The journal represents original scientific researches of scientists from the East-European region. The Journal welcomes articles on different aspects of physical education, sports and health of students which cover scientific researches in the related fields, such as biomechanics, kinesiology, medicine, psychology, sociology, technologies of sports equipment, research in training, selection, physical efficiency, as well as health preservation and other interdisciplinary perspectives.

In general, the editors express hope that the journal “Physical Education of Students” contributes to information exchange to combine efforts of the researchers from the East-European region to solve common problems in health promotion of students, development of physical culture and sports in higher educational institutions.
**Key title:** Physical education of students

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The influence of low-performing students’ motivation on selecting courses from the perspective of the sport education model

Chun-Chieh KaoABC, Yu-Jy LuoABCD

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Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: Most studies on the sport education model (SEM) have focused on curriculum content and assessed students’ learning outcomes on the basis of teaching units and items. In contrast to the SEM, direct instruction (DI) emphasizes the learning of each unit and involves a shorter learning period. Few empirical studies have explored the moderating effect of elective motivation on the relationship between the SEM and low student performance in PE.

Material: The present study employed a nonequivalent pretest–posttest quasi-experimental design with an experimental group, which received education under the SEM, and a control group, which received DI. The experiment was conducted in a university in Taiwan, with 115 students from two badminton classes selected as participants.

Results: The results revealed that when the SEM was employed in physical education (PE), students’ elective motivation toward PE courses improved significantly and was significantly higher than that of students receiving DI. The SEM also effectively increased the elective motivation of low-performing students.

Conclusions: Students can experience success in a teamwork setting, avoid a sense of loss and helplessness commonly experienced during individual competition-based learning, and change their elective motivation toward PE courses.

Keywords: curriculum, teaching strategy, physical education, education, sustainability.

Introduction

Morris Chang, a fellow of the Industrial Technology Research Institute and the founder of Taiwan Semiconductor Manufacturing Company, asserted that top universities should focus on cultivating leadership skills in students. In addition to education related to professional disciplines and research training, the cultivation of talented leaders should entail providing instruction on various general education topics [1]. Physical education (PE) is an essential component of general education [2] because it not only encourages students to engage in mutual communication in an environment of trust but also allows them to participate in sports activities to enhance their teamwork ability, which is required for future workplace scenarios [3]. Accordingly, PE is crucial to the development of the social skills of students [4, 5]. The importance of PE is attributable to its positive effect on students’ adherence to a healthy lifestyle as well as their physical fitness [6].

In Taiwan, PE is a compulsory subject in school [3]. The characteristics of this type of education and scenarios it provides facilitate the positive development of adolescents [7]. However, not all students enjoy PE. When children enter adolescence, their learning motivation toward PE usually decreases [8, 9], particularly for students with poor performance in such education [10]. Such students do not understand the subject, which then leads to their unwilling to learn [11]. Students who exhibit low learning performance learn slowly mainly because they are learning under an unfavorable cultural environment. Most schools in Taiwan do not offer remedial sessions for students with low PE performance. Rather, schools merely observe the overall PE performance of all students in each homeroom class and overlook individuals with poor performance. Most studies on the sport education model (SEM) have focused on curriculum content and assessed students’ learning outcomes on the basis of the teaching units and items. Further clarification is required to describe the relationship between the elective motivation of PE courses and teaching strategies and how this relationship affects students’ learning outcomes and intention to enroll in PE classes. In addition, few empirical studies have explored the intervention effect of SEM on the elective motivation of low-performing students in PE; therefore, further research is required to investigate this topic and clarify the relationship between the SEM and students with low PE performance.

Theoretical background

Sports education model based on play theory: Since the promotion of the SEM in the 1908s in middle and elementary schools in Ohio, United States, this model has gradually replaced conventional PE curricula that involve diverse activities and become prevalent in New Zealand and Australia [12]. Siedentop posited that the SEM is based on play theory [13]. A sports activity can be viewed as a complex competition that is considered a systemically designed game. In such a game, students can improve their teamwork ability and adaptation to society, both of which are the goal of active participation in sports. Conventional PE is skill-oriented and isolates physical movements from a competition scenario [14]. Specifically, such education requires students to repeatedly practice basic movements and skills but does not reflect a real competition scenario.
Consequently, students often do not experience the fun of participating in a sports game or learn to develop game strategies, causing their learning to become meaningless and neglecting the intended purpose of PE [13]. In summary, games play a critical role in PE and shows great value in this form of education. Specifically, employing games in PE can not only improve students’ learning motivation but also replace conventional skill-based learning with competitive game scenarios that encourage students to engage in voluntary and effective learning.

The SEM is a curriculum and teaching model based on play theory and stems from the aim of promoting participation in public sports [13]. The six characteristics of the SEM are seasons, affiliation, formal competition, keeping records, festivity, and culminating events. Grouping in the SEM differs from that in conventional PE in that SEM grouping entails role-playing, which is a crucial socialization process. Role-playing allows students with poor skills to become involved in different sports team mechanisms and provides students with comprehensive sports experience [15, 16]. Compared with conventional PE practices, the use of the SEM can better imbue students with a passion for PE [17] and help them develop their athletic potential [18].

A study reported that the SEM provides a real, attractive, and festive learning environment [19]. Specifically, the SEM involves holding formal competitions between teams, which are highly attractive to students [20]. Even after the class is over, students tend to maintain a high level of interest in such competitions [21]. Therefore, game-based teaching improves students’ participation in sports [22], learning motivation [17], and team cohesion [3], and encourages them to fulfill personal and social responsibilities [23]. Therefore, the SEM is considered a teaching strategy that attracts students’ attention. Implementing the SEM provides learners with real sports experience, increase their participation rate, and exerts a positive effect on their learning outcomes, motivational needs, decision-making, and interpersonal interaction. By contrast, direct instruction (DI) emphasizes the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period. The content of such instruction mostly entails the learning of each unit and involves a shorter learning period.

**Self-determination theory and the elective motivation of low-performing students:** Self-determination theory was proposed by [24]. It is a macro-level theory that concerns flexible human motivation and personality and facilitates understanding of human cognition, behavior, and emotion under general and specific scenarios. This theory posits that autonomous motivation, autonomous learning, and participation are the three basic psychological needs of students [25]. It emphasizes that a person’s motivation includes intrinsic motivation, extrinsic motivation, and amotivation, the degree changes with the self-determination degree, and these changes will affect the individual’s participation in an activity. In accordance with the Self-determination theory [24], even in the absence of external rewards, one will still choose to take physical education courses and be satisfied and feel happy in the classes, and thus promote the autonomous behavior towards the next step and also enhances one’s intrinsic motivation. This is also the benign behavior cycle pointed out by [26]. Therefore, when students perceive positive feelings of autonomy, competence, and relatedness, they will be positively influenced by their motives, that is, influence the type of motivation through psychological intermediaries, and then influence their behavioral outcomes. When individuals perceive that their internal control and behavior are determined by their free will, they tend to demonstrate higher levels of motivation to engage in self-determination [27].

The decision making factors when selecting physical education courses includes healthy and fitness, achievement assurance, personal relationship, teacher performance, facilities and equipment [28]. This indirectly echoes that the main benefits of the physical education do not only provide the development of sports skills, but also enhance the development of physical fitness [6], the cultivation of interpersonal relationships [3] and the affirmation of self-achievement [16]. However, students’ motivations when choosing courses are sometimes affected by factors including the institute’s venue and facilities, teachers’ teaching methods, attitudes, and academic literacy, etc. The current physical education implemented in colleges and universities in Taiwan is grouped teaching based on students’ interests. When the education is conducted based on students’ interests, students’ selection options, course selection motivations, willingness and factors of considerations should be made from students prospective. Thus, students’ willingness to take the courses will be increased when they can get what they expected for physical education courses. In other words, under an effective physical education curriculum, students can be assisted by physical education teachers through the courses.

From a constructivist perspective, learning is not a replication or reproduction of knowledge and skills but an active meaning-making process that a learner actively engages in [29]. Low PE performance is attributable to a lack of attention during class, which causes students to experience difficulty receiving information and leads to inappropriate self-efficacy and expectations [10]. Some scholars have proposed that low PE performance is mainly due to low self-esteem [30]. In higher education, low-performing students require social support different from their counterpart with relatively high performance [31], and students’ academic achievements can improve their learning motivation and provide them with self-confidence [32]. This indicates that the highly autonomous motivation of individuals activates and guides their subsequent behaviors [33], and behavioral choices improve behavioral intention and engagement [34]. In the case of PE, a teaching environment shaped by the appropriate teaching methods of the instructor effectively affects students’ learning motivation [35]. The teaching
behavior of the instructor also exerts a substantial effect on students’ self-determination, including their values and willingness to participate in class activities [36].

Equality in education opportunity has been a pertinent topic worldwide [37]. Several studies on low PE performance have indicated that students with unsatisfactory PE performance can gain real sports experience by participating in PE [15, 16]; this improves their peer relationships and promotes peer imitation [21]. During social interactions in PE, low-performing students can receive support and avoid a sense of loss and helplessness that is commonly experienced during competition-based learning [10]. Therefore, effective teaching strategies can be adopted to help students with poor performance receive peer support and encouragement, thus encouraging them and ensuring their success in a group scenario [38]. The aforementioned assertions indicate that students with poor PE performance are most in need of close attention and intervention using suitable teaching strategies. Help should be provided to assist students in addressing their learning difficulties and alleviate their aversion to playing sports.

The current education system in Taiwan provides information, including that related to books, knowledge, and hands-on activities, that can be easily accessed using the Internet. However, only PE has an irreplaceable function, which merits the deliberation of education workers regarding how the content of PE curricula can be presented and how to effectively integrate theory with practice. Exploring the elective motivation of students entails further exploration of the education environment provided in class.

**Research questions and hypotheses:** According to the aforementioned assertions, this study was conducted to examine whether the SEM can be employed to provide a supportive PE learning environment for low-performing students and to explore the effect of such an environment on the elective motivation of students. Under the premise of a student-oriented teaching strategy, this study designed a teaching experiment to examine the SEM and its effect on improving students’ PE performance, thereby attaining the ideal of homogenous educational benefits. The experimental results can also serve as a reference for subsequent research and education practice. Therefore, this study examined and identified solutions to the following questions: (1) the effect of the SEM on students’ motivation to select PE courses, (2) the difference between students’ motivation to select PE courses taught using DI and the SEM, and (3) the effect of the SEM on the motivation of low-performing students to select PE courses. According to the aforementioned factors and a literature review, this study inferred that the SEM can change students’ motivation to select PE courses. Three hypotheses are proposed regarding the selection of PE courses:

- **H1**: The SEM significantly improves the elective motivation of students.
- **H2**: The elective motivation of students being educated using the SEM is significantly higher than that of students receiving DI.
- **H3**: The elective motivation of low-performing students being educated using the SEM is significantly higher than that of low-performing students receiving DI.

**Materials and methods**

**Participants:** The experiment was performed in a university in Taiwan, where 115 students from two badminton classes were recruited as the participants. The experimental group comprised 59 students (32 men and 27 women; mean age: 21.42 ± 0.75 years). The control group comprised 56 students (29 men and 27 women; mean age: 21.38 ± 0.73 years). To reduce interference from irrelevant variables and extraneous variables, this study mainly recruited students who had not received SEM education or enrolled in any SEM course.

**Research design:** The present study employed the nonequivalent pretest–posttest quasi-experimental design with an experimental group, which received the SEM, and a control group, which received the DI. In consideration of ethical research, the research content, research activity design, feedback process for participants, possible harm or discomfort that may be experienced during the research, protection of privacy and information for participants, and freedom for participants to withdraw at any time were disclosed. All procedures, including the informed consent and the recruitment of participants, were reviewed and approved by the Research Ethics Office of National Taiwan University (NTU-REC).

**Procedures:** This study recruited students from two university-level badminton classes and performed 10-week quasi-experimental teaching to the classes. Prior to the experiment, the researchers explained the research objective and procedures to the students and informed them that they are free to determine whether they wanted to participate in the experiment. The badminton skills test of [10] was administered to the two groups of students one week before introducing the experiment. These students were then grouped into high-performing, medium-performing and low-performing groups using 33% and 66% of the test score as critical values. The students were randomly assigned into an experimental group and a control group. The two groups receive teaching with identical content objectives. Before the experiment, the students completed a basic information form and signed an informed consent form, followed by participating in a pretest by filling out the Elective Motivation Scale of Physical Education Curriculum (EMSPEC). On the 11th week, the students filled out another EMSPEC form to complete the posttest. In order to ensure the interference of teacher’s teaching behavior between the two groups, the teachers of the two groups conducted two focus meetings at the beginning of the experiment to determine the directions of the teaching materials of the experiment. Table 1 presents the course content.

**Elective motivation scale of physical education curriculum (EMSPEC):** The EMSPEC could access students’ elective motivation in physical education curriculum. This EMSPEC scale took reference from...
the scales developed by [28] and comprised a total of 25 items (e.g., I can learn skills and relevant knowledge from the elective physical education course; I will take elective physical education course again if there is a chance). The scale showed acceptable fit ($\chi^2 = 571.86, p < 0.05; \text{RMSEA} = 0.07, \text{SRMR} = 0.79, \text{CFI} = 0.95, \text{GFI} = 0.89, \text{AGFI} = 0.91, \text{IFI} = 0.95, \text{NNFI} = 0.94$). The average variance extracted (AVE) of the latent variable was 0.80, with a composite reliability (CR) of 0.95. Thus, we concluded that the EMSPEC was psychometrically sound, with adequate reliability and validity.

Data analysis: To ensure that the two groups of students were taught with different teaching methods under identical conditions, a homogeneity test on the pretest scores of the two groups of students was performed. The independent variable was teaching method and the dependent variables was the EMSPEC. In this study, a 2×3 factorial design was applied; the two independent variables were teaching strategy (i.e., the SEM group vs. the DI group) and ability level (i.e., high ability level, medium ability level, and low ability level) and the one dependent variables was elective motivation of physical education curriculum. The Statistical Product and Service Solutions software package was employed to calculate the statistics with respect to data processing, and five analytical methods were applied to the results: 1. Descriptive statistics were applied to analyze the distributions of the height, weight, and body mass index (BMI) of participants; 2. Chi-square testing was used to analyze the homogeneity of the height, weight, and BMI of participants; 4. Multivariate analysis of covariance (MANCOVA) was applied to compare and analyze the experimental and control groups in terms (i.e., teaching strategy and ability level) of EMSPEC posttest results after excluding the influence of pretest scores; and 5. Based on the standard proposed by [39], the Cohen’s d effect size was divided into three levels: small (0.2 or lower), medium (0.5), and large (0.8 or higher); the $\eta^2$ (eta squared) was used for MANCOVA, and the thresholds were set to ≤0.02 for small, 0.059 for medium, and ≥0.138 for large. The significance levels for all statistical tests in this study were set to $\alpha < 0.01$.

Results

Homogeneity test between the experimental and control group: The results for the demographic analyses indicated that there were no significant differences between the groups in terms of gender ($x^2 = 571.86, p < 0.05$), and age ($t = 0.07, p > 0.05$). The scale showed acceptable fit ($\chi^2 = 571.86, p < 0.05; \text{RMSEA} = 0.07, \text{SRMR} = 0.79, \text{CFI} = 0.95, \text{GFI} = 0.89, \text{AGFI} = 0.91, \text{IFI} = 0.95, \text{NNFI} = 0.94$). The average variance extracted (AVE) of the latent variable was 0.80, with a composite reliability (CR) of 0.95. Thus, we concluded that the EMSPEC was psychometrically sound, with adequate reliability and validity.

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Table 1. Course content.

<table>
<thead>
<tr>
<th>Teaching activities (SEM)</th>
<th>Stage</th>
<th>Week</th>
<th>Stage</th>
<th>Teaching activities (DI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction to the history and rules of badminton</td>
<td>Stage</td>
<td>1</td>
<td>Teaching activities</td>
<td>1. Introduction to the history and rules of badminton</td>
</tr>
<tr>
<td>2. Basic skills and game concept of badminton</td>
<td></td>
<td>2</td>
<td></td>
<td>2. Basic skills and game concept of badminton</td>
</tr>
<tr>
<td>3. Heterogeneous grouping</td>
<td></td>
<td>3</td>
<td></td>
<td>3. Random grouping</td>
</tr>
<tr>
<td>4. Discussion on game strategies and team names, and the determination of lineups</td>
<td></td>
<td>4</td>
<td></td>
<td>4. Game strategy description</td>
</tr>
<tr>
<td>5. Planning of the preseason games and refereeing practice</td>
<td></td>
<td>Preseason</td>
<td>5</td>
<td>1. Comprehensive practice of basic badminton skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>2. Learn about the rules of the game</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>3. Explanation on offense and defense concepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postseason</td>
<td>8</td>
<td>1. Group competition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>2. Game technology improvement instructions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Celebration Event</td>
<td>10</td>
<td>3. Announce the results of the competition</td>
</tr>
</tbody>
</table>

Table 2 summarizes the demographic characteristics and physical fitness of the participants in the two groups. Table 3 presents the results of homogeneity tests for the within-group regression coefficients of EMSPEC score. The regression line slope of EMSPEC score (F
As shown in Table 5, after pretest scores were excluded, the interaction of Factors A (group) and B (ability) was significant (F=14.66, p<.05, η²=0.21). Subsequently, the primary effects of covariance were analyzed. As shown in Figure 1, Tables 4 and 6, for the students at the high and medium ability levels, the effect of group on elective motivation was nonsignificant; for the students at the low ability level, the elective motivation of the experimental group (M=3.81) was significantly superior to that of the control group (M=3.20). For the experimental group, the effect of ability on elective motivation was significant; the elective motivation of the students at the low ability level (M=3.81) was significantly superior to that of the students at the high ability level (M=3.37). For the control group, the effect of ability on elective motivation was not significant.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental (n = 59; M[SD])</th>
<th>Control (n = 56; M [SD])</th>
<th>Total (n = 115; M [SD])</th>
<th>Significance (Effect Size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>32(M):27(F)</td>
<td>29(M):27(F)</td>
<td>61(M):54(F)</td>
<td>x²=0.07, p&gt;0.05(d=0.03)</td>
</tr>
<tr>
<td>Age</td>
<td>21.42[0.75]</td>
<td>21.38[0.73]</td>
<td>21.40[0.74]</td>
<td>t =0.35, p &gt; 0.05(d=0.07)</td>
</tr>
<tr>
<td>Height</td>
<td>1.66[0.08]</td>
<td>1.66[0.09]</td>
<td>1.66[0.09]</td>
<td>t =0.03, p &gt; 0.05(d=0.01)</td>
</tr>
<tr>
<td>Weight</td>
<td>59.37[11.77]</td>
<td>62.88[13.91]</td>
<td>61.08[12.92]</td>
<td>t =1.45, p &gt; 0.05(d=0.27)</td>
</tr>
<tr>
<td>BMI</td>
<td>21.41 [3.40]</td>
<td>22.70[4.37]</td>
<td>22.04[3.94]</td>
<td>t =1.77, p &gt; 0.05(d=0.33)</td>
</tr>
</tbody>
</table>

Table 4. Descriptive statistics on elective motivation of PE curriculum of the experimental and control groups.

<table>
<thead>
<tr>
<th>B factor (Ability)</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>A factor (Group)</td>
<td>SEM</td>
<td>3.37(3.38)</td>
<td>3.34(3.31)</td>
<td>3.81(3.78)</td>
</tr>
<tr>
<td></td>
<td>DI</td>
<td>3.29(3.33)</td>
<td>3.19(3.18)</td>
<td>3.20(3.23)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.33(3.35)</td>
<td>3.27(3.24)</td>
<td>3.51(3.51)</td>
</tr>
</tbody>
</table>

Table 5. Multivariate analysis of covariance for elective motivation of PE curriculum.

<table>
<thead>
<tr>
<th>Source (A)</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>Sig.</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>2.19</td>
<td>1</td>
<td>2.19</td>
<td>41.76*</td>
<td>0.00</td>
<td>0.28</td>
</tr>
<tr>
<td>Ability(B)</td>
<td>1.22</td>
<td>2</td>
<td>0.61</td>
<td>11.63*</td>
<td>0.00</td>
<td>0.18</td>
</tr>
<tr>
<td>(A)X (B)</td>
<td>1.53</td>
<td>2</td>
<td>0.77</td>
<td>14.66*</td>
<td>0.00</td>
<td>0.21</td>
</tr>
<tr>
<td>Error</td>
<td>5.65</td>
<td>108</td>
<td>0.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1317.77</td>
<td>115</td>
<td>0.52</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * p<.01.
Discussion
This study adopted a perspective based on the SEM to examine students’ elective motivation toward PE courses and explored the effect of the SEM on the motivation of low-performing students to select PE courses. The results revealed that after the SEM was employed in PE, students’ elective motivation toward PE courses improved significantly and was higher than that of students receiving DI. The SEM also effectively raised the elective motivation of low-performing students. Therefore, H1, H2 and H3 were validated, and the results concur with those of related studies [10, 15, 38, 40]. The inferences of this study were based on how the SEM can provide a game scenario in which students can demonstrate their skills. Moreover, such a scenario provides equal learning opportunities to all students and enables students to engage in interactive learning, thereby promoting peer imitation and allowing students to receive help and encouragement from peers. Accordingly, students can experience success in a teamwork setting, avoid a sense of loss and helplessness commonly experienced during competition-based learning, and change their elective motivation toward PE courses. The results of this study indirectly verified the discourse of several related studies [15, 16, 41-43]. The SEM can provide students with real sports experience. By playing different roles in a sports team, students can engage in a deeper level of learning and are more likely to exert great effort to learn. Accordingly, the team members can experience a sense of belonging and develop respect for one another. The SEM can also enhance students’ engagement in sports while improving their motivation to select PE courses.

From a curriculum-based perspective, research on autonomous learning motivation and self-regulation has reported that motivation exerts a noticeable effect on learning processes and outcomes [44]. Motivation to exercise is highly correlated with exercise behavior and emotion (e.g., a sense of fulfillment, satisfaction, and enjoyment) [45]. In terms of the three basic psychological needs of SDT, autonomy needs reflect the desire of individuals to make their own choices about their activities (for instance: I choose physical education course because I like it, not because the university or my parents want me to take it). A sense of ability means that the individual feels competent in the environment (for instance: I believe that I can achieve the technical skills required by the teacher.) Relevance relates to the emotional relationship between individuals and the environment and other related parties (for instance: I feel that both the teacher and my peer students are very supportive when I take elective

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>sig</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>A factor (Group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1 (High)</td>
<td>0.02</td>
<td>1</td>
<td>0.02</td>
<td>0.37</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>B2 (Medium)</td>
<td>0.15</td>
<td>1</td>
<td>0.15</td>
<td>5.60</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>B3 (Low)</td>
<td>3.05</td>
<td>1</td>
<td>3.05</td>
<td>30.66*</td>
<td>0.00</td>
<td>SEM&gt;DI</td>
</tr>
<tr>
<td>B factor (Ability)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1 (SEM)</td>
<td>2.64</td>
<td>2</td>
<td>1.32</td>
<td>15.58*</td>
<td>0.00</td>
<td>Low&gt;High</td>
</tr>
<tr>
<td>A2 (TP)</td>
<td>0.21</td>
<td>2</td>
<td>0.10</td>
<td>2.69</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

Note: * p<.01.

Fig. 1. Elective motivation performance between experiment group and control group.
physical education classes). When the above three basic psychological needs are met, the individual’s motivation for continuing taking the elective course is stimulated and strengthened.

Students’ time spent at university is a critical period they can develop regular exercise habits, and this period exerts a substantial effect on students’ regular exercise habits after they graduate [46]. If a student no longer exercises after graduation, it may be because he or she lacked a strong motivation to exercise while participating in PE classes [47]. The SEM emphasizes students’ autonomous learning and their respect for differences between individuals. During sports learning, this model encourages all students to comprehensively participate in related activities and learn in an enjoyable environment. As a learner-oriented model, the SEM creates a learning environment that elicits the intrinsic motivation of students and allows them to experience a sense of autonomy. Therefore, the SEM can serve as a teaching model that supports and improves students’ motivational needs [48]. Under this model, students experience a learning environment in a real-world context in which conventional game rules are adapted to students’ learning needs, and students can engage in discussion and make decisions with their teammates according to the athletic ability of each of them and of their opponents [49]. Students enjoy education under the SEM because it bestows them with the autonomy to make game decisions and improves their teamwork and decision-making abilities [16]. Accordingly, teachers can implement the SEM in an adequate manner to help students attain course objectives and respond challenges appropriately.

From the perspective of student capability, a related study asserted that perceived competence, autonomy, and relatedness are innate psychological needs [27]. When sports participants satisfy these needs, their self-determination is improved; conversely, their self-determination is reduced [50]. In the SEM, the various roles of students and the celebration ceremony of the model help teachers examine students’ individual differences. In addition to playing the role of players, students also learn to coach, referee, keep scores, and record each player’s performance, which are all essential roles in a sports game. Under the premise of heterogeneous grouping, students of different abilities can assume roles that best fit their aptitudes, thereby allowing them to best demonstrate their capabilities. In addition, a celebration ceremony is hosted to present awards, making students feel that they are participating in a large event. According to the SEM concepts, other activities are also arranged, including the design of the team name, slogan, and flag, to integrate in-class activities with real-world group activities and create an enjoyable learning atmosphere. An analysis from the perspective of self-determination theory indicates that interest, as an intrinsic motivation, is a type of autonomous motivation that is positively correlated with learning behavior and emotion [26]. Autonomous motivation creates a virtuous circle for the learning engagement of university students, whereas low performance in a subject prompts student to avoid selecting courses related to the subject [51]. In summary, autonomous learning motivation is crucial to the learning process of university students, who tend to select courses on the basis of their interests [44].

The SEM is a student-centered teaching model in which the teacher gradually transfers power to students. Games are scheduled between teaching activities, and before the course is over, a ceremony is hosted to create an enjoyable team atmosphere. The entire learning process is recorded to raise students’ interest in learning. The main form of learning in conventional narrative lectures involves receiving visual and auditory information. However, low-performing students usually demonstrate more favorable learning outcomes through experiential learning. This type of learning not only increases such students’ confidence and improves their interest in the subject but also provides them with more opportunities to participate in class activities according to their learning progress, allowing them to attain greater learning achievements. Moreover, employing a democratic and tolerant teaching approach to cultivating responsible, cultured, and passionate students is the fundamental component in the SEM [4, 5]. Adapting teaching strategies to the aptitudes of low-performing students is highly conducive to the learning of such students. Through such a teaching approach, the motivation of low-performing students to select PE courses can be improved.

Overall, this quasi-experimental study verified the effectiveness of the SEM in improving the elective motivation of low-performing students toward PE courses. The study results provided evidence that the SEM raised low-performing students’ motivation to select PE courses. The value of this study is that it provided valid evidence for PE instructors who are interested in using the SEM to improve elective motivation toward PE courses.

Conclusion and recommendations
In response to a growing awareness of the sustainable development of education worldwide, PE instructors tend to adopt innovative teaching strategies to design courses according to the needs and abilities of low-performing students, allowing such students to experience success in sport education. This study explored the effect of the SEM on the elective motivation of university students toward PE courses and supplemented the gaps in related research. The study results indicated that PE instructors can use the SEM to create effective course development strategies and improve the elective motivation of low-performing students. Therefore, this model holds considerable potential. The intervention employed in this study also provided strong evidence regarding the effect of the SEM on low-performing students. The findings may be applied to other PE activities to maximize students’ motivation to select PE courses. However, this study only examined badminton classes in one university. Subsequent research is required to confirm the effectiveness of the SEM in facilitating the overall development of PE curricula.

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The effect of somatotype characters on selected physical performance parameters

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Abstract

Purpose: The physical structure is considered as one of the elements for sporting success. The aim of this study was to investigate the effects of somatotype characters on selected physical performance parameters.

Material: This study was included 150 males (age: 22.10±2.46 years) participants who do not have habit of regular exercise. The somatotype characters of participants were determined and physical performance tests (30 m sprint, vertical jump, anaerobic power, aerobic capacity, and flexibility) were measured as an experimental design.

Results: As a result of the research, 9 different somatotype subgroups were identified. In this study, the statistically significant was found between groups in terms of explosive force, aerobic and anaerobic power output (p<0.05). We found no significant between groups in terms of flexibility (p=0.670), relative anaerobic peak (p=0.560) and mean power output (p=0.077). The results were obtained in favor of mesomorph-endomorph structure in terms of absolute peak and mean power, while mesomorph and ectomorph component contributed positively to explosive force and aerobic capacity scores.

Conclusions: Our study highlighted the fact that the subgroups of somatotype have an effect on performance parameters. The body-performance relationship can be examined in detail with more participants representing each somatotype group.

Keywords: body composition, performance, physical fitness, somatotype components.

Introduction

Exercise planning, ability level and genetic predisposition can be mentioned as the constituent structures of sporting success. In addition, it is possible to emphasize the need for a branch-specific body structure in order to achieve optimal sporting success. Since Sheldon’s first studies on somatotypes, many researchers have attempted to determine the effects of somatotype on physical performance [1, 2]. Somatotype is a taxonomy that allows the interpretation of a body structure based on different elements. Carter and Heath [3] developed a three-dimensional and formula-based concept for the detailed classification of body structure This involves a classification based on 3 components (endomorph-mesomorph-ectomorph) and examines the body in detail.

All branches of sport have a unique set of specialized biomotor performance requirements. However, in addition to performance indicators such as strength [4], power [5], flexibility [6], endurance [7] and agility [8] among the factors that have a positive effect on the performance of athletes, physical structure is also considered as one of the elements for high performance [9]. It can be mentioned that the body type of elite or successful athletes competing in a particular sport has features that can provide a template in terms of current performance parameters. For example, while the mesomorph component of elite boxing athletes was noted to be high [10], it was stated that elite wrestlers had mesomorph-endomorph body type [11]. However, it can be seen that within a particular branch of team sport, body types differ depending on the position of the player. Busko et al. [12] found that in the somatotype classification of 14 female volleyball players, the lowest ectomorph and highest endomorph components were found in libero and setters respectively, the highest ectomorphs and lowest endomorphs were found in hitters and opposites respectively. It is considered that the role of somatic elements in the display of the relevant performance parameters can be used for the selection and development of athletes.

This research was based on the 9 groups of the somatotype characters proposed by Carter and Heath. In this context, we believe that the findings as to how the 9 different body types affect motor performance scores may contribute significantly to the literature.

The hypothesis was determined as follows: “somatotype body type differences would affect biomotor performance scores”. This study aimed to evaluate the effect of different body types on selected physical test scores.

Material and Methods

Participants

A total of 150 volunteers, including 150 males participated in the study (age: 22.10±2.46 years). All participants were informed about the possible risks and details of the research before beginning the study and were made to sign voluntary consent forms. The study was approved by the Clinical Research Ethics Committee (code:2015/211) and conformed to the Helsinki declaration. The criteria for inclusion in the study were: (a) absence of any health problems in the participants during the performance of the tests, (b) having obtained
consent from the participants (c) regular participation in all the tests and measurements in the study. The criteria for exclusion from the study were: (a) the occurrence of any health problem, (b) irregularity participation in the measurements, (c) careless behaviors with regard to the optimal execution of performance.

Procedure

Anthropometric measurements and field test protocols were applied to volunteers participating in the study. Participants were told to rest 24 hours before the measurements, away from any heavy physical strain. They were informed a day in advance, that they should not consume stimulants such as tea, coffee, and fizzy drinks. All the measurements and test protocols applied in the study were applied in the faculty of sport sciences physiology laboratory and sports hall. Somatotype measurements were made on all participants in a resting state in the morning after 8 hours of fasting. The participants’ motor tests were measured between 09.00 and 11.00. A 5-min general warm-up protocol was applied to the volunteers participating in the study before all tests in order to minimize the risk of disability and to achieve optimal performance.

Somatotype

All the anthropometric measurements of the subjects were made in accordance with the measurement techniques and standards recommended by the International Society for the Advancement of Kinanthropometry. Carter-Heath [3] method was followed for somatotyping rating as follows:

\[
\text{Endomorphy} = -0.7182 + 0.1451 (X) - 0.00668 (X)^2 + 0.0000014 (X)^3
\]

Where \(X\) = sum of triceps, subscapular and suprailiac skinfold and for height corrected endomorphy multiplied by 170.18 / body height in cm.

\[
\text{Mesomorphy} = (0.858 \times \text{humerus breadth}) + (0.601 \times \text{femur breadth}) + (0.188 \times \text{corrected arm girth}) + (0.161 \times \text{corrected calf girth}) - (0.131 \times \text{height}) + 4.5
\]

Corrected arm girth: arm girth (cm) – (triceps skinfold / 10) (mm);

Corrected calf girth: calf girth – (calf skinfold / 10) (mm);

\[
\text{Ectomorphy} = (0.732 \times \text{HWR}) - 28.58
\]

If HWR was found as 38.25 < RPI < 40.75, Ectomorphy = (HWR x 0.463) - 17.63.

If HWR was found as an equal to or less than 38.25 give a rating of 0.1

HWR: height (cm) / weight \(^{-1/3}\) (kg)

In the study, each participant’s body height was measured with a stadiometer with a sensitivity level of 0.01 meter (m) and their body weight was measured with an electronic scale (SECA, Germany) with a sensitivity level of 0.1 kilogram (kg). Then body girths (flexed and tensed upper arm girth and calf girth) were measured using flexible but non-stretchable tape (Holtain Ltd, Croswell, UK) to the nearest 0.1 cm. Biepicondylar humeral and femoral breadth were measured using bicondylar caliper (Holtain Ltd, Croswell, UK) to the nearest 0.1 cm. The participants’ skinfold thicknesses values were determined with a skinfold caliper (Holtain Ltd, Croswell, UK) from 4 sites (triceps, suprailiac, subscapula, calf).

Field Tests

30 m Sprint Test

A “30 m sprint test” was performed to determine the participants’ sprint times. Running scores were recorded in seconds using electronic timing gates placed on the start and finish lines (Smart Speed; Fusion Sport, Australia). Passive resting intervals of 3 min were applied between the repetitions. The test was repeated three times for each participant for the reliability of the test and the best performance score was recorded [13].

Counter Movement Jump (CMJ)

A single vertical jump test was performed to assess the participants’ jumping heights. The participants jumped to the highest distance on the floor platform with their knees stretched and hands on their waist in the starting position (Smart Jump; Fusion Sport, Australia). Passive resting intervals of 3 min were applied between the repetitions. The test was repeated three times for each participant for the reliability of the test and the best performance score was recorded [14].

Wingate Anaerobic Test (WANT)

The participants’ body weights were calculated before the test began. Then, the sitting heights were adjusted for each participant, so that there would not be more than 5 degrees of flexion during pedaling. A resistance of 7.5% of the body weight of each participant was calculated for the Wingate weight basket. A 5-min warm-up period was provided for each participant before the test began. The participants warmed up with 3 repetitions of maximal pedal speed for 5 sec. The test lasted for 30 seconds and the participants were verbally encouraged. At the end of 30 seconds the participants were allowed to pedal without weight on the bicycle until their heart rate was about 120 bpm [14]. The parameters obtained as a result of the test which was performed with the Monark 894 E (Sweden) bicycle ergometer connected to a computer and operating with a compatible software were calculated with the software in the computer as anaerobic peak power, anaerobic mean power absolute and relative values.

Maximal Oxygen Consumption (Vo2max)

With the purpose of determining the Vo2max of the participants, the YoYo-1 was used to evaluate people with low fitness levels [15]. The participants were given detailed information about the test procedures and after a routine warm-up the test started. The Vo2max values of the participants were calculated according to the YoYo-1 test result using the formula; “Vo2max (mL/min/kg) = Running distance (m) * 0.0084 + 36.4”.

Flexibility Test

The sit and reach test was used to measure flexibility. This test was performed firstly to measure the knee-back tendon flexibility of the participants and secondly to measure the lower back, hip and calf flexibility. Each participant performed 3 repetitions, and only the best one was considered for statistical analysis.

Statistical Analysis

Looking at the “kurtosis and skewness” values (between +1.5 and -1.5) and because the number of
participants was greater than 50, whether the research data were homogeneous or not was tested with the “Kolmogorov Smirnov” test. It was determined in the study that the data showed non-normally distribution. The data were analyzed using the “Kruskal Wallis H”, one of the non-parametric tests used for evaluating more than two independent variables. When there was a statistically significant difference between groups, the “Mann-Whitney U” test was used to find out in which group’s favor it was. All statistical analyses were performed with the “IBM SPSS 23” software package. All tests taken were expressed as median (min-max). The level of significance in the study was accepted as p < 0.05.

**Results**

The measured values somatic and demographic parameters were presented in Table 1 as median (med.), minimum (min.) and maximum (max.) values. The somatochart maps of the participants identified as a result of the research were presented in Figures 1. The identified subtypes were shown in Table 2.

The somatotype values of participants were found as endo (2.8) - meso (4.3) - ecto (2.6) in Table 1. These results showed that 150 male participants had balanced mesomorph body type.

Table 2 shows that 9 different subtypes were identified. The highest variance was found in endomorphic mesomorph body type (n=44). However, the least variance was seen in the mesomorphic endomorph group (n=7).

When Table 3 is examined; there was a significant difference between the groups in terms of vertical jump (p = 0.015), 30 m sprint (p = 0.002) and V o2max (p = 0.000).

**Table 1.** Median and min-max values of the descriptive statistics of the participants (n=150)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Median</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>22</td>
<td>18</td>
<td>34</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>22.2</td>
<td>16.5</td>
<td>32.6</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>176</td>
<td>160</td>
<td>190</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>67.6</td>
<td>49</td>
<td>101</td>
</tr>
<tr>
<td>Medial calf skinfold (mm)</td>
<td>7</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Triceps skinfold (mm)</td>
<td>9</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Subscapular skinfold (mm)</td>
<td>13</td>
<td>7</td>
<td>33</td>
</tr>
<tr>
<td>Supra-iliac skinfold (mm)</td>
<td>7</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>Flexed upper arm girth (cm)</td>
<td>31.7</td>
<td>26.5</td>
<td>38.5</td>
</tr>
<tr>
<td>Medial calf girth (cm)</td>
<td>36.4</td>
<td>29</td>
<td>45.5</td>
</tr>
<tr>
<td>Bi-Femoral breadth (cm)</td>
<td>6.5</td>
<td>5.6</td>
<td>7.9</td>
</tr>
<tr>
<td>Bi-Humeral breadth (cm)</td>
<td>9.3</td>
<td>7.5</td>
<td>11.8</td>
</tr>
<tr>
<td>Endomorphy</td>
<td>2.8</td>
<td>1.3</td>
<td>6.9</td>
</tr>
<tr>
<td>Mesomorphy</td>
<td>4.3</td>
<td>.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Ectomorphy</td>
<td>2.6</td>
<td>.1</td>
<td>6.2</td>
</tr>
</tbody>
</table>

**Table 2.** Determined somatotype body types of participants.

<table>
<thead>
<tr>
<th>Somatotypes</th>
<th>N</th>
<th>ENDO</th>
<th>MESO</th>
<th>ECTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced ectomorph</td>
<td>16</td>
<td>2.39</td>
<td>2.21</td>
<td>4.88</td>
</tr>
<tr>
<td>Balanced mesomorph</td>
<td>20</td>
<td>2.74</td>
<td>4.53</td>
<td>2.64</td>
</tr>
<tr>
<td>Central</td>
<td>13</td>
<td>3.20</td>
<td>3.76</td>
<td>3.07</td>
</tr>
<tr>
<td>Ectomorphic mesomorph</td>
<td>9</td>
<td>1.97</td>
<td>4.87</td>
<td>3.18</td>
</tr>
<tr>
<td>Endomorphic mesomorph</td>
<td>44</td>
<td>3.49</td>
<td>5.15</td>
<td>1.83</td>
</tr>
<tr>
<td>Mesomorph-ectomorph</td>
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<td>2.11</td>
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<tr>
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<td>7</td>
<td>4.93</td>
<td>3.73</td>
<td>2.24</td>
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</table>
Table 3. Median and min-max values of field performance tests and Kruskal Wallis H test results of somatotype

<table>
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<tr>
<th>Somatotype</th>
<th>VJ (cm)</th>
<th>30 m sprint (sec)</th>
<th>Flexibility (cm)</th>
<th>Vo2max ml/kg/min</th>
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</thead>
<tbody>
<tr>
<td>Balanced ectomorph</td>
<td>36.8</td>
<td>32.4 - 36.8</td>
<td>3.9 - 4.1</td>
<td>30.5 - 30.5</td>
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<td>26.9 - 35.9</td>
<td>3.9 - 4.5</td>
<td>29.6 - 30.5</td>
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<tr>
<td>Central</td>
<td>34.3</td>
<td>29.8 - 44.7</td>
<td>4 - 4.2</td>
<td>29 - 48</td>
</tr>
<tr>
<td>Ectomorphic mesomorph</td>
<td>41.3</td>
<td>30.5 - 41.3</td>
<td>3.8 - 4.1</td>
<td>26 - 41</td>
</tr>
<tr>
<td>Endomorphic mesomorph</td>
<td>35.2</td>
<td>20.6 - 64.4</td>
<td>3 - 4.1</td>
<td>34 - 48</td>
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<td>28.9 - 52.1</td>
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<td>27.5 - 44.4</td>
<td>4.1 - 4.3</td>
<td>35 - 42</td>
</tr>
<tr>
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<td>35.2</td>
<td>29.6 - 41.5</td>
<td>4 - 4.2</td>
<td>29 - 39</td>
</tr>
<tr>
<td>Mesomorphic endomorph</td>
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<td>28.3 - 42.1</td>
<td>4.2 - 4.3</td>
<td>32 - 42</td>
</tr>
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<td>19.056</td>
<td>24.217</td>
<td>5.801</td>
<td>28.726</td>
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<td>df</td>
<td>8</td>
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<td>8</td>
<td>8</td>
</tr>
<tr>
<td>p value</td>
<td>p=0.015*</td>
<td>p=0.002*</td>
<td>p=0.670</td>
<td>p=0.000*</td>
</tr>
</tbody>
</table>

*=p<0.05; VJ = Vertical jump; Vo2max = Maximum oxygen capacity; P value was calculated by Kruskal-Wallis Test

Figure 1- Individual somatoplots of participants and the mean somatoplott for all participants (circle).
Table 4 shows the difference between the body types. No correlation was found between flexibility and somatotype ($p = 0.670$).

There was a significant difference between the groups in terms of anaerobic power jump ($p = 0.019$), anaerobic capacity ($p = 0.018$) in Table 5. Table 6 shows the difference between the body types. No correlation was found between relative values and somatotype ($p > 0.05$).

**Discussion**

The results of the study showed that somatotype body types have an important effect on the range of performance scores. It was seen that the mesomorphic character has a positive effect on sprint performance scores, while the endomorphic character has a negative effect on vertical jump scores. In addition, the mesomorphic and ectomorphic character has a positive effect on aerobic capacity. Also, it was found that those with a center type obtained the highest performance score in terms of anaerobic power values, while those with a mesomorphic ectomorph character showed the lowest performance scores. These findings reveal the importance of the morphological structure and anthropometric elements that significantly affect motor performance scores including power, strength, speed and endurance.

The average somatotype scores of the participants indicated a balanced mesomorph structure (2.8-4.3-2.6). As a rational explanation of this situation, it is known that even though the participants in the research group did not do sports at a professional level, they had a sports background, because they were students of the sport science faculty. It can be suggested that a dominant

---

**Table 4.** Mann-Whitney U test results of body types and performance tests with significant differences

<table>
<thead>
<tr>
<th>Parameters</th>
<th>U</th>
<th>Z</th>
<th>p</th>
<th>Somatotypes</th>
</tr>
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<tbody>
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</table>

(1) Balanced ectomorph; (2) Balanced mesomorph; (3) Central (4) Ectomorphic mesomorph (5) Ectomorphic mesomorph; (6) Mesomorphic-ectomorph; (7) Mesomorphic-endomorph; (8) Mesomorphic ectomorph; (9) Mesomorphic endomorph. P value was calculated by Mann-Whitney U test.
<table>
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</table>

$X^2$ = 18.365, df = 8, p = 0.019*<br>Table 5. Median and minimum-maximum values of Wingate Test and Kruskal Wallis H test results of somatotype

<table>
<thead>
<tr>
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<th>U</th>
<th>Z</th>
<th>p</th>
<th>Somatotypes</th>
</tr>
</thead>
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<td>Wingate Mean Power</td>
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<tr>
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<td>40.000</td>
<td>-2.649</td>
<td>0.008</td>
<td>7&gt;8</td>
</tr>
</tbody>
</table>

(1) Balanced ectomorph; (2) Balanced mesomorph; (3) Central (4) Ectomorphic mesomorph (5) Ectomorphic mesomorph; (6) Mesomorph-ectomorph; (7) Mesomorph-endomorph; (8) Mesomorphic ectomorph; (9) Mesomorphic endomorph. P value was calculated by Mann-Whitney U Test

* = p<0.05; P value was calculated by Kruskal-Wallis Test
mesomorphic character was detected for this reason. In research into the somatotype body types of similar age groups, Gualdi and Graziani [16] determined the somatotype scores of 717 male young sports participants and found them to be 2.7-4.7-2.7 for males. Similarly, Gasparini [17] found that the mesomorphic character of 19 football players (mean age = 18.8 years) was greater than the other two components (2.9-4.5-2.9).

In this study, which used the 9 different body type classification proposed by Carter and Heath, statistically significant differences were found between the groups in terms of 30 m sprint and vertical jump performance. In this study, endomorphic mesomorphic participants (3.4-5.1-1.8) scored best in terms of the 30 m sprint. In the literature, the results obtained in many studies where linear speed is important do not differ from this. Gontarev et al. [18] examined 5 different age groups in football players, and stated that the dominant component was mesomorphic. Arjunan [19] examined the somatotype classification of 15 male 100 m and 200 m sprinters and found that the athletes had a dominant mesomorphic character (3.4-5.5-4.1). According to Marta et al. [20] mesomorphy may have a significant positive influence on sprint running gains, and the ectomorphic component may be positively associated with sprint running gains. A study found that somatotype rate influences the running time to 30.4% and also that the endomorphic rate was said to make a substantial contribution to the regression of the run split time [21]. In terms of vertical jumping, the best performance was obtained by the participants of the ectomorphic mesomorphic (1.9-4.8-3.1). Pastore et al. [22] stated that beach volleyball players under the age of 19 and 21 who competed in the European championship were mesomorphic-ectomorphic. It can be said that the endomorphic component, which is an indicator of fatness on the part of athletes, may have a negative effect in the case of beach volleyball, where the jump performance on difficult ground is exhibited. Moss et al. [23] reported that counter movement jump height was also negatively-affected by higher body fat values. Busko et al. [12] found that there was a significant negative correlation between the rate of elevation of the center of body mass and the endomorphic component (r = -0.59). In the light of the findings obtained in this study, it can be said that the dominant mesomorphic component in terms of 30 m sprint and the mesomorphic-ectomorphic component in terms of vertical jumping contribute positively to the performance results.

There was no significant difference between the groups in terms of flexibility performance and somatotype component (p = 0.670). In the literature, there are studies indicating that there is no relationship between hamstring flexibility and somatotype component [24]. Singh et al. [25] found a negative relationship between endomorph and flexibility in 8-year-old children, and in the same study found a significant positive relationship between endomorph and flexibility in 9-year-old children. This suggests that somatotype elements may cause inconsistent findings in terms of flexibility performance.

One of the reliable parameters in determining the sporting performance and the exercise levels of individuals is maximal oxygen capacity. In a study examining the effect of the somatotype character on ventilatory threshold and VO2max values - the determinants of aerobic capacity – those participants (mean age: 21.4 years) with a mesomorphic-ectomorphic and mesomorphic body type were found to have the greatest improvements scores in terms of aerobic capacity [26]. In a further study it was reported that the greatest gains in aerobic fitness were for individuals with ectomorphic dominance (odds ratio, 3.84; 95% CI, 1.20–12.27) [20]. In this study, a significant difference was found between the groups according to the results with regard to maximal oxygen capacity (p = 0.000). The highest scoring group was ectomorphic mesomorphic (53.8 ml / kg / min), while the lowest scoring group was mesomorph endomorph (44.8 ml / kg / min). Simrkavak et al. [27] found that there was a significant negative correlation between maximal oxygen consumption and body fat ratio per kilogram in women (r = -0.92), men (r = -0.52) and regardless of gender (r = -0.62). These findings show that mesomorphic and ectomorphic components make a positive contribution to performance in terms of aerobic capacity, but there may also be a negative correlation between endomorphic score and VO2max.

Peak power and mean power scores were significantly different between somatotype components (p = 0.019; p = 0.018, respectively). The highest score in terms of both peak power (747.9 watts) and mean power (512.5 watts) was shown by the mesomorphic-endomorphic participants. When absolute peak power output scores are examined, Sanchez-Puccini et al. [28] found a 591.9 ± 91.0 watt PP score in the case of elite male karate athletes who had a mesomorphic-endomorphic somatotype character. Also, Ramirez et al. [11] reported a 602.5 ± 89.3 watt PP score in the case of elite male wrestlers who had a mesomorphic-endomorphic somatotype character. Lewandowska et al. [29] examined the maximal muscle torques of the elbow, shoulder, hip, knee and trunk flexor-extensors of 13 judo athletes identified as endomorphic mesomorphic. They found a significant positive correlation between the power outputs of all regions and the mesomorphic component, together with a negative correlation between the power outputs of all regions and the ectomorphic components. Quarría and Wilson [30] found that rugby players with more endo-mesomorphic structures produce higher scrubbing forces than ectomorphic athletes. The body fat and therefore the endomorphic and mesomorphic components can be said to have a positive effect on achieving peak power output.

Acknowledgements
This study was written by abridging Fahri Safa ÇINARLI’s İnönü University Institute of Health Sciences, Physical Training and Sports Department master’s thesis. We would like to thank students who participated in the study and İnönü University Scientific Research Projects Coordination Unit that provided financial support with the project number 2016/31 for the purchase of materials.
used in the research.

**Conclusion**

According to the findings obtained from this study, somatotype body types have a significant role to play in terms of motor performance scores. In general, when explosive force and Vo2max scores are examined, it can be said that meso-ecto components can contribute positively to performance scores. When power output scores are examined, it can be said that meso-endo components can contribute positively to performance scores. It is thought that the relationship between basic sport performance skills and somatotype components may act as a selection and guidance tool for athletes in lower age groups.

**Conflicts of Interest**

The authors declare no conflict of interest.

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**References**


Acceptance of the sense of implementing safe fall programs for people with visual impairments or after amputation of limbs – the perspective of modern adapted physical activity

Gaśienica Walczak B.

Podhale State College of Applied Sciences in Nowy Targ, Poland

Abstract

Purpose: The aim of the study was to find out whether safe falling programs for patients with visual impairment or limb amputees, as a prospective modern adapted physical activity, gained acceptance from physiotherapy students and people with disabilities.

Material: The study consisted of three stages. The sample included 189 participants. The preset inclusion criterion (adequate attendance during the training) was met by 134 students and all the participants with visual impairment (n = 6) and after limb amputation (n = 8).

Results: The opinions that implementation of STSFT programs for patients with visual impairment or after limb amputation, expressed by physiotherapy students (about 94% and 95% of students at stages I and II respectively) and patients with disabilities (100% of amputees and 83% of patients with visual impairment at stage III), who learned to protect their bodies during collisions with the ground, indicate that the aforementioned empirically verified programs are effective.

Conclusions: 1. Implementation of safe falling programs as an adapted physical activity for patients with visual impairment or after limb amputation may adversely affect their feeling of safety and motivation for practicing sports, tourism or other physical activities. 2. Physiotherapy students specializing in safe falling will contribute to a growing number of new workplaces and innovative services, both for able-bodied people and people with disabilities. Such a specialty will be essential for public health including improvement of the patient's quality of life.

Keywords: susceptibility to body injuries during the fall, health-focused training, theory and methodology of safe falls courses.

Introduction

Falls are a major public health problem worldwide. Every year 37 million of falls are noted and the consequences are so severe that the patients require medical intervention and 646 people die from falls every year [1]. According to World Health Organization definition a fall is: “inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects” [2]. American Geriatric Society (AGS) or British Geriatric Society (BGS) define a fall as: „an event whereby an individual unexpectedly comes to rest on the ground or another lower level without known loss of consciousness.” [3]. According to Polish school of safe falling (Jaskólski and Nowacki [4] and Kalina [5]) fall is “a controlled motor activity ensuring optimal protection of the body when falling on the ground or, under certain circumstances, minimizing damage or death prevention”. According to this definition, there are two types of incidents, namely: 1) “sudden loss of balance (especially due to external forces), e.g. on a slippery surface, when a trained person immediately controls both his/her individual body parts according to falling direction or under other important circumstances (e.g. when stumbling against objects, etc.)” 2) “a deliberate fall or a motor response to sudden threat identified by the falling person, to prevent undesired consequences”. The behaviors described under both circumstances will be impossible when a person who falls from a high place losses consciousness and therefore, is unable to control his or her body properly [6]. The definitions cited above differ, yet they share some elements.

Many groups of people at high risk of falling have been identified. These include people with disabilities (after limb amputation, with visual impairment including blindness, etc.), especially those with poor mobility who are obviously at risk of body injuries associated with falls. It is essential, especially for these individuals to participate in sessions of exercise-based adapted physical activity (APA) including the following training elements: improving their postural stability (muscle strength, flexibility and balance) and locomotion; enabling safe contact with surface after losing body balance or collisions with various obstacles; avoiding collisions with moving objects (e.g. cars in motion) [7-11]. There should be no barriers for their participation in APA, such as their degree of disability or motor impairment. Contrary, they should be motivated to improve their motor abilities to provide effective protection for their bodies in cases of balance loss when falling onto the ground during collision with vertical objects.

The cited definitions are the main prerequisites for implementation of two sorts of programs including fall prevention and the consequences of falling. The former
Table 1. The age and somatic characteristics of physiotherapy students obtained from the first stage of the research

<table>
<thead>
<tr>
<th>Variable (index)</th>
<th>Group with 90-100% attendance (n = 90)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Age (years)</td>
<td>K (n=68)</td>
</tr>
<tr>
<td></td>
<td>21.2</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>K (n=68)</td>
</tr>
<tr>
<td></td>
<td>167.4</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>K (n=68)</td>
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<tr>
<td></td>
<td>57.9</td>
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<tr>
<td>BMI</td>
<td>K (n=68)</td>
</tr>
<tr>
<td></td>
<td>20.7</td>
</tr>
</tbody>
</table>
failing theory; approaches to diagnosing susceptibility to
body injuries during falls and motor competences of safe
falling; specificity, safety conditions and methodology
of safe falling teaching in people with various degrees
of visual and motor impairment; conception of motor
adaptation in safe falling teaching and collision avoidance
in patients with different degrees of visual and motor
impairment.

Stage II. Core assessment

The core study included the program extended with
fun forms of martial arts [10], additionally considering
a higher number and frequency of specific motor
simulations [28]. The preset criterion of 80% attendance
(or participation in 8 cyclic training sessions within
10 weeks) was accepted as an optimal organizational
criterion and the period necessary for cumulation of the
stimuli to obtain the expected adaptive effects.

The sample included 62 (42 women and 20 men
third-year physiotherapy students from PSCAS in Nowy
Targ (2010/2011). The accepted attendance criterion (80-
100%) was met by 30 women and 14 men (Table 2).

The core study was carried out in a room bigger than
the one used during the pilot study. During that stage, the
educational aids additionally included protective helmets
used in kickboxing, orthosis, orthopedic crutches and
walking sticks. The structure of the course was identical
to that of the pilot study. At that stage, the students were
randomly paired. When the first participant in a pair
performed motor tasks (the participant was treated like a
patient), the second one was responsible for protection,
assistance, safety and providing information about
progress and errors (the therapist’s role); the tasks were
identical to those verified during stage I (as was the
content of the presented lectures).

Table 2. Age and somatic characteristics of the physiotherapy students during the second stage of the study.

<table>
<thead>
<tr>
<th>Variable (index)</th>
<th>Age and somatic characteristics Group with 80-100% attendance (n=44)</th>
<th>Group with 80-100% attendance (n=44)</th>
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<tr>
<td></td>
<td>X</td>
<td>SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>K (n=30)</td>
<td>M (n=14)</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>168.3</td>
<td>182.6</td>
</tr>
<tr>
<td>Body mass (kg)</td>
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<td>85.4</td>
</tr>
<tr>
<td>BMI</td>
<td>22.02</td>
<td>25.6</td>
</tr>
</tbody>
</table>

Table 3. Age and somatic characteristics of participants with disabilities during the third stage of the study.

<table>
<thead>
<tr>
<th>Variable (index)</th>
<th>Age and somatic characteristics Participants with sight defects (n=6)</th>
<th>Participants after limb amputation (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
</tr>
<tr>
<td>Age (years)</td>
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<tr>
<td>Body height (cm)</td>
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</tr>
<tr>
<td>Body mass (kg)</td>
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</tr>
<tr>
<td>BMI</td>
<td>22.7</td>
<td>4.8</td>
</tr>
</tbody>
</table>
The training was performed on the playground with an artificial surface (soft surface, therefore mattresses were not used).

The study (regarding clinical observations) was conducted within the research projects: Resolution No. 04/2013 Bioethics Committee at the Jerzy Kukuczka Academy of Physical Education, Katowice, Poland.

Diagnostic poll approach

On completion of the first course (TMSF1), during the first and the second stage of the study, a questionnaire on the acceptance of the sense of teaching safe fall techniques (STSFT) was distributed among patients with visual impairment. On completion of the second course (TMSF2), during the first and the second stage of the study, a questionnaire was distributed among the students. It provided information on the participants’ acceptance of STSFT for patients with visual impairment or after limb amputation. The preset diagnostic criterion was the answer to the following question: Now, when you have completed the course, do you think that teaching safe fall techniques in visually impaired patients or patients after limb amputation makes sense? [a] Yes; [b] I don’t know; [c] I have some doubts [d] it doesn’t make sense.

On completion of the clinical assessment (stage III) the patients with disabilities filled in the questionnaire which provided information on their acceptance of STSFT teaching in patients with the same disabilities (visual impairment or limb amputation). Now, when you have completed the course, do you think that teaching safe fall techniques in visually impaired patients or patients after limb amputation makes sense? [a] Yes; [b] I don’t know; [c] I have some doubts [d] it doesn’t make sense.

Statistical analysis.

The statistical analysis was based on estimation of the empirical variables; the mean values, standard deviations (SDs), the range (minimal and maximal values), skewness and kurtosis were calculated. It was carried out using PQStat version 1.6.8 statistical package. Whether the research data were homogeneous or not was tested with the “Kolmogorov Smirnov”. The distribution of values turned out to differ from normal distribution therefore further analyses were conducted using non-parametric approaches. The results were compared using Wilcoxon’s signed rank test. The correlations between selected scales were analyzed by estimation of Spearman’s rank correlation coefficients. The significance level was set at p<0.05.

Results

Stage I

On completion of the experiment almost 95% of all students were convinced that teaching safe fall techniques (STSFT) made sense, both in case of healthy individuals and those from high risk groups (Figure 1).

Stage II

On completion of the experiment over 95% of the surveyed students were convinced that STSFT in healthy participants and those from the increased risk group made
sense and none of the students denied it (Figure 2).

Stage III

On completion of the experiment all the amputees and over 83% of visually impaired patients were convinced that TSFT in the groups with an increased risk of falls made sense. One response from a visually impaired patient (16%) was “I don’t know” and none of the respondents denied the sense of TSFT (Figure 3).

Discussion

The opinions that implementation of STSFT programs for patients with visual impairment or after limb amputation, expressed by physiotherapy students (about 94% and 95% of students at stages I and II respectively) and patients with disabilities (100% of amputees and 83% of patients with visual impairment at stage III), who learned to protect their bodies during collisions with the ground, indicate that the aforementioned empirically verified programs are effective. The answers obtained from all the persons who participated in the two specialist (stage I and II) courses or kinesitherapy sessions are the most reliable recommendations for widespread education on safe falling techniques, providing an optimal solution in prevention of body injuries due to falls. None of the physiotherapy students (participating in the two stages of the study and none of the patients voluntarily participating in stage III) questioned the sense of safe falling teaching in patients with visual impairment or after limb amputation. The significantly higher level of acceptance of the innovative TSFT program compared with the level of innovative specialty sense acceptance (EKO-AGRO-FITNESS©) from tourism and recreation students at the same academic center (PSCAS in Nowy Targ) is an additional recommendation for TSFT implementation [29].

The World Health Organization (WHO) [1] emphasizes that fall prevention strategies should be focused on education, training, enabling safe conditions, prioritizing assessment of fall consequences and settling successful policies, aimed at risk diminishing (reduction). However, according to Polish School of Safe Falling [4, 6, 20, 30] combining fall reduction programs with programs aimed at elimination of fall consequences. These goals can be achieved through adapted physical activity (APA) training (for people with disabilities) and health-focused training (for people with no contraindications for physical exercise), based on teaching and developing safe falling techniques and collision avoidance).

Adapted physical activity (APA) is defined by International Federation of Adapted Physical Activity as a „cross-disciplinary body of knowledge directed towards the identification and solution of individual differences in physical activity. It is a service delivery profession and an academic field of study which supports an attitude of acceptance of individual differences, advocates enhancing access to active lifestyles and sport, and promotes innovation and cooperative service delivery programs and empowerment systems. Adapted Physical
Activity includes, but is not limited to, physical education, sport, recreation, dance and creative arts, medicine, and rehabilitation” [31]. APA recipients are persons with special needs, namely people with disabilities (in terms of law, biology, and social activities), the elderly, chronically ill individuals, etc. The domains of adapted physical activity may include: rehabilitation, tourism, sport, physical education, health promotion and other forms of motor activity [32], not excluding the prevalence of mental activity offered by innovative agonology [33, 34, 35, 36] or a relatively balanced effect of cognitive and behavioral factors [37]. Safe falling programs (programs eliminating consequences of falls) for people with visual impairment or after limb amputation should be included in the above-cited APA definition. Thanks to such activities, people with disabilities learn to perform controlled motor activities, ensuring optimal body protection (e.g. minimization of lesions). Persons with adverse experience due to the consequences of falling (e.g. fractures, hospitalization, fear for falling again) limit their physical activity as well as their involvement in tourism- or sport -related activities. The skills of falling safely can reduce the above limitations and enable participation in active pastimes in many people with disabilities. The evidence is presented by Gaśienica-Walczak et al. [38] who described 10 kinesitherapy sessions based on safe falling training and collision avoidance in 5 males with visual impairment. The assessment of program outcome included the application of susceptibility to body injuries during the fall test (SBIDF) [6], applied before and after 10 sessions of safe falling training. All the participants managed to reduce their susceptibility to injuries through effective control of their key body parts that are most prone to injuries during falls, protecting them against injuries.

The ability to fall safely may contribute to reduction of the number of body injuries and contusions, not only in persons who do not practice any sports, but also in athletes with disabilities. Moilik et al. [39] characterized the injuries sustained by competitive level athletes, involved in the main disciplines included in summer Paralympics. The high risk sports (according to the division by Ferrera et al. [40]) comprised: cycling, horse riding, judo, football, basketball on wheelchairs and rugby on wheelchairs. The authors did not analyze the fall-related injuries, but the sports believed to be risky and thus, inseparably connected with falls. Derman et al. [41] described sport-related injuries during the winter Paralympics in Peyong Chang in 2018. Most of the injuries were noted during para-snowboard competition, next during alpine skiing, hockey on sledge and cross-country skiing while the fewest injuries were noted during curling on wheel-chairs. As before, the authors did not analyze the fall-related injuries. They reported, however, that the athletes practicing para-snowboard usually sustained injuries within the upper limbs, probably due to inadequate protection of their most exposed body parts during falling.

The simple recommendations for healthy people and Paralympic formula competitors, indicating that judo, sambo and every martial art including teaching safe fall techniques are the suitable complementary sports, are...
insufficient. No matter that e.g. judo training, stimulates muscle strength, endurance and other motor abilities [42-45]. As a sport, judo entails high risk of injuries and even death [46, 47].

Conclusion
Implementation of safe falling programs as an adapted physical activity for patients with visual impairment or after limb amputation may adversely affect their feeling of safety and motivation for practicing sports, tourism or other physical activities.

References
22. Toronjo-Hornillo L, DelCastillo-Andrés Ó, Campos-Mesa MDC, Díaz Bernier VM, Zagalaz Sánchez ML. Effect of the Safe Fall Programme on Children’s Health and Safety. Dealing Proactively with Backward Falls in Physiotherapy students specializing in safe falling will contribute to a growing number of new workplaces and innovative services, both for able-bodied people and people with disabilities. Such a specialty will be essential for public health including improvement of the patient’s quality of life.

Conflict of interest
There were no conflicts of interest.
Areas of Involvement of Students of Tourism and Recreation


Possibilities and limitations of judo (selected martial arts) and innovative agony in the therapy of people with mental disorders and also in widely understood public health prophylaxis. Arch Budo, 2017;13:211–226.
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Effect of 8-week core training exercises on physical and physiological parameters of female handball players

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Abstract

Purpose: Aim of this study was to investigate the effect of 8 weeks core training program on some physiological and physical parameters of handball team’s female players.

Material: Volunteers were separated two groups as CTG (training group) and CG (control group). CTG was applied core strength training 30 min sessions 8 weeks and 3 days per week additionally handball trainings. CG wasn’t applied any core training. Effects of different core training regimes were compared after eight weeks with repeated measures MANOVA for the tests.

Results: Neither group demonstrated difference for body composition measurements for repeated test scores and between groups comparisons. Significant difference was found BFP (body fat percentage) parameters on CTG. Sprint, agility, SLJ (standing long jump) scores did not increase in any groups and no difference was found between groups. Significance was found in VJ (vertical jump), back and leg strength, right and left hand grip strength, flexibility, balance parameters on CTG. Also significance was found in all core parameters on CTG.

Conclusions: Results indicate that core trainings were very effective on performance based features especially on strength and core stability. So these exercises should be included in the training programs of female handball players.

Keywords: core training, female students, handball, performance analysis.

Introduction

The aim in sport is to develop sporty athletes’ physical suitability and maximize sporting success. In order to achieve the desired sporty success, it is necessary to have a high morphological structure in the branch as well as the motoric characteristics that can fulfill the requirements of the branch. Core training can be done by helping to maximize these features. Because the greater the core power, the greater the power generation in the arms and legs [1].

The “core musculature” can be defined generally as the 29 pairs of muscles that support the lumbo-pelvic-hip complex in order to stabilize the spine, pelvis, and kinetic chain during functional movements [2]. The core muscle is defined as the muscles around the spine and the abdomen, and functions essentially to maintain spinal stability and pelvic balance [3]. Core strengthening has come into prominence in sports training as a method to condition athletes with the hope of preventing injury to the spine and/or extremities. The main emphasis of core strengthening is focused on muscular stabilization of the abdominal, paraspinal, and gluteal muscles to provide better stability and control for sporting activity [4].

Handball is a very strenuous body-contact team sport that places heavy emphasis on running, jumping, running speed, and throwing, and requires substantial strength levels to hit, block, push, and hold during game actions [5]. Core strength is an essential part of any athlete’s total fitness. Handball athletes cannot ignore this facet in their physical training because handball is not a one-dimensional game; players are constantly shifting their body from side to side or rotating their bodies toward the ball. One strategic level of handball requires that one keeps their opponents running and off-balance, hence many directional changes during a match.

In order to improve athletic performance, we need to work out what features core training has developed, which is a type of training that teams use frequently, and in which period it should be applied. It’s thought that with the strengthening of the core area the needed features when playing handball such as balance, agility, speed and jump will increase.

In this study, it is aimed to measure the effects of core training applied to handball players on these parameters. It is thought that knowing the effect of the core training sessions on the physical and physiological characteristics of the athlete will guide the athletes and the coaches as well as contribute to the sports sciences.

Material and Methods

Subjects: After the pre-test period, 20 athletes were divided into two groups; 10 core training group (CTG) and 10 control group (CG). For the sake of no difference between the groups in terms of both physical and physiological terms; the final state of the groups was determined in the form of 10 CTG (age=17.80±1.4 years, height=153.2±5.8 cm, weight=60.03±7.9 kg), 10 CG (age=17.60±1.89 years, height=166.6±5.8 cm, weight=63.30±6.3 kg). In addition, parental signed consent was obtained from parents of each player to participate in the study.
Procedures: During the application phase of the study, subjects were applied an 8-week core training program, except for their own training days. During the training period, subjects did not participate in any training programs for basic motoric features, they just participated in technical and tactical training programs of their team. CTG participated in the core training program for approximately 60 minutes, including 20 minutes of warm-up and 10 minutes of cool-up exercises in 3 days (Monday, Wednesday, Friday).

Training Plan: The trainings of the CTG were carried out in the sports hall of the club under the supervision of the researchers. The training hour was 18:00 for each training. The training program was planned to be 10 repetitions and 2 sets for each movement for first week and the subjects were given 1 minute between repetitions and 3 minutes between sets in order to provide full recovery. Besides, the number of repetitions was increased each week, additional movements were added in fifth and seventh weeks, adhering to the principle of progressive increase of load [6] as the athletes develop adaptations to the training. In Table 1, there is an 8-week training program applied to CTG.

Physical Measurements: In this section under the title of physical measurements, the information about height, weight, body mass index (BMI) and body fat percentage (BFP) measurements of the subjects participating in the study will be explained.

The height of the subjects participating in the study was measured with Holtain brand stadiometer with a sensitivity of 0.01 cm. The length of the subjects was determined in anatomical position (barefoot) and the result was recorded as “cm”. The weight measurements of the subjects were measured with a sensitivity of 0.01 kg in anatomical position (barefoot) and the result was recorded as “kg”. BMI values were determined by “BMI = weight (kg) / (height)²” formula. BFP values were obtained by bioimpedance analysis (Tanita MC 780; Tokyo, Japan).

Motoric Performance and Field Measurements: In the study, various tests were used to determine the performance characteristics of handball players.

Dynamometers were used especially when determining strength characteristics. Pro Agility and 505 tests to determine agility skills, 10 and 30 m test to assess their speed and acceleration abilities were applied to handball players. In addition, the lower extremity explosive force of the athletes was evaluated with standing long jump in horizontal direction and vertical jump tests. Sit and reach test was also applied to subject to determine flexibility and Star Excursion Balance Test (SEBT) was used to measure balance skills. Besides, plank, isometric back extension endurance, sit up and push up tests were applied to determine core stability and endurance features of subjects. Before the measurements, the athletes were warmed up and flexibility exercises were applied.

Muscular strength tests: Handgrip strength was measured for right and left hands with a dynamometer (Takei, Japan). The subjects were placed sitting with 0° of shoulder flexion, 90° of elbow flexion, and the forearm in neutral. Maximal back strength and leg strength were measured using a back and leg muscle dynamometer (Takei, Japan). The length of the handle chain was adjusted to fit each subject, so that the angle of the subjects’ knees was at 45°. Two trials were performed in each exercise. The best score of two measurements was recorded [7].

Pro agility test: Markers were placed at 0, 5, and 10 yards with timing gates on the 5-yard line, to indicate where participants start and finish. Participants began in a neutral 3-point position with feet either side of the midline, participants then turned and ran 5 yards to the right side and touched the line with the right hand, and then ran 10 yards to the left, touched the line with their left hand the ran back through the start line to the finish. The trial was then completed in the other direction, with a third trial completed off the preferred foot. The fastest trial was recorded [8].

505 agility test: Subjects sprinted forward from the 15-m cones and the timing began once they passed the 5-m cones. When the subjects reached the 0-m cones, the subject made a 180° change of direction and sprinted.

<table>
<thead>
<tr>
<th>Movements</th>
<th>1st Week</th>
<th>2nd Week</th>
<th>3rd Week</th>
<th>4th Week</th>
<th>5th Week</th>
<th>6th Week</th>
<th>7th Week</th>
<th>8th Week</th>
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</thead>
<tbody>
<tr>
<td>Uneven Plank</td>
<td>2X10</td>
<td>2X15</td>
<td>2X20</td>
<td>2X25</td>
<td>2X25</td>
<td>2X30</td>
<td>2X30</td>
<td>2X35</td>
</tr>
<tr>
<td>Crunch</td>
<td>2X10</td>
<td>2X15</td>
<td>2X20</td>
<td>2X25</td>
<td>2X25</td>
<td>2X30</td>
<td>2X30</td>
<td>2X35</td>
</tr>
<tr>
<td>Abdominal Oblique Side Plank</td>
<td>2X10</td>
<td>2X15</td>
<td>2X20</td>
<td>2X25</td>
<td>2X25</td>
<td>2X30</td>
<td>2X30</td>
<td>2X35</td>
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<tr>
<td>Super Plank with Leg Raise</td>
<td>2X10</td>
<td>2X15</td>
<td>2X20</td>
<td>2X25</td>
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<td>Lying Side Crunch</td>
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<td>2X30</td>
<td>2X35</td>
</tr>
<tr>
<td>Superman</td>
<td>2X10</td>
<td>2X15</td>
<td>2X20</td>
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<td>2X25</td>
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<tr>
<td>V-Up</td>
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<td>2X35</td>
</tr>
<tr>
<td>Windshield Wipers</td>
<td>2X25</td>
<td>2X30</td>
<td>2X30</td>
<td>2X35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Arm / Leg Plank Balance</td>
<td>2X25</td>
<td>2X30</td>
<td>2X30</td>
<td>2X35</td>
<td></td>
<td></td>
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<tr>
<td>Mountain Climber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2X30</td>
<td>2X35</td>
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<tr>
<td>Single Leg Plank Bridge</td>
<td>2X30</td>
<td>2X35</td>
<td></td>
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<td></td>
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</tbody>
</table>
The vertical jump (VJ) is one of the most frequently used tests of power and explosiveness in strength and conditioning [10]. Standing erect with the feet flat on the floor, the client reaches as high as possible on the tape, with the arm and fingers fully extended and the palm toward the wall. This is recorded as the beginning height. Standing about a foot away from the wall, the individual brings the arms downward and backward, while bending the knees to a balanced semisquat position, and then jumps as high as possible, with the arms moving forward and upward. The tape should be touched at the peak height of the jump with the fingers of the arm facing the wall [11]. The best of three trials were recorded as “cm”.

**Standing long jump test**

The standing long jump (SLJ) is another frequently used test of lower body explosive performance. This test may be used in conjunction with the VJ test, because it provides information about vertical and horizontal displacement. The measurement was made between the heel where the subject touched down after the horizontal jumping from the starting line and the best of three trials were recorded as “cm” [10,12].

**10m-30m speed and acceleration tests:** The speed skills of the subjects were measured by 10 and 30 meter tests. The subjects started the test from the starting line located 1 meter behind the starting photocell (Newtest 2000; Newtest Oy, Oulu, Finland). Acceleration and speed values of the subjects were recorded through the photocells placed at 10th and 30th meter. Each participant repeated the test twice, and the best one was recorded as “seconds”.

**Flexibility test:** Flexibility of the trunk was determined from a sit-and-reach test using a standard sit-and-reach box. The subjects sat in front of a sit-and-reach testing box, where the feet meet the testing box. The subjects were informed to reach forward, with palms down and one hand on top of the other along the measuring scale of the testing box. The recorded score for this test was the average of 2 trials [7].

**Star Excursion Balance Test (SEBT):** The SEBT was performed with the participants standing in the middle of a grid formed by eight lines extending out at 45° from each other. The participant was asked to reach as far as possible along each of the eight lines, make a light touch on the line, and return the reaching leg back to the center, while maintaining a single-leg stance with the other leg in the center of the grid. Participants were instructed to make a light touch on the ground with the most distal part of the reaching leg and return to a double-leg stance without allowing the contact to affect overall balance. They began with the anterior direction and progressed clockwise around the grid. All participants began with a right stance leg in the center of the grid. After completion of the three trials in the eight directions and 5-min rest period, the test continued with a left stance leg. The balance score was calculated by using the formula, “reach distance/leg length x 100” [13].

**Core stability and endurance tests:** Plank, isometric back extension endurance, sit up and push up tests were applied to determine core stability and endurance features of handball players.

**Plank test**

The plank protocol required participants to maintain a static prone position with only forearms and toes touching the ground. Proper form required feet together with toes curled under the feet, elbows forearm distance apart, and hands clasped together against the floor mat. Participants maintained eye contact with their hands, a neutral spine, and a straight line from head to ankles. The child was given one 5-s practice trial, and the examiner instructed the child into the proper position, followed by a brief period of rest. The test began when the participant demonstrated the correct position. Participants were allowed to deviate from the correct position once and could continue the test if they immediately resumed the correct starting position. The test was terminated on the second deviation from the correct position or if the participant did not return to the correct position after the first warning [14].

**Isometric back extension endurance test**

Endurance was evaluated by timing (holding time measured in seconds) how long the subject was able to hold the upper part of the body horizontal, while lying prone, with no support beyond the upper border of the iliac crest. The hands were kept behind the neck and the thighs and ankles were fixed to the table by 2 wide straps. Subjects were instructed to hold the position as long as they could. During testing, subjects received encouragement once if their position fell under the horizontal level. The position was indicated by a plumb bob hanging from the ceiling that was adjusted to contact the back when the horizontal position was maintained. If the position was not immediately corrected, or if the subject claimed that the position could no longer be held due to fatigue or discomfort, the test ended and the holding time was recorded [15].

**Sit up and push up tests**

These tests were applied to subjects for 1 minute and only proper applications of subjects in this time were recorded as sit up and push up scores.

**Statistical Analysis.**

The data obtained from the pre and post-training measurements of handball players were analyzed in the IBM SPSS 19 statistical program. Descriptive statistics are categorized according to all handball players and groups. The pre and post-test distributions of the variables were examined according to groups, the normality of the distributions and the homogeneity of the variance were determined by the Mauchly's Sphericity Test and the Levene Test. Analysis of intergroup, intra group and the effect of training was carried out with multiple analysis of variance (MANOVA) in repeated measurements. Bonferroni test was used for Post Hoc comparisons, the significance level was accepted as 0.05.
Results
The average age, height, weight and BMI of 20 handball players were seen as 17.7±1.6, 166.1±5.6, 61.6±10.80, 22.14±2.4, respectively.

There is no significant difference between groups before the training period for all descriptive variables (tabl. 2).

The pre and post-test measurements of physical characteristics of the subjects, such as weight, BMI and BFP, are compared in terms of inter-group, intra-group and group*test interaction (tabl. 3). According to this, the increase in the weight and the decrease in BMI values of CTG was statistically significant, whereas these data were not statistically significant. In the BFP values, group*test interaction was seen and it was understood that this interaction resulted from CTG.

As can be seen from the results that significance was found in VJ, back and leg strength, right and left hand grip strength, flexibility, balance parameters in favor of CTG. Also significance was found in all core parameters on CTG. These significances affect the test*group interaction (p<0.05).

Table 2. Descriptive statistics of handball players and comparison of physical measurements among groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean-Standard Deviation</th>
<th>Min.</th>
<th>Max.</th>
<th>Comparison Between Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTG</td>
<td>Age 17.80±1.4</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>(n=10)</td>
<td>Height (cm) 153.2±5.8</td>
<td>145.6</td>
<td>171.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight (kg) 60.03±7.9</td>
<td>43.1</td>
<td>69.6</td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>Age 17.60±1.89</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>(n=10)</td>
<td>Height (cm) 166.6±5.8</td>
<td>153.4</td>
<td>171.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight (kg) 63.30±6.3</td>
<td>51.1</td>
<td>70.4</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>Age 17.7±1.6</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>(n=20)</td>
<td>Height (cm) 166.1±5.6</td>
<td>145.6</td>
<td>171.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight (kg) 61.6±10.80</td>
<td>43.1</td>
<td>70.4</td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05

Table 3. Comparison of pre and post-test changes of physical features of groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Intra-Group Change (%)</th>
<th>Test*Group F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Features</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>60.03±7.9</td>
<td>60.19±7.8</td>
<td>0.16 (0.27)*</td>
<td>0.075</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>63.30±6.3</td>
<td>63.43±6.2</td>
<td>0.13 (0.21)</td>
<td>0.615</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>22.07±1.91</td>
<td>21.98±1.84</td>
<td>-0.09 (-0.41)*</td>
<td>0.575</td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>22.21±2.07</td>
<td>22.16±2.02</td>
<td>-0.05 (-0.96)</td>
<td></td>
</tr>
<tr>
<td>BFP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>13.57±2.32</td>
<td>13.44±2.32</td>
<td>-0.13 (-0.96)*</td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>13.63±2.49</td>
<td>13.59±2.46</td>
<td>-0.04 (-0.29)</td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05, BMI: Body Mass Index, BFP: Body Fat Percentage
## Discussion

When the body composition changes of handball players are examined, it was observed that BMI and BFP of CTG decreased by 0.41% and 0.96% respectively after the training program and this decrease created statistical significance in the test*group comparison (Table 3). The existing studies which show the effect of core stabilization exercises on body compositions give quite different results from each other and it is considered that this difference is due to the study groups. While studies on sedentary individuals show that in general positive effects have been achieved on body composition [16-19], this effect has not been shown in some other studies [20,21], however a change is mostly not seen in studies with athletes [22]. For example, a Pilates training program that consisted of 7 exercises of 2 to 3 sets with 15 to 20 repetitions each with a 45-sec rest interval twice a week for 6 weeks (in addition to basketball team training), was not sufficient to change body composition in young basketball athletes [23]. In this study, the application of the training program at the beginning of the season and the differences in body composition in the intra-season, half season stages of athletes [24,25] can explain the change in body composition with training.

Explosive power, agility and speed tests showed that there was a difference between groups for VJ test only and that the core training group increased the jump height by 0.8% (Table 4). Both correlation and experimental studies investigating the effect of core training programs on agility and speed tests reveal different results. Many studies show that the positive effect of core stabilization studies on athletic skills such as jump, speed, agility in which the ability to produce quick power is important remains low [26-30]. In the systematic review carried out by Reed et al., 13 of the 24 studies were conducted with athletes and the majority of the positive performance improvements resulting from these studies were due to sports-related training and sport-specific measurements. It was revealed that the change in performance skills such as basic strength, sprinting and jumping was not sufficiently provable by core stabilization studies [30]. In another study, both dynamic and static working groups, who practice core training on unstable surface, did not develop vertical jump, health ball throwing, 20 m sprint scores. Increased core stabilization ability as a result of both types of training did not affect sports-related performance [29].

### Table 4. Comparison of pre and post-test changes of explosive force, agility and speed and acceleration tests of groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Intra-Group Change (%)</th>
<th>Test * Group F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explosive Force Tests</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VJ (cm)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>32.54±4.02</td>
<td>32.80±4.02</td>
<td>0.26 (0.80)*</td>
<td>24.816*</td>
<td>0.001</td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>31.56±2.49</td>
<td>31.59±2.46</td>
<td>0.03 (0.10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>163.80±20.48</td>
<td>164.75±20.64</td>
<td>0.95 (0.58)*</td>
<td>1.692</td>
<td>0.210</td>
</tr>
<tr>
<td>SLJ (cm)</td>
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<td></td>
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<tr>
<td>CG</td>
<td>10</td>
<td>154.50±13.96</td>
<td>155.20±14.11</td>
<td>0.70 (0.45)*</td>
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<tr>
<td><strong>Agility Tests</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pro Agility (sec)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>8.17±0.51</td>
<td>8.14±0.50</td>
<td>-0.03 (-0.37)</td>
<td>3.060</td>
<td>0.096</td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>8.15±0.40</td>
<td>8.15±0.20</td>
<td>-0.001 (-0.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>4.86±0.19</td>
<td>4.83±0.19</td>
<td>-0.03 (-0.62)*</td>
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<tr>
<td>505 Agility (sec)</td>
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<td></td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>4.86±0.20</td>
<td>4.83±0.20</td>
<td>-0.03 (-0.62)*</td>
<td>0.450</td>
<td>0.511</td>
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<tr>
<td><strong>Speed and Acceleration Tests</strong></td>
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<tr>
<td>10 m (sec)</td>
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</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>2.10±0.20</td>
<td>2.09±0.20</td>
<td>-0.01 (-0.48)</td>
<td>0.096</td>
<td>0.760</td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>2.14±0.13</td>
<td>2.13±0.12</td>
<td>-0.01 (-0.47)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>5.13±0.52</td>
<td>5.12±0.51</td>
<td>-0.01 (-0.19)*</td>
<td></td>
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<tr>
<td>30 m (sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>5.25±0.37</td>
<td>5.24±0.36</td>
<td>-0.01 (-0.19)*</td>
<td>0.356</td>
<td>0.558</td>
</tr>
</tbody>
</table>

*p<0.05, VJ: Vertical Jump, SLJ: Standing Long Jump
Some studies also show positive development in lower extremity power output with core stabilization training [31-33]. For example, as a result of core strength training applied to 19 young players on stable and unstable surfaces with football training, while trunk extension strength increased by 5%, this increase improved 10-20 m sprint performance by 3% and shot speed by 1% [33]. However, it was revealed some developments in core rotational power related to the upper extremity, such as hitting, throwing in many studies [34-36]. It can be generally said that the contribution of core stabilization studies to various power tests differ, but the effect of lower extremity power and power tests is less than the effect of upper extremity tests. As in this study, core exercises only include body stabilization exercises to strengthen global and local muscles, hip joint muscles that provide the link to the lower extremity cannot activate enough in these exercises may explain this situation.

It was observed that the training program had a significant impact on both the sit and reach test and the balance test (Table 5). After the training program, the sit and reach score increased by 13.54% in CTG, and the right and left SEBT scores increased by 5.74% and 2.2%, respectively. In all tests, the test*group relationship was statistically significant. In this respect, the core training program has significantly increased the flexibility of the spine (especially thoracic and lumbar), hamstring flexibility and balance skill. There are many studies in the literature that show that balance test scores have increased thanks to the development of core stabilization skills [19, 29, 37-40]. In a 12-week body stabilization study conducted with 17 male footballer, the static and dynamic balance skills of athletes increased significantly compared to the control group [41]. In addition, the opposite of this, it was said that balance exercises also increased the test performance of core stability [42]. The relationship between flexibility and core stabilization training is not seen as much. However, the development of flexibility in this study can be explained by assuming that studies involving the applications of pilates [20, 43] in which similar core exercise structures are being studied. For example, as a result of pilates exercises applied by 20 people for 45 minutes and two days per week for 8 weeks, measurements were made using sit and reach and lombo-pelvic stabilization tests. In 0, 4 and 8 week scores of subjects were 27.69 cm, 31.77 cm and 34.89 cm, respectively. In the study, in addition to lombo-pelvic stabilization, the flexibility characteristics of the subjects were improved [43].

For all muscular strength and endurance measurements, the CTG shows significant improvement compared to CG (Table 6). According to this, the right-left hand grip strength for CTG was 3.14%, 3.24%, and the leg and back strength were 14.1%, 13.7%, respectively. The increase in core stability and endurance tests was more pronounced for CTG and the rates of change were seen as %26.27, %25.09, %19.8, %17.44 in plank, back extension endurance, sit up, push up, respectively. Similar developments were introduced in studies examining core stabilization training and the development of core stabilization and endurance skills [22, 28, 29]. While the core test-specific performance increased with the Swiss ball stabilization exercises applied twice a week for 6 weeks (Swiss ball prone stabilization core stability test and Sahrmann test of core stability), no change was observed in the running economy at different speeds, myoelectric fatigue level in different muscles, and the running posture [7]. In a study consisting of 10 experimental and 10 control group, 50 m swimming time developed by 2% with 12-week core trainings. In addition, medium and high-level

<p>| Table 5. Comparison of pre and post-test changes of flexibility and balance tests of groups |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Intra-Group Change (%)</th>
<th>Test * Group</th>
<th>F</th>
<th>p</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Stand and Reach Test</td>
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<td></td>
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<tr>
<td>Flexibility (cm)</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>24.00±6.41</td>
<td>27.25±7.22</td>
<td>3.25 (13.54)*</td>
<td>6.746*</td>
<td>0.018</td>
<td></td>
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</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>24.65±8.26</td>
<td>25.15±8.26</td>
<td>0.50 (2.03)*</td>
<td>519.154*</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star Excursion Balance Test (SEBT)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>SEBT (right)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>637.74±72.39</td>
<td>674.32±73.84</td>
<td>36.58 (5.74)*</td>
<td>519.154*</td>
<td>0.000</td>
<td></td>
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</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>643.07±63.55</td>
<td>648.40±62.87</td>
<td>5.33 (0.83)*</td>
<td>38.948*</td>
<td>0.000</td>
<td></td>
<td></td>
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<tr>
<td>SEBT (left)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTG</td>
<td>10</td>
<td>655.96±102.74</td>
<td>670.41±100.07</td>
<td>14.45 (2.20)*</td>
<td>38.948*</td>
<td>0.000</td>
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</tr>
<tr>
<td>CG</td>
<td>10</td>
<td>658.84±81.07</td>
<td>663.20±80.79</td>
<td>4.36 (0.66)*</td>
<td>38.948*</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05
developments were observed in asymmetric straight arm–pull-down test compared to control group. At the same time, EMG activity of maximal voluntary contraction of core muscles was increased [44].

**Conclusion**

As the results show that both training types let the players improve movement related measurements of core stability but did not transfer into any anaerobic skills and body composition. Core stability training is not generate sufficient stimulus to improve power and strength dependent performance skills like sprint and agility and not required to be the main part of handball conditioning programs.

**Conflict of interest**

The authors report no conflict of interest.

Table 6. Comparison of pre and post-test changes of muscular strength and core stability and endurance tests of groups

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>N</th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>Intra-Group Change (%)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
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<tr>
<td><strong>Muscular Strength Test</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hand Grip Right (kg)</td>
<td>CTG</td>
<td>10</td>
<td>31.17±4.79</td>
<td>32.15±4.70</td>
<td>0.98 (3.14)*</td>
<td>24.816*</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>10</td>
<td>28.30±4.68</td>
<td>28.54±4.67</td>
<td>0.24 (0.85)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>27.74±3.71</td>
<td>28.64±3.71</td>
<td>0.90 (3.24)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Grip Left (kg)</td>
<td>CG</td>
<td>10</td>
<td>27.93±3.76</td>
<td>28.04±3.76</td>
<td>0.11 (0.39)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>104.25±16.41</td>
<td>118.95±15.90</td>
<td>14.70 (14.10)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Strength (kg)</td>
<td>CG</td>
<td>10</td>
<td>95.70±18.36</td>
<td>98.30±16.61</td>
<td>2.60 (2.72)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>92.65±12.52</td>
<td>106.35±12.40</td>
<td>13.70 (14.79)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Strength (kg)</td>
<td>CG</td>
<td>10</td>
<td>88.75±10.23</td>
<td>93.70±10.07</td>
<td>4.95 (5.58)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>93.01±22.58</td>
<td>117.44±21.44</td>
<td>24.43 (26.27) *</td>
<td>282.79*</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>CG</td>
<td>10</td>
<td>87.00±14.85</td>
<td>89.10±15.53</td>
<td>2.10 (2.41) *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>110.85±25.24</td>
<td>138.66±25.33</td>
<td>27.81 (25.09) *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Extension Endurance</td>
<td>CG</td>
<td>10</td>
<td>107.08±18.56</td>
<td>110.18±18.05</td>
<td>3.10 (2.90) *</td>
<td>171.313*</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>20.20±1.89</td>
<td>24.20±1.62</td>
<td>0.50 (3.23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit up (reps)</td>
<td>CG</td>
<td>10</td>
<td>19.90±2.47</td>
<td>20.40±2.68</td>
<td>0.50 (2.51)</td>
<td>66.818*</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>CTG</td>
<td>10</td>
<td>19.50±2.72</td>
<td>22.90±2.56</td>
<td>3.40 (17.44) *</td>
<td>47.676*</td>
<td>0.000</td>
</tr>
<tr>
<td>Push up (reps)</td>
<td>CG</td>
<td>10</td>
<td>18.60±2.50</td>
<td>19.20±2.90</td>
<td>0.60 (3.23)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<0.05
References


32. Myer GD, Ford KR, Palumbo JP, Hewett TE. Neuromuscular training improves performance...


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Integrative pedagogical technique of physical education of female students with overweight

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Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: design and testing of the integrative pedagogical technique of physical education, aimed at the female students’ overweight correcting.

Material: The anthropometric examination of 1st-year female students (n = 397) was carried out. The female students were referred to the special medical group according to the health condition. Overweight female students (n = 86) were selected for the pedagogical experiment. The female students were divided into 2 groups: experimental (n = 42) and control (n = 44). Anthropometric and physiometric parameters were determined. The body mass index, Robinson index, and power index were calculated. The motor qualities of female students were evaluated by tests. The female students attended the academic classes “Elective courses in physical education and sports” 2 times a week. The pedagogical technique “inverted class” was applied: the previous self-study of the material on electronic gadgets or on the Internet; subsequent detailed analysis of the gained knowledge in the classroom.

Results: By the end of the pedagogical experiment, the female students of the experimental group demonstrated the decrease in body mass in 12.6%, functional characteristics of the cardiovascular system improved, and power and motor abilities’ parameters increased (p <0.05). The body mass index corresponded to normal values in 20 female students (47.6%) at the end of the experiment. The body mass index decreased by 13.8% in 12 female students (28.6%). The body mass index did not change in 10 female students (23.8%). The female students of the control group demonstrated lower results than female students of the experimental group.

Conclusions: The integral pedagogical technique is based on a combination of the “inverted class” method and digital learning. Pedagogical techniques considered to be more effective for female students’ body mass correcting than the traditional one.

Keywords: female students, body mass correction, integral pedagogical technique, physical education.

Introduction

The World Health Organization (WHO) experts note that in many countries of the world there is a decrease in the number of people with normal body mass [1]. The particular importance in scientific research is given to the study of the body mass deviations from the norm among students.

The important task of the higher education system is to create conditions for students’ health maintaining and promotion. The special role is given to physical education, which is a leading factor in health promotion [2] and students’ mental performance optimizing.

Physical educations classes are conducted according to the standard methodology (2-3 times a week) and do not always lead to a positive result on the students’ body mass correction. It is not possible nowadays to increase the number of academic classes in physical education. Therefore, some authors propose the additional use of corrective classes programs at the out-of-lesson time [3]. However, elective physical education classes are not always highly effective [4]. Therefore, an important direction of the health-saving process is the search for new pedagogical techniques (form organization of academic classes) to increase motor activity and students’ body mass correction.

The important issue in the physical education of students is the use of information and communication technologies. Such a direction is a good promotion of fitness systems and physical activities. This is especially important for the younger generation and students.

One of the important parameters of the physical development of an individual is a person’s body mass. The body mass is considered as an integral level characteristic and condition of metabolic, hormonal, growth, energy processes in the body [5, 6]. The body mass deviation from the norm should be considered as a predictor of human health deterioration.

Overweight and obesity can significantly affect the somatic, physical, reproductive and mental health of the person. This contributes to type 2 diabetes, atherosclerosis, hypertension [7], which leads to coronary and cerebral blood supply disturbance [8]. The hormonal status disorders [9], impaired productivity [10] and a decrease in life expectancy [11] are fixed in obese people.

The body mass deviation from normal indicates a serious violation of energy processes in the body [12, 13]. This parameter negatively affects the professional
sphere of activity [14], complicates pregnancy and childbirth [15], and may affect the biological function of motherhood [16].

Recent studies show that body mass deviations from the norm are widespread among the world’s population. In 2016, more than 39% of the world’s adult population has overweight, and 13% were obese [1]. The Russian Federation is not an exception, where the annual increase in obesity is 0.4% [17] of the population. The number of students with body mass deviation at educational institutions of the Russian Federation reaches 30–40% [18]. The following results were revealed In Russian universities: 10.7% of medical students in Kemerovo had overweight, and 4.8% are obese [19]; the overweight was revealed in 18.6% of students in Tomsk [11]; the overweight was revealed in 7.2% of students in Ufa [20]; 10% of female students in Yaroslavl had obesity [21]. The similar results were determined in Polish universities: during the last fifty years, the average percentage of fat in students from a technological university increased by 6.3%, while this parameter in students from physical education university increased by 3.5% [22]. The average body mass index in the United States students was 27.29 ± 6.20 kg/m² in the overweight range [23]. Students in Ghana have 12.2% of overweight [24]. 12.1% of Ukrainian students had obesity [25].

The reasons for body mass deviation from the norm can be the follows: eating disorders and disruption of the hormonal condition of a person [11]; decrease of the physical activity [26]; mental trauma [27]; adverse environmental and anthropopressor factors. More obese people live in urban areas than in rural areas [2]. Insufficient physical activity is observed in almost 40% of the population of Russia: 37.0% of men, 42.0% of women [28].

In the WHO documents [29], the leading role in overweight prevention is given to increasing the level and quality of the motor activity. This is related to educational institutions and the nutritional correction of various population groups. The use of fitness technologies helps to normalize body mass [30, 31], especially in combination with nutrition correction [32]. Some researchers offer programs for extra health classes at an out-of-lesson time for students [18]. Regular sport exercises can solve many problems associated with overweight [33, 34]. The urgent problem remains the search for new methods and improvement of existing methods and forms of fitness techniques aimed at body mass correction.

The use of information and communication platforms in physical education and sports is considered to be a promising direction [35, 36]. The pedagogical technique “inverted class” provides for the previous self-study of the material on electronic gadgets or on the Internet; subsequent detailed analysis of the gained knowledge in the classroom [37]. However, this technique is not presented in the literature related to body mass correction.

The method of self-study using video cases, which represent the short and understandable programs is becoming popular [38]. The use of the integrative pedagogical technique (a combination of the “inverted class” teaching method and the digital learning method) for body mass correcting of female students of the special medical group is not presented in the literature.

**Purpose of work:** design and testing of the integrative pedagogical technique of physical education, aimed at students’ overweight correction. The basis of this technique is a combination of the “inverted class” method and the digital method.

**Material and methods**

*The participants.* The study was conducted during the school year (35 weeks, September 2018–May 2019). It was performed using standard methods [39], anthropometric and physiometric monitoring of 1st-year female students (n = 397) (Russia, Irkutsk National Research Technical University). The female students were referred to the 3rd functional group (special medical group) according to health reasons. 86 students with a high body mass index (BMI) were selected for the pedagogical experiment. Among them 73 female students (18.3%) had overweight. 13 female students (3.3%) had first-degree obesity. The female students divided into 2 groups: experimental (EG, n = 42) and control (CG, n = 44).

To characterize the anthropometric and physiometric parameters of the female students the following parameters were determined:

- body length, cm;
- body mass, kg;
- chest circumference (CC), cm;
- Martine-Kushelevsky test (physical activity in the form of 20 squats in 30 sec);
- heart rate before loading (HR), beat/10 s;
- heart rate after 20 squats in 30 s (HR), beat/10 s;
- recovery time of heart rate after 20 squats, min;
- systolic blood pressure (SBP) and diastolic blood pressure (DBP), mm Hg;
- Hand dynamometry, kg (Handgrip Strength Test, kg).

It was expected the following:

- the Kettle’s mass-height index (body mass index) [40];
- BMI = body mass / body length², kg/m²;
- Robinson index [41] [IRob = (HR x SBP) / 100 c.u.];
- power index [SI = (muscle strength of the hand / body mass) x 100%] [42].

BMI was evaluated according to the WHO classification (1999) [43]. The following parameters determined: body mass deficit (BMI <18.5 kg/m²); norm (BMI = 18.5–24.99 kg/m²); overweight (BMI = 25.0–29.9 kg/m²); various degrees obesity (BMI> 30 kg/m²).

During the same periods of observation, students’ motor qualities were evaluated. A set of tests was used [38, 39]:

1) 1000 m run, min, s;
2) 30 m run from a high start, s;
3) Bent Arm Hang Test (two hands), s;
4) Standing Forward Bend, cm;
5) Standing Long Jump Test (Broad Jump), cm;
6) Cadence Push-Up Test, the quantity of times;
7) Eurofit Sit Up Test (for 30 s), the quantity of times.

Organisation of research. The pedagogical experiment performed from September 2018 to May 2019.

Students attended academic classes “Elective courses in physical education and sports” 2 times a week. The students had a doctor’s permission to perform prolonged aerobic exercise.

To increase the weekly motor activity and motivation of the female students from the EG, the “Do it by yourself” video exercise complex was used. The video system sent to the personal email address of each female student. The video complex designed at the Department of Physical Culture of the Irkutsk National Research Technical University (Russia). The video complex aimed at reducing body mass. The video complex contains comments and recommendations on self-study of 10 body-oriented physical exercises of a power orientation. 30 s was given for performing each exercise. 30 s was given to take rest after the exercise. The duration of the full complex was 10 min. The female students were recommended to perform 2 sets (only 20 minutes per day) 5 times a week.

At the end of the preparatory part of the academic class of the discipline “Elective courses in physical education and sports”, students of the EG performed pre-learned exercises (1 set of “Do it by yourself” complex of 10-12 min). The motor density of the lesson was increased by reducing the time for explanation and demonstration of exercises. We consider such a teaching method as an element of pedagogical technique “inverted class”. In the main part of the class (40-45 min), power exercises with physical activity of aerobic nature of low and medium intensity were offered. The final part of the lesson (10-15 min) includes relaxation exercises, movements’ coordination, and flexibility, breathing recovery. The directed physical activity of the EG female students was 280 minutes per week (180 minutes of classes and 100 min of self-study). The weight in the form of 0.5 kg dumbbells and body mass was proposed to use. Additionally, the female students of the EG were recommended a list of Internet web sites devoted to eating behavior and motor condition.

The female students of the CG have engaged only in the standard curriculum of the discipline “Elective courses in physical education and sports”: weekly physical activity is 180 minutes.

The carried out work does not infringe upon the rights and does not endanger the well-being of students following the ethical standards of the Committee on Experimental Rights of the 2008 Helsinki Declaration [46].

Statistical analysis. The arithmetic mean of the indicators (M), standard deviation (σ) and standard error (m) were determined. The significance of differences in the average values of independent samples evaluated by parametric methods applying Student’s t-test. The differences between the values of indicators with a level of p <0.05 were considered significant.

Results
At the beginning of the experiment (September 2018), the morphofunctional values of the indicators of the female students of the EG and CG did not significantly differ, p> 0.05.

At the end of the experiment (June 2019), a significant difference was found in the values of the body mass index of female students in the EG, p <0.05 (Table 1).

By the end of the experiment, female students of EG had a decrease in body mass by 12.6% and an average BMI of 14.2%. Body mass and BMI in female students of

Table 1. Morphological and functional indicators of female students in the EG and CG before and after the experiment (M ± m)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Experimental group (n=42) Before</th>
<th>After</th>
<th>Control group (n=44) Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body length, cm</td>
<td>163.6±0.70</td>
<td>164.7±0.73</td>
<td>163.8±0.68</td>
<td>164.4±0.72</td>
</tr>
<tr>
<td>Body mass, kg</td>
<td>73.5±0.93</td>
<td>64.2±0.89 *</td>
<td>72.8±0.89</td>
<td>70.2±0.93</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>27.5±0.35</td>
<td>23.6±0.29  *</td>
<td>27.1±0.34</td>
<td>26.3±0.33</td>
</tr>
<tr>
<td>Chest circumference, cm</td>
<td>84.6±0.58</td>
<td>84.1±0.57</td>
<td>85.1±0.55</td>
<td>85.9±0.56</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>122.6±1.35</td>
<td>117.0±1.42 *</td>
<td>125.4±1.33</td>
<td>123.5±1.44</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>69.8±1.26</td>
<td>66.3±1.18  *</td>
<td>65.3±1.23</td>
<td>67.7±1.32</td>
</tr>
<tr>
<td>Martine-Kushelevsky test (HR, b/10 s)</td>
<td>14.9±0.35</td>
<td>14.5±0.32</td>
<td>14.3±0.24</td>
<td>14.2±0.34</td>
</tr>
<tr>
<td>Before load</td>
<td>22.2±0.31</td>
<td>21.3±0.36</td>
<td>21.6±0.16</td>
<td>20.8±0.20  *</td>
</tr>
<tr>
<td>After load</td>
<td>95.03±0.3</td>
<td>78.8±0.45  *</td>
<td>94.4±0.34</td>
<td>93.8±0.46</td>
</tr>
<tr>
<td>Recovery time of heart rate after 20 squats, s</td>
<td>109.6±1.23</td>
<td>101.8±0.72  *</td>
<td>107.6±0.87</td>
<td>105.5±0.70</td>
</tr>
<tr>
<td>Robinson index, c.u.</td>
<td>23.3±0.46</td>
<td>26.8±0.53  *</td>
<td>24.3±0.28</td>
<td>26.4±0.29  *</td>
</tr>
<tr>
<td>Handgrip Strength Test, kg</td>
<td>24.5±0.32</td>
<td>27.1±0.37  *</td>
<td>25.0±0.29</td>
<td>27.4±0.28  *</td>
</tr>
<tr>
<td>Left hand</td>
<td>31.7±0.49</td>
<td>41.8±0.53  *</td>
<td>33.1±0.58</td>
<td>37.6±0.68  *</td>
</tr>
<tr>
<td>Right hand</td>
<td>33.3±0.41</td>
<td>42.2±0.55  *</td>
<td>34.3±0.53</td>
<td>39.0±0.71  *</td>
</tr>
</tbody>
</table>

Note. * The significant difference in values at the end of the experiment (p <0.05)
CG decreased by 3.6% and 4.1%, respectively.

There was a decrease in the values of the Martine-Kushelevsky test parameter “before the load” among female students of EG by 2.7%, in the CG – by 0.7%. After performing 20 squats, the female students of EG showed a decrease in heart rate by 4.05%, the CG – by 3.7%. The recovery time of heart rate “after exercise” in the CG decreased by 0.6%, in the EG by 17%. This indicates that the recovery of heart rate in the EG occurred 28.3 times faster than in the CG. The Robinson index in female students of EG decreased by 3.6 times relative to the CG (7.1% and 1.95%, respectively). After the experiment, the values of functional indicators of the cardiovascular system in female students of the EG were higher compared to the CG.

**Discussion**

The WHO materials [29] emphasize the importance of controlling and preventing overweight and obesity by normalizing the nutrition of people and the widespread use of physical activity of all population groups in different countries.

The physical aerobic activity allows the body to not only split fats [47], but also helps to improve the functional characteristics of the cardiorespiratory system. This is confirm with studies carried out by other authors [48]. This is especially important for overweight female students, because they have lower values of the cardiovascular system and external respiration parameters than students with normal mass.

At the end of the experiment, the female students of the EG increased the strength of the left hand by 15.0%, the right hand – by 10.6%. The increase of strength value indicator of the left and right hands in the female students of the CG was lower: 8.6% and 9.6% (left and right hand), respectively.

Compared to the beginning of the experiment, the power index increased in both groups. The power index in the EG increased 2.3 times for the left hand and in 1.9 times for the right hand. Other researchers [49] determined the similar dependence of the physiometric indicators of the human body on the body mass index.

The increase in the physical fitness of the female students in the EG and the CG was determined at the end of the experiment. The results of their motor tests confirm that (Table 2).

The significant improvement in motor qualities in female students of EG was defined in five out of seven tests (Table 2). Indicators of speed (30 m run test), muscle strength of the upper shoulder girdle [Bent Arm Hang Test (two hands), s; Cadence Push-Up Test, quantity of times], trunk muscle strength [Eurofit Sit Up Test (for 30 s), quantity of times] and dynamic strength of lower limb muscle [Standing Long Jump Test (Broad Jump), cm]. The significant increase is fixed in three out of seven motor tests. In female students of the CG: trunk muscle strength indicators, flexibility and dynamic strength of the lower limb muscle improved.

Improving the indicators values of motor qualities of female students in EG is associated with their higher physical activity and increased muscle component in the body. It is also associated with BMI normalizing. Studies [50-52] showed that the physical fitness of youth with overweight is significantly lower than that of students with normal mass. These data and the results of our research confirm the relevance of body mass normalizing in female students to increase their physical fitness.

It was shown [3] that classes only according to the standard methodology of physical education do not always lead to a positive result. Therefore, researchers [53] think that additional classes on correction of body mass are necessary.

High efficiency of mastering the educational material of the discipline was shown: Testing of pedagogical technologies “inverted class” [37]; the use of digital technologies for physical training in higher military educational institutions [54]; the use of information and communication technologies in students’ physical

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Experimental group (n=42)</th>
<th>Control group (n=44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 m run, min, s</td>
<td>7.20±0.56</td>
<td>7.04±0.55</td>
</tr>
<tr>
<td>30 m run of the high start, s</td>
<td>6.23±0.06</td>
<td>5.86±0.06*</td>
</tr>
<tr>
<td>Bent Arm Hang Test (two hands), s.</td>
<td>2.89±0.30</td>
<td>3.82±0.32 *</td>
</tr>
<tr>
<td>Cadence Push-Up Test, quantity of times</td>
<td>16.1±0.55</td>
<td>19.5±0.63*</td>
</tr>
<tr>
<td>Eurofit Sit Up Test (for 30 s), quantity of times</td>
<td>15.7±0.37</td>
<td>17.6±0.43 *</td>
</tr>
<tr>
<td>Standing Forward Bend, cm</td>
<td>14.1±0.56</td>
<td>14.7±0.58</td>
</tr>
<tr>
<td>Standing Long Jump Test (Broad Jump), cm</td>
<td>150.2±2.4</td>
<td>158.2±2.9 *</td>
</tr>
</tbody>
</table>

Note. * The significant difference in values at the end of the experiment (p <0.05)
education [35, 36].

The results of the pedagogical experiment on the correction of the body mass of students using the integrative method “inverted class” and digital learning given in the figure.

The BMI corresponded to normal values in 20 female students of EG (47.6%) at the end of the experiment. The BMI decreased by 13.8% in 12 female students (28.6%). The BMI did not change in 10 female students (23.8%). The BMI decreased to normal values in 3 female students (6.8%) in the control group. The BMI decreased by 5.4% in 4 female students (9.1%). The body mass index did not change in 37 female students (84.1%).

The use of visual familiarization of female students with educational material (“Elective courses in physical education and sports”) allows improving the quality of teaching the subject; increase the motor density of the class; reduce the time for the explanation and demonstration of motor actions; to achieve the body mass normalization in a significant number of students.

**Conclusion**

The use of standard physical fitness technologies in physical education to normalize the mass characteristics of students is not always effective. This provokes the necessity to improve the pedagogical methods and of training and education means aimed at body mass correcting.

The integrative pedagogical technique proposed by the article authors based on cognitive teaching methods. The combination of the “inverted class” method and digital learning considered to be a more effective pedagogical technique than the traditional one.

Such organization and conducting the academic classes and independent work of female students allowed increasing the motor density of the class; correct body mass; improve the functional characteristics of the cardiovascular system and the physical fitness of female students; increase motivation and interest in physical activity.

**Conflict of interest**

The authors report no conflict of interest.

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Comparative analysis of the athletes’ functional condition in cyclic and situational sports

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Abstract

Purpose: The athletic potential of athletes depends on functional condition parameters. They determine physical and mental performance. Their evaluation is part of the athletes’ condition monitoring in many sports. The purpose of the study was the comparative analysis of the athletes’ functional condition in cyclic and situational sports.

Material: The study involved 31 students from specialized sport school aged 16-17. The participants were divided into two groups depending on the sport: 1st group – 20 martial arts athletes (Greco-Roman wrestling, freestyle wrestling, judo), 2nd group – 11 water sports athletes (swimming). The level of sportsmanship was Candidates and Masters of Sports. The following tests were applied: determination of the individual minute duration (IM) (s), measuring of a 10 cm segment, (cm), and determination of simple hand-eye coordination (SHEyC), (s), and simple hand-ear coordination (SHEaC), (s). “Figures memorizing” technique, solution of 10 sums.

Results: The IM test results reflect the predominance of earlier completion of the test. This tendency more expressed in martial arts athletes. The results of measuring a segment were lower in all tests in the 1st group and in 9 tests in the 2nd group. The vision reaction in 4 tests out of 10 was better in martial arts athletes. The response to the auditory stimulus in 5 tests out of 10 and the average result was better in martial arts athletes. The results of figures memorizing test were most often average. The swimmers memorize significantly fewer figures according to 3 tests. The results of the solution of sums were similar.

Conclusions: The use of a battery test allows giving a comparative analysis of the functional condition of different sports athletes. The stability of IM test results indicates sufficient adaptation reserves of the participants. The analysis of the results of the measuring of segment test allows evaluating the ability to spatial orientation as an important for success quality in martial arts and water sports. The importance of the response rate for the success of both martial arts athletes and swimmers confirmed. The martial arts athletes’ results were significantly better. This confirms their ability to concentrate, to stay focused longer. The results allow considering the response rate to an auditory stimulus as an important indicator for predicting success. The figures memorizing test also reflects the specificity of sports. It illustrates the ability of athletes to control the environment, manage the situation. This ability is significantly better in martial arts athletes. The dynamics of solving sums results suggest some complexity with a long focusing on the swimmers and better parameters in martial arts athletes. The simplicity, accessibility and informative nature of the used tests suggest their use in the athletes’ functional condition monitoring.

Keywords: martial arts, swimming, athletes, psychophysiologial tests, functional condition.

Introduction

Functional condition considered one of the important criteria that determine a person’s physical and mental performance. The sporting potential is largely dependent on these parameters. They have a significant effect on the possible increase in athletes’ skills. The evaluation and analysis of functional condition by means of special tests is part of athletes’ condition monitoring in different sports.

Ziagkas et al [1] determine that response time is one of the person’s abilities that determines sports activities and is an important factor for the victory. Special training improves this parameter. Ferreira et al [2] obtained the similar data. The authors consider that response time is an important factor in martial arts. It suggested to use response time as a preparation criterion and athletes’ monitoring tool [3].

Krawczyk et al [4] evaluated the psychophysiological condition of football goalkeepers. It was confirmed the high parameters of response time, choice response time, the ability of athletes to predict the development of the game situation. Romanenko et al [5] obtained the similar data. The application of choice response as a screening test in martial arts athletes allows recommending this test for monitoring.

Table tennis is a sport in which players perform technical actions at a high rate [6]. The response rate and processing time are key factors that influence on player’s success. The results of Sanabria et al [7] demonstrate the different response rates in different sports. This parameter is better in sports with extrinsic rhythm (football) than in sports with independent rhythm (triathlon).

Monfort et al [8] used visual and verbal memory parameters, response rate, and information processing time as criteria for evaluating the football players’ progress. The evaluation of visual-spatial memory parameters...
provides information for neuromuscular control disorders. Cognitive abilities determine the progress of athletic achievement [9]. Among these are attention, memory, information processing rate, spatial orientation. Training these skills increases the mental performance of the athlete, helps to make more decisions that are effective in the game.

The response rate in basketball has particular importance, especially for predicting and making decisions. Leonte et al [10] compared the results of response time in female athletes with results of non-athletes. It confirmed that there are significant differences between the groups.

Albuquerque et al [11] evaluated the correlation of functional parameters of football players. Players with better tactical characteristics responded more quickly to the given tasks. Biscia et al [12] analyzed differences between handball players with different levels of training in speed and accuracy of information processing. More experienced players have better response time and are more accurate. Increasing athletic experience leads to reduced information-processing time, especially in difficult situations.

Yuksel et al [13] investigated the response time of national badminton teams’ athletes to simple visual and auditory stimuli. It is emphasized the importance of this factor for success along with technique and tactical data.

Athletes in sports related to the ball or racket are under constant time pressure [14]. Optimal visual-motor characteristics of athletes mostly related to visual perception and, to a lesser extent, to motor processes.

Thus, the available data make allow considering the direction of work devoted to the study of psychophysiological features of different sports athletes. The purpose of the study is a comparative analysis of the athletes’ functional condition in cyclic and situational sports.

**Materials and methods**

**Participants**

The study involved 31 students from a specialized sport school aged 16-17 years. The participants were divided into two groups, depending on the sport: 1st group – 20 martial arts athletes (Greco-Roman wrestling, freestyle wrestling, judo), 2nd group – 11 water sports athletes (swimming). The level of sportsmanship was Candidates and Masters of Sports.

**The study design**

The following battery tests were performed: determination of the individual minute duration (IM) (s), measuring of a 10 cm segment, (cm), and determination of simple hand-eye coordination (SHEyC), (s), and simple hand-ear coordination (SHEaC), (s), “Figures memorizing” technique (abs), solution of 10 sums (% of correct answers).

IM duration. The participant counted seconds silently (from 1 to 60); started on a signal of the researcher and said aloud the number 60. The stopwatch also fixed the time. The test repeated 10 times. The IM duration fixed.

Measuring of the segment. The 10 cm segment drawn on a piece of paper. Then the same segment drawn without visual control. Its length fixed. The test repeated 10 times. The length of the segment fixed.

Determination of simple hand-eye coordination (SHEyC) and simple hand-ear coordination (SHEaC) performed using the chronoreflexometry. The study repeated ten times. The response rate fixed.

“Figures memorizing” technique. The participants shown tables with 10 double figures for 30 seconds to remember. The participant recorded these figures after the table put off. The test repeated 10 times. The number of correctly remembered figures fixed.

The solution of 10 sums. Participants asked to solve mentally 10 sums with double figures. The test repeated 4 times. The percentage of correctly solved sums fixed.

**Statistical analysis**

Statistical analysis performed using licensed MS Excel. The following indicators of descriptive statistics were determined: arithmetic means, standard deviation, and error of the mean. The significance of differences in the groups evaluated using the Student’s t-test (t) and the non-parametric Rosenbaum’s test (Q).

**Results**

The results are given in Tables 1-3.

The individual minute was shorter than the actual one in athletes of the 1st group. This was determined in 8 tests out of 10. In 2nd and 3rd tests the individual minute was more than the actual one. The count lasted longer than necessary. This tendency less expressed in swimmers. They finished the count earlier in 6 tests out of 10. The number of later test completions was 3. Swimmers accurately completed the test only in 1 test.

The comparison of the groups confirmed some differences in the performance of this test. The results of the 2nd group were significantly higher in performing the 5th test $(t = 2.14, Q = 9, p <0.05)$, as well as the average test result $(Q = 8, p <0.05)$.

The results of segment measuring were less than the standard in all tests in the 1st group and 9 tests in the 2nd group. The results of the 8th test in the 2nd group were more than the standard segment. There were discovered differences between groups. The results of martial art athletes were significantly higher $(t = 2.42, p <0.05)$ in the 1st test. The results of water sports athletes were higher in 7th and 8th tests, respectively, $Q = 8, (p <0.05)$ and $t = 3.90, Q = 13, (p <0.05)$.

The response to the visual stimulus in 6 tests out of 10 had no significant differences between the groups. The results of martial art athletes were significantly better in $2\text{nd}$, $7\text{th}$, $8\text{th}$ and $10\text{th}$ tests, respectively $(t = 2.34, Q = 7, p <0.05), (t = 3.06, Q = 9, p <0.05), (t = 2.93, p <0.05), (t = 2.40, p <0.05)$.

The response rate to the auditory stimulus had more expressed differences. Significantly better response rate determined according to the following tests: in $2\text{nd}$ test $(t = 2.84, Q = 9, p <0.05)$, in $3\text{rd}$ test $(t = 2.99, Q = 18, p <0.05)$, in $4\text{th}$ test $(t = 2.31, Q = 9, p <0.05)$, in $5\text{th}$ test $(t =
# Table 1. Results of psychophysiological testing of cyclic and situational sports athletes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>1st group (n=20)</th>
<th>2nd group (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IM duration, 1 test, s</td>
<td>56.42±4.03</td>
<td>59.04±3.45</td>
</tr>
<tr>
<td>IM duration, 2 test, s</td>
<td>60.76±1.61</td>
<td>65.34±2.29</td>
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<tr>
<td>IM duration, 3 test, s</td>
<td>60.78±1.73</td>
<td>63.90±1.61</td>
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<tr>
<td>IM duration, 4 test, s</td>
<td>58.86±1.44</td>
<td>60.32±2.01</td>
</tr>
<tr>
<td>IM duration, 5 test, s</td>
<td>57.11±1.62</td>
<td>61.78±1.45</td>
</tr>
<tr>
<td>IM duration, 6 test, s</td>
<td>57.96±1.1</td>
<td>59.66±1.24</td>
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<tr>
<td>IM duration, 7 test, s</td>
<td>57.34±1.10</td>
<td>57.36±1.60</td>
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<tr>
<td>IM duration, 8 test, s</td>
<td>58.54±1.43</td>
<td>59.01±0.89</td>
</tr>
<tr>
<td>IM duration, 9 test, s</td>
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<td>58.25±1.23</td>
</tr>
<tr>
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<td>59.68±0.93</td>
</tr>
<tr>
<td>IM duration, average value, s</td>
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<td>60.43±0.93</td>
</tr>
<tr>
<td>Measuring of segment, 1 test, cm</td>
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<td>6.23±0.62</td>
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<tr>
<td>Measuring of segment, 2 test, cm</td>
<td>8.38±0.40</td>
<td>7.58±0.51</td>
</tr>
<tr>
<td>Measuring of segment, 3 test, cm</td>
<td>9.16±0.33</td>
<td>8.73±0.44</td>
</tr>
<tr>
<td>Measuring of segment, 4 test, cm</td>
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<td>9.06±0.42</td>
</tr>
<tr>
<td>Measuring of segment, 5 test, cm</td>
<td>9.25±0.25</td>
<td>9.67±0.32</td>
</tr>
<tr>
<td>Measuring of segment, 6 test, cm</td>
<td>9.45±0.32</td>
<td>9.63±0.24</td>
</tr>
<tr>
<td>Measuring of segment, 7 test, cm</td>
<td>9.51±0.20</td>
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</tr>
<tr>
<td>Measuring of segment, 8 test, cm</td>
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<td>10.17±0.12</td>
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<tr>
<td>Measuring of segment, 9 test, cm</td>
<td>9.46±0.15</td>
<td>9.44±0.33</td>
</tr>
<tr>
<td>Measuring of segment, average value, cm</td>
<td>9.17±0.21</td>
<td>9.03±0.22</td>
</tr>
</tbody>
</table>

Notes. 1 – differences with the 1st group are significant (p<0.05)

# Table 2. Results of response rate evaluation of cyclic and situational sports athletes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>1st group (n=20)</th>
<th>2nd group (n=11)</th>
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</thead>
<tbody>
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<td>0.24±0.01</td>
</tr>
<tr>
<td>SHEyC, 2 test, s</td>
<td>0.21±0.01</td>
<td>0.26±0.02</td>
</tr>
<tr>
<td>SHEyC, 3 test, s</td>
<td>0.20±0.01</td>
<td>0.18±0.02</td>
</tr>
<tr>
<td>SHEyC, 4 test, s</td>
<td>0.21±0.01</td>
<td>0.22±0.01</td>
</tr>
<tr>
<td>SHEyC, 5 test, s</td>
<td>0.22±0.01</td>
<td>0.24±0.01</td>
</tr>
<tr>
<td>SHEyC, 6 test, s</td>
<td>0.21±0.01</td>
<td>0.22±0.01</td>
</tr>
<tr>
<td>SHEyC, 7 test, s</td>
<td>0.19±0.01</td>
<td>0.24±0.01</td>
</tr>
<tr>
<td>SHEyC, 8 test, s</td>
<td>0.19±0.01</td>
<td>0.24±0.01</td>
</tr>
<tr>
<td>SHEyC, 9 test, s</td>
<td>0.21±0.01</td>
<td>0.24±0.01</td>
</tr>
<tr>
<td>SHEyC, 10 test, s</td>
<td>0.20±0.01</td>
<td>0.24±0.01</td>
</tr>
<tr>
<td>SHEyC, average value, s</td>
<td>0.21±0.01</td>
<td>0.23±0.01</td>
</tr>
<tr>
<td>SHEaC, 1 test, s</td>
<td>0.19±0.01</td>
<td>0.21±0.02</td>
</tr>
<tr>
<td>SHEaC, 2 test, s</td>
<td>0.17±0.01</td>
<td>0.22±0.02</td>
</tr>
<tr>
<td>SHEaC, 3 test, s</td>
<td>0.17±0.01</td>
<td>0.21±0.01</td>
</tr>
<tr>
<td>SHEaC, 4 test, s</td>
<td>0.16±0.01</td>
<td>0.21±0.02</td>
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<tr>
<td>SHEaC, 5 test, s</td>
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<td>0.20±0.01</td>
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<tr>
<td>SHEaC, 6 test, s</td>
<td>0.19±0.01</td>
<td>0.21±0.01</td>
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<tr>
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<td>0.18±0.01</td>
<td>0.21±0.01</td>
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<tr>
<td>SHEaC, 8 test, s</td>
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<td>0.21±0.02</td>
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<tr>
<td>SHEaC, 9 test, s</td>
<td>0.15±0.01</td>
<td>0.19±0.02</td>
</tr>
<tr>
<td>SHEaC, 10 test, s</td>
<td>0.16±0.01</td>
<td>0.18±0.02</td>
</tr>
<tr>
<td>SHEaC, average value, s</td>
<td>0.17±0.01</td>
<td>0.20±0.01</td>
</tr>
</tbody>
</table>

Notes. 1 – differences with the 1st group are significant (p<0.05)
We applied a battery of six tests. The ability for temporal and spatial orientation, short-term memory, logic, and analytical capabilities evaluated in addition to the response rate. The applied tests provide a comprehensive analysis of the psychophysiological features of athletes.

The comparison of different sports athletes often used in sports science. A similar design used in the work of Krenn et al [15]. The authors compared the athletes’ executive functions of static, interceptive and strategic sports. The strategic sports athletes in comparison with static sports had better indicators of mean response time, cognitive shifts, and memory.

Aksoy et al [16] used a similar design. The authors studied the psychophysiological and physiological parameters of playing sports and martial arts athletes. The expressed differences in athletes’ response rate, power, and anaerobic abilities confirmed.

The repeat of the tests is also quite common in sports research. Luis del Campo et al [17] used a succession repeat of ten tests to evaluate the motor performance of boxers. The importance of response rate and motor skills of athletes for success is determined.

Hromcik et al [18] evaluated the dynamics of the accuracy of sensorimotor skills, which play an important role in ball games. Participants passed a computer test for 45 minutes. The response rate and the movement time checked with the different numbers of tasks consisting of hitting the target. The importance of motion synchronization for the prediction emphasized. Analysis of the results of almost all tests allows us to consider the condition of the athletes similar. Our data are close Le Mansec et al [19]. The authors evaluated the dynamics of the response time depending on different loads. It shown that neither mental nor physical load has a significant effect on the response rate to simple stimuli.

The stability of IM test results allows speaking about the balance and strength of the nervous processes, to evaluate the adaptation reserves of the participants as sufficient and confirms the high level of athletes’ health. It was determined a tendency for all participants to finish the count earlier. In comparing groups, we can conclude that this tendency more expressed in martial arts athletes. It could considered as a reflection of the influence of the specificity of the sport on the reactivity of the nervous system.
system and mobilization abilities. The average result of this test in swimmers is closer to the standard than in martial arts athletes. Our data are close to the results of Koryagina [20]. It confirmed that this test most accurately performed by playing sports athletes (volleyball players, football players) and weight lift athletes. The earlier completion of the test demonstrated by cyclic sports athletes (skiers, track and field athletes, skaters) and difficult coordination (gymnasts) sports. Basketball players, hockey players, and boxers characterized by a later completion of the test.

The measuring of the segment test evaluates the ability of athletes to spatial orientation. There are no significant differences in this quality between the athletes of the studied groups. The error of most results is 10-15%, which coincides with Koryagina’s data [20]. She showed that most athletes performed this test exactly (an error within 15%). The increase in error found in skiers, wrestlers, and non-athletes. The analysis of this test results makes it possible to evaluate the ability to spatial orientation as an important quality for success in martial arts and water sports.

Response rate considered one of the most important predictors of success in many sports. De la Fuente et al [21] proposed using it as a selection criterion and predictor of success in taekwondo.

At the same time, Martinez de Quel et al [22] emphasized that there was no clear consensus that response time was a good predictor of success in martial arts. However, comparison with the results of other sports athletes confirmed that experienced martial arts athletes predict better the actions of the opponent based on information received before and during the attack.

Studies of Podrigalo et al [23] confirmed the importance of response to different stimuli as predictors of martial arts athletes’ success. The specificity of the sport determines the different information content of the tests, gives the necessary information to predict the athletes’ success. This information can be used for athletes’ condition monitoring.

The obtained results confirm the importance of the response rate for the success of all participants. The indirect confirmation of this fact is the absence of significant differences in 6 tests out of 10 for the visual stimulus. The results of martial arts athletes in the final tests were significantly better. This confirms their ability to concentrate, to keep their attention longer than swimmers.

This assumption confirmed by the analysis of the response rate to the auditory stimulus. The martial arts athletes have demonstrated the best results in 6 tests of a series and in the average result. This reflects the specificity of the sport. The starting response is the most important for the swimmer as shown by the results of the 1st test. For martial arts athletes is important to keep constant concentration. The athletes of the 1st group keep a high response rate in all tests of the series. The results allow us to consider the response rate to an auditory stimulus as an important indicator for predicting success.

The results obtained are close to those of Koryagina [20]. The author demonstrated the best response rate to light in boxers, then in the order of its increase followed by weight lifter athletes, football players, and track and field athletes. The worst response to light observed in volleyball players and weight lifter athletes. The study of simple hand-ear coordination duration showed the best values of this indicator in football players, weight lifter athletes, skaters, and boxers. Then, in the order of its increase followed by hockey players, track and field athletes, volleyball players, basketball players, wrestlers, non-athletes, skiers, weight lifter athletes, and gymnasts.

In our opinion, the figures memorizing test also reflects the specificity of sports. Swimmers do not need to focus on any objects in the swimming process. The minimum number of activities performed by swimmers causes a low level of concentration on the environment. In martial arts, on the contrary, this is a significant criterion. It reflects the ability of athletes to control the environment, manage the situation. The martial arts athletes are under constant time pressure and must make decisions, take actions, and correct them according to the current situation.

The importance of such functions reported by Montuori et al [24]. Constant changes in conditions require correction of the athletes’ behavior. This achieved by continuous changes between different tasks. The results showed a minimal degree of cognitive flexibility for highly specialized athletes and a maximum level for mixed performers. The authors propose to use tests to evaluate these functions in selecting process and defining a sports position.

Solving the sums test allows evaluating the logic and analytical abilities of participants. In our opinion, the results demonstrate the complexity of the task for all participants. In martial arts athletes after the average result in 1 test, there is a diminishing of results in the 2nd test. The other tests participants solved with a good result. The zigzag results were observed in swimmers as 2nd and 4th tests showed diminishing of results compared to 1st and 3rd tests. The difference between the results suggests some difficulties with analytical abilities, extrapolation and more rigidly fixed behavioral stereotypes in swimmers and better performance in martial arts athletes. Perhaps the obtained results reflect the gradual formation of fatigue due to the full battery tests.

The results of Fard et al [25] can confirm this assumption. [25] The authors evaluated mental fatigue during long-term simple testing in athletes compared with non-athletes. It shown that athletes demonstrated greater resistance to mental fatigue than non-athletes. Therefore, it suggested that physical exercise could reduce the negative impact of mental fatigue on a long-term cognitive task.

**Conclusion**

The use of a battery test (response rate, spatial and temporal orientation, logic and analytical capabilities) allows giving a comparative analysis of the functional condition of different sports athletes. The stability of IM test results indicates sufficient adaptation reserves of the participants. The analysis of the
results of the measuring of segment test allows evaluating the ability to spatial orientation as an important for success quality in martial arts and water sports.

The importance of the response rate for the success of both martial arts athletes and swimmers was confirmed. The martial arts athletes’ results were significantly better. This confirms their ability to concentrate, to stay focused longer. The results allow considering the response rate to an auditory stimulus as an important indicator for predicting success.

The figures memorizing test also reflects the specificity of sports. It illustrates the ability of athletes to control the environment, manage the situation. This ability is significantly better in martial arts athletes.

The dynamics of solving sums results suggest some complexity with a long focusing on the swimmers and better parameters in martial arts athletes.

The simplicity, accessibility and informative nature of the used tests suggest their use in the athletes’ functional condition monitoring.

Conflicts of Interest
The authors declare no conflict of interest.

References


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Modelling of the competitive activities of qualified female short-distance runners, taking into account their individual characteristics

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Abstract

Purpose: to develop an individual model of competitive activity of qualified female runners to achieve the planned sports result of 100 m.

Material: for qualified athletes (n = 88), using video-computer analysis, individual characteristics of speed dynamics in running for 100m and kinematic parameters of running for different distances were recorded. The tensodynamograms of the manifestation of the strength of muscle groups carrying the main load in the structure of the sprint run of 18 short-distance runners of various qualifications were recorded and processed.

Results: promising models of competitive activity in the 100m race for the planned sports result have been developed. Based on the model of a specific athlete, the main areas of work are determined, means and methods of training effects are selected.

Conclusions: Practical realization of the developed model provided the necessary increase in indicators. This made it possible for female athletes (n = 8, age 19-21 years) to improve the average result in running the main distance (compared with the previous year) by 0.18 s.

Keywords: female runners, model, competitive activity, individualization, sprinting, structure.

Introduction

In recent years, the interest of specialists in analyzing the athlete’s behavior in competitive activity [1-4]. Previously, the main attention of trainers and researchers was focused more on a comprehensive study of the process of sports training, while the analysis of behavioral activity directly in the process of competition was empirical and, mainly, ascertaining.

The effectiveness of competitive activity can be judged, for example, according to results in competitions. However, the sports result does not contain much information about the course of the competition, it does not reveal the strengths and weaknesses of the athlete’s preparedness and, on this basis, outline promising areas for sports and technical improvement. These goals are indicators that can be obtained in the process of objective registration of competitive activity.

As emphasized by V.N. Platonov [5], the study of the structure of athletes’ preparedness in isolation from the structure of their competitive activity leads to an underestimation of the role of significant factors, to insufficiently clear and substantiated results, and makes it difficult to implement the data obtained in developing a system for diagnosing an athlete’s preparedness. In other words, the evaluation of competitive activity is the determining link in the feedback when analyzing the success of the activity and the effectiveness of the training process. In many works devoted to the problems of sprinting, individual characteristics of athletes were noted [1, 4, 6, 7]. The latter are manifested in a different ratio of length and frequency of steps when running at maximum speed, in the ability to accelerate, relax, etc. It has been shown, that athletes with various anthropometric data [3, 4, 8, 9], distance dynamics [1, 7, 10, 11], the level of development of motor qualities, etc. achieve success in sprint [2, 12, 13, 14]. At the same time, the individual and not always steady development of individual sides of preparedness, the mechanism of manifestation of which is often in a certain antagonism, objectively reflects the logic of training, the natural data of a particular athlete [15, 16, 17], as well as the laws of the complex manifestation of various qualities and abilities, which is not always taken into account when planning training effects. Consideration of the current state of athletes is also important, taking into account the biorhythm of their body [18-21]. Analysis of specialized literature shows [6, 7, 22, 23] that, despite a large number of studies on the study of competitive activity in sprinting, there are very few data and guidelines on the basis of which an individual model of competitive activity of runners can be developed to achieve the planned sports result.

Hypothesis. The choice of individually acceptable training programs in solving sports training problems aimed at achieving a promising model of competitive activity, well-timed changing of the nature and direction of training influences the individual links and structural elements of kinesiology systems of specific female athletes, contributes to a more significant increase in sports results in sprinting.

The purpose of the study is to develop an individual model of competitive activity of qualified female runners to achieve the planned sports result for 100 m.

Material and methods

The research was carried out in two stages. The main task of the first stage of the experiment was to register the
individual characteristics of the dynamics of speed in the run for 100m, the kinematic parameters of the run (length and frequency of steps) of qualified female athletes (n = 88) at different distance segments.

The technology for conducting a biomechanical video computer analysis of the competitive activities of short-distance female runners included shooting and processing the videograms (photographs) obtained using specialized computer software [24]. Video shooting was carried out using a «CANON DIGITAL IXUS 970 IS» video camera. Processing was carried out on a personal computer using the ACDSeePro 4 and AdobePhotoshop XCV edition programs with frame-by-frame motion detection.

For instrumental control of the strength and speed-strength capabilities of the muscles of the lower extremities of athletes, the method of computer tensodynamography was used, which consists of recording and analyzing the “force-time” curve [1, 13]. This technique allows to assess the level of special strength training, based on a set of specific data characterizing a person’s ability to manifest “explosive forces” that cannot be measured directly. The tensodynamograms of the manifestation of the strength of muscle groups bearing the main load in the structure of the sprint run, which are muscles, leg extensors in the knee and hip joints and plantar flexor of the foot of 18 short-distance runners of various qualifications were recorded and processed. In the isometric mode, the guideline to show the maximum (absolute) arbitrary force in the explosive isometric mode (for the rapid achievement of maximum force in the shortest period of time) was given. Based on the obtained tensi-dynamometric curves, the maximum isometric muscle strength (Fmax), manifested in the described movement, and the time during which the maximum force (tmax) was achieved, were determined. The differential index (gradient) of explosive force (J) was calculated, which characterizes the rate of rise of the force to the maximum and is numerically equal $J = \frac{F_{\text{max}}}{t_{\text{max}}}$. Since the repulsion phase in women’s run lasts 0,10-1,15 s [7, 12, 22], the value of the force developed by the athletes in 0,1 s ($F_{0,1}$) was also determined.

In order to compare the group and individual models of the competitive activity of short-distance female runners of high qualification, we conducted two series of experiments. Using a video camera and an electronic timekeeping system, the running time of 30, 60 and 80 m long distances was recorded, and the frequency and length of steps of 28 highly qualified athletes were measured. Then, during the competitive period, the time of covering 100 m of the distance by 12 athletes from this group was determined 16-18 times, and the similar indicators were calculated.

At the second stage of the study, on the basis of the data obtained, a technology was developed to build an individual perspective model of the competitive 100m running structure for a specific female athlete. Qualified athletes (n = 8, age 19-21 years) - students of F. Skorina Gomel State University, specializing in short-distance running, participated in the pedagogical experiment. An analysis of the ratio of the length and frequency of steps when running on different segments of a distance of 100 m made it possible to distinguish two groups of athletes from participating in the pedagogical experiment. The first group (4 athletes) at a distance in general and in its individual sections showed the optimal frequency of steps for their individual parameters. Increasing the result by enlarging the last component was problematic, because considering these athletes, the frequency has reached significant values. In this regard, it was decided to achieve the planned improvement in sports results by increasing the length of the running steps with the relative stabilization of their frequency. The second group (4 athletes) had a length of running steps, which, considering step module, corresponded to the normative indicators for athletes of this qualification level. In this case, it was necessary to increase the running speed mainly by increasing the frequency of steps while maintaining their optimal length.

The data obtained underwent correlation analysis. In the first case, R was used, in the second P – analysis [25]. The classic R-analysis was used, which is based on the correlation between the tests, carried out in a group of participants with similar conditions, as well as the P-analysis, based on the consideration of the correlation between achievements in a number of tests of the same participant, shown in different conditions. [18].

Results
As a result of the analysis of competitive activity in a series of international and national competitions, we obtained the average indicators of time, running speed, as well as the ratio of the length and frequency of steps in sections of a distance of 100 m of female athletes (n = 88) of various qualifications (Tables 1-3). It was revealed, that with the growth of sportsmanship of runners from the level of city competitions to the results of the international class, the speed of running in all four selected sections of the distance increases ($p<0.05$).

Based on the obtained data, the regression equations of the form $Y=A+BX$ were calculated to determine the time and speed of running in the distance sections (Y) for the planned result in 100m (X) running. Using these equations, model average statistical indicators of the running time of the selected sections of the sprinter distance of 100 m were developed:

$$T_{30} = 1.251 + 0.262 \times T_{100}$$
$$T_{60} = 0.879 + 0.565 \times T_{100}$$
$$T_{80} = 0.472 + 0.769 \times T_{100}$$

where, $T_{30}$ –is the running time of 30 m, $T_{60}$ – running time of 60 m, $T_{80}$ - running time of 80 m.

Since the running speed is directly determined by the ratio of the length and frequency of steps, it is of considerable interest to analyze the differences in these components among athletes of one or another qualification at a distance of 100 m (Table 2). The study of this issue showed that there are no significant and statistically significant differences (for a 5% significance level) in the total number of steps and the average length of steps at a distance of 100m between groups of athletes. However,
if we express the length of the steps in relative units (for example, relative to the length of the legs of the athletes), we can be noted statistically significant differences in these indicators only between city-level runners and extra-class athletes (the first run with a larger relative step length).

The presence of the data presented in tables 1 and 2 allows to:

1. Determine the model running time of the distance sections in accordance with the planned result (T
\text{100})

2. Predict the result in the 100m race based on test data at shorter distances;

3. To identify the strengths and weaknesses of preparedness by comparing individual indicators in each area with the model ones, and on this basis to identify promising areas of sports improvement.

Thus, the “lag” in time in the first section indicates the need for focused work on improving the efficiency of start and starting acceleration; on the second - maximum running speed; on the third - fourth - special sprinting endurance.

It is clear, that the anthropometric parameters, in particular, the length of the leg, affect the length of the steps and their number in the distance sections. In order to statistically exclude this influence, as well as to determine the relationship between running time on a particular distance of 100 m and indicators of special strength training, a partial correlation coefficient was calculated. The latter allows us to evaluate the relationship of the two characteristics with the exception (elimination) of the influence of the third indicator on it. Thus, we can find out what the relationship would be between the time taken for a particular section of the distance and indicators of special strength training if the length of the legs of all the athletes was the same.

The calculated partial correlation coefficients between the running time (x) for a particular distance segment and the explosive strength of the muscles (gradient of the extensors of the foot and plantar flexors of the foot), as well as the results in triple and tenfold jumps from the spot (y) when eliminating the length of the legs (Z) of the athletes are shown in Table 3.

### Table 1. The average running time of sections of a 100 meters distance by qualified female runners,

<table>
<thead>
<tr>
<th>The result of 100 meters run</th>
<th>Sections of the distance</th>
<th>0-30 m</th>
<th>0-60 m</th>
<th>0-80 m</th>
<th>30-60 m</th>
<th>60-80 m</th>
<th>80-100 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.30</td>
<td>4.24</td>
<td>7.23</td>
<td>9.24</td>
<td>2.99</td>
<td>2.01</td>
<td>2.06</td>
<td></td>
</tr>
<tr>
<td>11.40</td>
<td>4.27</td>
<td>7.29</td>
<td>9.31</td>
<td>3.02</td>
<td>2.02</td>
<td>2.09</td>
<td></td>
</tr>
<tr>
<td>11.50</td>
<td>4.30</td>
<td>7.33</td>
<td>9.38</td>
<td>3.03</td>
<td>2.05</td>
<td>2.12</td>
<td></td>
</tr>
<tr>
<td>11.60</td>
<td>4.32</td>
<td>7.39</td>
<td>9.47</td>
<td>3.07</td>
<td>2.08</td>
<td>2.13</td>
<td></td>
</tr>
<tr>
<td>11.70</td>
<td>4.34</td>
<td>7.46</td>
<td>9.55</td>
<td>3.12</td>
<td>2.09</td>
<td>2.15</td>
<td></td>
</tr>
<tr>
<td>11.80</td>
<td>4.37</td>
<td>7.50</td>
<td>9.61</td>
<td>3.13</td>
<td>2.11</td>
<td>2.19</td>
<td></td>
</tr>
<tr>
<td>11.90</td>
<td>4.40</td>
<td>7.58</td>
<td>9.70</td>
<td>3.18</td>
<td>2.12</td>
<td>2.20</td>
<td></td>
</tr>
<tr>
<td>12.00</td>
<td>4.42</td>
<td>7.62</td>
<td>9.78</td>
<td>3.20</td>
<td>2.16</td>
<td>2.22</td>
<td></td>
</tr>
<tr>
<td>12.10</td>
<td>4.45</td>
<td>7.68</td>
<td>9.85</td>
<td>3.23</td>
<td>2.17</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td>12.20</td>
<td>4.48</td>
<td>7.73</td>
<td>9.94</td>
<td>3.25</td>
<td>2.21</td>
<td>2.26</td>
<td></td>
</tr>
<tr>
<td>12.30</td>
<td>4.51</td>
<td>7.79</td>
<td>10.01</td>
<td>3.26</td>
<td>2.22</td>
<td>2.29</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. The average group indicators of competitive activity of athletes of various qualifications in sections of a distance of 100 meters

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KMS</td>
</tr>
<tr>
<td>Time at 100m, s</td>
<td>12.2 ±0.1</td>
</tr>
<tr>
<td>Time at 30m, s</td>
<td>4.48 ±0.04</td>
</tr>
<tr>
<td>Time at 60m, s</td>
<td>7.76 ±0.19</td>
</tr>
<tr>
<td>Time at 80m, s</td>
<td>9.97 ±0.20</td>
</tr>
<tr>
<td>Time at 30-60m, m/s</td>
<td>9.15 ±0.10</td>
</tr>
<tr>
<td>Speed at 60-80m, m/s</td>
<td>9.05 ±0.15</td>
</tr>
<tr>
<td>Speed at 80-100m, m/sec</td>
<td>8.97 ±0.11</td>
</tr>
<tr>
<td>The number of steps per distance</td>
<td>52.63 ±1.9</td>
</tr>
<tr>
<td>The average length of steps, m</td>
<td>1.96 ±0.01</td>
</tr>
<tr>
<td>The average frequency of steps, step/s</td>
<td>4.43 ±0.11</td>
</tr>
<tr>
<td>Step module, rel. units</td>
<td>2.14 ±0.04</td>
</tr>
</tbody>
</table>

Note: *step module is the ratio of step length to foot length.*

KMS - runners of the level of city competitions; MS - runners of the republican level; MSIG - Extra Class Runners
The data obtained indicate that, considering other conditions being equal, an advantage in running distance segments is on the side of the runners who have higher indicators of explosive muscle strength - extensors of the foot and plantar flexors of the foot. A properly organized training process contributes to the systematic improvement of the results of athletes, which entails a change in the indicators of competitive activity. The most common, typical changes in the competitive structure of running athletes with increasing skill are presented in Table 4.

It should be noted, that the changes in the observed group can be traced in a faster run of all sections of the distance due to an increase in the frequency of steps. Differences in the length of steps (especially in the first two sections) are less pronounced: there are no significant differences between groups of athletes and in anthropometric indicators. In addition, it must be borne in mind that the above data on the predominant effect of the pace of steps reflect only the most typical way to increase the running speed of qualified female runners. Using appropriate pedagogical influences and taking into account the natural predisposition of runners in each case, improvement in the results can be achieved in two ways: by increasing one or both components (length and frequency of steps), while decreasing one component and increasing the other (more significant).

The indicators of special strength preparedness at the beginning of the pedagogical experiment and in the summer competitive period are presented in Table 5. The analysis indicates that most of the indicators of this side of the special preparedness correspond to or exceed the planned level.

A statistically significant (p<0.05) increase in a number of indicators over the period of the experiment confirms the effectiveness of the tools and training methods used and the correct distribution of training effects of the corresponding orientation at the stages of the annual cycle.

An analysis of the data on the competitive activity of female athletes in the summer competitive period shows that the increase in the running speed in the distance sections was achieved mainly by increasing the length of the steps, while the pace of running did not change significantly. At the same time, the runners of the second group slightly increased the frequency of steps (especially at the beginning of the distance of 100 m), preserving, basically, their length, which made it possible to increase the athletic performance.

Discussion

In study, factors for the complex individualization of training athletes, both for short-distance running and generalized for all speed-power types of athletics were identified. A methodology for determining the group and individual characteristics of competitive activity and the preparedness of athletes was developed, which allows finding the most effective solution to motor problems. These results are consistent with data available in the literature [3, 4, 7, 22]. It has been proved, that the technology of constructing models of the individualization of the training process of athletes specializing in sprinting is the priority, considering different composition of training tools in the annual cycle, adequate to the nature of

### Table 3. Results of a particular correlation analysis

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Sections of the distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-30</td>
</tr>
<tr>
<td>( r_{xy} ) (gradient of the extensors of the foot) ( Z )</td>
<td>-0.871</td>
</tr>
<tr>
<td>( r_{xy} ) (gradient of the plantar flexors of the foot) ( Z )</td>
<td>-0.882</td>
</tr>
<tr>
<td>( r_{xy} ) (triple jumps) ( Z )</td>
<td>-0.634</td>
</tr>
<tr>
<td>( r_{xy} ) (tenfold jumps) ( Z )</td>
<td>0.406</td>
</tr>
</tbody>
</table>

### Table 4. Spatial-temporal indicators of competitive activity of qualified athletes in sections of a distance of 100 m (average group data)

<table>
<thead>
<tr>
<th>Qualification groups</th>
<th>Sections of the distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-30</td>
</tr>
<tr>
<td></td>
<td>( L )</td>
</tr>
<tr>
<td>MSIG</td>
<td>1.67</td>
</tr>
<tr>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>MS</td>
<td>1.68</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>KMS</td>
<td>1.68</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
</tr>
</tbody>
</table>

Note: \( L \) - step length (m), \( f \) - step frequency (steps/s), \( M \) - step modulus (step length/foot length)

KMS - runners of the level of city competitions; MS - runners of the republican level; MSIG - Extra Class Runners
the competitive activity and the individual characteristics of the runners, and not a copying technique of training men, runners for short distances [5, 11, 26]. Often, experts determined the correlation of the final result in running with the kinematic indicators of a group of athletes of various qualifications and, on this basis, made conclusions about the organization of training effects to improve the athlete’s motor apparatus in order to show a higher result in the sprint [7, 8, 17]. Based on the structure of the group model, it is necessary to build the training process in such a way so as to mainly affect the abilities that determine the ability to quickly run the last 20 meters of the distance with a high step frequency [7, 23].

Meanwhile, the analysis of individual correlation relationships obtained by us shows, that runners don’t have correlation coefficients between the running time at a distance of 100 m and its structural components correspond to the group average. This fact indicates the influence on the considered dependencies of the individual data of each subject. So, the correlation coefficients between the sports result and its structural components, calculated according to the results of a single test of the subjects (average group indicators), should differ from the similar indicators of the correlation coefficients calculated according to the results of the multiple testing of one subject (intraindividual indicators). The noted discrepancy should not, however, be a reason for refusing to take into account the average group data. They are necessary, but only as some general basis for drawing up a long-term plan for training an athlete [2, 4, 23, 27].

The specific distribution of the load, its size and the target orientation of the training process to achieve the planned structure of the competitive activity should be based on the individual characteristics of a particular athlete. In our opinion, the key to success most likely lies in the training methodology, which is optimally oriented to the development of natural dominant inclinations for running with a certain motor structure. Of course, one should take into account most general laws that are characteristic of all runners and which determine the growth of sportsmanship.

It is noteworthy that the running speed at the starting acceleration (0-30m) and finishing (80-100m) section is interconnected with the work of the same muscle groups, while the latter affect the running time of the middle distance to a lesser extent [6, 7, 11]. In our opinion, achieving maximum speed and maintaining it at the finish lies in the plane of the individual ability to switch efforts in a timely manner as one runs from one muscle group to another, which is expressed in terms of length and frequency of steps. In that way, the that two-time Olympic champion V. Borzov could successfully change (2-3 times) at this short speed distance the running technique [10]. It is significant that a similar technique, based on the concentration of a biologically expediently balanced power development of muscles with the aim of their “contribution” to the athletic performance in the 100m race, was also used in the preparation of the Olympic champion in the 100m race by Yulia Nesterenko [15].

Thus, the conducted studies show that the individualization of the training process should be based on information about the structure of the manifestation of motor abilities and indicators of the technique of competitive exercises for each athlete [3, 6, 9, 13, 28, 29]. The hypothesis stating, that by using the appropriate pedagogical influences and taking into account the individual characteristics of female athletes, an increase in speed can be achieved both by increasing the length and frequency of steps, is confirmed. However, it should always be remembered that the maximum development of individual inclinations should be combined with a fairly harmonious and versatile training, which does not,
Conclusions
1. It was revealed that the nature of the main exercise and its individual elements in a competitive environment, being a comprehensive indicator, reflects a kind of “synthesis” of the individual characteristics of a female athlete and the level of her technical and physical fitness. Individual characteristics can be a “handwriting” of competitive activity and its components, and targeted correction of the latter can eliminate individual shortcomings and ultimately lead to an increase in sportsmanship. The training of qualified athletes, based on this concept, should be differentiated and built on the basis of individual characteristics.

2. Competitive activity should predetermine the entire training program, the choice of means and methods, the volume and intensity of training influences. The model of competitive activity in sprinting, based on the individual characteristics of the athlete and the development technology of which is focused on the planned result, should be aimed at emphasizing the strengths of the athlete and, to a certain extent, pulling up the lagging ones.

3. The choice of individually acceptable training programs in solving sports training problems aimed at achieving a promising model of competitive activity, timely changing the nature and orientation of the training effects on individual links and structural elements of the kinesiology systems of specific athletes, contributes to a more significant increase in athletic performance in sprinting.

The technique used allowed us to differntially influence mainly the components of the running speed (length and frequency of steps), while focusing on the individual characteristics of the athletes. The average group increase in the sports result for the period of the experiment was 0.18 s, which was statistically significantly (p<0.05) higher than the initial level and is a good result for athletes of this qualification.

4. Results of the study allow us to conclude, firstly, the informativeness of the assessment of the competitive structure of running and the level of special strength training of qualified short-distance female runners, and secondly, about the practical effectiveness of the developed methodology for the formation of a specific competitive structure of running female athletes and the individualization of their training process.

The principle approach to individualizing the training of qualified short-distance runners developed and tested in the experiment can be constructively adapted to other disciplines of athletics and sports.

Conflict of interest
The authors of the article declare that there is no conflict of interest.

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Exercise-induced fatigue impairs visuomotor adaptability in physical education students

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Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: Physical exercise has been shown to exert various effects on visuomotor processing and motor learning. The present study aimed to examine the impact of exercise with progressively increased physical load on consecutive stages of perceptual-motor learning. We compared the effectiveness of visuomotor adaptability in four subsequent trials during a complex coordination task performed in different conditions, including under conditions of progressively increased physical load, and in non-exercise resting control conditions.

Material: Twenty-seven physical education university students participated in this study. Participants were randomly assigned to one of two groups: (1) an exercise experimental group (n = 14), or (2) a non-exercise resting control group (n = 13). Participants in the experimental group performed three 10-minute effort-tests with increasing intensity on a cycloergometer. Each participant was assigned individual workload values below the lactate threshold (40% VO2max), at the lactate threshold (60% VO2max), and above the lactate threshold (80% VO2max). Four sessions of the two-hand coordination test included in the Vienna Test System were used to examine visuomotor adaptability variation. The total time duration, total error duration, and coordination difficulty were analyzed.

Results: There was a significant interaction between number of test repetitions and group (experimental, control) for total duration (F(3,75) = 3.54, p = 0.018). In particular, there was a significant reduction (p = 0.006) in duration in the control group after fourth test repetitions as compared to the baseline. In the experimental group, in contrast, there was a tendency for duration to increase after exercise above the lactate threshold intensity. There was also a significant interaction between test repetitions and group for total error duration (F(3,75) = 3.14, p = 0.03).

Conclusions: The results suggest that high intensity exercise can disrupt visuomotor processing during complex skill acquisition. These findings highlight the interplay between exercise intensity and motor control and learning, which in turn, has practical implications for developing and improving motor training and physical education programs.

Keywords: physical education students, motor control, learning, exercise.

Introduction

Physical education of students requires effectiveness methods of motor learning to the attainment of expertise in complex skills in different sports. Students need daily practice to acquire motor skills, coordinate large parts of muscles, and improve speed, accuracy, and coordination performance of fine, narrow movements that depend on visuomotor adaptation [1]. Visuomotor adaptation can be defined as the capacity to modify coordinated movements to adjust to changes in new environment conditions [2, 3]. Visuomotor adaptation is required for many basic tasks of daily living such as reaching and grasping objects, walking, cycling, car driving, and sports activity. To coordinate accurate and/or fast movements, the motor control system must adapt via dynamic changes in the musculoskeletal system and the configuration of body segments [4]. For effective visuomotor adaptability (VMA), several sensorimotor systems – including the visual system, central processing, and effector components – must function synergistically. In particular, integral components of hand-eye coordination task performance include projection of the visual field onto the retina, sensory transmission of information to the visual cortex, cognitive planning and motor programming, activation of arm muscles to initiate a particular action, focus of attention, and visual feedback [5].

It is generally assumed that visuomotor adaptation is the key factor that influences motor skill learning [6]. The level of an individual’s motor learning improves with practice, which leads to relatively permanent changes in the acquisition of motor skill [7]. With practice, the control of movement execution becomes less dependent on cognitive processing and progressively switches to more automatic functioning [8].

Research studies have revealed different factors that can affect the effectiveness of perceptual-motor learning and performance, including task difficulty [9, 10], attention [11, 12], and memory abilities [13]. Moreover, stress and anxiety have been shown to decrease motor performance during the early stages of learning, but have no effect (or may even improve performance) during later learning stages [14, 15]. Furthermore, Hordacre et al. [16] reported perceptual-motor learning benefits during a pinch task following increased stress and anxiety induced by...
the mental arithmetic task. In particular, the investigators observed a reduction in both reaction time and movement time across the learning period. These findings suggest that levels of stress and anxiety are associated with adaptive changes in motor learning.

Physical exercise has been reported to exert various effects on visuomotor processing and motor learning [17–20]. On one hand, researchers have concluded that exercise has a beneficial effect on the excitation and activity of the peripheral and central nervous systems [21, 22]. On the other hand, other groups have reported that intense physical activity may interfere with neural signal transmission [23–25]. The mechanism of exercise-induced effects on visuo-motor processing remains unclear [26].

The purpose of motor learning is to produce more effective movements [3]. The present study aimed to systematically investigate the effects of exercise on VMA in physical education students. Thus, we examined the effect of exercise with progressively increased physical load on consecutive stages of perceptual-motor learning. We compared the effectiveness of VMA in four subsequent trials during a complex coordination task performed in different conditions, including under conditions of progressively increased physical load, and in non-exercise resting control conditions.

Material and methods

Participants.

Twenty-seven physical education students from University of Szczecin, Poland (M ± SD age: 20.19 ± 1.4 years) participated in this study. Participants were randomly assigned to one of two group: (1) an exercise experimental group (n = 14), and (2) a non-exercise resting control group (n = 13). The local Bioethical Committee approved the research project.

Research Design.

Preliminary protocol

Participants in the experimental group completed an effort test that involved an incremental increase in intensity using a cycloergometer (Monark E834, Varberg, Sweden). The experiment began with a 10-min rest period in a reclined position. After 10 min, a blood sample was collected from a finger for biochemical determinations. Participants then completed a 5-min warm-up period at 25 watts (W). The effort-test commenced at 70 W, with 70 revolutions per min (rpm). The exercise continued with an increasing workload (20 W increments every 3 min) until refusal. During the last 15 sec of each 3-min effort at a given workload, capillary blood samples were drawn from a fingertip for enzymatic determination of blood lactate concentration (Dr. Lange Cuvette Test LKM 140, Germany). Lactate concentration was determined using miniphotometer LP 20 Plus (Dr Lange, Germany). Resting heart rate and change in heart rate during exercise were measured using a Polar S610 heart rate monitor (Polar, Finland). Oxygen consumption during exercise was estimated using an Oxycron gas analyzer (Jaeger, Germany). Individual lactate threshold was calculated using a linear regression graph log lactate and the log of effort intensity. Based on the results of the exercise test, each subject was assigned an individual workload value (W) at various levels: (1) a 40%VO2max (i.e., load value below the lactate threshold), (2) a lactate threshold range, which in the case of all participants was between 65-75% VO2max, and (3) an 80%VO2max (i.e., above lactate threshold).

The two-hand coordination test (i.e., the VMA test) included in the Vienna Test System (Schuhfried, Austria) was used to examine VMA. During the VMA test, participants used two control elements (i.e., joysticks) to move a cursor along a track shown on a monitor (see Figure 1). The cursor can be moved horizontally using one joystick, and moved vertically using the other joystick. Participants were instructed to run the track through from start to finish as quickly as possible. An error is counted each time the cursor goes off the track. The track consists of three sections of varying difficulty (circular arc, V-shape, inverted L). Speed and accuracy of the run on each track was scored, including the following variables: total mean duration [s], total mean error duration [s], and coordination difficulty [s] (i.e., time difference standardized to the length of the path between sections with or without need for coordination).

Procedure

The experiment was carried out 5 days after the effort-test that determined the maximal oxygen uptake (i.e., VO2max). The first VMA test (T1) was performed at rest. Next, all participants completed a 5-min warm-up on the cycloergometer (25 W). Participants then completed a 10-min effort at intensity below lactate threshold (i.e., 40% VO2max). The second VMA test (T2) was performed immediately after the effort test. Participants then performed a 10-min effort at lactate threshold (i.e., 60% VO2max) and after that, the third VMA test (T3) was conducted. Next, participants performed a 10-min effort at intensity above the lactate threshold (i.e., 80% VO2max), which was followed immediately by the VMT test (T4). During cycling, participants maintained a constant...
frequency of revolutions (68-72 rate per min). Heart rate was monitored throughout the experiment. For the non-exercise resting control group, four VMA test (T1-T4) were conducted, with a 10-min break between each test.

**Statistical methods**

All data are expressed as mean ($M$) ± standard deviation ($SD$). The assumption of normality was tested using the Shapiro-Wilk test. The dependent measures (i.e., total mean duration, total error duration, coordination difficulty) were analyzed separately using a two-way repeated measures analysis of variance (ANOVA) to test for significant effects of the between-subjects factor (group: experimental, control) and the within-subjects factor (test repetitions: T1, T2, T3, T4). Post hoc tests were performed, results were considered significant at $p < 0.05$, Bonferroni corrected.

**Results**

Descriptive statistics of the VMA test parameters for the experimental and control groups are presented in Table 1.

**Effects on total mean duration of visuomotor adaptability test**

The analyses of the total mean duration of VMA test revealed no significant main effect of group ($F_{(1,55)} = 0.01, p = 0.938, \eta^2_p = 0.001$), a significant main effect of test repetitions ($F_{(3,75)} = 5.14, p = 0.003, \eta^2_p = 0.17$), and a significant group x test repetitions interaction ($F_{(3,75)} = 3.54, p = 0.018, \eta^2_p = 0.12$) (Figure 1). The test repetitions factor significantly differentiated the plot of the total mean duration changes in the control group (i.e., VMA test trials at rest) as compared to the experimental group (i.e., VMA test trials in progressively increase physical effort). In the control group, the total duration of the fourth VMA test (T4) was shorter than in the initial measurement (T1) (delta: 2.275 s, $p = 0.006$). In contrast, there were no significant changes ($p > 0.05$) in subsequent VMA test trials in the experimental group.

There was a significant reduction (T1 vs. T4, $p = 0.006$) in total duration in the control group (denoted with *). In contrast, in the experimental group, the total duration did not significantly change during VMA test repetitions in exercise conditions.

**Effects on total error duration of visuomotor adaptability test**

The total error duration did not significantly differ between groups ($F_{(1,25)} = 0.39, p = 0.537, \eta^2_p = 0.02$), or vary by test repetitions ($F_{(3,75)} = 1.90, p = 0.136, \eta^2_p = 0.07$). However, there was a significant interaction between group and test repetitions ($F_{(3,75)} = 3.14, p = 0.03, \eta^2_p = 0.11$) for total error duration (Figure 2). Indeed, in the experimental group there was a tendency for total error duration to decrease after the first effort (T1), and increase after the second (T2) and third efforts (T3). In the control group, in contrast, total error duration gradually decreased over time.

**Effects on coordination difficulty of visuomotor adaptability test**

Types of variances in the coordination difficulty did not differ between the experimental and control groups.

**Table 1.** Mean, standard deviation (SD) of VMA test parameters in the experimental and control groups.

<table>
<thead>
<tr>
<th>VMA test parameters</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mean duration [s]</td>
<td>$M \pm SD$</td>
<td>$M \pm SD$</td>
</tr>
<tr>
<td>T1</td>
<td>16.58 ± 3.43</td>
<td>16.90 ± 4.18</td>
</tr>
<tr>
<td>T2</td>
<td>15.35 ± 3.63</td>
<td>15.99 ± 3.08</td>
</tr>
<tr>
<td>T3</td>
<td>15.13 ± 3.07</td>
<td>15.47 ± 2.95</td>
</tr>
<tr>
<td>T4</td>
<td>16.32 ± 4.11</td>
<td>14.63 ± 3.12</td>
</tr>
<tr>
<td>Total error duration [s]</td>
<td>$M \pm SD$</td>
<td>$M \pm SD$</td>
</tr>
<tr>
<td>T1</td>
<td>0.67 ± 0.42</td>
<td>0.65 ± 0.50</td>
</tr>
<tr>
<td>T2</td>
<td>0.47 ± 0.37</td>
<td>0.53 ± 0.40</td>
</tr>
<tr>
<td>T3</td>
<td>0.48 ± 0.23</td>
<td>0.47 ± 0.29</td>
</tr>
<tr>
<td>T4</td>
<td>0.78 ± 0.32</td>
<td>0.37 ± 0.22</td>
</tr>
<tr>
<td>Coordination difficulty [s]</td>
<td>$M \pm SD$</td>
<td>$M \pm SD$</td>
</tr>
<tr>
<td>T1</td>
<td>2.02 ± 0.69</td>
<td>2.24 ± 0.64</td>
</tr>
<tr>
<td>T2</td>
<td>1.94 ± 0.65</td>
<td>2.10 ± 0.48</td>
</tr>
<tr>
<td>T3</td>
<td>1.91 ± 0.47</td>
<td>2.00 ± 0.57</td>
</tr>
<tr>
<td>T4</td>
<td>2.00 ± 0.33</td>
<td>1.88 ± 0.48</td>
</tr>
</tbody>
</table>
The main finding in our study was that exercise did not improve VMA, as compared to motor practice alone. Increased physical effort did not cause significant changes in the speed and accuracy of VMA in the experimental group. We observed only a tendency for the direction and size of changes that depended on the intensity

Discussion

The main finding in our study was that exercise did not improve VMA, as compared to motor practice alone. Increased physical effort did not cause significant changes in the speed and accuracy of VMA in the experimental group. We observed only a tendency for the direction and size of changes that depended on the intensity
of the physical effort. Specifically, as the intensity of physical effort increased, the speed and accuracy of VMA improved until a critical value of exercise intensity was reached. Following the critical value, speed and accuracy parameters worsened. However, the results of the experimental versus control group showed significantly different plots in terms of variation in the recorded parameters. Indeed, total test duration was significantly better after four repetitions in the control group. This was in contrast to the experimental group, which tended to show a worsening of parameters after four repetitions (Figure 2). A similar tendency was observed for total error duration (Figure 3).

Exercise has an influence on human visuomotor processing and results of several studies indicate that the motor learning process can be facilitated. For instance, Statton et al. [20] investigated the effects of acute bouts of moderate intensity aerobic exercise on the acquisition and retention of a new motor skill (i.e., a sequential visual isometric pinch task). The investigators found that aerobic exercise led to significantly greater performance on the motor skill learning, but no effects on results of a retention test. Perini et al. [22] demonstrated that aerobic exercise can enhance the ability of young adults male to acquire skills during an orientation discrimination task that involved primary visual cortex activity, and also during a simple thumb abduction motor task that relies on primary motor cortex activity. In light of these results, the authors suggested that moderate intensity exercise can enhance brain plasticity. There is also evidence that brain-derived neurotrophic factor (BDNF) moderates the effects of physical activity on the resultant cognitive and neuroplastic changes [26]. Furthermore, various experimental studies have concluded that acute and long-term participation in moderate-intensity exercise can enhance working memory, short- and long-term memory, and executive function [18, 19, 27], which can promote motor learning effects. It is generally confirmed that exercise at higher intensity can disrupt visuomotor processing, which cause significant effects on attentional, perceptual, and working memory processing by increasing neural blood-glucose levels [28]. Specifically, enhancements were noted in noradrenaline-modulated cortical processing, which has a crucial influence on physiological arousal, cognition, and attention [16, 29, 30].

Relevant to our results, several experimental studies applied visuomotor tasks that require tracking patterns presented on a screen and did not find improved learning and retention of motor accuracy after moderate and intensity exercise. For example, in Snow et al. [31], participants completed a procedure that included aerobic exercise followed immediately by practice with a novel tracking motor task. Exercise consisted of 30 minutes of continuous cycling at 60% peak O2 uptake. There were no differences in visuomotor skill acquisition between rest and after exercise (p = 0.066), and for retention test (p = 0.761) that occurred 24 hours after the intervention. Similarly, Singh et al. [32] used a moderate-intensity exercise protocol to assess response time during a bimanual task and did not obtain any significant differences between the exercise and control groups. A recent study by Stranda et al. [33] found no effects of moderate-intensity aerobic exercise (i.e., 65 % HRmax) conducted before each practice trial (3x/ week for 4 weeks) on speed and accuracy parameters in a novel keyboard typing task. Similar to our procedure, the experiments include both an exercise and a non-exercise resting control group. All participants in the Standa et al. [33] study showed an improvement in both speed and accuracy during the keyboard typing task. However, the range of improvement on both speed and accuracy task parameters did not significantly differ between the exercise and control groups in the retention test.

In our opinion, it is possible that intensity is a key modulator of the effects of exercise on changes in complex VMA. Moreover, we argue that the learning of more complex coordination tasks are not facilitated by high intensity exercise-induced fatigue [28]. For example, Hu et al. [34] investigated the effects of muscle fatigue (i.e., continuous submaximal pinch strength) on coordination of force directions during precision grip. Muscle fatigue interfered with grasping stability by decreasing the average coordination angle across the thumb and index finger, and by reducing the projection angle of the index finger in the ipsilateral hand. Moreover, fatigue may influence sensorimotor integration, thereby causing a reduction in movement precision [35]. Due to fatigue, the central nervous system may not adapt to the altered relation between neural output and sensory feedback. In our study, this lack of adaptation may have led to the observed variation in the experimental and control groups during the T4 task, wherein the experimental group performed effort above lactate threshold (i.e., 80% V\textsubscript{O}_{2\text{max}}). Previous results from electrophysiology studies indicate that exercise-induced fatigue can affect different stages of information processing, i.e. sensory, central, and effector [25, 36, 37].

Conclusions
Results of the present study suggest that high intensity exercise can disrupt visuomotor processing during complex skill acquisition. This observation has important implications for the methodological approach of a physical education study program. These findings highlight the interplay between exercise intensity and motor control and learning, which in turn, has practical implications for developing and improving motor training and physical education programs.

Conflicts of Interest
The authors declare no conflict of interest.
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