both an individual’s abilities and task specificity. The higher the motor control level, the more sophisticated and diverse criteria of efficiency. For example, a different kind of E-level creativity is necessary for a painter, and a different – for a musician, physicist, technician or economist. Accordingly, in biology, motor control and psychology, the Cheshire Cat’s grin is much more elusive than in physics.

By the by: each of the modalities’ ladder “rungs” has its own “identity”, among other things the rate of specific ability fatigue and recovery, as well as trainability and sustainability of training effects. This makes the basis for heterochrony, i.e., different speed of fatigue elimination in different mental-motor abilities [31], and periodization of an athlete’s training [30].

**Conclusions**

This paper may be perceived as an attempt at joining the physical, biological and psychological phenomena with a series of “footbridges” linked together with the structure analogous to the Cheshire Cat’s grin.

Carrol wrote “*Alice’s Adventures in Wonderland*” in 1863, and published it in 1865. In 1900, Planck presented the concept of quant, and in 1923, Bohr formulated the correspondence principle. It states that in the region of high energies, the language of quantum mechanics becomes identical with the language of classical physics [3]. Hence, it makes up specific Cheshire Cat’s grin, linking two qualitatively different regions of quantum and Newtonian physics. Physicist and philosopher Jammer describes this principle as follows:

*There was rarely in the history of physics a comprehensive theory which owed so much to one principle as quantum mechanics owed to Bohr’s correspondence principle [32].*

In physics, there exists one such “Cheshire Cat’s grin”, whereas in psychology – at least four analogous ones:

1. A–B (proprioceptive-contactceptive);
2. B–C (contactceptive-teleceptive);
3. C–D (teleceptive-verbal);

Each of the modalities has its own specificity, different from that of others. For example, the obvious verbal D-level message that “Poland is not yet lost” has another meaning (for Polish people) at symbolic E-level. It is hardly possible to explain verbally (D-level) to a blind person what is the characteristic of the red hue (C-level).

Still more difficult is “translatability” between the levels more distant to each other. For example, it is impossible to explain verbally (D-level) how to keep balance while cycling (B-level).

Each of these “Cheshire Cat’s grins” or “correspondence zones” produce their own unpredictable system effect. Hence, in fact, this apparently frivolous term denotes a serious qualitative change (in the sphere of information processing – modality transformation), usually of non-linear nature. Just the nonlinearity is – at least to a great extent – responsible for an elusive, mysterious and simply miraculous system effect [23]. It is worth noticing that here we speak not of a “self-organization” – which to me is a close cousin of the behavioristic “black box”, literary “catch 22”, or fairy-tale “genie in a bottle”, so it slightly touches upon charlatanry – but is of much more rational emergency.

In this respect, the words of psychologist Kalat are highly instructive, who wrote:
A great brain without muscles would be like a computer without a monitor, printer, or other output. No matter how powerful the internal processing, it would be useless. Nevertheless, most psychology texts ignore movement (my emphasis—WP), and journals have few articles about it [33].

The presented paper may be also regarded as a contribution to the broader idea by neuroscientist Cacioppo, who stated:

Contemporary psychological scientists stand on the shoulders of those who went before. From this perch it is now possible to see that the bounded fields of the 20th century are related parts of the same landscape. This is a requisite step for bringing research on pieces of related problems together to address bigger questions and to develop more comprehensive scientific theories [34].

While climbing up to a still higher perch, one might learn that this statement could well concern the whole contemporary science. And as long as those “bounded fields” make separate “knowledge islands”, and not one coherent system, they are not able to produce a qualitatively new, valuable, brilliant system effect.

However, to achieve this, mental effort is inevitable. In this respect, the following words by psychologist Gigerenzer sound rather ominous:

Some years ago I spent a day and a night in a magnificent library reading through issues of the “Journal of Experimental Psychology” from the 1920s and 1930s. (…) What depressed me was that nearly all of this meticulous work has been forgotten. Most of it involved collecting data without substantive theory. Data without theory is like a baby without a parent: Its life expectancy is low. Are these the kind of babies we want to produce? [35].

When some years ago, I asked my American friend: “What do you need to be a good scientist in America?”, he answered without a single second of hesitation: “You have to have a good lab”. However, science is born in a scientist’s mind, and not in a lab, even in the most sophisticated one. Especially in biology, motor control and psychology, it cannot be lightly, easily and safely produced, often nearly mechanically, according to the pattern “material – methods – results – discussion – conclusion”. All the more, in experimental papers the latter is often a sheer statement of experimentally established facts and not a result of original reasoning and their intellectual processing. Thus, living beings have to obey physical laws, indeed, but cannot be fully described using mathematical language, specific to them. Hence, in the contemporary world, fascinated by modern techniques, biology, motor control and psychology still wait for an “egg-headed” founder of their “general theory of relativity”…

References

Efficiency in physics, biology, and motor control; the lessons from Cheshire Cat


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EFFECTS OF EXERCISE TRAINING AND CREATINE MALATE SUPPLEMENTATION ON VENTILATORY THRESHOLD AND ANAEROBIC WORKING CAPACITY IN LONG-DISTANCE RUNNERS

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Key words: runners, creatine malate, ventilatory threshold, VO2max, total anaerobic work, body composition.

Summary

Purpose. The aim of this study was to investigate the influence of a 6-week physical training programme and creatine malate supplementation on forming aerobic and anaerobic exercise capacity in long-distance runners in an experimental group (n = 7) and control group (n = 7).

Basic procedures. The ventilatory threshold, the distance covered to the threshold, oxygen uptake per minute, heart rate, the percentage of maximal oxygen uptake, as well as the total distance, and maximal oxygen uptake were analysed. In a jumping test (single jump and a series of 15 jumps), total work and height of the gravity centre elevation were registered.

Main findings. Only the experimental group showed a significant lengthening of the run distance to the ventilatory threshold and to the total distance, while in the jumping test (series of 15 jumps) an increase of anaerobic work was registered.

Conclusions. Changes observed in runners suggest an ergogenic effect of creatine malate supplementation. In the control group, no significant changes in the analyzed variables were noted.

Introduction

Enriching one’s daily diet with supplements as dictated by increased demand for energy has become a standard practice in professional athletes. This is due to, inter alia, the body’s limited ability to absorb nutrients. In training, it is recommended to enrich the diet of professional athletes with ergogenic supplements [1–3].
The worldwide popular effect of creatine compounds on the human body (creatinine monohydrate, creatine pyruvate, creatine citrate, creatine ethyl ester, creatine malate) gives absolutely no side effects [4–9]. Many years ago, it was observed that creatine makes an excellent phosphate medium. By creating phosphocreatine, it becomes a key substance in the process of ATP re-synthesis in the muscle cells, providing an adequate level of this high-energy compound essential in the mechanism of muscle contraction [1]. Creatine is considered a physiological aid in cellular metabolic processes that determine muscle strength and the amount of the generated power, what is particularly vital for sprint athletes. The ATP re-synthesis in anaerobic conditions using phosphocreatine is a considerably more effective metabolic pathway than substrate phosphorylation, as it contributes to lower muscle acidification, which in turn, affects the increased workout intensity [10].

An interesting aspect of creatine supplement administration is its concentration variation in muscle cells. It is suggested that creatine supports exercise by participating in several metabolic mechanisms. Firstly, together with increased creatine concentration in the skeletal muscle, it raises the ability of ADP re-phosphorylation or ATP-re-synthesis, resulting in better performance during high-intensity activities, particularly if they are interspersed with restitution periods [11, 12]. Examples of such activities are sprint runs, weightlifting or jumping. Secondly, creatine enhances penetration of phosphate between the mitochondria and chains of myosin resulting in positive impact on muscle ability of maximum contraction. Thirdly, creatine acts as a buffer by neutralising the pH caused by progressive metabolic acidosis, utilising hydrogen ions during the ADP re-phosphate reaction to ATP catalyzed by creatine kinase. Fourthly, by lowering the PCr level due to increased ATP demand during exercise, it can re-stimulate phosphofructokinase by accelerating glycolysis, which results in increased production of ATP [11, 13]. Creatine (Cr) is produced endogenously by the liver or delivered to the body with food, whereas the daily pool of endogenous Cr is about 2 g for a person of 70 kg BM. Its resources are mainly located in the muscles; 40% is free creatine, and the remaining 60% is phosphocreatine (PCr). The PCr concentration is significantly higher in the II type of muscle fibres and depends on gender (higher concentration was observed in men [14]) and age. A slight decrease occurs with the aging of the body, however, it is not certain whether this is related to age as such, or to decreased physical activity [15]. In the body of a person of 70 kg BM, there is c. 130 g of creatine. The body loses approximately 2 g of it per day, half of which the amount is recovered by means of synthesis in the liver. The remaining 1 g should be provided through food [13]. The increase of creatine concentra-

### Materials and Methods

**Participants**

Out of the 20 professional athletes selected for the study, finally qualified were 14 individuals aged 18–30, having practised running for a minimum of 4 years, specializing in long-distance runs >5 km, who had not received any creatine formulations for at least 1 year. All volunteers were informed on the purpose, methodology, and possible risks during the studies, and then, having been familiarised with the procedure, signed written informed consent for participation, with the right to
resign at any time. The tests were conducted during an introductory mesocycle and basic preparatory period, during which the physical strain during training sessions were at a predominant percentage maintained below the ventilatory threshold (VT). The sportsmen in the experimental group (E) n = 7 were administered creatine malate (CML), and the ones in the control group (P) n = 7 received a placebo (blind test). Runners were allocated into groups E and P in pairs, so as during the experiment they could undergo a similar training programme. The runners in the groups E and P did not differ regarding their morphological body structure. In the initial research, the structural and biometric body indicators showed the following values, respectively: BH 176 ± 3.46 cm and 175 ± 4.11 cm, BM 65.88 ± 3.77 kg and 65.31 ± 3.55 kg, PF 6.44 ± 0.23% and 7.35 ± 1.82%, and LBM 61.20 ± 3.80 kg and 60.34 ± 4.85 kg. No significant differences were registered in their level of VO2max (E = 70.10 ± 7.35 ml kg⁻¹ min⁻¹ and P = 69.46 ± 7.20 ml kg⁻¹ min⁻¹), either. The research project obtained consent from the Bioethics Commission for Scientific Research at the Regional Medical Chamber in Krakow to carry out the experiment (Opinion No. 76 KBL/OIL/2008).

Measurements

Body height (BH) was measured with a Martin (USA) anthropometric device, body mass (BM) with the Sartorius scales type F 1505 – DZA (Germany). The percentage of fat (PF), lean body mass (LBM) and body mass index (BMI) were measured with Densitometer DEXA 2013 Lunar Prodigy Primo Full, with the body composition option, manufactured by GE Healthcare Technologies (USA). The graded exercise test was executed on a mechanical treadmill, type Saturn-250/100 R h/p/Cosmos (Germany). It took place in an air-conditioned laboratory of the Department of Physiology and Biochemistry in an ambient temperature of 21±0.5°C, and relative humidity of 45±3%. The warm-up was carried out using the Corival Ergometer (Lode BV) (Netherlands). Respiratory and cardiovascular exchange ratios were measured with OxyconPro apparatus (Care Fusion Healthcare GmbH), Jaeger (Germany), while in the jumping test, the amount of total work (TW) and the height (h) of raising the gravity centre was measured with the Optojump V3-high Microgate (Italy) Device.

Jumping Test

After a 5 minute warm-up at 50% VO2max intensity on an ergometre, pedalling frequency of 70 rpm, and three maximum accelerations in the last 5 seconds in the 2nd, 4th, and 5th minutes, the subjects began the jumping test. It consisted in executing on a platform one, maximum vertical jump without an arm swing (RR), and after the next 2 minutes of rest, a series of 15 jumps at a frequency dictated by a metronome; 1 jump per second. During the test, the height (h) of raising the gravity centre and total work (TW) were measured.

Exercise test

On the second day, a graded exercise test on a treadmill was carried out. It was preceded with a 3-minute warm-up (WU) at a running speed of 2.3 m s⁻¹, followed by an every-three-minute increased running speed by 0.5 m s⁻¹. The exercise continued until refusal, i.e. to the point, when the tested person was not able to run at the imposed speed any more. During the run, the following were measured: tidal volume (TV), respiratory frequency (FR), minute ventilation (V), minute oxygen uptake (VO2), volume of carbon dioxide (VCO2), respiratory rate (RER), percentage of carbon dioxide in the air exhaled from the lungs (FeCO2), breathing equivalent VE·CO2, which were used to determine the second ventilatory threshold (VT) [28–30], and heart rate (HR).

Procedures

The research was carried during a nine-week period, between 8:00 a.m. and 12:00 a.m.. In the first week, the athletes underwent pilot studies to eliminate the psychological factor associated with stress arising from a new situation. Physiological body reactions to graded exercise were examined. In the second week, for two days, basic examinations were done (I-test). On the first day, biometric and structural measurements of the body were performed, and a jumping test was carried out: a single jump test without arm swing (RR), and a series of 15 jumps RR swing. On the second day, a graded exercise test until exhaustion was performed. Then, for six weeks, every day, two hours after breakfast, the men were orally administered capsules containing 0.07 g · kg⁻¹ LBM of creatine malate manufactured by OLIMP (Poland), corresponding to about 5 g of this preparation for a person of lean body mass (LBM) of 70 kg [14]. The supplement was taken with 250 ml of plain, boiled water. During that time, the athletes trained according to the plan and used a standard, given diet. In an identical manner, the athletes in the control group (P) were given placebo capsules. The E and P athletes were not informed about different contents of the administered capsules (blind test). They just received information that for 6 weeks, they would be receiving an identical, permitted supplement. During that period, the athletes trained in pairs, according to the training plan, and applied a typical diet, which they registered in their record-books. During the course of the study they declared not to take other supplements. Once the saturation of the body with CML or placebo was completed, they started the second main tests. All tests were carried out in an air-conditioned laboratory.
Statistical Analysis

For statistical analysis of numerical material, the Statistica 9.0 package for Windows by StatSoft was used. The results were presented as mean (x) and standard deviation (SD). Changes in the indicators due to training were evaluated by using two-way analysis of variance (ANOVA) with repeated factor measurement (measurement I vs. measurement II) and one-factor intergroup (group E vs. group P). Evaluation of the differences at one level of a factor was made by using the strategy of planned comparisons. When the cases did not meet the assumptions of normal distribution, due to the small sample size (7 people), results were compared with the nonparametric U Mann-Whitney test for two unrelated trials and the Wilcoxon test for two related ones. As the results of these analyses were consistent, we decided to present the results of analysis of variance, as it is greatly more versatile and resistant to deviate from the assumptions of normality of distribution. The adopted level of statistical significance was p < 0.05.

Results

After 6 weeks, there were no significant changes in the level of biometric (BH and BM) and structural (PF and LBM) body indicators among the runners from the E or P groups. In the E group supplemented with CML, despite no essential differences, a slight tendency to increase in PF and LBM was observed. Also registered was a significant increase in the running distance to the ventilatory threshold (DVT) by about 19% (p < 0.018), which was not observed in the placebo group (P) undergoing a similar training programme. In both groups, E and P, in the second tests (after), the distance to the ventilatory threshold (DVT) was extended respectively, by 555 m (p < 0.018) and 100 m (p < 0.654) (Table 1). In both groups, E and P, no significant changes in cardiopulmonary indicators were registered at VO2max level. (Tab. 2). Meanwhile, in the experimental group (E), in the graded exercise test a significant (p < 0.017) increase of the covered distance (D) was registered. In the

<p>| Table 1. Physiological indicators registered at the ventilatory threshold (VT) |
|------------------------------------|---------------------------------|---------------------------------|--------------------------------|</p>
<table>
<thead>
<tr>
<th>Indicators</th>
<th>Group</th>
<th>Training period</th>
<th>Changes* (p &lt; 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>%VO2max</td>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HRVT E 168 ± 7.67</td>
<td>166 ± 8.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>168 ± 7.67</td>
<td>166 ± 8.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HRVT P 173 ± 8.99</td>
<td>172 ± 7.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO2VT E 3.35 ± 0.63</td>
<td>3.32 ± 0.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO2VT P 3.76 ± 0.68</td>
<td>3.61 ± 0.98</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%VO2max E 73.9 ± 6.99</td>
<td>78.9 ± 8.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>%VO2max P 83.5 ± 5.58</td>
<td>80.5 ± 7.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DVT E 3159 ± 389.14</td>
<td>3714 ± 281.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DVT P 3082 ± 389.14</td>
<td>3182 ± 364.21</td>
</tr>
</tbody>
</table>

<p>| Table 2. Physiological indicators registered in the graded test at the VO2max level |
|------------------------------------|---------------------------------|---------------------------------|--------------------------------|</p>
<table>
<thead>
<tr>
<th>Indicators</th>
<th>Group</th>
<th>Training period</th>
<th>Changes* (p &lt; 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HRmax E 183 ± 5.40</td>
<td>178 ± 4.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HRmax P 178 ± 6.14</td>
<td>181 ± 5.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO2max E 4.67 ± 0.62</td>
<td>4.62 ± 0.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO2max P 4.49 ± 0.67</td>
<td>4.46 ± 0.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO2max E 70.10 ± 7.35</td>
<td>70.02 ± 5.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VO2max P 69.46 ± 7.20</td>
<td>68.89 ± 7.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D E 5080 ± 334.14</td>
<td>5340 ± 362.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D P 4958 ± 263.06</td>
<td>5005 ± 265.98</td>
</tr>
</tbody>
</table>
placebo group (P), these changes were not statistically significant. The results of the covered distance (D) in the second tests (after) between E and P groups were statistically significant ($p < 0.037$).

In runners from groups E and P, in the first and second tests, in the test consisting of a single jump ($p$) the results of total work ($TWP$) and the elevation of the gravity centre height ($h_p$) did not differ significantly (Table 3). Whereas in the 15 jumps test ($s$), in the runners supplemented with CML significant increases in total work ($TW_s$) ($p < 0.042$) and elevation of the gravity centre height ($h_s$) ($p < 0.037$) were found, which was not present in the placebo group (P). In the second tests (after) the results of TWs and $h_s$ were significantly higher in the E than P group, $p < 0.045$ and $p < 0.036$, respectively.

### Discussion

In the last twenty years, a number of studies on the morphological and functional changes resulting from creatine compounds supplementation: creatine monohydrate, creatine pyruvate, creatine citrate, creatine ethyl ester, or creatine malate have appeared [2, 3, 16–18, 21–26, 29–31]. These publications focus mainly on very specific issues such as the impact of its administration on the ability to generate power as well as speed and power endurance, or training adaptation in athletes [7, 3]. Until now, it has been empirically demonstrated that administration of creatine provides an ergogenic effect in sportsmen practicing speed or strength disciplines. There are also suggestions that the ergogenic effect of creatine supplementation may be greater in men than in women. Our team has conducted research aiming at assessing the impact of CML supplementation in sprinters and long-distance runners – athletes involving the efforts of different systems for power generation. In these groups of athletes, a different ergogenic effect of the administered CML was found. In sprinters, it showed a considerable increase in peak power and total work in the Wingate test [32], and progression of lean body mass. However, in long-distance runners, it only showed a slightly significant increase in aerobic capacity, as in the graded exercise it showed a significant increase in the covered running distance. Much less information is available regarding its impact on exercise capacity in typical endurance sports representatives. The present study has made an attempt to verify the body’s response to CML administration in long-distance runners. In order to determine the influence of CML supplementation and physical training, the runners presenting an identical sports class were selected into groups E and P in pairs, so as in the over the 6-week period of the study they could undergo almost the same exact training program, in identical conditions of the external environment. In long-distance runners, in graded exercise, the ergogenic effect of body supplementation with CML showed a significant shift of the anaerobic threshold towards a higher speed, yet without any changes in VO$_{2\text{max}}$. This indicates that supplementation with CML may increase the total work in a long-term graded test. This is attributed to accelerated aerobic phosphorylation during exercise at lower intensities, which affects oxygen balance [33]. It also shows the indirect effects of CML supplementation on aerobic fitness. Engelhardt et al. [34] noted that administration of creatine in a low dosage of 2 x 3 g daily for 6 days to athletes in endurance sports does not affect the circulatory system, oxygen uptake or lactate concentration in the blood. However, although the triathletes’ endurance during interval exercises increased by as much as 18%, the indicators defining aerobic capacity did not change at all. It was therefore concluded that administration of creatine could have positive impact on short-term physical activity, which might be an intrinsic element shaping endurance. This is in line with our

### Table 3. Total work and height of gravity centre elevation in the jumping test [maximum single jump ($p$) and a series of 15 jumps ($s$)]

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Group</th>
<th>Training period</th>
<th>Changes*</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>$TWP_p$ (J)</td>
<td>E</td>
<td>196.1 ± 24.56</td>
<td>196.5 ± 26.87</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>185.1 ± 26.65</td>
<td>185.5 ± 26.58</td>
</tr>
<tr>
<td>$TW_s$ (J)</td>
<td>E</td>
<td>2194 ± 42.89</td>
<td>2553 ± 42.14</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>2208 ± 60.13</td>
<td>2103 ± 60.36</td>
</tr>
<tr>
<td>$h_p$ (cm)</td>
<td>E</td>
<td>32.21 ± 3.41</td>
<td>32.80 ± 4.55</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>28.97 ± 3.23</td>
<td>30.06 ± 2.34</td>
</tr>
<tr>
<td>$h_s$ (cm)</td>
<td>E</td>
<td>22.65 ± 1.89</td>
<td>26.53 ± 2.11</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>22.33 ± 2.21</td>
<td>22.85 ± 1.36</td>
</tr>
</tbody>
</table>
results of the long-distance runners tests. Meanwhile, Nelson et al. [35] studied the response of the cardiorespiratory system to a graded test on a cycle ergomètre. Creatine caused a significant increase in working time. Maximal oxygen uptake and maximum heart rate decreased in the test group. The ventilatory threshold occurred by a much higher percentage of oxygen consumption (increase from 66% to 72% VO\(_{2\text{max}}\)). It was concluded that creatine affects various components of the metabolic systems during initial phases of graded exercise. This contributes to the athlete's ability to endure a sub-maximal training load at a lower oxygen cost and by a reduced load of the circulatory system. Moreover, the Chwalbińska-Moneta's study [23] has shown that creatine supplementation enhances aerobic capacity, regardless of the intense endurance training effects. Jones et al. [36] examined the impact of creatine on VO\(_{2\text{max}}\). Their research evidenced that creatine supplementation does not result in changes in maximal oxygen uptake, but significantly influences the reduction of the VO\(_{2}\) temporary components at the initial phase of high-intensity exercise. In the above study, the vastus lateralis muscle biopsy was carried out. It turned out that the percentage of type II fibres was closely correlated with the reduction level of sub-maximal VO\(_{2}\), which indicates that supplementing with creatine may be associated with changes in the amount of motorneurons recruited during exercise, or with the volume of activated muscles [36]. In our research, administering CML to the runners resulted in significant prolongation of the running distance to the ventilatory threshold (VT), and the total running distance (D). Similar changes were observed in our previous studies in which, however, we found no anaerobic ergogenic effect of CML supplementation. In the Wingate test, in the individuals supplemented with CML, no progression in peak power or total work results was observed. In the present study, after 6 weeks of training and CML supplementation, we observed progression in group E of anaerobic performance in the series of 15 jumps on a dynamographic platform, and no effect in the single jump test. Such structure of the results suggests that the improvement in aerobic endurance in runner athletes also originated from an increased speed and endurance strength. In other studies, in a jumping test — series of 10 jumps in 60 seconds — after supplementation, an increase in the average elevation of the gravity centre was observed, despite a simultaneous, negligible increase in body weight, suggesting large influence of creatine on the ability to overcome short-term high-intensity workloads [37]. In some opinions, creatine can stimulate aerobic capacity by increasing the ability to carry out intensive interval efforts [38]. It seems that for determining the peak power and anaerobic work of athlete runners, due to the nature of the movements, running or jumping tests should be employed, rather than, for example, cycling tests, e.g. Wingate [32]. Routine tests on runner athletes conducted in our laboratory show that the results of PP and TW in the cycling test are quite remotely correlated with the results of these indicators in running and jumping tests. Many researchers have noted that creatine supplementation combined with specific physical training has a direct relationship not only with the increase of maximum strength and ability to manage higher and higher physical loads during a resistance training, but also with lean body mass [15, 19, 39, 40]. Some reports indicate that after creatine compound supplementation and physical training, the LBM changes are not the same in sprinters and long-distance runners, which is likely due to the different nature of the training types and body composition of the athletes. In our study, we found no significant changes in the composition, however, in the runners from group E, we observed a tendency for LBM to increase.

**Conclusions**

The physical training and supplementation with creatine malate applied for six weeks have led to increased aerobic and anaerobic endurance in long-distance runners, but without any significant changes in VO\(_{2\text{max}}\) and body composition (BM, PF, LBM), and has also resulted in later occurrence of ventilatory threshold and longer distance covered to VT. The positive ergogenic effect of supplementation observed in men indicates validity of supplementing the body with CML not only in speed and strength sports athletes, according to the reference literature data, but also in the long-distance runners.

**References**


Effects of exercise training and creatine malate supplementation on ventilatory threshold... 


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Changes in Morphological-Rheological Blood Properties of Hutnik Club Football Players

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Key words: football, blood morphology, blood rheology

Abstract

Study aim. The aim of the study was to investigate the effect of long-term football training on the morphological-rheological properties of the blood.

Study material. The study was conducted among a group of 16 footballers playing for the Hutnik Nowa Huta Club. The average age of subjects was 22 years. Practices are held 5 times a week, all year round with the exception of the last 3 weeks of December and the last 2 weeks of June. In addition, championship or sparring matches are played every weekend. Venous blood was collected at the end of the football season, in the morning on an empty stomach. Examination of morphological-rheological parameters of the blood was performed in the footballers and the control group.

Results. Compared to the control group, a statistically significant decrease in RBC, HGB, HCT, MCV, PLT and plasma viscosity were found for the footballer group. And a statistically significant increase in fibrinogen and MCHC as well. There were no statistically significant changes in the amount of WBC and MCH. Significant changes were also noticed in erythrocyte aggregation and elongation for the footballers. AI reduced, while AMP and T½ increased. Elongation index at shear-stress for the range of 0.30–1.13 [Pa] significantly increased, while for the value ranges of 2.19–59.97 [Pa], a decrease was observed in this parameter.

Conclusions. Long-term, regular football training does not cause pathological changes in the morphological-rheological properties of the blood.

Introduction

Football is the most popular sport in the world. Its earliest variant was already played in the Chinese army, B.C. [26]. The modern history of football began about 150 years ago in England [2]. Currently, the International Football Federation covers almost every part of the world, consisting of 209 national associations. It is responsible for the most prestigious sports tournament – the FIFA World Cup. [23]

The scientific branch dealing with the phenomena of blood flow through blood vessels is hemorheology.
Research focuses on whole blood, plasma and the cellular components. Analyzing the rheological properties of blood, we obtain information on how it behaves in the vascular system [16]. Blood flow is determined by its physicochemical properties, it is non-uniform, and its viscosity varies depending on shear rate. Plasma is a non-Newtonian liquid, the viscosity is determined by high-molecularity protein content [14]. Blood rheology plays a very important role in the aggregation of erythrocytes, the phenomenon is dynamic and reversible. Erythrocytes are connected via macromolecular bridges forming single aggregates called Rouleaux which can create spatial branches [11]. The deformability of erythrocytes is based on the changes in their shape necessary to pass through a vessel with a diameter smaller than the erythrocytes themselves. This is a reversible process and does not affect the surface or volume and does not alter the properties or functions of erythrocytes [15].

The aim of the study was to investigate the effect of regular training on the morphological-rheological properties of the blood in football players.

Material and study methods

Study group

The study group was formed from a group of 16 footballers belonging to the Hutnik Nowa Huta Club. The men were aged 19–31 years, the mean age 22 years. Practices are held 5 times a week, all year round with the exception of the last 3 weeks of December and the last 2 weeks of June. In addition, championship or sparring matches are played every weekend.

The study took place on July 11, 2014 in the Laboratory of Locomotor Pathology at the University School of Physical Education in Krakow. The footballers arrived for examination in the morning, on an empty stomach. A qualified nurse collected the blood into Vacuette – type test tubes with potassium EDTA. The morphological-rheological indicators of the blood were tested. The study was authorized by the Bioethics Committee at the Regional Medical Chamber in Krakow.

The measurement of basic hematological indicators

The HORIBA ABX Micros 60 blood analyzer was used to measure basic morphological indicators:

- WBC [G/L] – number of white blood cells
- RBC [T/L] – number of red blood cells
- HGB [g/L] – hemoglobin
- T[L/L] – hematocrit
- PLT[G/L] – platelets
- MCV[IL] – mean corpuscular volume
- MCH[fMol] – average mass of corpuscular hemoglobin
- MCHC[mMol/L] – mean corpuscular hemoglobin concentration

Rheological blood testing

To study the aggregation and deformability of red blood cells, the LORCA lasik-optical analyzer constructed by Max R. Hardeman was used. The instrument has two cylinders in between which the blood is placed. The outer cylinder rotates relative to the inner one. In this method, the red blood cells scatter the laser light which is in a stationary cylinder [22].

Elongation index determination

For the determination of the elongation index, a 25μl blood sample was taken and put into 5 ml of 0.14 mM polyvinylpyrrolidone (PVP, M = 360000) solution. The measurement was performed at 37°C. The sample was placed between the cylinders and submitted to centrifugal force. The laser light passing through the red blood cells is diffracted. The compressed computer system records the scattering of the laser beam, and then computes the elongation index (EI) according to the following formula: EI = (A – B) / (A+B), A – is the length of the red blood cell B – is the width of the red blood cell

The results of the elongation index (EI) were given in the range of 0.30 to 59.97 of shear forces expressed in Pascals [Pa]. The collected measurements determined the degree of erythrocyte flexibility [10] [22].

Aggregation index determination

To test the aggregation index, 1 ml of blood was put into the chamber located between two cylinders. The computer launched rotational movement of the cylinder, 120 s at a shear rate of > 400 s⁻¹. After ten 10 seconds, the cylinder stops and aggregation of red blood cells occurs. Its measurement is the change in laser light intensity, until its maximal value within a range of 0.5–2.0 sec. After reaching 2 seconds to 1 minute or longer, erythrocyte aggregates are subjected to different shear rates from 6 to 700 s⁻¹ [9] [22].

The computer calculated the following parameters defining the kinetics of erythrocyte aggregation:

- AI [%] – aggregation index calculated from the formula:
  AI = A/A + B×100 %
  A – area above selectogram
  B – area below selectogram
- AMP [au] – degree of total aggregation
- T½ [s] – half-life of total aggregation

Biochemical testing

Determination of fibrinogen concentration

Fibrinogen concentration [g/l] was determined using the Chrom – 7 coagulometer. The Bio-Ksel PT reagent containing thromboplastin with calcium chloride was...
Changes in morphological-rheological blood properties of Hutnik Club football players

...added to the plasma which resulted in plasma coagulation and clot formation. Conversion of fibrinogen to fibrin occurred. The standard for fibrinogen is from 2 to 5 g/l.

**Determination of blood plasma viscosity**

Examination of plasma viscosity [mPa] was performed using the Myrenne viscometer (model: D-52159, Germany). 0.5 ml of plasma, obtained after centrifugation of the morphotic components of the blood, was put into the measurement capillary. The measured value is the time in which the tested string of plasma covered the distance from the L3 to L4 light-points, thanks to constant pressure. The device was standardized using standard Myrenne NP1 and NP2 solutions before the measurement. In order to obtain high accuracy (approx. ± 3%), NP1 was a standard solution for the lower range of measurements with the viscosity of 1.10 [mPa]. NP2 was the standard solution for high range measurements.

**Statistical analysis**

The results were obtained using Microsoft Office Excel. Analysis of the study took into account, inter alia, the number of people in the group, the mean and standard deviation. To compare data between the group of footballers and the control group, the Tukey test was used. Statistically significant values were found at the significance level of p < 0.05.

**Study results**

The analysis of morphological and rheological indicators of the blood:

1. **HGB [g/L], HCT [L/L], MCV [fL], MCH [fmol], MCHC [mmol/L]**

Comparing the group of footballers to the control group, the following statistically significant changes were found:
   - average concentration of HGB [g/L] decreased by 8.52% in footballers
   - average number of HCT [L/L] decreased by 13.79% in footballers
   - average value of MCV [fL] decreased by 5.05% in footballers
   - average value of MCHC [mmol/L] increased by 6.26% in footballers

Analyzing the changes in the average value of the MCH [fmol], no statistically significant changes were

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![Fig. 1. Graph presenting average values of HGB [g/L], HCT [L/L], MCV [fL], MCH [fmol], MCHC [mmol/L] in footballers compared to the control group.](image1)

![Fig. 2. Graph presenting average values of WBC [G/L], RBC [T/L], fibrinogen [g/l], blood plasma viscosity [mPa] in footballers compared to the control group.](image2)
found in the group of footballers compared to the control group.

2. WBC [G/L], RBC [T/L], fibrinogen [g/l], blood plasma viscosity [mPa]

Analyzing the changes in the average number of WBC [G/L], no statistically significant changes in the group of footballers were found compared to the control group.

Comparing the group of footballers to the control group, the following statistically significant changes were found:
- average number of RBC [T/L] decreased by 9.4% in footballers
- average value of fibrinogen [g/l] increased by 24.61% in footballers
- average value of blood plasma viscosity [mPa] decreased by 16.39% in footballers

3. PLT [G/L]

![Graph presenting average values of PLT [G/L] in footballers compared to the control group](image)

Fig. 3. Graph presenting average values of PLT [G/L] in footballers compared to the control group

4. EI [Pa]

Comparing the group of footballers to the control group, the following statistically significant changes were found:
- average EI concentration at 0.30 [Pa] shear-stress increased by 179.76% in footballers
- average EI concentration at 0.58 [Pa] shear-stress increased by 235.53% in footballers
- average EI concentration at 1.13 [Pa] shear-stress increased by 51.32% in footballers
- average EI concentration at 2.19 [Pa] shear-stress reduced by 30.37% in footballers
- average EI concentration at 4.24 [Pa] shear-stress reduced by 29.34% in footballers
- average EI concentration at 8.23 [Pa] shear-stress reduced by 20.89% in footballers
- average EI concentration at 15.96 [Pa] shear-stress reduced by 14.29% in footballers
- average EI concentration at 31.04 [Pa] shear-stress reduced by 10.75% in footballers
- average EI concentration at 59.97 [Pa] shear-stress reduced by 6.85% in footballers

5. AI [%], AMP [au], T½ [s]

Comparing the group of footballers to the control group, the following statistically significant changes were found:
- average AI [%] numerical values decreased by 15.31% in football players
- average AMP [au] numerical values increased by 69.14% in football players
- average T½ [s] numerical values increased by 69.18% in football players

![Graph presenting average values of EI [Pa] in footballers compared to the control group](image)

Fig. 4. Graph presenting average values of EI [Pa] in footballers compared to the control group
Discussion

Association football belongs to a group of sports with a very particular training programme which escapes the simple distinction between endurance and strength training. A football match lasts 90 minutes and is divided into two halves, 45 minutes each; during this time, players engage in physical activity of both aerobic and anaerobic nature. Most of the time, a player’s metabolism is aerobic, however, some distances must be covered with great speed, with anaerobic intensity and a heart rate at 80-90% of maximum heart rate [1] [17].

The objective of the present study is to demonstrate the effect of regular training on association football players’ morphological and rheological properties of the blood. Many studies have already proved the effect of regular training on the properties of blood flow. Research indicates a decrease in haematocrit, haemoglobin concentration and a decrease in the number of red blood cells due to endurance training; the condition is explained by the increased volume of plasma occurring during and after physical exercise [18] [24]. However, the above-mentioned research only applies to strength or endurance training [20].

Research on the impact of association football training programmes on haematological parameters is limited. In their research, Bruno et al. (1991) showed that regular football training improves blood fluidity and has positive impact on blood rheology [4]. In their research, Edwards and Clark (2006) observed a significant decrease in the volume of plasma, measured after a non-professional (7.2%) and professional (11.6%) football match [7]. To my knowledge, the study by Edwards and Clark is the only one showing a decrease in plasma volume in response to years of exercise. Schumacher et al. (2002) explain this state as resulting from congestion of the blood caused by fluid loss, in turn caused by increased sweating resulting from intense exercise [20].

The decrease in plasma volume is also common in dehydrated athletes [6].

While studying 99 association football players, Varlet-Marie et al. (2011) showed, among other things, the correlation between VO2 max and haematocrit. The existence of the correlation confirms the results of earlier studies, performed on a smaller number of athletes. Another relation revealed in the aforementioned study concerns the influence of the appearance of lactate in the blood on the aggregation of red blood cells. The relationship is consistent with many previous reports by Varlet-Marie et al. and confirms that red blood cells are more likely to aggregate when the muscles at work release more lactate [25].

In my study, a statistically significant increase (24.60%) of fibrinogen as compared to the control group was proven. The impact of association football training on fibrinogen is poorly investigated, however, there is no doubt that fibrinogen and blood rheology are closely linked since the former is the main determinant of erythrocyte aggregation [19].

Furthermore, a statistically significant decrease in plasma viscosity, possibly attributable to increased plasma volume, was noticed. Karakoc et al. (2005) argue that the increase of lactate in the blood has no negative effects on plasma viscosity in football players since they develop a defence mechanism through regular training during the season. Analysis of the study by Karakoc et al. (2005) shows that blood viscosity tends to decrease as a result of this type of training; this is due to a decrease in mean red cell volume by 5.05%, also showed in my study [12].

My research on the aggregation and elongation of erythrocytes in association football players is pioneering. All these parameters were statistically significantly different from the control group. The study by Bilski et al. (2014) showed that physical exercise affects the rheology of blood in that it significantly changes the deformability of erythrocytes; the elongation index is also
statistically significantly reduced. These changes may be partly due to an increase in lactate levels in plasma after exercise. Lactate reduces the size of red blood cells, which in turn decreases their formability [3]. My research showed a decrease in the deformability by 2.19-59.97 [Pa] in the shear-stress interval; formability increased significantly for lower shear rates: 179.76% for EI 0.30 [Pa], 235.53% for EI 0.58 [Pa] and 51.32% for EI 1.13 [Pa].

Detailed mechanisms of correlation between erythrocyte aggregation and physical exercise are not known yet. Bilski et al. (2014) found a significant increase in AI after exercise. Lactate reduces the size of red blood cells, which in turn decreases their formability [3]. However, the present study showed a 15.31% reduction in AI and an increase in AMP and T½ (69.14% and 69.18%, respectively), which proves that football training improves indicators of blood aggregation.

Kilgore et al. (2002) put forward the hypothesis that for the change in the number of erythrocytes, haemoglobin concentration, haematocrit, and the size of changes in plasma volume, a particular training program that includes endurance, strength, power, sprint and jumping is to be deemed mostly responsible [13]. The present study reported a statistically significant reduction in erythrocytes (9.40%), haemoglobin (8.51%) and haematocrit (13.79%); the studies by Ciorsac et al. (2010) and Silva et al. (2008) also found a statistically significant decrease in haematocrit at the end of the football season [5] [21].

Silva et al. (2008) published a study that demonstrated that association football training does not affect the immune system: leukocytes, lymphocytes, eosinophils and monocytes remained at a constant level [21]. In the present study, there were no statistically significant differences in the number of leukocytes in the football players compared to the control group.

The study by Filaire et al. (2003) verified the behaviour of haematological parameters for a particular football training programme. The study showed no significant changes in the number of platelets, and it lacks information about the concentration of haemoglobin and haematocrit [8]. In contrast, an analysis of original research showed a significant reduction in the number of platelets (18.86%) in football players compared to the control group.

Both my study and the study conducted by Silva et al. (2008) showed a statistically significant increase in the average haemoglobin concentration in red blood cells (6.26%) at the end of the football season [21].

From the conducted study, it may be concluded that training on a regular basis causes changes in morphological-rheological properties of the blood in football players. However, obtaining exact knowledge on the response requires further research.

Acknowledgment
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References
Changes in morphological-rheological blood properties of Hutnik Club football players


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SELECTION OF THE APPROPRIATE LUBRICANT AND ADJUVANT FOR MASSAGE THERAPY

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Abstract

Study objectives: Massage is a form of physical therapy which involves working and acting on the body with pressure. In this study, we focus on lubricants and drugs which are commonly used in massage therapy. Special attention was paid to the physicochemical properties of those chemicals, which enable their skin permeability.

Study design and methods: Based on a review of literature, it was found that this subject is not sufficiently discussed. Physiotherapists should take into consideration that agents from the group of semi-solid (lotions, gels) and liquid (olives and oils) have their specific characteristics causing changes in the permeability of the stratum corneum or other layers of the skin.

Results and Conclusions: The possibility of improving the results of therapeutic massage agents seem important and concern the following issues: selection of the appropriate massage lubricant and adjuvant. We also propose an algorithm which could help physiotherapists in the selection of appropriate lubricants and/or pharmaceuticals.

Introduction

Massage is one of the procedures in physical therapy used in the process of rehabilitation. Massage is based on the particular techniques – forms of elastic deformation of the tissues affected by the mechanical energy to elicit the desired response from the individual tissues, organs and systems. Classic massage affects the body indirectly via the nervous, cardiovascular and endocrine systems, and the skin and muscles directly or locally. Massage performed as a general procedure induces both systemic and local reactions [1, 2]. The aim of the study is to produce an overview of the lubricating and medicinal substances used for massage, with particular emphasis on the problem of permeation of medicinal substances or their components through the skin. In the present study, it was decided to attempt a holistic approach to the problem, that is to indicate the scientific rationale for choosing for massage an appropriate combination of the medicinal and aiding substances.

Skin – Anatomy and permeation

The skin is a heterogeneous structure, meaning that it consists of three layers: the subcutaneous tissue, the dermis and the epidermis. On the skin hair follicles can be found, accompanied by the sebaceous and sweat glands. The individual layers of the skin are not homogeneous and consist of a variety of cell types, both dermic and sensory (dendritic cells – melanocytes) or related to the immune system. From the point of view of pharmacotherapy, physiotherapy and cosmetology, the most important feature of the skin is its function as the protective barrier between the inside of the body and the external environment. Therefore, the individual layers of the skin differ not only in thickness but also in composition. Most of the barriers of the body have a characteristic protein-lipid structure, and the thickness of each layer determines the mode of transport of active substances. Particular attention should be paid to the large differences in the composition of the individual
layers in physiological (especially disease) states, both local and general.

Stratum corneum (SC) comprises the outer layer of skin cells and is created by closely arranged, flat, dead skin cells. Its main component is alpha-keratin; it contains only 10% water and a small amount of lipids. The lipid substances in SC are mainly accumulated in the intercellular spaces. Lipids can function as a barrier, and may also provide biochemical effects in the primary shaping of the cell. Stratum corneum prevents the penetration of external substances into the skin, creating a so-called barrier. Therefore, physical removal of it, e.g. by means of massage, causes a significant increase of penetration of water and other substances into the body. In epidermis, apart from the cornified layer (stratum corneum, consisting of three layers: stratum lucidum, stratum compactum and stratum disjunctum), also distinguished can be: the granular layer (stratum granulosum), the spinous layer (stratum spinosum) and the basal/germinal layer (stratum basale). The next layer is dermis, containing blood vessels, nerve endings and the skin appendages. The most deeply located tissue is the subcutaneous tissue (hypodermis), composed of loose connective tissue [3, 4].

**Permeation through the skin and the factors determining the speed of absorption after applying on the skin**

The term “permeability” describes the journey of a substance molecule through the layers of the skin until it penetrates into the system [5]. The transport speed through the skin is determined by its overall condition, the physical and chemical nature of the drug (i.e. a substance having pharmacological properties) and the basis of the drug/cosmetic.

Factors determining the speed of the process of absorption through the skin can be divided into:

- biological factors (skin thickness, age, blood flow, metabolism, hydration of the skin area)
- properties of the permeating substance (molecular weight, oil-water partition coefficient, solubility, binding with the structural elements of the skin, the degree of dissociation, the difference in concentrations, particle size)
- the base of the cosmetic (penetration properties, the presence of absorption promoters, the formation of occlusion, the release of the active compound, thermodynamic activity, pH)
- physical factors (temperature, climate, time of day)

In this context, it is necessary to point to the important difference between cosmetic sand drugs/medicinal substances as far as penetration through the skin is concerned. Cosmetics or their particular components should not penetrate through all layers of the skin, but should instead have local effects on selected layers of the skin. Different requirements are set for therapeutic applications to the skin: in addition to local effects, general effects are also expected. In the case of therapeutic preparations, an increase in the transport rate is also desired, and in the ointments a reduction or even elimination of permeation to undesired layers of skin.

1.1. Biological factors

Skin is an organ of the body that constitutes an important barrier for the process of permeation, on both the mechanical and the immune level. The mechanical barrier is stratum corneum, especially its closely arranged and completely dry dead skin cells. Keratin and fats of the stratum corneum, as well as fatty acids and surface pH are also responsible for the barrier effect. It is also important to mention the specialized lymphoid tissue of the skin, a part of the human immune system [6]. In practice, massage can have a significant impact on the degree of hydration of the stratum corneum through the use of occlusive dressings and essential oils. Currently, a great interest is in the absorption promoters called accelerators. They are compounds altering the skin structure, and thus increasing its permeability. The most commonly used accelerators include glycols (propylene, ethylene), alcohols (ethanol, isopropanol), amides (urea), fatty acids and surfactants, esters, pyrrolidones and sulfoxides often added to the base (substrate) of the drug or cosmetic.

1.2. The nature of the active substance

Physicochemical analysis of the most pharmacologically active substances showed that the permeation through the skin is facilitated for molecules of low molecular weight and unbranched structure. In addition, the physicochemical properties of the active substance such as the oil-water partition coefficient, solubility in lipids and the polarity/presence of electrical charge on the surface of particles determine the efficiency of absorption [7].

The partition coefficient and solubility of the compound in lipids and in water determine the lipophilicity of the compound. Its behaviour within the biological structures (e.g. binding to blood plasma proteins) or passing through the cell membrane, the blood-brain barrier, and skin structures, depend on the lipophilicity of a compound [8, 9]. Lipophilicity is expressed as the decimal logarithm of the oil-water partition coefficient (logP). The partition coefficient is expressed as the ratio of the concentrations of the substances in the two phases. Substances with high logP values (i.e., substances with high lipophilicity) penetrate very easily into stratum corneum,
but their penetration into the living layers of the epidermis is already inhibited due to the hydrophilic nature of these layers. The situation is opposite in the case of hydrophilic substances (with low logP): they can easily diffuse through the living layers of the epidermis and dermis, however, they are not able to overcome the SC lipophilic barrier. In conclusion, substances with optimum penetrability will be characterized by an average lipophilicity, exhibiting significant solubility in both water and lipids, with a maximum of 1.0-3.0 logP values.

1.3. Form of the drug/cosmetic

In the process of manufacturing drugs, the pharmacologically active substances are mixed with suitable excipients and shaped into the form suitable for particular drugs, a form that facilitates dosage and application. Thus, the common understanding of the term drug differs significantly from what pharmacists understand by it – that is the pharmaceutical form of the drug. In the case of massage and beauty treatments, most commonly used are the following dosage forms: ointments, lotions, creams and gels. In each of these dosage forms—in addition to the pharmacologically active substance—there are also excipients, called the cosmetic base in cosmetology [9, 10].

Ointments [11] are impermeable mixtures of animal, vegetable or mineral fats (e.g. white petrolatum, lanolin) that do not dissolve in water. Ointments usually cause a sensation of greasy and sticky skin, and increasing the amount of water in these preparations makes them easier to smear and improves their cosmetic qualities. Ointments may cause undesirable effects associated with occlusion of the hair follicle, such as heat rash, acne and folliculitis. Some of the commercially available products blur the distinction between ointment and cream; for example, some “ointments” are actually greasy creams. Given the depth to which the active substance contained in ointments reaches, they can be divided into epidermal (surface), endodermal (penetration) and diadermal ointments (general). The effectiveness of an ointment is largely determined by the type of substrate—it concerns the release of an active substance from the system and its absorption through the skin. Selection of ointment base is of great importance for the degree of hydra-
tion of the stratum corneum and the ability of the active substance to be released from the substrate. Creams [11] are emulsions of fat and water. The proportions of these components affect the structure, the occlusive and softening properties of the formulation. Creams with improved cosmetic properties are fat emulsions in water and are usually very easily absorbed. The benefits of their cosmetic properties do not always compensate for the relatively low effectiveness of moisturizing very dry skin, and their constituent emulsifiers and preservatives, dyes and fragrances only increase the risk of skin irritation and allergies. Gels [11] are colourless, oily substances which liquefy in contact with skin. They contain highly concentrated alcohol, which have astringent properties but often cause a burning sensation of the skin. Most gels are composed primarily of water, acetone, alcohol or propylene glycol suspended in organic polymers. In many cases, gels are the most effective medium for improving absorption through the epidermis.

In addition to the physicochemical properties of the active substance, the cosmetic base also has a significant effect on the ability to penetrate through SC. Cosmetic or ointment base should contain such ingredients that facilitate the penetration of active substances, appropriately relax the structure of the intercellular cement and adequately hydrate the stratum corneum. If the affinity of the cosmetic base and the active substance is greater than the of the active substance and the cement lipids, the active compound will not diffuse into the stratum corneum [12, 13]. The vast majority of cosmetics applied on the skin are emulsions. The conducted research indicates that both the type of emulsion and the level of fragmentation of the internal phase are of importance [14, 15, 16]. Comparative analysis of different formulations of 5% ibuprofen for topical application to the skin [17] showed that the composition of cosmetic/pharmaceutical bases has significant impact on the drug permeation through the skin. Therefore, different formulations of the same medicinal substance can neither be considered to be pharmaceutically and clinically equal, nor interchangeable.

Discussion

As a rule, lubricants should facilitate and assist the massage procedure by reducing the coefficient and force of friction between the body of the person massaged and the masseur’s or masseuse’s hands. According to physiotherapists, substances used as lubricants are chemically inert. Yet while analysing this group of agents, the pharmacist-cosmetologist will turn his or her attention to the fact that semi-solid (lotions, gels) and liquid (olives and oils) agents display their specific characteristics leading to changes in the permeability of the stratum corneum or other layers of the skin. For example, a popular borage seed oil contains essential fatty acids and 18 to 25% of gamma-linolenic acid (GLA), which is a component of lipid structures present in biological membranes and skin barriers [18, 19]. Drying oil is recommended, thanks to its properties, for very dry, sensitive, flaky skin. Applied topically, it restores the physiological balance of the skin, strengthens the lipid barrier of the epidermis, protects against infections and eliminates inflammation. Another product is grape seed oil, rich in
unsaturated fatty acids and phospholipids similar to liposomes in structure. The oil has the highest linoleic acid ratio among all known fats – 85%. It forms a protective filter on the surface of the skin that captures the moisture inside [20, 21]. At the very end of the paragraph devoted to the lubricants of the oil family, the authors pay particular attention to the problem of allergies and the possibility of triggering an allergic reaction by essential oils. These compounds are added to the formulations to improve their organoleptic (odour) characteristics. On the other hand, some physiotherapists accentuate the importance of aromatherapy as additionally stimulating the occurrence of the positive effects of the massage [22].

The agent facilitating massage, apart from containing a biologically active substance, should have a suitable pharmaceutical form facilitating the penetration of the individual layers of the skin. This means that from the point of view of the benefits for the patient undergoing massage treatment, the difference between ointment and cream (which contains pharmaceutically active substance) is not only a problem for aesthetic reasons but mainly medicinal reasons. There are many agents on the market that differ in composition and the form in which they have been registered – medicinal products, medical agents, food supplements, cosmetics. The most important difference is the way the product works, which in the case of medical agents is usually physical in nature (e.g. mechanical effect, physical barrier, replacement or support of organs or physiological functions). The way a medical agent works is substantially limited compared with that of a medicinal product. And cosmetics, as by regulation of the European Parliament and Council (No. 1223/2009) [23], are defined as any substance or mixture intended to be in contact with the external parts of the body, whose sole or main purpose is to clean it, perfume it, change its appearance, protect, keep it in good condition or ameliorate body odour. All excipients or substances facilitating the massage procedure, as well as massage in itself can significantly modify the rate of penetration of the active ingredient through the skin. These types of problems at the point of contact of pharmacy, cosmetology and physiotherapy are widely represented in literature.

Put under scrutiny was the effect of massage on the absorption of methyl salicylate from the pharmaceutical preparations; it was shown that, depending on the type of formulation, the percutaneous absorption rate increased from 34 to 158%. It should be emphasized that methyl salicylate belongs to the group of compounds with documented anti-inflammatory, analgesic and fomenting properties [24]. The early work on the effect of massage on the permeation rate of a substance through the skin has shown that in the case of lubricants containing lavender oil, its main ingredients such as linalool and linalyl acetate were found in the blood. The authors showed that the therapeutic effect of lavender oil is the result of penetration of its main ingredients into the body by inhalation and through the skin [25]. Safety and the possibility of preventive use of limonene – the main component of citrus oil – in preventing the formation of breast cancer in women was studied on modified mice (strain SKH-1) [26]. It has been shown that limonene penetrates into breast tissue after topical application of citrus oil. According to the authors, breast massage with the addition of the oil appears to be a safe and easy preventive measure for use in healthy women. The research by Solanka’s group of paediatricians [27] concerned the possibility of transdermal penetration of preparations traditionally used in massaging infants and children, with particular emphasis on coconut oil. Studied was the effect of possible percutaneous absorption of components massage oil components on fatty acid profile in the blood of infants. The results showed that topical application causes the absorption of oil and changes in the fatty acid profile. This leads to an increase in triglycerides and saturated fatty acids as compared to the control group. Such formulations may have not only nurturing, but also nutritious value. Also studied was the effect of fatty acids derived from various sub-classes: saturated (lauric acid), monounsaturated (oleic acid), and polyunsaturated (linoleic and linolenic acid) on the percutaneous absorption of Piroxicam [28]. An increase in the absorption of Piroxicam was found in the case of lauric acid and oleic acid used in the initial treatment (beautifying and massage). A similar effect was observed for gels containing 5% fatty acid. Okabe et al. [29] have shown (on the example of rats) the effect of menthol added to the ointments or gels for percutaneous absorption of Diclofenac sodium. It was shown that the higher the concentration of menthol in the ointment is, the higher the rise in concentration of the agent in blood plasma. A review by Phuong [30] concerning the impact of massage on the percutaneous absorption showed that massage changes the penetration of chemicals. However, the problem calls for an exhaustive study in order to clarify the exact mechanisms and factors associated with the possible effect of enhancing the effect of the pharmacologically active compounds.

Conclusions

From the point of view of the possibility of improving the results of physiotherapists’ work, particularly of therapies facilitated by the use of therapeutic agents, the following issues seem important: selection of the appropriate lubricant and massage adjuvant.

When buying different products at one’s accord –
Selection of the appropriate lubricant and adjuvant for massage therapy

OTC drugs, medical agents, nutritional supplements and cosmetics – the package leaflet should be carefully read, and the composition of these products, the use and possibilities of combining them should be analysed. It must be kept in mind that there are always cheaper substitutes for the same medicinal substance that will present the same effectiveness.

The proposed algorithm of conduct:
1. The selection of a suitable massage adjuvant by identifying specific therapeutic needs of the patient (Table 1).
2. The selection of the dosage form (gel, cream, ointment, emulsion).
3. The choice of lubricant complementary to the chosen substrate of the massage adjuvant/

Table 1. Summary of agents facilitating massage, including pharmaceutical form and therapeutic prescription

<table>
<thead>
<tr>
<th>Active substance</th>
<th>Trade name</th>
<th>Pharmaceutical form</th>
<th>Therapeutic prescriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diclofenac (sodium)</td>
<td>Diclozija, Diclofenac LGO, Diclonat P, Felogel, Naklofen, Olfen Gel, Ratiogel, VoltarenEmulgel, Voltaren Max, Veral,</td>
<td>Gel</td>
<td>Analgesic, anti-inflammatory</td>
</tr>
<tr>
<td>Ketoprofen</td>
<td>Fastum, Ketonal, Ketoprocin, Koprofenil, Ultrafastin</td>
<td>Gel</td>
<td></td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>Dolgit, Dip Rilif, Ibufen, Ibum, Ibuprom, Ibalgin Sport, Metafen, Nurofen,</td>
<td>cream gel</td>
<td>Anaesthetic</td>
</tr>
<tr>
<td>Meloxicam</td>
<td>OpokanActigel</td>
<td>Gel</td>
<td></td>
</tr>
<tr>
<td>Naproxen (sodium)</td>
<td>Aleve, Naproxen, Neoxen, Tarproxen,</td>
<td>gel</td>
<td></td>
</tr>
<tr>
<td>Etofenamate</td>
<td>Traumon Rheumon</td>
<td>gel</td>
<td></td>
</tr>
<tr>
<td>Aescin</td>
<td>Aescin, Latan, Lioven, Reparil, Sapovin,</td>
<td>Single- or multi-ingredient gels</td>
<td>Anti-edema, anti-inflammatory, improvement in vascular tension</td>
</tr>
<tr>
<td>Salicylic acid and heparin derivatives</td>
<td>Dip Hot, Heparin, Lioton 1000, Lumbolin, Mobilat, Saldiam,</td>
<td>Ointments, creams, single- or multi-ingredient gels</td>
<td>Tending post-trauma conditions and local inflammation</td>
</tr>
<tr>
<td>Arnica flower extract</td>
<td>Arcalen, Arnicam, Arnigel, Artroziel, Hautbalsam, Maścarneckowa, Traumeel S, Uzarin</td>
<td>Ointments and single- or multi-ingredient gels</td>
<td>Facilitating absorption of hematoma</td>
</tr>
<tr>
<td>Essential oils</td>
<td>Analogol, Argolrheuma, Ben-Gay, Balsami Menthol, Compositum, Maścamforowera, Rheumotherapia, Rheumatol,</td>
<td>Single- or multi-ingredient ointments</td>
<td>Analgesic, fomenting</td>
</tr>
<tr>
<td>Glucosamine</td>
<td>ArthroStop, Artresan,</td>
<td>Gel, cream</td>
<td>Protective agents</td>
</tr>
<tr>
<td>Capsaicin</td>
<td>Capsigel</td>
<td>emulsion</td>
<td>Irritating, analgesic, topically fomenting</td>
</tr>
<tr>
<td></td>
<td>Icy Rub Gel</td>
<td>gel</td>
<td>Cooling, analgesic, topically anaesthetic</td>
</tr>
<tr>
<td></td>
<td>Maść borowinowa [mud]</td>
<td>ointment</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td>Compound</td>
<td>Maść końska [horse] Maść niedźwiedzia [bear]</td>
<td>Ointment</td>
<td>Cooling, Fomenting</td>
</tr>
<tr>
<td></td>
<td>Viprosal B</td>
<td>Ointment</td>
<td>Analgesic, anti-inflammatory</td>
</tr>
<tr>
<td></td>
<td>NeuroTerapiażel</td>
<td>Gel</td>
<td>Transmitting forces and twists of the massage</td>
</tr>
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References


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EVALUATION OF THE USEFULNESS OF CLUSTER ANALYSIS IN THE IDENTIFICATION OF MOTOR ABILITY STRUCTURE IN LEADING POLISH BADMINTON PLAYERS FROM DIFFERENT AGE CATEGORIES

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Key words: badminton, level of sports, ontogeny, taxonomy

Abstract

Study aim. The main aim of the study was to identify clusters of players with similar motor ability profiles from a group of badminton players at different calendar ages. In addition, the level of significant differences was determined in terms of the analyzed variables between the particular groups.

Study design. The study was conducted among a group of at 30 most highly classified badminton players (youngsters 11–13 years, younger juniors 14–16 and juniors 17–19 years). The scope of research included 19 variables from the group of condition and coordination abilities. Statistical analysis used the k-means method as well as one-way ANOVA variance analysis.

Results and conclusions. On the basis of cluster analysis, the first cluster was assigned 6 juniors and 2 younger juniors (cluster 1 – juniors), the second: 7 younger juniors, 5 juniors and 1 youngster (cluster 2 – younger juniors), the third: 8 youngsters and 1 younger junior (cluster 3 – youngsters). The k-means method made it possible to identify separate clusters with similar motor capacity in the group of badminton players. On this basis, evaluation of the cluster content was conducted, as well as the affiliation of players from different calendar age categories. In the master model, a very important role is played by anaerobic and aerobic capacity as well as motor skill coordination with a higher degree of organization.

Introduction

Sport performed by children and youth is quite specific. This is reflected not only in the methodology used in the exercises, but is primarily concerned with the specific objectives of action. All proceedings carried out in successive phases of player development should therefore, be procedurally specified and create a closed cycle of high-class athlete development. It should be focused on achieving a championship level of sports in the future [1–4].

For the purpose of sports practice, it is necessary to isolate and identify the most important variables determining the efficiency of actions. However, the precise description and diagnosis of complex variables that determine success in sport is extremely difficult. Thus,
all disciplines of sports are trying to construct the so-called “Masters models” [5]. The basic criterion for the development of this type of model is always taking leading variables in a given discipline of sports into account, which at the same time are strongly genetically determined [6–8].

Analysis of literature indicates that such attempts have been undertaken to identify the characteristics of the leading features in badminton. Among these variables, typically emphasized are: somatic parameters [9, 10], maximum non-lactic-acidic anaerobic power and aerobic capacity, absolute force, speed abilities [11–13]. An important place in this model is also occupied by coordination motor abilities [14, 15]. Therefore, badminton, due to its high complexity of movements and the domination of open movement structures during the game, belongs to the third category of most difficult sports [16]. In the proposed model, psychological characteristics of players should also be taken into account [17, 18].

Starting each consecutive stage of training, one should place different and increasing demands on him/herself. This is determined by the specifics of the game, the level of a player’s disposal, his/her developmental age and stage goals. In Poland, organization of training based on these assumptions closes in three specific calendar age categories, namely: youngsters (age 11–13 years old), younger juniors (14–16 years) and juniors (17–19 years). This division seems to be debatable, since it does not take into account the inter-individual variability in terms of advancement in the development of physical, motor and mental health of the training players. The sizes of the leading characteristics, typical for different age groups, should be the starting point in the recruitment and selection process as well as planning and implementation of training in each age group [19–22].

The main objective of this study is to answer the following research questions:
1. Does the k-means method allow to identify three distinct clusters of players with similar motor skill profiles from the group of badminton players at different calendar ages?
2. What is the internal structure of the motor skill ability of the young badminton players in the particular clusters?
3. Are there any statistically significant differences between the profiles of motor efficiency indicators characterizing the particular groups?

**Study design**

The study was conducted starting at the end of April and the beginning of May 2009. This was the final stage of preparation for the key tournaments organized in Poland in three calendar age groups, namely: youngsters (11–13 years old), younger juniors (14–16 years) and juniors (17–19 years). 30 players were qualified for the study – the 10 best classified from each of the above categories. The criterion for selection was the current PZBat ranking list.

The general characterization of the players selected for the study included determining their calendar age, competing experience, body height, body mass and percentage of body fat. Arithmetic means of these values are given in Table 1.

**Scope of research**

Measurements of morphological features were made using the Martin technique:

(a) body height – measured in upright standing position (b-v),
(b) body mass – measured in training outfit, without shoes, determined on the basis of results using the Tanita TBF-551 scale,
(c) fat percentage – determined using the Tanita TBF-551 scale.

In accordance with the principles of the study, motor effects (related to abilities associated with energy and information) were taken into account in the research. In the selection of samples it was assumed that the tests should measure the comprehensive motor ability of a badminton player. In this context, seven tests for motor ability were conducted, namely:

**Table 1. Numerical characteristics of calendar age and experience as well as basic somatic features of the studied badminton players.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit of measurement</th>
<th>Juniors (N = 10)</th>
<th>Younger juniors (N = 10)</th>
<th>Youngsters (N = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calendar age</td>
<td>years</td>
<td>17.40 ± 0.52</td>
<td>15.30 ± 0.82</td>
<td>12.60 ± 0.84</td>
</tr>
<tr>
<td>Experience</td>
<td>years</td>
<td>7.90 ± 1.29</td>
<td>6.30 ± 1.95</td>
<td>4.05 ± 1.57</td>
</tr>
<tr>
<td>Body height</td>
<td>cm</td>
<td>179.78 ± 4.93</td>
<td>174.36 ± 4.69</td>
<td>152.54 ± 11.62</td>
</tr>
<tr>
<td>Body mass</td>
<td>kg</td>
<td>73.55 ± 6.03</td>
<td>66.91 ± 6.60</td>
<td>43.30 ± 11.09</td>
</tr>
<tr>
<td>% fat</td>
<td>%</td>
<td>15.13 ± 2.50</td>
<td>14.35 ± 4.35</td>
<td>17.03 ± 5.73</td>
</tr>
</tbody>
</table>
a) dynamometric measurement of the static force of the upper limb,
b) differentiation of muscle strength (determined – using a hand dynamometer – as the difference between the maximum strength and ½ of strength measurements) – differentiation of kinaesthetic force parameters;
c) throwing a 2 kg-medicine ball with both hands backwards, from over the head in open stance – explosive strength of upper limbs,
d) a zigzag run over an envelope-shaped track (analysed was the total time of three repetitions without interruption) – the ability to mobilise the muscles quickly,
e) sit-ups, according to the ICSPFT instructions [23] – the dynamic force of the abdomen,
f) standing long jump – explosive strength of the lower limbs [24],
g) endurance shuttle run – “Beep Test” [24] (the distance covered was measured in m) – cardio-respiratory endurance,
h) VO₂max value – calculated with “Beep Test”.

Coordination motor abilities were also subjected to analysis and tested using a specially developed set of computer-based tests [25]:
a) the kinaesthetic differentiation – time parameters,
b) the frequency of hand movements,
c) the average visual response time,
d) the average auditory reaction time,
e) the average response time for a choice of visual/auditory stimulus,
f) rhythmisation of movements,
g) coupling of moves – maze to the left (number of errors and time were analysed),
h) hand-eye coordination – any mode,
i) the spatial orientation – any mode,
j) the spatial orientation – forced mode (the sum of correct responses was analysed).

Statistical methods of working on the material

The method of k-means was used to identify players with similar profiles of motor abilities; it belongs to methods of ordering and classifying objects (taxonomy). The method allows one to create k clusters differing from one another to as high a degree as possible. Computationally, this method may be regarded as the inversion of variance analysis [26]. In the present study, statistical analysis was performed for k = 3. Identification of groups was carried out with the number of players in different age groups taken into consideration.

In variance analysis, the F-test or Kruskal-Wallis H test were used depending on the distribution and homogeneity of variance. To study the differences between the averages of the individual groups, Tukey’s HSD test (for uneven numbers) and Mann-Whitney U test were used. In the Mann-Whitney U test the Bonferroni correction was used, which involves dividing the significance p ≤ 0.005 by the number of comparisons made. The Shapiro-Wilk test was used to test the normality of the distributions. Homogeneity of variance was tested with Levene’s test [27].

The STATISTICA 10.0 PL Suite was used to work out the results of the study.

Results

Thanks to the statistical procedure used it was possible to extract, from a group of 30 highest ranked players (differing from one another in terms of age), three fractions of badminton players similar to one another in the structure of the motor potential (conventionally called “motor age”). Based on cluster analysis (k = 3), 6 juniors and 2 younger juniors were assigned to “1st cluster – juniors”; 7 younger juniors, 5 juniors and 1 youngsters were assigned to “2nd cluster – younger juniors”; and 8 youngsters and 1 younger junior were assigned to “3rd cluster – youngsters”. The identification of groups was carried out with the number of players in different age groups taken into account. The first cluster was dominated in number by juniors, with the second and third clusters being dominated by younger juniors and youngsters, respectively. Figure 1 illustrates a graph of the standardised means of each cluster.

By far the largest inter-cluster variability (over 2 SD) was observed for the maximal anaerobic power of the upper limbs. Variability oscillating around 1.8 SD was noted for running endurance, eye-hand coordination, aerobic capacity, spatial orientation (in forced mode) and the response time to auditory stimulus. Inter-cluster variation of 1.6 SD was observed during the following tests: response time to visual stimulus, response time with selection, spatial orientation (any mode) and the power of the lower limbs measured with a zigzag run over an envelope-shaped track.

On the other hand, an analysis of diversity within each cluster reveals that in the 3rd cluster (youngsters), the variation between the variables introduced into the model is about 1.22 SD. A slightly smaller diversity of the participation of individual variables in shaping the motor model is observed in younger juniors; for the totality of variation in this cluster of badminton players is 1.08 SD. Yet another structure of the tested model is observed in the cluster of juniors. The diversity of individual variables forming a module is the biggest here: it amounts to 1.49 SD.
In addition, by analysing the differences between particular motor performance indices, statistically significant differences were found in 15 out of 19 cases (Table 2).

By comparing the arrangement of means it can be concluded that Tukey’s procedure allowed to determine statistically significant differences between the first and third clusters, and between the second and third clusters. Such regularities were obtained for the following variables: average visual response time, the average reaction time with selection; eye-hand coordination; spatial orientation in any mode; spatial orientation in forced mode; standing long jump; VO₂max; run over an envelope-shaped track; a backward medicine ball throw; static force. On the basis of multiple comparisons the following homogeneous groups were created:

- juniors and younger juniors,
- youngsters.

Higher results were characteristic for the first and second cluster, in relation to the values of the variables in the third cluster.

In terms of frequency of movements and the strength of the abdominal muscles the following homogeneous groups were formed on the basis of multiple comparisons:

- younger juniors,
- juniors and youngsters.

Taking into account the means in each group of players it was noted that younger juniors obtained better results than juniors and youngsters.

In the case of coupling movements (the maze to the left test – time trial), Tukey’s procedure allowed for the creation of the following homogeneous groups:

- juniors,
- younger juniors and youngsters.

Comparing the means enabled the observation that the best results of this test were achieved by juniors, and worse by younger juniors and youngsters.

In terms of mean auditory response time, Tukey’s procedure allowed for the creation of the following homogeneous groups:

- juniors,
- younger juniors,
- youngsters.

Thus, it can be concluded that the best results occurred in the juniors group, and the worst in the youngsters group.

As to the shuttle run time, following homogeneous groups were created:

- younger juniors,
- juniors,
- youngsters.

Figure 1. Standardized arithmetical means of motor ability in three separate clusters.

Note: variable designation as in Table 2.
Evaluation of the usefulness of cluster analysis in the identification of motor ability structure... i

Taking into account the means in each group, it was observed that the best results were obtained by younger juniors, and the worst by the youngsters.

On the other hand, no significant difference was observed between the clusters for the following variables: kinaesthetic differentiation of force and time parameters, rhythmisation of movement and movement coupling (maze to the left errors).

Discussion

These observations were designed to fill the gap in the area of complex explorations of the multi-faceted conditions of sport class of young badminton players. A pragmatic way of resolving this priority issue was sought after: the method of k-means was used initially for identifying groups of leading badminton players having similar motor performance profiles. The method applied allowed to distinguish three uniform clusters of players significantly different in terms of the levels of motor ability complexes.

For it is essential for coaching practice to set the values of the variables characteristic for particular age groups.

The level of particular condition and coordination abilities – as important elements of technical and tactical training – determines the efficiency of sports competition [28-30]. Following only age as the criterion, false conclusions may be drawn since the indices of individual players may be significantly different from the values characteristic for a particular group; the consequence may be targeting training at higher levels of particular indices than recommended [1–3].

<table>
<thead>
<tr>
<th>No.</th>
<th>Variable</th>
<th>Unit of measurement</th>
<th>1st Cluster – Juniors (N = 8)</th>
<th>Mean ± SD (1)</th>
<th>2nd Cluster – Younger juniors (N = 13)</th>
<th>Mean ± SD (2)</th>
<th>3rd Cluster – Youngsters (N = 9)</th>
<th>Mean ± SD (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kinaesthetic differentiating, force parameters</td>
<td>% error</td>
<td>20.77 ± 11.57</td>
<td>14.50 ± 11.44</td>
<td>24.03 ± 14.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Kinaesthetic differentiating, time parameters</td>
<td>pixel</td>
<td>24.29 ± 8.64</td>
<td>32.54 ± 15.85</td>
<td>41.60 ± 27.51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Movement frequency **</td>
<td>n- number</td>
<td>38.71 ± 5.59 (2*)</td>
<td>48.54 ± 5.58 (3**)</td>
<td>38.80 ± 8.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Average time of visual response **</td>
<td>ms</td>
<td>219.00 ± 16.24 (3**)</td>
<td>234.77 ± 14.02 (3**)</td>
<td>257.20 ± 28.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Average time of auditory response **</td>
<td>ms</td>
<td>183.14 ± 11.04 (2*, 3**)</td>
<td>201.00 ± 16.44 (3*)</td>
<td>217.10 ± 15.16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Average time of reaction w/ selection**</td>
<td>ms</td>
<td>394.57 ± 24.88 (3**)</td>
<td>366.38 ± 47.53 (3*)</td>
<td>487.40 ± 77.47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Rhythmisation</td>
<td>ms</td>
<td>127.86 ± 9.31</td>
<td>156.77 ± 77.40</td>
<td>135.90 ± 57.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Movement coupling, maze to the left **</td>
<td>s</td>
<td>43.43 ± 5.29 (2*, 3**)</td>
<td>52.15 ± 7.21</td>
<td>53.90 ± 6.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Movement coupling, maze to the left</td>
<td>n- errors</td>
<td>12.86 ± 7.73</td>
<td>13.15 ± 7.66</td>
<td>18.20 ± 10.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Eye-hand coordination**</td>
<td>s</td>
<td>38.86 ± 2.34 (3**)</td>
<td>39.52 ± 1.55 (3**)</td>
<td>46.20 ± 5.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Spatial orientation, in any mode**</td>
<td>s</td>
<td>57.43 ± 7.83 (3##)</td>
<td>53.85 ± 6.97 (3##)</td>
<td>78.20 ± 14.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Spatial orientation, forced mode**</td>
<td>n- correct</td>
<td>37.86 ± 6.94 (3##)</td>
<td>43.08 ± 7.45 (3##)</td>
<td>20.00 ± 11.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Standing long jump **</td>
<td>cm</td>
<td>238.86 ± 16.30 (3**)</td>
<td>233.46 ± 11.37 (3**)</td>
<td>190.90 ± 22.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Shuttle run **</td>
<td>m</td>
<td>1928.57 ± 255.83 (2*, 3**)</td>
<td>2272.31 ± 187.89 (3**)</td>
<td>1626 ± 264.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>VO2max **</td>
<td>ml/kg/min</td>
<td>50.53 ± 3.78 (2*, 3*)</td>
<td>55.55 ± 2.70 (3**)</td>
<td>45.93 ± 4.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>&quot;Envelope&quot; run **</td>
<td>s</td>
<td>22.43 ± 0.92 (3**)</td>
<td>22.48 ± 0.73 (3**)</td>
<td>24.50 ± 1.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Abdominal muscles strength **</td>
<td>n-number</td>
<td>33.57 ± 1.40</td>
<td>35.23 ± 4.07 (3**)</td>
<td>29.70 ± 4.57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Backward medicine ball throw **</td>
<td>m</td>
<td>17.59 ± 2.87 (2*, 3**)</td>
<td>13.62 ± 2.14 (3**)</td>
<td>8.26 ± 3.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Static force **</td>
<td>kG</td>
<td>47.57 ± 8.16 (3**)</td>
<td>43.00 ± 9.33 (3**)</td>
<td>25.50 ± 10.41</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: p < 0.05; **: p < 0.01. When conducting multiple comparisons using Mann-Whitney test - #: p < 0.016; ## #: p < 0.01.
It seems that the correct solution is to select subjects for uniform teams in terms of their motor potential. Then, exercises suited to the structural and functional capabilities of young players may be chosen. Additionally, the availability of model motor performance profiles facilitates the evaluation and selection at various levels of players’ training. In practice, wrong decisions and distortions often occur in this respect. Not taking into account the biological and motor age of young athletes in applying training is a major mistake. Overload and “early specialisation” are very often the cause of eliminating talented (albeit developing more slowly) candidates from sports in general. The so-called acceleration do not hold promise either and should, if possible, practice in groups of higher age category. Exercise that is unsuited to the developmental age of the trainees sometimes leave a lasting mark on their psyche and have a negative effect on their bodies. Waddell and In Hong pointed to these problems to some extent [31]: they pointed to the necessity of adjusting the applied exercises for young badminton players to development potential of training children, as well as to reasonable shaping of competition technique that would stay in accordance with the physical capability of badminton adepts. Pursuit of championship at an early stage is bad forward thinking and often limits full development of the player [3, 32].

Training children and youths must therefore be subordinated to supporting individual development processes. It should be characterized by versatility turning to specialisation gradually and systematically. This versatility is based on selective stimulation of those abilities that, during the period of the development of a child’s organism, are characterized by the greatest susceptibility to physical activity [33].

Trainers – despite the modest amount of literature on the subject – formed a view that badminton belongs to the group of sports of non-standard properties and requires high level of motor coordination [16]. Elements mentioned most often include: simple and complex reaction time, coupling and diversification of movement, balance, orientation, rhythmisation and adaptation [14, 15]. It would seem that each of these elements play an essential role in badminton as far as the quality and effectiveness of the motor tasks on the pitch are concerned, diverse in spatial and temporal terms. Given the class of the studied group it should be assumed that the highest variables recorded for a particular group are directly connected with the class of their achievements. In the younger juniors group, highest values were recorded for movement frequency, abdominal muscles strength and shuttle run time. For juniors, the highest values were recorded for coupling moves/maze to the left (s) and the average auditory reaction time. It seems that emphasis should be put on shaping these players’ motor preparation variables during the training periods in question. However, it should be noted that training in the younger age groups should be subordinated to achieving high results in seniors groups. As it was already mentioned, in this age group the importance is attributed to coordination motor abilities. Taking into account the sensitive periods of coordination motor abilities, training at younger levels should focus on shaping these particular abilities. The importance of hand-eye coordination and reaction time for the game is also confirmed in research by Yuan et al. [34]; the role of these abilities in teaching technique is emphasized, among others, by Chin et al. [35] Sakurai and Ohtsuki [36] and Mooney and Mutrie [37].

The variables determining the energy-related abilities (including Maximal Aerobic Power) proved to have a very significant share in shaping sport class, especially in groups who were older in terms of motor abilities. The observed facts correspond to the opinions of other authors classifying badminton as a speed/strength discipline [11, 13, 38].

Great importance in this regard should also be attributed to aerobic endurance, especially among younger juniors; it probably affects maintaining high efficiency in the final phase of the play, as well as in subsequent matches. In studies on judokas, it was found that high VO2max values were associated with increases in activity of players in the second half of the fight and during extra time [39].

Conclusions

1. The k-means method made it possible to identify distinct clusters with similar motor capacity potential profiles from the group of badminton players.
2. Usage of this method also allowed to assess the level of development of the analyzed variables in the different clusters.
3. The structure of variables construing the sports level at various stages of training, marks a certain trend in shaping the model of a future champion. The ideal is an individual with high anaerobic and aerobic exercise capacity and higher degree of organization and specifics of motor coordination.
Evaluation of the usefulness of cluster analysis in the identification of motor ability structure...
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APPLICATION OF LIFE KINETIK
IN THE PROCESS OF TEACHING
TECHNICAL ACTIVITIES TO YOUNG
FOOTBALL PLAYERS

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Key words: intellectualization of education, training effectiveness, creativity.

Summary

Aim of the study. To verify the concept of effective teaching of young association football players based on the Life Kinetik creative method.

The fundamental research question asked was: does the implementation of the Life Kinetik method into association football training increase the effectiveness of teaching football?

Material and methods. The study of the impact of the Life Kinetik creative method on the effectiveness of learning football was conducted in the years 2010-2014. The study involved 48 young football players (in the younger junior category), studying at a sports school in Krakow. To assess their disposition for the game, the following tests were conducted: special knowledge test ($r = 0.87$); mobility test ($r = 0.87$) and didactic games test ($r = 0.86$).

Results and conclusions. The results of the study show that teaching association football by means of the Life Kinetik method increases the motor effectiveness of players, and searching for reserves in the sphere of mental disposition of players can help to increase the effectiveness of their training.

Introduction

Life Kinetik is a modern technical action training programme based on the formation of a locomotive habit paired with high activity of the nervous system – especially the athlete’s intellect. The method has been spread (in training football) by Horst Lutz, a German association football coach. The essence of the method lies in combining different motor activities (often disrupting basic movement techniques) which activate and shape associative cortical fields and, at the same time, improve the efficiency of an athlete’s thought processes. This method not only shapes the movement technique but activates, first and foremost, the cortical representations for the movements (which are usually used to a negligible degree) [1].

Training the muscles without activating the associative cortical fields (i.e. at the level of controlling the lower representations of centres in the central nervous system) shapes motor habits that are mechanical in character. They can be fast, accurate even (resembling animal training), however, they remain imitative [2, 3]. By training the muscles and activating the associative cortical fields, more control may be gained over muscles in the way the movement is executed. Thus, we can execute intentional movements more efficiently, and adjust them to the decision to perform the movement. [4] Such an activity – adjusting movement to the situation – is defining for a sports game. It can therefore be concluded that the Life Kinetik method shapes cortical representations of a higher level (the development of associative fields,
improvement in nerve connections in the brain), allowing conscious execution of the movement, as opposed to mechanical execution. Using this method in football training prepares players to act rationally and make apt decisions during the game.

Using Life Kinetik benefits health through a broad, tailored training programme – our brains function better through newly formed synapses [1]. The method is suited both for children and elderly people, for individual and team sports players.

The Life Kinetik method is being popularized in Western Europe (Germany, the Netherlands, France, Spain, to name just a few). The programme is increasingly successful and is becoming more and more significant in association football training as it effectively prepares players for the peculiarity of the game which requires not only great technique but, above all, performing motor activities in constantly changing conditions to reach the objective of the game [1].

Mental training (i.e. activating mental faculties) can have decisive influence on increasing the effectiveness of a player’s actions aimed at the realisation of objectives of motor activities in a sports game. It has been proven that the better the athlete knows the activities and the application there of (in other words, the more consciously they participate in the action), the easier and the application there of (in other words, the more consciously they participate in the action), the easier it is for them to perceive particular situations in the game and effectively implement the appropriate objectives [3, 5].

Assuming that the effective development of motor habits in sports games takes place at the semantic-motor level [6, 3], it is believed that teaching the Life Kinetik method (which activates mental faculties) will increase the effectiveness of training in young players.

**Study aim, questions and hypotheses**

The research in the present study is utilitarian in character, for its main purpose is to modify the existing concept of methodology of teaching sports games with association football as the example. The method is connected with activating mental faculties of the player and can greatly improve their motor performance [1].

To confirm this thesis, institutions training young talented players (adepts of football) were put under scrutiny.

The following questions have been posed in the research:

- Does the implementation of the Life Kinetik method into teaching football techniques increase its effectiveness?
- Does the use of the Life Kinetik method in teaching football increase the in-game effectiveness of young football players?
- Can football training be improved by means of implementing the *Life Kinetik* method?

Demonstrating these relationships will allow one to look for reserves in other fields of influence in the player’s training. Solving this problem can result in large educational and health-related benefits since the effectiveness of such a mode of teaching increases the efficiency of the player and reduces the physical overload in sports training, which, in turn, reduces the risk of exploitation of the athlete’s body.

Given the above, the following hypothesis has been put forward:

- the *Life Kinetik* method improves the performance of motor activities of young football players,
- improving the training process by introducing the *Life Kinetik* method to technique training helps to increase the in-game effectiveness of players.

**Material and methods**

To assess the efficiency of learning and teaching special motor skills, the method of pedagogical experiment was used; the technique of parallel groups (experimental “E” and control “C”) were used [7].

In experimental research, the independent variable comprised the way of processing and transmitting information using the *Life Kinetik* method based on mental action taken by players in the process of teaching motor activities (the so-called special technique).

The dependent variables comprised the quantifiable results concerning the player’s level of mastery of technical activities in isolated conditions and in the game.

The continual research was carried out on an annual basis (over a four-year span, from 2010 to 2014) among the students of the School of Sports Championship (Szkoła Mistrzostwa Sportowego) in Krakow. The subjects constituted a younger juniors group – 14-15 years of age.

The continual research in four annual training cycles included 48 young participants, organised and divided into two subgroups: the experimental (E) and control (C) group, numbering six players each.

Throughout the course of the study, the experimental group participated in the experimental training unit once a week – a 90-minute class combining theoretical and practical elements (Fig. 1). The classes were conducted using the *Life Kinetik* method for teaching techniques and were characterized by higher mentalisation of the exercises (i.e. by mental commitment, concentration and attention divisibility).

In sum, 75 training lessons were conducted using the *Life Kinetik* method for each experimental group in the annual training cycle.
Topic: Improving change in direction while moving with the ball in different situations.

Knowledge: The pupils should be informed that changing direction is one of the most important elements of football; variations of changing direction, its effectiveness in different situations and proper use of the element should be commented upon.

Number of participants: 6
Duration: 90 min
Equipment: ball × 16, marker × 8, cone × 20, ring × 30

<table>
<thead>
<tr>
<th>COURSE</th>
<th>CONTENT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part One – Introduction</td>
<td>The pupils line up; a formal greeting. A summary of the techniques to change direction efficiently. A: General exercises with balls (a warm-up) B: Exercises pertaining to the topic of the lesson Exercise description: Ex. 1. Each pupil has a ball, they keep distance between one another. They lead the ball closely, in limited space. A one whistle signal means changing direction by stopping the ball with one’s sole and dragging it backwards, then turning. Two whistles mean changing direction by playing the ball with the inner part of the foot underneath one’s body, then turning. Three whistles mean leading the ball without any reaction.</td>
<td>Presentation and explanation of correct change in direction. Special emphasis put on resuming of leading the ball, when the player should be in a good position to continue the exercise and hold their head high to observe and control the pitch. Continuous control of the ball is of high importance as it prevents collisions with other exercising pupils. Emphasis is put on accuracy. Exercises mixed with stretching in regular intervals.</td>
</tr>
</tbody>
</table>

Ex. 2. (Fig. 1.) Two markers are placed in a line with a 6-metre distance between them. The pupils lead the ball towards the marker, in front of which they drag the ball backwards with their right foot, make a turn to the right and continue leading the ball with their left foot. Then they head to the other marker, where they do the mirror image of the exercise.

Ex. 3. (Fig. 2.) The markers make up rectangles (about 4 × 6 metres). 2 pupils for each rectangle; pupils lead the ball outside the rectangle and along the diagonals. When they reach the marker, they change direction using the outer/inner part of their foot (both right and left).
### COURSE CONTENT COMMENTS

**Part Two – Main part – 55 minutes.**

**Description:**

**Ex. 4.** (Fig. 3.)

48 pieces of paper are marked on both sides. Side A: a number from 1 to 4 or a name of one of four colours (red, yellow, blue or green); Side B: a number from 1 to 8 or a name of one of eight colours (red, yellow, green, orange, purple, brown, navy blue). The pieces of paper are then put loosely on the pitch, about 5 metres apart. Pupils perform the following exercises, depending on their skills:

- **Exercise 1:** A turn to the right using the outer side of the right foot.
- **Exercise 2:** A turn to the left using the inner side of the right foot.
- **Exercise 3:** A turn to the left using the outer side of the left foot.
- **Exercise 4:** A turn to the right using the inner side of the left foot.

Pupils lead the ball slowly, then make a turn around a given piece of paper. The number or the name of the colour define which exercise to do, namely:

- 1 and 5, yellow and brown = Ex. 1,
- 2 and 6, red and purple = Ex. 2,
- 3 and 7, green and navy blue = Ex. 3,
- 4 and 8, blue and orange = Ex. 4.

**Fig. 3. Individual exercise [1]**

**Ex. 5.** (Fig. 4.)

On a 15x15 m field, six conjoined squares (side – 5 metres) are made using the markers. In case the players outnumber the squares, more of them can stand in one square, along the diagonal.

The pupils lead the ball to a given marker and make a 90-degree turn to the next marker. The change in direction is performed with the use of a given technique, e.g.:

- the outer part of the right foot to the right where it is taken by the outer side of the left foot, and then, analogously, to the other side,
- the inner part of the left foot to the right where it is taken by the outer side of the right foot, and then, analogously, to the other side,
- the side of the left foot sole to the right and leading begins with the outer side of the right foot, then, analogously, to the other side.

The coach decides how the players should change the direction.

**Fig. 4. Outline of the group exercise [1]**

During exercises, the players are expected to be highly active and accurate. Emphasis is put on keeping the head high and observing the situation on the pitch while keeping control of the ball. The exercises require immense focus and concentration in each move. The exercises form peripheral vision, spatial orientation and foster the efficiency of intellectual processes.
Ex. 6. (Fig. 5.)
The players are divided into two teams; the field, made up with the use of markers, is 15 × 15 metres. On each side there are two markers in different colours, about a metre from the field.
The ball is lead inside the field. One of the players is chosen to pick the marker that the teams must encircle and return to the field without disturbing one another – they say its colour out loud. The team to find themselves back in the field first scores a point. Then, the person to choose the marker changes.

Fig. 5. Outline of the group exercise [1]

Ex. 7. (Fig. 6.)
The field is marked out to be 15 x 15 metres. There is a 1 x 1 metre square in each corner, each in a different colour. The discs are placed freely on the field. All the players are divided into equally numerous groups, one for each square (“base”).
Each colour is associated, then, with a name of a fruit, e.g. red = apple, yellow = banana, green = pear, orange = orange. On signal, a marker must be brought single-handedly, as quickly as possible. The players let go of the marker they are holding with each new signal and run to get a new one. The team that collects the largest number of markers wins.
If all markers have been collected, the game is reversed. Once again, the base must be emptied as quickly as possible, however, markers from one’s own base cannot be taken.
To win, the number of markers in other bases must be constantly traced.
The rules are not introduced from the onset; they are introduced with regard to what happens during the exercises, e.g.:
– the markers may be passed between team members
– the markers may be stolen from the opposing teams
– they may be taken from other bases
– one’s own base may be defended
– the enemy can be blocked
– the ball may be knocked out of the enemy’s hands

Fig. 6. Outline of the exercise (formal task) [1] – be continued next page
Part Three – Closing part – 10 minutes.

Static stretching. Each player comes up with an exercise for the group.

Ex. 8. (Fig. 7.)
Juggling in pairs, with the increasing number of contacts with the ball. The first player hits the ball once, the other must bounce it before returning (two contacts), the first player has three contacts and so on. The contacts are counted, from 1 to 10, and then from 10 to 1.

The pair who finishes the task first wins.

In the other group (the control group), the teaching process was carried out with the use of traditional methods. The same programme of teaching techniques was implemented, albeit without the influence of the Life Kinetik method.

The research was conducted in two stages. In the first stage – preliminary studies (pre-tests) were made to determine the base values and to select two research subgroups that would be as similar as possible (that is, with no statistically significant differences) in terms of the level of expertise and motor abilities. The groups were selected based on organised selection [3] – the players were classified using rank tables. In the second stage, the studies were repeated (post-tests); they tested the knowledge, motor abilities and efficiency of technical action both in isolated conditions and during the game.

Teaching, both in the experimental and control group, was based on the following assumptions:

1. The didactic objectives for the classes were identical.
2. The number of classes was the same for both the “E” and “C” group.
3. The duration of the class was the same in both groups (90 minutes).
4. Selection of players for training groups took into account similar age, similar level of motor abilities, technical skills and knowledge of the game (differences statistically insignificant).
5. The difference in didactic proceeding between the experimental group and control group was the way of teaching motor activities which took into account the Life Kinetik method (in the experimental group).
6. In the annual cycle of training, 75 more training units were used for practical teaching (WITHOUT the use of the Life Kinetik method) in the control groups than in the experimental groups.
7. In the annual cycle of training, 75 more training units were used for practical teaching (WITH the use of the Life Kinetik method) in the experimental group.
Application of life kinetik in the process of teaching technical activities to young football players

*Life Kinetik* method) in the experimental groups than in the control groups.

In the course of the experiment, the following was assumed for both the “E” and “C” group:
1. That the programme assumed would be realised to the letter.
2. That the classes would be conducted by the same trainers.
3. That the classes would be attended by the same pupils (players). In both groups, subjects with the same overall attendance were considered for calculating the results of the study (the overall attendance in the groups amounted to 91%).
4. That the classes’ intensity in both groups would be the same (aerobic and mixed changes for teaching individual and group actions in strict terms; mixed and anaerobic changes for teaching by playing the game).
5. That teaching of technical activities in both groups would be in accordance with the training programme of SMS-PN in Krakow.

The experimental training made use of intellectual teaching of motor activities (special techniques) – the *Life Kinetik* method.

The purpose of the training was to form a level of motor image or an idea of the taught motion technique. In the process of intellectual teaching, verbal and visual methods (treated as didactic reinforcement) were used, which took into account the stages of teaching association football [3]:

To check the knowledge of football players’ motor activities, a standardised (t = 0.95, r = 0.87) technical knowledge test was used [3]; the test contained closed-ended, open-ended and synoptic problem questions which, just as on the field, deal with the alternatives to choose from while performing a movement. Questions concerned the regularities of (technical) motor activities and took into account movement analysis, biomechanical principles and the rules for effective actions during the game (Fig.2).

A standardised test (t = 0.88, r = 0.87) for measuring technical (special) skills was used to evaluate the mobility of young players [3]. The test used a selection of technical skill trials which tested ball handling (juggling with legs and the head), leading the ball while slaloming, hitting the ball with the head and the leg for distance, the accuracy of a long pass, the accuracy of a hit to the ball (i.e. a shot to a designated part of the goal).

The evaluation of players’ actions during the game (both defensive and offensive) was made using objective

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**Fig. 2.** Example task in knowledge of movement activity test [8]. The photos show the player’s movement sequences when hitting the ball with straight instep.
sheets of observation ($t = 0.93, r = 0.86$) in the 3 vs. 3 simulation games, in which team members, selected in an organised manner (according to their ranks for special skills) were evaluated by competent judges [3].

The assessment of technical skills in isolated conditions and in the simulation game was converted into a standardised 10-point scale (point tables). The experimental teaching was conducted by trainers from SMS-PN in Krakow, with the cooperation and supervision of the Department of Theory and Methodology of Football at the University School of Physical Education in Krakow.

When evaluating the assessments of the studied groups, what was analysed was the amount of information about motor activities mobility of a football player.

For calculating the results of the study, basic statistical operations were used: arithmetic mean, standard deviation, Student’s t-test which determined the level of significance of differences [9].

**Results**

The research assumptions of the paper were that the players participating in experimental interactions (creative teaching with the use of the Life Kinetik method in teaching technical actions) achieve better results as far as expertise, mobility and in-game activity are concerned. Therefore, to verify the assumptions, detailed studies of the parameters mentioned were carried out in the two established groups: the experimental and the control group.

At the initial stage of research (as a potential base), the level of motor skills was also assessed.

Tables 1-4 present the study results of: motor level, the level of knowledge on motor activities, technical skills and efficiency in terms of sportsmanship (in simulation games) of the two groups in two phases of research –the initial and final phase.

While analysing the results of the study of selected dispositions of a football player’s effective action, it should be noted that prior to the experiment, because of the structured selection of players, the two groups (experimental and control group) did not show any significant differences in these fields ($p > 0.05$).

Significant changes can be seen by analyzing the results obtained by players of both groups during the second test. The exception is the progression level of motor skills and the progression level of knowledge on the technical operation; no significant changes for Test 1 or 1 were noted – Tab. 1–2.

We may note other results when analyzing the level of values for technical skills (Tab. 3), for which there was a significant increase in Test 2 for the experimental group. The difference between the experimental and control group is significant at the level $a = 0.05$ [9].

The significant variation between the experimental and control group in motor (technical) activities is also confirmed by the progress among the groups that was made between the first and second tests. It can be noticed that in Test 2 the experimental group achieved significantly higher values than the control group (0.0185 * < 0.3046), hence it could be said that the progression in results in the experimental group is significant. This fact confirms higher efficiency of the didactic progress with the use of the Life Kinetik method in the training process.

Interesting results can be seen when analysing the subjects’ progress in mastering (technical) motor activities in the simulation game (Table 4): these parameters indicate the level of mastery in the technical activities under conditions similar to the game proper. Although the second study showed no significant differences between the two groups [9], the difference between the results of the first and second tests are in favour of the experimental group, whose members have achieved significant

| Table 1. Characteristics of motor ability level of studied groups in Test 1 and 2. |
|-----------------------------------------------|----------------|----------------|
| **Test 1**                                  | **Experimental group (pts.)** | **Control group (pts.)** |
| Arithmetic mean                             | 45.94          | 46.14          |
| Standard deviation                          | 6.71           | 7.02           |
| Variability coefficient                     | 14.60          | 15.22          |
| Significance of differences between groups  |                | 0.484          |
| **Test 2**                                  |                |                |
| Arithmetic mean                             | 47.68          | 48.37          |
| Standard deviation                          | 6.44           | 6.42           |
| Variability coefficient                     | 13.51          | 13.27          |
| Significance of differences between groups  |                | 0.441          |
| Significance level of differences between Test 1 and Test 2 in given group | 0.361 | 0.327 |
Table 2. Characteristics of knowledge level on technical activity of studied groups in Test 1 and 2.

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Control group (pts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>39.90</td>
<td>39.17</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>4.98</td>
<td>3.21</td>
</tr>
<tr>
<td>Variability coefficient</td>
<td>12.49</td>
<td>8.20</td>
</tr>
<tr>
<td>Significance of differences between groups</td>
<td>0.337</td>
<td></td>
</tr>
</tbody>
</table>

Test 2

<table>
<thead>
<tr>
<th></th>
<th>Experimental group (pts)</th>
<th>Control group (pts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>45.42</td>
<td>44.69</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>5.65</td>
<td>5.57</td>
</tr>
<tr>
<td>Variability indicator</td>
<td>12.44</td>
<td>12.46</td>
</tr>
<tr>
<td>Significance of differences between groups</td>
<td>0.376</td>
<td></td>
</tr>
<tr>
<td>Significance level of differences between Test 1 and 2 in given group</td>
<td>0.004**</td>
<td>0.009**</td>
</tr>
</tbody>
</table>

** p < 0.01

Table 3. The level of significance of differences in evaluation of movement actions in isolated conditions (technical test) in the studied groups

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Control group (pts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>53.21</td>
<td>53.58</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>4.76</td>
<td>4.31</td>
</tr>
<tr>
<td>Variability coefficient</td>
<td>8.95</td>
<td>8.05</td>
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<td>Significance of differences between groups</td>
<td>0.4208</td>
<td></td>
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</table>

Test 2

<table>
<thead>
<tr>
<th></th>
<th>Experimental group (pts.)</th>
<th>Control group (pts.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>57.92</td>
<td>54.46</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>5.58</td>
<td>3.95</td>
</tr>
<tr>
<td>Variability coefficient</td>
<td>9.63</td>
<td>7.24</td>
</tr>
<tr>
<td>Significance of differences between groups</td>
<td>0.0474*</td>
<td></td>
</tr>
<tr>
<td>Significance level of differences between Test 1 and 2 in given group</td>
<td>0.01885*</td>
<td>0.3046</td>
</tr>
</tbody>
</table>

** p < 0.05

Table 4. The level of significance of differences in the evaluation of movement actions in simulation games in the studied groups

<table>
<thead>
<tr>
<th></th>
<th>Test 1</th>
<th>Control group (pts.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>52.46</td>
<td>52.88</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.35</td>
<td>2.55</td>
</tr>
<tr>
<td>Variability coefficient</td>
<td>6.39</td>
<td>4.82</td>
</tr>
<tr>
<td>Significance of differences between groups</td>
<td>0.3677</td>
<td></td>
</tr>
</tbody>
</table>

Test 2

<table>
<thead>
<tr>
<th></th>
<th>Experimental group (pts.)</th>
<th>Control group (pts.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic mean</td>
<td>56.46</td>
<td>54.42</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.31</td>
<td>2.79</td>
</tr>
<tr>
<td>Variability coefficient</td>
<td>5.87</td>
<td>5.14</td>
</tr>
<tr>
<td>Significance of differences between groups</td>
<td>0.0587</td>
<td></td>
</tr>
<tr>
<td>Significance level of differences between Test 1 and 2 in given group</td>
<td>0.0038**</td>
<td>0.0861</td>
</tr>
</tbody>
</table>

** p < 0.01
progress in controlling motor activities (0.0038**, the level of significance α = 0.01). No significant differences were observed in the control group (0.0038 <0.0861). These results are very important in terms of application, for they show that mentalisation of the movement teaching process (using the Life Kinetik method) brings significant benefits to the trained players.

According to Williams and Ford [10], this way of teaching playing has impact not only on the realm of physicality but also on the mental sphere of the player, which greatly facilitates their decision-making processes.

Discussion

The above analysis of the results of the research shows, beyond any doubt, that the experimental teaching of motor activity, based on intellectualisation (that is, conscious participation of the player in training) deserves special attention, for it may increase the effectiveness of teaching and training players. This position was confirmed by Lutz [1], who sees in the Life Kinetik method not only a way to make training more attractive, but above all the possibility of activating mental processes and enhancing the creativity of the player. This paradigm results from the very specific nature of sports games, which, according to Duda [3] [11] and Panfil [4], is characterised by a high degree of mentalisation of the player’s actions; it is associated with situational operations of the player (alternativity of decision) based on the efficiency of thought processes. Thus, taking into account the fact that Life Kinetik shapes mental capacity (in that it fosters formation of special abilities to act) [1], it seems that one can greatly accelerate the process of learning a game. This position was confirmed in a significant way for learning football, where creative training [12] and in the application of complex methods (activation of the mental sphere) – [13] and in the decision-making practice, [14] enhanced efficiency was achieved. Also in other games (like basketball, handball, golf), taking into account human mental faculties in the Life Kinetik method significantly streamlines the process of educating players [15, 16].

The conclusion must be that the above information, confirmed by the results of the study, require special reflection on the intellectualisation of teaching football, and the unpopularity of using this type of methods in traditional training and the importance of creative activities for the effectiveness of the game allow for the adoption of a new direction in learning sports games [8]. This direction is consistent with teaching the game with understanding, which is opposed to the traditional (less efficient) approach to teaching team sports [17, 14]; thus, it sets a new paradigm in teaching sports games.

Conclusions

1. Proceedings in the Life Kinetik method, based on intellectually supporting the player movement actions, accelerate teaching elements of the football techniques.
2. Usage of the Life Kinetik method diversifies training, making football practice more attractive.
3. On the basis of the results obtained in the study and the importance of decision making processes in a sports game, it may be concluded that this line of research is an important source of progress in achieving a championship level in football players.

References

Application of life kinetik in the process of teaching technical activities to young football players


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Abstract

Study aim. The aim of the study is to examine the major aspects of sport and recreational activity of university students from the German Land of Thuringia. The focus is at the same time on the motives, frequency and location of performing recreational sports, as well as statements regarding the students’ intention to play sports after graduation.

Material and Methods. The focus of our study was a group of 342 participants, 19-20-year Thuringian university students. In the study group, there were 178 women and 164 men. In order to examine the significance and motives for taking up sports and recreational activities, we used the so-called scale of values developed by Baur and Burrmann [1]. In addition, we used the attitude and behavior questionnaire developed by Winiarski in regard to sports activity [2].

Results and Conclusions. Sport and recreational activities are very important in the lives of students from Thuringia. The most important reason for taking up sports and recreational activity by the students is to maintain a healthy and aesthetic body shape. The students show high activity (frequency) of sports performance mainly during activities organized by universities. Furthermore, the students intend to perform sports after graduation. The gender of the subjects is differentiated by behavior and attitudes, which are in favor of more frequent membership in sports clubs, domination of emotional motives, rivalry and performance in sports, as well as increased frequency of sports performance.

Introduction

Sport and recreational activity is one of the most preferred forms of free-time activities among the German youth. This fact is confirmed in many research papers [1, 3, 4, 5]. The level of sports activity is determined by various factors, which include age, gender, environmental conditions, as well as educational, psychological or economic factors. The sports activity of a young student is made up by his/her participation in sports activities organized by their college or university, and sport as part of free-time activities, wherein, clearly obvious is the bilateral relationship between these types of activity and in particular, the influence of school physical education on the decision to perform sports and recreational activities in adulthood. Balz [6], Maj [7] as well as Gracz and Sankowski [8] emphasize the mainly systematic development of appropriate skills, abilities, habits and attitudes of the pupil or student determining their active participation in recreational sport activities. Sport and recreational activity consists of various elements, and the most important undoubtedly include the intensity of the performed sport expressed by the frequency of performing this activity, the place of performing sports, as well as the number and types of sports disciplines performed regularly during free time.

The results of studies devoted to sports activity of the German youth are confirmed by their generally high level of sportiness. Wydra [9], Brettschneider et al. [10] emphasize the high frequency of sports performance. On average, the youth practice 2 to 4 times a week and often, even daily. Another manifestation of great involvement in sport activities is the youths’ membership in sports clubs, in which they perform their favorite discipline of sport.
According to Baur and Burrmann [1] as well Kurz and Tietjens [4], about 50% of the female youth and 60% of young men are current members of sports clubs.

In numerous research papers, the role of factors such as e.g. age and sex, is highlighted. These factors can significantly vary the level of activity of the studied youth. Alfermann [11] draws attention to the significant differences in preferences regarding the forms of sports activities among the sex of the youth. The male youth appreciates sports based more on fierce competition, while women tend to prefer forms of gymnastics and dance, characterized by harmony of movement and expression. Much attention is paid to the issue of involving young people from different age groups in sport performance. Baur and Burrmann [1] point to a much higher level of sports activity in representatives of the age group 7-14 years, who often play sports in sports clubs, compared to young people aged 15-18 years and older. Apart from that, Kuhlmann [12] and Sass [13] highlight that open air locations for sports performance is of much greater popularity among the German youth.

Due to the small number of studies on the sport and recreational activity of the youth from Thuringia, in relation to other German lands, the objective of this paper is the examination of major aspects of sport and recreational activity of students from this Land. The importance, motives, frequency and place of performing recreational sports are presented and analyzed. Moreover, considering the mutual relationship between school physical education and free-time sports activity, the declarations of the studied students intention to continue performing sports after graduation are also shown.

Research methodology

Research questions

In the study, the following research questions were formulated:

1. What is the role of sport and recreational activity in the lives of the studied students?
2. What are the subjects' main reasons (motives) for performing recreational sports?
3. What is the frequency of performing recreational sports by the students?
4. In what places are the sports performed?
5. What are the studied students’ statements regarding the intention to perform sports after graduating?
6. Does the gender of the study participants influence the level of sports and recreational activity of the students?

Study group

The focus of our study was a group of 342 participants, 19-20-year-old Thuringian university students. In the study group, there were 178 women and 164 men. The students participating in the study were matched according to the principle of random sampling. The study was personally conducted in 2015 by the authors of this work.

Research methods

In order to examine the importance and motives for taking up sport and recreational activity, the so-called scale of values, developed by Baur and Burrmann [1] was used. In the part diagnosing the importance of sports activity, a three-grade scale was used:

- Performing sports is:
  - Very important (indispensable)
  - As important as other free-time activities
  - Not very important

The main reasons (motives) for performing sports include:

1. Health/body shape
2. Relaxation
3. Social interactions
4. Physical fitness/sport competition
5. Emotions connected with performing extreme sports.

In addition, the attitude and behavior questionnaire towards sports activity created by Winiarski [2] was used in the study. It consists of the following three parts:

1. Frequency of performing sports in free time (no performance, once a week, a few times a week)
2. Location of performing sports (sports club, extracurricular activities at university, open air, public sport facilities)
3. Statements regarding performing sports after graduating from university (will perform, will not perform, not sure yet).

Methods for statistical analysis

The collected material was subjected to mathematical-statistical analysis. To determine the significance of differences within the gender of subjects, the Chi-square test was used [14].

Results

The importance of performing sports

According to the results presented in Table 1, for more than half of the studied students, sport is a very important, even indispensable free-time activity. It should be stressed that performing sports is much more important for the male (66.7%) than female subjects (44.3%), as shown by the Chi-square test (p < 0.01). This is confirmed by the results for the second category...
of responses, according to which only 21.4% of men and 38.6% of women place performing sports on an equal footing with other activities undertaken in their free time. In this category of responses, statistically significant differences in favor of the young men \( (p < 0.01) \) were shown.

Motives for taking up sports and recreational activities

The most important motive for performing recreational sport of the university students in Thuringia, regardless of gender, turned out to be maintaining health or body shape (Table 2). More than half of the respondents connect free-time sport activity with networking, as well as maintaining social interactions. Physical fitness and sport competition proved to be much important to the male youth compared to females, as well as the desire to experience strong emotions associated with extreme sports. In both cases, the Chi-square test showed a statistically significant difference in favor of men at the level of \( p < 0.01 \).

Frequency of sports performance

One of the most important elements of sports and recreational activity is the frequency at which the sport is performed in one’s free time. The study results presented in Table 3 confirm the high level of commitment to sport of the young German students coming from Thuringia. Nearly three quarters of all the subjects state that they perform sports several times a week. The studied men (79.4%) show a statistically significantly higher frequency of sport performance than women (66.3), as confirmed by statistical analysis \( (p < 0.05) \).

Place of performing sports

The most popular location to perform sports for \( \frac{3}{4} \) of the studied students, regardless of gender, turned out to be their own university, which organizes extracurricular sports activities (Table 4). Apart from this, half of the respondents practice sports in sports clubs, which are much more popular among the male (58.6%) than female students (41.2%). The Chi-square test showed statistically significant differences in this regard at the level of \( p < 0.01 \). Also noteworthy is the large popularity of open air locations as a place to perform sports (49.2%). In this category, however, no statistically significant differences related to gender of the respondents were shown. The test results also confirm (presumably for financial reasons) the relatively low popularity of public sports facilities as a place for students to perform sports.

Declarations regarding the intention to perform sports after graduating from university

The positive attitude of the young students towards sports and recreational activity can be validated by the test results regarding commitment to sports after gradu-
The vast majority of respondents (84.6%) declared an intention to continue playing sports after graduating. Nonetheless, the results confirm a somewhat greater interest in sporting activities in the future of the studied boys, but the results of statistical analysis showed no significant differences in this respect. In addition, the low percentage of students (3.3%) who have not yet made a decision regarding the intention to perform recreational sports in the future is also quite noteworthy.

**Table 5.** Declarations regarding the intention to perform sports after graduating from university (data in percentages)

<table>
<thead>
<tr>
<th>Sports performance after graduating</th>
<th>Women</th>
<th>Men</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>81.8</td>
<td>87.3</td>
<td>84.6</td>
</tr>
<tr>
<td>No</td>
<td>12.8</td>
<td>11.4</td>
<td>12.1</td>
</tr>
<tr>
<td>Not sure yet</td>
<td>5.4</td>
<td>1.3</td>
<td>3.3</td>
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</table>

**Discussion**

The research in this study included several important elements of free-time sport and recreational activity of German students from the Land of Thuringia. Our results showed the importance of recreational sports in the everyday lives of students, especially the males. The dominant role of sport and recreational activity of the German youth among other free-time activities, such as watching television, computer usage, reading, etc. is also confirmed by the results of Nagel [15], Burrmann [16] and Sawicki [17].

The studied young students are guided by different motives when it comes to sports activity, the most important, especially for women, turned out to be health issues and maintaining an aesthetic body shape. Men are more in favor of physical fitness and sports competition, as well as the strong emotions associated with practicing dangerous sports. Similar results concerning the motives behind sports activity were obtained by Opaschowski [18], Steffgen and Schwenkmezger [19], Sawicki [20] and Burrmann [16].

One of the most important factors determining the level of sports activity among the youth is the frequency at which the sport is performed in their free time. Our results confirm the high level of involvement of students, especially male, in practicing sports. Nearly three-quarters of respondents state that they perform sports several times a week, while a low percentage of subjects do not practice any sport at all. A similar level is shown in the test results achieved by Steffgen and Schwenkmezger [19], Baur and Burrmann [1] and Nagel [15].

Another important element of sports activity is the location of its performance. According to our research, sports activities organized by universities (65.6%) are the most popular among students from Thuringia. More than half of the respondents play sports in both sports clubs, as well as open air locations, however, the clubs statistically associate more male (58.6%) than female students (41.2%). Comparable research results on this topic are also presented by Kurz and Tietjens [4], Brettschneider and Kleine [21] and Baur and Burrmann [1].

The positive attitudes of the young students towards sports performance can be evidenced by the results of our research regarding the students’ intentions to perform sports after graduation. Almost 85% of students intend to perform sports in the future, and these results are also confirmed by other studies in this field [5, 15, 16].

**Conclusions**

1. Sport and recreational activity is of great importance in the lives of Thuringian students.
2. The most important motive for taking up sports and recreational activity for students is maintaining health and an aesthetic body shape.
3. The studied students are characterized by a great frequency of performing sports, mainly during classes organized by their university/college.
4. The majority of students state their intention to continue performing sports after graduating from university.
5. The gender of the respondents is differentiated by behavior and attitudes, in favor of the males; greater affiliation to sports clubs, more apparent dominance of emotional and competitive motives, and sports efficiency, as well as greater frequency of sports performance can be observed for the young men.

**References**

Selected aspects of sport and recreational activity of students in Thuringia


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