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
Abbreviated key title: Phys. educ. stud.

ISSN 2308-7250 (English ed. online)

Founders: Iermakov Sergii Sidorovich (Ukraine); (doctor of pedagogical sciences, professor, Department of Physical Education, Kharkov National Pedagogical University).


Address of editorial office:
P.O.Box 11135, Kharkov-68, 61068, Ukraine.
Tel. +38 099 430 69 22
e-mail: sportart@gmail.com

Frequency - 6 numbers in a year.

http://www.sportedu.org.ua

Journal is ratified Ministry of Education and Science of Ukraine (online):
physical education and sport: (11.07.2019, № 975, “A” - 24.00.01, 24.00.02, 24.00.03; 017); (13.03.2017, № 374).
pedagogical sciences: (07.05.2019, № 612, “A” - 13.00.02; 011, 014); (22.12.2016, № 1604).

Indexing:

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Do e-athletes move? A study on physical activity level and body composition in elite e-sports

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

Abstract

Purpose: The aim of this study is to determine the effect of e-sports on physical activity level and body composition.

Material: The athletes who participated in the study were 19.92± 2.21 years of age, 1.73±0.04 m body height and 78.35±6.52 kg body weight. A total of 137 athletes participated in the study, including 27 from Turkey, 47 from South Korea and 63 from the United States (USA). The data was collected by e-mail from the sports clubs. The athletes who representing their country in international competitions involved in the study. The data obtained were evaluated in the SPSS program.

Results: According to the findings of the study, the body mass index (BMI) of e-sport athletes is 26.03±1.85, the number of physical activity steps is 6646±3400 and the daily e-sport hours are 9.34±1.12. The BMI was determined as USA 26.12, South Korea 26.02 and Turkey 25.84 respectively. The number of physical activity steps was identified as 5255 steps in the US, 7785 steps in South Korea and 7909 steps in Turkey. The daily e-sports hour is set at US 9.63 hours, Turkey 9.29 hours and South Korea 8.97 hours. In comparison of country-based athletes, there was a significant difference between physical activity level and daily e-sports hours at p<0.05. The value of BMI is not different. Although it is not statistically related to the physical activity level and BMI. There was no statistically significant relationship between daily e-sports hours and BMI and physical activity step counts. However, as the time of e-sports increases, BMI increases and the number of physical activity steps decreases.

Conclusions: As a result it is seen in the findings of the research that athletes dealing with e-sports are included in the fat group as a body composition and their daily physical activity steps are low. In addition, according to the results of the research, e-sports are thought to have negative effects on physical health. Thanks to the physical activity programs to be applied to these athletes, it is thought that their body composition and physical activity levels can be improved.

Keywords: e-sports, physical activity, body composition.

Introduction

In recent years, a new concept called e-sports has entered our lives. e-Sports is defined as a sport where people from all over the world can meet and play via the internet, or people from different parts of the world can meet and play through international big electronic sports organizations organized at certain times. Most people are not yet aware of the concept of e-sports. But e-sports events also have star players, fan base, teams, jerseys and leagues. Only all events take place online or on local networks [1].

Today, many national and international e-sports tournaments are held. These tournaments have made a great contribution to the development and expansion of electronic sports and athlete concepts by providing players with a professional environment in which to compete. The number of official and private tournaments held every day and the interest shown to these tournaments is increasing, and accordingly, e-athletes are allowed to perform this as a professional profession. Nowadays, e-sports tournaments have become big events, with prizes of up to millions of dollars and thousands of viewers watching live broadcasts in arenas and hundreds of thousands on the internet. Hundreds of e-sports clubs have been established that operate in different areas of e-sport and are gathered under the umbrella of various companies and sponsors, and these clubs train regularly, compete in various leagues and tournaments, and strengthen their staff by making transfers when necessary. In addition, e-athletes in various countries of the world are now counted as athletes and have started to receive athlete licenses. A research in recent years has shown that e-sports has increased as well as its audience [2]. With each passing year, the e-sports economy is growing rapidly [3], and experts say that it will grow even bigger, especially with the covid-19 outbreak occurring in 2020.

Despite all this popularity, e-sports has some negative physical and spiritual aspects, because the players mostly do not even act [4]. Also, e-sports tournament awards have reached surprising amounts in recent years. For this reason, e-athletes started to spend more time at the computer [5]. Thus, unhealthy changes such as physical inactivity and increase in body composition occur in these athletes. The main difference between e-sports and traditional sports is physical mobility. The most alarming
thing about e-sport is that players sit at a computer for hours. Rudolf, who has been studying e-sport performance and health at the Cologne sports academy for 8 years, states that amateur or professional e-athletes play an average of 24-25 hours a week [6]. In addition, during the tournament players stated that they stayed in the seat for more than 12 hours daily [7].

The aim of this study is to determine the effect of e-sports on physical activity level and body composition.

This section contains information from studies on how e-sport affects players and what the potential health effects are. Selected studies highlight the negative effects of e-sport on health from different perspectives.

It is stated that e-sports players are not physically active due to sedentary time for a long time. In some studies, it is claimed that long-term sedentary life will result in obesity, cardiovascular disorders, chronic diseases, mental illnesses, weakening in motor skills and low cognitive development [8, 9]. DiFrancisco-Donoghue et al. [10] reported that players complain more about physical health, eye strain, neck and back pain rather than wrist and hand pain. In addition, while talking about the effects of e-sports on health [11, 12], potential “addiction” and “psychological disorders” should not be ignored [13, 14]. As a different approach; such addictive e-sports games can be compared to gambling, alcohol or smoking. With esports games, gambling addiction increases and it is stated that esports players experience stress during competition activities [15, 16].

Research shows that sitting 6 hours a day for two weeks in a row can increase bad cholesterol levels. When the muscles begin to degenerate [17, 18], they prevent blood flow to the heart [19, 20] and increase the risk of weight gain [21, 22] and heart disease [23, 24]. Rudolf et al [25] even states that the exercise performed after the sedentary period does not compensate for the damage caused by excessive sitting. In addition, the study is stated that these observations are confirmed and “players must move between the games and leave the screen for a while”.

**Purpose.** The aim of this study is to determine the effect of e-sports on physical activity level and body composition.

**Material and methods**

**Participants**

The athletes who participated in the study had an average body length of 19.92±2.21 years old, a height of 1.73±0.04 m and a body weight of 78.35±6.52 kg. A total of 137 male athletes participated in the study, including 27 from Turkey, 47 from South Korea and 63 from the United States (USA). The data was collected by e-mail from the sports clubs. The athletes who representing their country in international competitions involved in the study. In addition, having been licensed in e-sports and representing the country in international competitions has been determined as the criteria for participation in the research.

**Determination of sample size**

G*Power 3.1.9.4 software was used to determine the number of samples in the study. Power analysis was conducted in the light of available data from similar studies in the literature. In the power analysis, the Alpha meaning level (Type I error) was taken as α=0.05 and the Power Value (Type II error) was taken as β=0.95. In order for the validity of our study to be high, the width of the effect was taken as |ρ|=0.1. As a result of these, the number of people to be included in the study was determined to be at least 64.

**Collection of Data**

**Age, body height, body weight, number of physical activity steps and daily e-sport times**

The data obtained were evaluated in the SPSS 23 package program. Arithmetic mean and standard deviation values of age, height of body weight were calculated according to countries. One-way variance analysis of BMI, physical activity level and daily e-sports hours by country was compared with Anova. Tukey HSD test [28, 29] was used to determine the difference in case of Anova result. In addition, correlation analysis was applied to determine the relationship between variables.

**Results**

The participants in the study were 19.92±2.21 years of age, 1.73±0.04 m height length and 78.35±6.52 kg body weight (shown in Table 1).

The BMI value of e-sport athletes is 26.03±1.85 kg/m², the number of physical activity steps is 6646±3400 steps and the daily e-sport hours are 9.34±1.12 hours. Body mass index value was determined as USA 26.12 kg/m², South Korea 26.02 kg/m² and Turkey 25.84 kg/m², respectively. The number of physical activity steps was determined as 5255 steps for USA, 7785 steps for South Korea and 7909 steps for Turkey. Daily e-Sports time was determined as 9.63 hours for USA, 9.29 hours for Turkey and 8.97 hours for South Korea. In comparison of country-based athletes, there was a significant difference between physical activity level and daily e-sports hours at p<0.05. There was no difference in BMI values (Table 2).
Although there is no statistically significant relationship between physical activity level and BMI, it is seen in the table that this relationship is negative. There was no statistically significant relationship between daily e-sports hours and BMI and physical activity step numbers. However, as the time of e-sports increases, BMI increases and the number of physical activity steps decreases (Table 3).

Discussion

Long-term sedentary behavior is considered a risk factor for many chronic diseases [30, 31] and mortality due to these diseases [32, 33]. Because of the nature of e-sports, time is spent in front of the screen for a long time, and the risks of disease due to physical inactivity increase [6, 34]. E-Sports are reported to have health advantages and disadvantages [35]. However, the main disadvantage is physical inactivity and the risk of obesity. Our study is important because it aims to reveal these disadvantages.

In addition, with the rise of the e-game industry, the concept of “professional game career” emerged. Professional e-sports players have the same athlete status as people in other sports. The gaming industry is now a sports event and the rewards reaching million dollars have made the professional gaming career even more attractive. The interest in traditional sports has decreased and interest in e-sports has increased. Today, some of the young people are thinking about earning their lives by playing games or publishing their games. Since e-sports is a type of sports sitting by the screen, sedentary life time

**Table 1. Average age, height and body weight values of participants by country**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Countries</th>
<th>N</th>
<th>x±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>Turkey</td>
<td>27</td>
<td>20.14±2.29</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>47</td>
<td>19.14±2.18</td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>63</td>
<td>20.41±2.06</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>137</td>
<td>19.92±2.21</td>
</tr>
<tr>
<td>Length (m)</td>
<td>Turkey</td>
<td>27</td>
<td>1.71±0.03</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>47</td>
<td>1.70±0.03</td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>63</td>
<td>1.76±0.04</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>137</td>
<td>1.73±0.04</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>Turkey</td>
<td>27</td>
<td>75.85±6.24</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>47</td>
<td>75.91±5.23</td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>63</td>
<td>81.23±6.40</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>137</td>
<td>78.35±6.52</td>
</tr>
</tbody>
</table>

**Table 2. Comparison of participants’ BMI, physical activity level and daily e-sports hours by country**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Countries</th>
<th>N</th>
<th>x±SD</th>
<th>F</th>
<th>p</th>
<th>Tukey HSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Mass Index (BMI)</td>
<td>Turkey</td>
<td>27</td>
<td>25.84±2.23</td>
<td>.213</td>
<td>.808</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>47</td>
<td>26.02±1.94</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>63</td>
<td>26.12±1.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>137</td>
<td>26.03±1.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Activity Level</td>
<td>Turkey</td>
<td>27</td>
<td>7909±2982</td>
<td>11.238*</td>
<td>.000</td>
<td>USA- Turkey*</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>47</td>
<td>7785±3018</td>
<td></td>
<td></td>
<td>USA- South Korea*</td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>63</td>
<td>5255±3350</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>137</td>
<td>6646±3400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily e-Sports (hour)</td>
<td>Turkey</td>
<td>27</td>
<td>9.29±.82</td>
<td>4.848*</td>
<td>.009</td>
<td>USA- South Korea*</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>47</td>
<td>8.97±1.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>USA</td>
<td>63</td>
<td>9.63±1.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>137</td>
<td>9.34±1.12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3. Correlation results between participants’ research variables**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Body weight (kg)</th>
<th>BMI (kg/m²)</th>
<th>Physical Activity Level (Step)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index (BMI)</td>
<td>.735**</td>
<td>- .080</td>
<td>-.156</td>
</tr>
<tr>
<td>Physical Activity Level</td>
<td>-.080</td>
<td>-.013</td>
<td></td>
</tr>
<tr>
<td>Daily e-Sports (hours )</td>
<td>.074</td>
<td>.033</td>
<td>-.156</td>
</tr>
</tbody>
</table>

*p<0.05
has started to increase. With the sedentary life, people started not moving and gaining weight.

Daily e-sports playing or training times vary in the literature. In our study, daily e-sports duration was determined as 9.34±1.12 hours. The daily e-sports duration is approximately 5-6 hours. The time difference between our study and the literature is thought to be due to players doing e-sport professionally or recreationally. Mustafaoglu et al. [36] found that e-athletes had weekly offline training time of 17, 10±15.40 hours and weekly online training time of 25.10±23.80 hours and weekly total training time of 42.09±34.8 hours. It was found that around six hours of e-sports were performed when it was calculated on a daily basis. In their study with elite e-athletes, Kari & Karhulahti [37] stated that the daily e-sports duration was 5.28 hours. Rudolf et al [6] set the players’ daily e-sports time at 7.7 hours.

BMI’s of e-athletes subject to our study were determined to be 26.03±1.85 kg/m². This finding is indicated as obesity according to BMI assessment criteria [26]. In their study on e-sports players, Rudolf et al [6] found BMI to be in the 24.6 ± 4.8 kg/m² and fat group. Mustafaoglu et al. [36] determined the BMI of e-sports players to be 24.3±5.1 kg/m². It is stated that body fat tissue increases with the increase of sedentary time [9, 16] and this time will cause obesity formation with more than 8 hours, thus many diseases will occur [38].

Physical inactivation and sedentary behaviors were reported in athletes in association with e-sports [8, 10], while some studies have reported that these athletes are physically active and healthy [39, 40]. In our study, physical activity levels of e-sports players were found to be physically poor with 664±3400 steps according to Tudor-Locke & Bassett [41] physical activity level Determination criteria. Despite not included in the subject of our study, many studies have reported that physically sedentary e-athletes feel pain in different parts of their bodies [10]. Furthermore, Kari & Karhulahti [37] stated that more than half (55.6%) of elite e-athletes believe that e-sport performance will improve by integrating physical activity into the exercise program.

**Conclusion**

As a result, BMI increases as the level of physical activity decreases, BMI increases as the daily e-sport hours increase, and the level of physical activity decreases. It is thought that physical activity or training programs to be implemented with e-sports will increase the level of physical activity, and thanks to this, BMI will remain within the normal limits.

**Acknowledgements**

This study was written by abridging Akan Bayrakdar, Yağmur Yıldız and Işık Bayraktar. No grants or financial aids were taken in this Project.

**Financial support**

There is no financial support.

**Conflict of interest**

The authors declare no conflict of interest.

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Cite this article as:
https://doi.org/10.15561/20755279.2020.0501

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Received: 17.06.2020
Accepted: 12.08.2020; Published: 30.10.2020
Relationships between body composition and anaerobic performance parameters in female handball players

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

Abstract

Purpose: The purpose of this study was to investigate of the relationships between total/segmental body composition and anaerobic performance parameters in female handball players.

Material: Voluntary 16 women handball players (age= 19.6±2.6years, body height= 168.0±5.5cm, body weight= 64.7±10.7kg), trained last 3 years, were participated to the study. Twelve of them were students from Faculty of Sports Sciences. All measurement and tests were completed in the week right after Turkish Women Handball 1th League. Total and segmental body composition parameters (body fat percentage, body fat mass, lean body mass, leg fat percentage, leg fat mass, lean leg mass, torso fat percentage, torso fat mass, and lean torso mass) of each player were evaluated with dual-energy X-ray absorptiometry method. Squat jump test for explosive power, countermovement jump test for elastic (reactive) power, and Wingate test for anaerobic power (WAnT AP) and anaerobic capacity (WAnT AC) were used. Relationships of total/segmental body composition parameters with jump and anaerobic power-capacity parameters were analysed with Pearson correlation and the probability level was set to p<0.05.

Results: As a result of statistical analyses, there were negative relationships (p<0.05) between anaerobic performance parameters (countermovement jump and anaerobic power-capacity) and total/segmental body composition parameters except for lean body mass, lean leg mass, and lean torso mass.

Conclusions: Total/segmental body composition parameters based on endomorphy had negative effects on explosive power, elastic power, WAnT AP and WAnT AC. It is suggested that coaches should not allow female handball players to rise in ectomorphy for the anaerobic performance loss in the season finale.

Keywords: handball, segmental body composition, squat jump, counter movement jump, anaerobic power-capacity

Introduction

Body composition analysis is one of the common evaluation methods in professional sport, allowing changes in anthropometric and physiological status to be monitored [1]. Accordingly, an accurate body composition assessment is necessary for coaches, strength and conditioning specialists and athletes. Body composition is well known to be relevant to performance in with special attention being paid to the total and regional fat and lean mass proportions. Over the last several years, dual-energy X-ray absorptiometry (DEXA) has become the gold standard for body composition analysis, allowing reproducible estimates of total and segmental body composition parameters (body fat percentage, body fat mass, lean body mass, leg fat percentage, leg fat mass, lean leg mass, torso fat percentage, torso fat mass, and lean torso mass) [2].

Team handball is an intermittent team sport, characterized by high-intensity explosive movements such as sprints, jumps, throws and physical confrontations, which are interspersed with periods of low-intensity activities such as standing, walking and jogging [3]. Success in team handball is determined by a variety of technical and tactical, mental, anthropometric and physical performance characteristics [3, 4]. Several studies have reported that, in handball players, in addition to the technical skills and tactics, the anthropometric characteristics, and highs levels of force, and power constitute the determining factors for the competitive success [4, 5]. Testing and evaluating for performance are the main subjects of sports sciences studies because they play key roles in training and competition [6]. Sportive performance is influenced by the sex and age of the players but, relative to those of male players, there are few studies of female players.

Sportive conditioning is usually divided into 3 training phases (pre-season, in-season, and post-season). Pre-season training aims at maximizing the physical and fitness parameters before the start of the competitive season; in-season, the goal is to maintain the physical and fitness levels achieved during the pre-season. It may be suggested that physical status should peak by the end of the pre-season phase and be maintained throughout the entire competition period [7].

Information on the variations in anthropometry of handball players over the competitive season is quite limited. Monitoring the body composition of handball players throughout a competition cycle could provide valuable information to create an anthropometric profile of each individual player. This can also help prevent changes in body composition that may be detrimental to performance, and provide reference body composition values that can be targeted after a period of detraining

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doi:10.15561/20755279.2020.0502
or injury, and act as an indicator of physiological status and training. Actually, the role of body composition in functional performance of association male handball players has been extensively investigated. However, to our knowledge, very few studies have analysed the relationships between anaerobic power-capacity and jump ability with body composition in female handball players. The purpose of this study was to investigate the relationship between total/segmental body composition and anaerobic performance parameters in female handball players.

Material and Methods

Participants

Volunteered 16 female handball players (age= 19.6±2.6years, body height= 168.0±5.5cm, body weight= 64.7±10.7kg) from the Super League Team participated in this study. Twelve of them were students from Faculty of Sports Sciences. All participants performed regular handball training at least six times a week (including a competitive game once a week) and strength/power training at least three times a week for a minimal period of 5-years. All procedures of the study were explained to the subjects. A written informed consent was obtained from each participant to participate in the study in accordance with the ethical standards of the Helsinki Declaration. The study was approved by the Clinical Research Ethics Boards of Osmangazi University. Participants were told not to take any drugs, coffee or alcohol and not to be physically active at least 24 hr before test day.

Procedures

All measurement and tests were completed in the week right after Turkish Women Handball 1st League after the laboratory visit for 120 min of total tests at a specific time (09:00-11.00) of days on three occasions to complete familiarization and main trials. Subjects were measured with dual-energy X-ray absorptiometry method for total and segmental body composition parameters (body fat percentage, body fat mass, lean body mass, leg fat percentage, leg fat mass, lean leg mass, torso fat percentage, torso fat mass, and lean torso mass). They took part in squat jump test (SJ) for explosive power, countermovement jump test (CMJ) for elastic (reactive) power, and Wingate anaerobic test (WAnT) for anaerobic power (WAnT AP) and anaerobic capacity (WAnT AC).

Anthropometric Characteristics

Body weight was measured to nearest +0.1kg with a scale (SECA, Hamburg). Body height was measured to the nearest +0.1cm between head’s vertex point and foot using a wall mounted stadiometer (Holtain Ltd, UK) after a deep inspiration. Each subject was only her athletic body suit and barefoot. Whole body and regional composition (body fat percentage, body fat mass, lean body mass, leg fat percentage, leg fat mass, lean leg mass, torso fat percentage, torso fat mass, and lean torso mass) was evaluated by means of DEXA using a total body scanner the Dual-energy X-ray absorptiometry (Lunar Prodigy Pro; GE, Healthcare, Madison, WI, USA) according to the manufacturer’s procedures. The scanner calibration was completed using phantoms as per manufacturer’s standard directions in the morning before the measurements. All scanning and analyses were performed by the same operator to ensure consistency. Prior to the assessment all subjects were advised not to wear any jewellery or to have any metal on their bodies during the scanning process. In order to ensure a standard supine position was adopted during the scans, the subjects’ knees and ankles were tied with a Velcro strap while their arms were extended by their sides. Typical duration of the examinations was from 6 to 8 min, depending on the height of the subject.

Wingate Anaerobic Test (WAnT)

The WAnT (Monark Exercise AB, Sweden) was performed on a cycle ergometer (894 Ea Peak Bike, Monark Exercise AB, Sweden), for 30 s, at an “all out” pace. The ergometer was calibrated, and seated height was adjusted for each subject’s leg length. Each subject pedalled up to his maximum rpm level at least 3 times during the 5 min warm-up period (at 60-70 rpm) and then a 5-min recovery was followed. The researcher placed the appropriate amount of weight (between 1 kg and 100 gr) on the weight carriage. Subjects were instructed to begin pedalling with all resistance of the flywheel until they reached their maximum rpm within 4 s. At this point, immediately the predetermined fixed resistance (75 gr per kg of body weight) was released to the flywheel and remained there till the end of the test [8]. Players were motivated in all test period. WAnT AP was the highest power output in 5s interval of the test. WAnT AC was the mean power output in 30 s test. WAnT AP and WAnT AC were expressed as W.kg⁻¹ for statistical analysis.

Vertical Jump Measurements

The subjects performed SJ and CMJ tests using by a jump test device (Smartjump, Fusion Sport Pty Queensland, Australia) as described Kale et al. (9). Each subject had a 15-min warm-up including self-paced running, calisthenics and flexibility exercises before the tests. Subjects flexed the knees for SJ until a comfortable starting position, semi-squatting position occurred normally at a knee angle of about 85 degrees [10] without a preliminary downward movement. Each subject maintained his posture at least 2 seconds, which prevented the pre-stretching of muscles from any preliminary downward movement before SJ. CMJ was started from an upright standing position following a preliminary downward movement by flexing the knee approximately to the same knee angle as SJ starting position. Each subject performed 2 attempts for each jump test from the starting position and landed on switching mat with the legs kept straight and hands kept on the hips to provide standardization. One-minute rest period was given after each attempt. To prevent possible positional differences in each vertical jump test, the subjects were instructed to take off from and land on the switching mat in the same position and place. The best attempt expressed in cm for each jump test was used for the statistical analysis.

Statistical Analyses

SPSS 18 software (SPSS Inc., Chicago, IL, USA)
was used to analyse statistically the data. Shapiro-Wilk normality test was used to test of normality. All variables were distributed normally (p>0.05). Data are presented as mean and standard deviation (mean±SD). Relationships of total/segmental body composition parameters with jump and anaerobic power-capacity parameters were analysed with Pearson correlation analyses. Statistical significance was set to a probability level of p < 0.05.

**Results**

The descriptive statistics of physical and body composition parameters are presented in Table 1. The results of anaerobic performance tests are also presented in Table 2. Additionally, the correlation coefficients among the measured parameters are shown in Table 3. As a result of statistical analyses, CMJ and WAnT AC had only negative relationships (p<0.05) with body fat percentages, body fat mass, leg fat percentages, leg fat, torso fat mass, lean torso mass except for lean body mass, lean leg mass, lean torso mass. SJ and WAnT AP had no significant correlations with total/segmental body composition parameters.

Table 1. The descriptive statistics of physical and total/segmental body composition parameters (n=16). Data are reported as mean±SD.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.6±2.6</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>168.0±10.7</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>64.7±5.5</td>
</tr>
<tr>
<td>Body fat percentage (%)</td>
<td>32.3±4.9</td>
</tr>
<tr>
<td>Body fat mass (kg)</td>
<td>20.0±6.6</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>40.6±4.5</td>
</tr>
<tr>
<td>Leg fat percentage (%)</td>
<td>3.6±0.4</td>
</tr>
<tr>
<td>Leg fat mass (kg)</td>
<td>8.6±2.5</td>
</tr>
<tr>
<td>Lean leg mass (kg)</td>
<td>14.8±1.9</td>
</tr>
<tr>
<td>Torso fat percentage (%)</td>
<td>29.6±5.7</td>
</tr>
<tr>
<td>Torso fat mass (kg)</td>
<td>8.9±3.4</td>
</tr>
<tr>
<td>Lean torso mass (kg)</td>
<td>20.3±2.1</td>
</tr>
</tbody>
</table>

Table 2. The results of anaerobic performance tests (n=16). Data are reported as mean±SD.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SJ (cm)</td>
<td>22.9±3.82</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>24.4±3.69</td>
</tr>
<tr>
<td>WAnT AP (Watt.kg⁻¹)</td>
<td>6.80±1.02</td>
</tr>
<tr>
<td>WAnT AC (Watt.kg⁻¹)</td>
<td>5.25±1.29</td>
</tr>
</tbody>
</table>

Notes: SJ= Squat Jump; CMJ= Countermovement Jump; WAnT AP= Wingate Anaerobic Test Anaerobic Power; WAnT AC= Wingate Anaerobic Test Anaerobic Capacity.

**Discussion**

The primary result of the present study demonstrated that the end of the season led to significant negative body composition relationships with CMJ and WAnT AC. Additionally total/segmental body composition parameters had no significant relationship with SJ and WAnT AP. Due to the increase in the body fat of female handball players, this study result indicated that some performance parameters decreased at the end of the season.

There were some studies on monitoring the anthropometry and body composition of female handball players throughout the in-season. Granados et al. [11] were studied to examine the effects of an entire season on anthropometric characteristics in 16-elite first league Spanish female handball players. The results showed that, over the season, significant increases were occurred in fat-free mass (1.8±1.2%) and a significant decrease in body fat percentage (9.0±8.7%). Similar to this study, Milanese et al. [7] reported that the total body mass and lean body mass were unchanged. However, they stated that body fat mass and body fat mass percentage were slightly decreased (-2.24% and 0.40%, respectively) over the competitive phase in forty-three Caucasian female handball players. It indicates that female handball players who developed larger decreases in body fat percentage, showed larger decreases in maximal strength or muscle

Table 3. Relationships between total/segmental body composition and anaerobic performance parameters on female handball players

<table>
<thead>
<tr>
<th>Body Composition Parameters</th>
<th>Anaerobic Performance Parameters</th>
<th>SJ</th>
<th>CMJ</th>
<th>WAnT AP</th>
<th>WAnT AC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>r</td>
<td>p</td>
<td>r</td>
<td>p</td>
</tr>
<tr>
<td>Body fat percentage</td>
<td></td>
<td>0.114</td>
<td>0.674</td>
<td>-0.607*</td>
<td>0.013</td>
</tr>
<tr>
<td>Body fat mass</td>
<td></td>
<td>0.160</td>
<td>0.555</td>
<td>-0.579*</td>
<td>0.019</td>
</tr>
<tr>
<td>Lean body mass</td>
<td></td>
<td>0.018</td>
<td>0.948</td>
<td>-0.165</td>
<td>0.543</td>
</tr>
<tr>
<td><strong>Leg fat percentage</strong></td>
<td></td>
<td>0.176</td>
<td>0.515</td>
<td>-0.672**</td>
<td>0.004</td>
</tr>
<tr>
<td>Leg fat mass</td>
<td></td>
<td>0.204</td>
<td>0.448</td>
<td>-0.539*</td>
<td>0.031</td>
</tr>
<tr>
<td>Lean leg mass</td>
<td></td>
<td>0.081</td>
<td>0.766</td>
<td>-0.044</td>
<td>0.873</td>
</tr>
<tr>
<td><strong>Torso fat percentage</strong></td>
<td></td>
<td>0.040</td>
<td>0.884</td>
<td>-0.530*</td>
<td>0.035</td>
</tr>
<tr>
<td>Torso fat mass</td>
<td></td>
<td>0.150</td>
<td>0.578</td>
<td>-0.607*</td>
<td>0.013</td>
</tr>
<tr>
<td>Lean torso mass</td>
<td></td>
<td>0.141</td>
<td>0.602</td>
<td>-0.379</td>
<td>0.148</td>
</tr>
</tbody>
</table>

Notes: *p<0.05; **p<0.01; SJ= Squat Jump; CMJ= Countermovement Jump; WAnT AP= Wingate Anaerobic Test Anaerobic Power; WAnT AC= Wingate Anaerobic Test Anaerobic Capacity.
power of the upper and lower extremities. Decreases in muscle power were associated with decreases in body fat observed in elite male handball players and considered disadvantageous for handball playing [11].

Anthropometric characteristics play a highly important role for the successful sportive performance in women handball players [12]. Vertical jumping ability is also an essential component in women handball, and it is frequently displayed in both defensive actions (e.g., blocking and stealing) and offensive movements (e.g., passing and shooting) [13]. However, the most studies to assess the relationships between anthropometric characteristics and performance parameters in team handball had focussed on throwing velocity [3, 11, 14, 15].

The present study showed that CMJ were negatively correlated with body fat percentages and body fat mass, leg fat percentages and leg fat mass, and torso fat percentages and torso fat mass. In addition, there were no significant correlations between SJ with total/segmental body composition parameters. Contrary to the present study, Moss et al. [3] found that body mass was positively correlated to maximal and average power for CMJ ($r = 0.77$ and $0.69$; $p<0.05$, respectively) in female handball players. They also reported that higher skinfold values (body fat percentage) were found to negatively affect both maximal and average CMJ height ($r = -0.56$ and $-0.57$; $p<0.05$, respectively). The CMJ height were also negatively affected by higher body fat values that is showed the importance of team handball for the key performance determinant [3]. Similar to this study, Ciplak et al. [16] found that there was a positive relationship between fat free body mass and CMJ ($r= 0.35$; $p<0.05$) in Turkish female handball players. Unlike the current study, Saavedra et al. [17] didn’t found a significant relationship between CMJ and body composition in female handball players. The current study’ results showed that increase in total/segmental body fat percentage and body fat mass negatively affected to CMJ. Therefore, the decrease in fat mass may substantially improve elastic (reactive) power. Moss et al. [3] recommended that greater gluteal and calf girths were also beneficial for CMJ, suggesting that increased muscle mass in these areas contribute to movements involving a strength and power component.

The other physical parameters tested in this study were WAnT AC and WAnT AP. There were no significant relationships between WAnT AP and total/segmental body composition parameters but WAnT AC had negative significant relationships ($p<0.05$) with body fat percentages, body fat mass, leg fat percentages, leg fat mass, torso fat percentages, and torso fat mass. These results showed that increase in total/segmental body fat percentage and fat mass negatively affected to WAnT AC. In literature, there were similar results in Perez-Gomez et al., [18] and Nkolaidis [19]. Nkolaidis [19] found that WAnT AC had negative correlations with body mass and body fat percentage ($r = -0.40$, $r = -0.42$, $p<0.05$, respectively) in-season in female volleyball players. Perez-Gomez et al. [18] also reported that a significantly positive relationship between WAnT AC and lean leg mass in physical education students ($r= 0.90$, $p<0.01$). Contrary to the present study, Kucukkubas et al. [20] found that there was no relationship between body fat percent and WAnT (WAnT AP and WAnT AC) for female athletes (zumba, cross country runner, basketball, football, tennis, volleyball).

**Conclusion**

In conclusion, total/segmental body composition parameters based on endomorphy had negative effects on explosive power, elastic power, AP and AC. It is suggested that coaches should not allow female handball players to rise in ectomorphy for the physical performance loss in the season finale.

**Acknowledgements**

This study was supported by Anadolu University Scientific Research Projects (Project number: 1501S036). This study was presented as an oral presentation “Relationships of segmental and total body composition analysis with jumping, speed, agility, and anaerobic power-capacity parameters in-season in women handball players” in International Congress of Athletic Performance & Health in Sports. Special thanks are also given to Women Handball Super League Team Players of Anadolu University Youth and Sports Club to participate in the study.

**Conflicts of Interest**

The authors declare no conflicts of interest.
References


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Cite this article as:

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Received: 25.06.2020
Accepted: 12.08.2020; Published: 30.10.2020
The effects of 5x5 exercises on a quality of life of university students, who use smartphones during long periods

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

Abstract

Purpose: The present study investigated the effect of a 5x5 exercise program on sleep quality, fatigue, neck pain, head posture, daily walking, sitting, sleeping and smartphone usage time.

Material: An exercise program was applied to 54 university students (17 males, 37 females) between October and November 2019. The five exercises lasted approximately 15-20 minutes in each training session (diaphragmatic breathing, axial neck extension, cervical stabilization, pectoral stretch, and shoulder retractor strengthening) that was performed 5 times a day, 5 days a week for 5 weeks. The Pittsburgh Sleep Quality Index (PSQI), Fatigue Severity Scale (FSS), Neck Disability Index (NDI), Forward Head Posture (FHP), number of daily steps, sitting time, sleep time, and smartphone usage time were compared before and after the exercise program. The Paired Samples t-test was used to compare differences between the pre-exercise and post-exercise variables. Statistical significance level was set at 0.05.

Results: Following the 5-week exercise program, sleep quality improved, and levels of neck disability and fatigue were lower and the differences were statistically significant (p<0.05). No change was determined in FHP, daily sitting time and daily number of steps, sleep hours, and smartphone usage time (p>0.05).

Conclusions: The 5-week program of posture correction, stretching and strengthening exercises improved sleep quality, fatigue levels, and neck disability. The findings of this study can be used to improve the sleep quality, fatigue and neck problems of both students and sedentary workers.

Keywords: sleep, neck disability, fatigue, head posture, exercise

Introduction

The opportunities provided by current technology have significantly facilitated daily life, and the rapid developments in global technology are followed with great interest by young people. The use of technological devices has increased as they allow the user to access the internet and social media at any time and place, and to easily create content and access different content. However, increased usage of technological devices can create addiction [1-3]. These addictions, which are counted as a type of behavioural addiction have been defined as technology addiction [4, 5]. Technology addiction leads to psychiatric, behavioural and sociological problems, and has a negative effect in particular on the physical movement of young people [6, 7]. In studies of university students, long periods of sitting, being able to undertake daily work on the internet, and low levels of physical activity and habitual exercise have been determined as the primary factors in the emergence of neck, back and upper extremity problems, and especially headaches [8-10].

During long periods of use of computers and smartphones, there is a forced position change in body posture with the head and neck placed in forward flexion position (FHP). Repeated movements of the neck and upper extremities in this forced posture have been determined to cause the formation of musculoskeletal system symptoms [9, 10]. The FHP has been reported to be seen at the rate of 60% in individuals with neck problems and it has been emphasised that the tendency for FHP is increased in computer or smartphone users who remain seated for more than 2 hours a day [11]. This postural stress formed in the neck associated with FHP leads to musculoskeletal system problems such as pain and restriction, and these problems are seen not only in the neck but also in other regions of the body. Moreover, the duration of device use has been reported to be associated with sleep irregularities, reduced sleep quality, diurnal tiredness, headache, reduced levels of concentration, and increased levels of stress [12, 13].

There have been important changes in education systems throughout the world, especially in the most recent times. The increase in distance-learning educational programs in universities has increased the opportunities for student learning and self-development together with virtual reality applications, and the implementation of web-based projects and lessons. However, this system has caused university students to spend longer at a computer. Intense mental activity and long sedentary periods can result in individuals feeling more tired and stressed [14].

Raising awareness of the musculoskeletal system problems that can develop associated with the use of technological devices is important in respect of protective healthcare. Previous studies have examined the effects of a sitting posture on the neck and upper extremity musculoskeletal system symptoms [8-10]. However, not many studies have been conducted which have examined the usage time of devices by students and the effects on head and neck posture when sitting while using devices.
The hypothesis of this study was that posture, stretching and strengthening exercises applied actively during the day would have a positive effect on sleep quality, the severity level of tiredness, neck problems and head posture of university students. Therefore, the aim of this study was to examine the effect of an exercise program on the sleep quality, fatigue, neck problems and posture of university students and to increase the cognitive awareness of students of head posture when using a computer or smartphone, the time spent sitting daily and the number of steps taken per day.

Material and Methods

This study was conducted on 54 university students between October and December 2019 to investigate the effects of a 5 x 5 exercise protocol on sleep quality, fatigue and neck problems. The effects of the exercise program were also investigated on the time spent sitting each day, the number of steps taken each day, the duration of sleep, and the duration of smartphone usage. The study was conducted by physiotherapists (AUTHORS) in the Physiotherapy and Rehabilitation Department of a health sciences faculty.

Approval for the study was granted by the Non-Interventional Clinical Research Ethics Committee of AUTHORS’ University (No: 2019/27). All procedures were applied in compliance with the principles of the Helsinki Declaration.

Participants. The study enrolled 81 volunteer university students selected from the Physiotherapy and Rehabilitation Department students (49 females – 66.7%; 32 males – 36.4%). The study inclusion criteria were defined as age 19-30 years, voluntary participation in the study, no chronic physical disease, and smartphone use for at least 1 hour per day for at least 3 years. Students were excluded from the study if they had a history of a musculoskeletal system problem that had lasted at least 1 week in the previous 6 months, a history of surgery in the neck region or upper extremities, or if they had any cardiopulmonary problem. A total of 54 university students met the criteria, comprising 37 (68%) females and 17 (32%) males. The content of the 5 x 5 exercise protocol was explained and informed consent for participation in the study was obtained from all the participants.

Procedure. The descriptive data of the students was collected on a Sociodemographic Information Form prepared by the researchers. Age, gender, height, weight and general health information was obtained. From the pedometer application on the smartphone of each student the weekly number of steps taken was recorded and the daily average was calculated. The daily time spent sitting, daily usage time of the smartphone and daily duration of sleep were determined from the physical activity application on the smartphone.

The Forward Head Position (FHP) of each student was evaluated with the craniovertebral angle. The student was instructed to sit upright on a chair in a neutral posture, then the craniovertebral angle was calculated as the angle formed from the plane passing from the 7th cervical vertebra to the tragus of the ear horizontally parallel to the ground. Subjects with FHP were determined to have a smaller craniovertebral angle than healthy subjects. This angle has been reported to be a valid and reliable evaluation tool for the evaluation of FHP [15]. To determine the sleep quality of the students, the Pittsburgh Sleep Quality Index (PSQI) was used, for neck problems, the Neck Disability Index (NDI), and for the level of fatigue, the Fatigue Severity Scale (FSS).

Pittsburgh Sleep Quality Index (PSQI); The PSQI provides information about sleep quality in the last month, and the type and severity of sleep disorders [16]. The scale consists of 24 items in 7 components of subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. The total of the 7 component scores provides the total PSQI score. Each component has a total score of 0-3, so the total PSQI score ranges from 0-21. A total score of >5 indicates poor sleep quality. The Turkish version of the scale used in the study has been validated [17].

Fatigue Severity Scale (FSS); The scale consists of 9 items with a total score ranging from 9-63. A score of ≥36 indicates severe fatigue. The subject indicates their level of agreement with each of the items on a scale of 1-7, where 1 = I completely disagree and 7 = I completely agree. The total score is calculated as the average of the 9 item scores. A cut off value of ≥4 has been defined for pathological fatigue. The lower the total score, the lower the level of fatigue [18]. The Turkish version of the scale was used with a Cronbach alpha coefficient of 0.96 [19].

Neck Disability Index (NDI); The NDI consists of 10 sections related to the severity of pain, personal care, lifting loads, reading, headache, concentration, work, driving, sleep and leisure activities. Each item is scored from 0-5. A total score of 0-4 points indicates no disability, 5-14 points, mild disability, 15-24 points, moderate disability, 25-34 points, severe disability and >35 points, complete disability [20]. The validated Turkish version of the scale was used in the study [21].

The evaluation scales were applied to the 54 students who voluntarily agreed to participate in the study before the exercises were given. The exercises were then explained in detail to the students. The 5 x 5 exercise program consisted of 5 exercises, as shown in Table 1, to be performed 5 times a day, 5 days a week for 5 weeks. A form was prepared for the students to record the days and times of completing the exercises. A brochure detailing the exercises was also given to the students, who were then evaluated again after 5 weeks.

Statistical Analysis

Data obtained in the study were analysed statistically using IBM® SPSS© 21.0 software (SPSS Inc., Chicago, IL, USA). The conformity of the variables to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Shapiro-Wilks test). Descriptive data were expressed as mean ± standard deviation (X±SD), and minimum-maximum values. The Paired Samples t-test was used to compare the difference between pre-exercise and post-exercise...
variables. Statistical significance level was accepted as p <0.05.

Results
Evaluation was made of a total of 54 students comprising 37 females and 17 males with a mean age of 22.50±1.87 years, and mean BMI of 22.28 ± 3.45 kg/m² (Table 2). The pre and post exercise values of the students for PSQI, FSS, NDI, and FHP are shown in Table 3. A significant change was determined in the PSQI, FSS and NDI values following the 5x5 exercise program (p<0.05). No change was determined in the FHP compared to baseline data (p>0.05). The number of steps taken per day, the time spent sitting (hrs), the duration of sleep (hrs) and duration of smartphone usage (hrs) before and after the exercise program are shown in Table 4. No significant difference was determined in the daily number of steps, or time spent sitting, sleeping or using a phone or computer after the exercise program compared to the baseline data (p>0.05).

Table 1. The 5x5 Exercise Program

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragmatic Breathing</td>
<td>While seated, place one hand the upper chest and the other hand below the rib cage. Deep abdominal breathing in and out through the nose so that stomach moves out against the hand. Holding the breath 10 sec. and breathing out. The hand on the upper chest should remain as still as possible. Repeat 10 times.</td>
</tr>
<tr>
<td>Axial extension of the neck</td>
<td>While seated, pull the chin and head straight back until a good stretch is felt at the base of the head and top of the neck. Hold for 10 seconds, relax and bring the chin forward. Repeat 10 times.</td>
</tr>
<tr>
<td>(Chin tuck)</td>
<td></td>
</tr>
<tr>
<td>Cervical Stabilization</td>
<td>Lying supine, perform a nodding movement without lifting the head off the bed and push the head gently back to the surface, feeling the back of the head sliding in the sagittal plane. Hold for 10 seconds, relax and bring the head back to beginning position. Repeat 10 times.</td>
</tr>
<tr>
<td>(Craniocervical flexion)</td>
<td></td>
</tr>
<tr>
<td>Pectoral Stretching</td>
<td>Standing in an open doorway or corner with both hands slightly above your head on the door frame or wall. Slowly lean forward until you feel a stretch in the front of your shoulders. Hold for 10 seconds.</td>
</tr>
<tr>
<td>Shoulder /Scapular Retraction Strengthening</td>
<td>Standing or sitting, pull the shoulder blades together and downwards and hold for 10 seconds, relax.</td>
</tr>
</tbody>
</table>

Table 2. Descriptive data of the students

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>X±SD</th>
<th>min-max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.50±1.87</td>
<td>19-30</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.28±3.45</td>
<td>17-30</td>
</tr>
<tr>
<td>Female N (%)</td>
<td>37 (68)</td>
<td></td>
</tr>
<tr>
<td>Male N (%)</td>
<td>17 (32)</td>
<td></td>
</tr>
</tbody>
</table>

Note: BMI: Body Mass Index; X: Mean, SD: Standard Deviation

Table 3. The comparison of sleep quality, fatigue severity, neck disability, and head posture values pre and post exercise program

<table>
<thead>
<tr>
<th>Scales</th>
<th>Pre-exercise</th>
<th>Post-exercise</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X±SD</td>
<td>X±SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSQI (0-21)</td>
<td>7.13±3.34</td>
<td>5.55±2.86</td>
<td>3.296</td>
<td>0.002*</td>
</tr>
<tr>
<td>FSS (1-7)</td>
<td>4.64±1.25</td>
<td>3.78±1.60</td>
<td>4.053</td>
<td>0.000*</td>
</tr>
<tr>
<td>NDI (0-50)</td>
<td>10.78±6.91</td>
<td>8.65±5.73</td>
<td>3.122</td>
<td>0.003*</td>
</tr>
<tr>
<td>FHP (º)</td>
<td>40.62±9.60</td>
<td>43.6±6.46</td>
<td>1.813</td>
<td>0.076</td>
</tr>
</tbody>
</table>

NOTE: *p<0.05; PSQI: Pittsburgh Sleep Quality Index; FSS: Fatigue Severity Scale; NDI: Neck Disability Index; FHP: Forward Head Posture
NOTE: *p<0.05; X: Mean, SD: Standard Deviation

Sleep quality of the students after the 5-week exercise program was determined. At the end of the 5-week exercise program, there was determined to be a statistically significant increase in sleep quality, and a statistically significant decrease in the levels of fatigue and neck dysfunctions. No significant change was seen in the head posture angular value, number of daily steps or time spent sitting, sleeping, or using the smartphone.

The aim of this study was to examine the effect of a 5 x 5 exercise program on the sleep quality, neck disability, fatigue, head posture, number of daily steps, hours of sleep, time spent sitting and the duration of smartphone usage of university students. At the end of the 5-week exercise program, there was determined to be a significant increase in the level of fatigue, which decreased. Thus, it can be concluded that 15-20 mins of exercises applied during the day is effective on sleep quality and fatigue and could decrease serious problems in the long term.

Increased accessibility to information due to technological developments has made life easier for people and has increased the use of technological devices. However, while the long-term use of these devices consciously or subconsciously has a negative effect on all age groups, it is seen to be the greatest risk factor for the young age group [2, 3]. Technology addiction has been determined in this age group with inactivity, sitting in the same position for a long period and poor head posture [6, 27]. In this study which aimed to raise awareness in students, although the 5-week period of exercises repeated at certain intervals was not determined to have created a change in head posture, there was a significant reduction in the neck disability values of the students. Although the students in this study were healthy individuals with no neck pain or other complaints, there were deviations in head posture. The results obtained by Lee et al. [27] support these findings. They reported that cervical angles showed increased flexion in asymptomatic subjects during visual display terminal work. Head and neck posture deviation seen in individuals without a neck problem can be explained by the changing motor control of the neck muscles associated with incorrect postural habits [28].

In the frequent observation of neck problems, there has been said to be a direct biomechanical relationship between the head and cervical region [29]. Many people may use smartphones with the head shifted forward and the smartphone placed near the waist or lap while in a sitting position, maintaining a static sitting posture during smartphone use. This flexed neck posture can increase the movement of the cervical spine and may induce muscle strain in adjacent portions of the cervical spine [9, 30]. A smaller craniovertebral angle, in other words, FHP, which is frequently seen in office workers and those who are seated for long periods, is a syndrome which can emerge

### Table 4. The comparison of the assessments before and after the 5x5 exercise program

<table>
<thead>
<tr>
<th>Assessments</th>
<th>Pre-exercise X±SD</th>
<th>Post-exercise X±SD</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steps (number/daily)</td>
<td>5715.56 ± 2512.05</td>
<td>6543.64 ± 2477.19</td>
<td>1.91</td>
<td>0.062</td>
</tr>
<tr>
<td>Sitting time (hour/daily)</td>
<td>5.26 ± 1.98</td>
<td>5.40 ± 2.35</td>
<td>0.508</td>
<td>0.614</td>
</tr>
<tr>
<td>Sleep time (hours/night)</td>
<td>7.48 ± 1.22</td>
<td>7.42 ± 1.20</td>
<td>0.401</td>
<td>0.690</td>
</tr>
<tr>
<td>Smartphone use time (minutes/daily)</td>
<td>218 ± 148</td>
<td>221 ± 135</td>
<td>0.182</td>
<td>0.857</td>
</tr>
</tbody>
</table>

Discussion

The aim of this study was to examine the effect of a 5 x 5 exercise program on the sleep quality, neck disability, fatigue, head posture, number of daily steps, hours of sleep, time spent sitting and the duration of smartphone usage of university students. At the end of the 5-week exercise program, there was determined to be a statistically significant increase in sleep quality, and a statistically significant decrease in the levels of fatigue and neck dysfunctions. No significant change was seen in the head posture angular value, number of daily steps or time spent sitting, sleeping, or using the smartphone.

Addiction to technological devices is seen to increase in university students for reasons such as the change in surroundings, intense academic life, examinations, messaging and following social media [3, 5]. Going to bed late, insomnia and impaired sleep quality emerge in individuals associated with addiction to technological devices [12, 13]. With good sleep quality, an individual is refreshed in the morning and feels physically and mentally ready for a new day. However, poor quality and insufficient sleep is associated with low cognitive performance in the long term, slowing of the metabolism and weight problems, and an increased cardiovascular risk develops [5-7]. Studies that have examined the sleep quality of university students have determined that more than half have poor quality sleep [22-24]. It has been emphasised in literature that young people aged 19-29 years do not have sufficient sleep and therefore experience more physical, psychosocial and health problems [12].

Demirci et al [25] found that sleep quality, depression, and anxiety may be associated with Smartphone overuse. It has also been reported that there is a strong association between sleep quality and physical and mental status, and those with poor sleep experience problems such as daytime fatigue, and sleepiness, stress and depression [24, 25]. One of the first evident symptoms of poor quality and insufficient sleep is daytime tiredness [26]. In the current study, the sleep quality of the students was seen to be at an extremely low level at the beginning of the study. A PSQI score of ≥5 is accepted as poor sleep quality. Despite a statistically significant increase in the sleep quality of the students after the 5-week exercise program, the mean PSQI score was determined as >5. Nevertheless, the improvement in the sleep quality after the exercise program had a positive effect on the level of fatigue, which decreased. Thus, it can be concluded that 15-20 mins of exercises applied during the day is effective on sleep quality and fatigue and could decrease serious problems in the long term.
with abnormal posture in the shoulder girdle [31]. Loss of motor control involves failure to control joints, because of lack of coordination of the agonist-antagonist muscle co-activation [29].

Head posture and balance of the neck muscles are important for postural stability and functionality before musculoskeletal system problems develop. With a combined program including stretching, strengthening and behavioural active control for the correction of postural deviations, Lee et al [32], obtained significant results in patients with neck and thoracic region problems. Kendall recommended strengthening of weakened postural muscles and stretching of shortened muscles for a balanced posture [33]. In the context of an exercise program to be given with the principles of stretching and strengthening for FHP, soft tissue balance can be obtained with strengthening of the deep cervical flexors and shoulder retractors, and stretching of the pectoral muscles [32-34]. In a study by Han et al, decreased activity of accessory respiratory muscle activity was determined in subjects with FHP compared to subjects without FHP [35]. In the current study exercise program, the students were instructed to breathe diaphragmatically in a controlled manner without disrupting the correct head posture and to concentrate on their breathing. It has been reported that diaphragmatic breathing exercises provide a reduction in blood pressure and pulse rate by stimulating the parasympathetic system, lower the stress level of the individual and create a sedative effect [36]. In a study of Canadian university students, the duration and frequency of use of mobile handheld devices was found to be related to the prevalence of neck pain [37]. Kim et al. investigated the effect of the duration of smartphone use on neck and shoulder muscle fatigue and pain in adults with FHP. The cervical flexion angles were affected by the duration of smartphone use, with pain and fatigue observed to worsen with longer periods of use. Correct posture and break time of at least 20 minutes were recommended when using smartphones [10]. In the current study, the students were instructed to repeat the exercises 5 times during the day. It was aimed for the students to be active during the day by eliminating the inactivity and static posture formed by a long period of sitting. It can be considered that the ability to adjust the correct sitting posture, the time spent sitting and the time spent using technological devices of young people and to create habits of these will make a positive contribution to their general health.

It has been reported that individuals with neck problems have a greater tendency to make adaptations in the head and neck, and a significant relationship has been found between FHP and neck pain [31, 38]. In a study that compared patients with severe chronic neck pain with subjects with no neck pain, those with chronic pain were found to have a reduced ability to maintain an upright neutral posture at a computer [31]. Reasons for chronic pain can include altered muscle length relationships, postural changes, muscular imbalances, and variations in location of the centres of mass and of pressure [39]. Therefore, the most effective and cheapest method is to take precautions before the problems develop. In the current study it was aimed to move the healthy students from the same long-term static position, even if for a short time, with the application of exercises 5 times a day. With the gaining of habits of an aware use of technological devices, protection of correct head and neck posture during use, reduction in the time spent using devices, and increasing daily physical activity levels, it is possible to say that university students could reduce the risk of primarily, pain in the neck region and the development of musculoskeletal system problems in other regions.

There were some limitations to this study, primarily the small sample size as only healthy young adults were included. Further studies could make comparisons with subjects with neck pain. As the study group was a homogenous group of healthy university students, it is not possible to generalize the findings to the whole population. In addition, the study was limited to a 5-week exercise program. There is a need for further studies of a longer duration to examine the effect of the exercise program and to make comparisons with a control group.

**Conclusion**

The results of this study demonstrated that the 5x5 exercise program administered to university students increased sleep quality, and decreased neck disability and fatigue levels. The 5x5 exercise program, which focused on posture and stability of the head and neck region of the spine, can be used for postural pain and misalignment of the spine, problems related to forward head posture, and neck disorders.

**Conflict of interests**

The authors have no conflict of interests to declare.
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Cite this article as:


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Received: 25.08.2020
Accepted: 02.10.2020; Published: 30.10.2020
Effects of varied packages of plyometric training on selected motor ability components among university students

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

Abstract

Purpose: The main focus of the study was to examine the effect of varied packages of plyometric training on speed, leg explosive power, and muscular endurance among university students.

Material: Sixty students (age= 21.37±1.40) were divided into two groups namely, Control Group (CG, n=15) and Experimental Group (EG, n=45). The EG was further divided into three different groups based on the different training packages such as Low, Medium, and High-Intensity plyometric training. The .05 level of confidence was fixed as the level of significance to test the ‘F’ ratio obtained by the analysis of covariance, which was considered as appropriate. Plyometric training for a period of eight weeks offered to the participants of the Experimental Group.

Results: The results revealed that various plyometric training programs have produced significant development in improving motor ability components such as speed, leg explosive power, and muscular endurance of the participants (p<.05). The results indicated that high-intensity plyometric training was noticed as superior then low and medium intensity plyometric training in the perspective of the effect of varied packages of plyometric on selected motor ability components among participants.

Conclusions: Keeping in view the utility and importance of plyometric training, we recommended that the exercise protocol used in this study may helpful for the development and improvement of such components to get peak performance in sports.

Keywords: effect, varied packages, speed, muscular endurance, leg explosive power

Operational Definitions of the Terms:

Plyometric Training: Plyometric training refers to exercise that enables a muscle to reach maximal strength in a short time as possible.

Speed: Speed is generally defined as quickness. In the field of physical education and sports, the term speed refers to the quick action of the limbs.

Explosive Leg Power: A maximum or near maximum power output in the shortest possible is called.

Muscular Endurance: Muscle endurance is the ability of a muscle or group of muscles to exert force for a longer duration.

Introduction

Sports training is a planned and controlled process aimed to promote motor performance as well as to positively change the behavior of a person [1]. For the positive outcome of training, it is considered important to perform the training according to its principles [2].

The importance of sports training can be assessed by the fact that all other kinds of facilities provided to athletes may prove to be futile if the athletes are not provided with effective sports training. Without proper sports training, one cannot achieve or fulfill his/her potentials [3]. Comprehensive sport training has paramount significance in producing peak performance in sport [4].

Sedaghati [5] single out that body adaptations and the high level of achievement in different sporting fields depend on the degree of fitness and training. Among the numerous types of available exercises, plyometrics assist in the development of power, a foundation from which the athlete can refine the skills of their sport [6].

Regular participation in plyometric training is considered important for improving the standard of muscular endurance [7]. According to researchers [8], plyometric training is basically done for improving the endurance of muscle as well as adopting of muscles. Plyometric is not inherently dangerous, but the highly focused and intense movements used in repetition may increase the potential level of stress on joints, muscles, and tendons units [9].

El-Ashker et al. [10] assessed the impact of 8-weeks plyometric training program on the sprint and jump performance. The authors defined the plyometric training can be recommended to athletics coaches as an additional training alternative to improve sprint and long jump abilities in athletes.

Golzari et al [11] compared the impact of 6-weeks strength and plyometric exercises on some of the kinematic parameters of the lower extremities in the impact on female football players aged 20 to 25 years. The findings show that 6-week strength and plyometric exercises can significantly improve the speed parameters of the ball, the angular velocity of the knee joint and the angular velocity of the hip in the impact performance on
the foot of female soccer players.

The other investigations defined that:
- Specific stretching exercises combined with plyometrics may be more beneficial than other training strategies in young sprint-hurdlers [12];
- The use of progressive plyometric exercise on an unstable surface shows an improvement in the results of the functional movement screening test and movement performance [5].
- A proper progression and detailed program planning should be utilized when implementing plyometric exercises due to their different impact kinetics and how they might influence the body upon ground contact [13].

Plyometric preparation adds to change in upright hop execution, quickening, leg quality, strong power, the increment of joint mindfulness, and in general game particular aptitudes [14].

However, little scientific information is currently available to determine whether plyometric training truly boosts skill performance in individuals [15].

Different training methods are used to develop physical fitness components. Each method aims to develop one or the other components. The selection of the method depends upon the period of training, level of athlete, age, and sex of athletes. The selection of the correct training method is very much important for the type of training being offered to the athletes. This particular study focused to examine the effect of varied packages of plyometric training on speed, leg explosive power, and muscular endurance among untrained university students.

Research Hypotheses
Based on available data its was hypothesized that:
HA 1. There is a significant effect of varied packages of plyometric training on speed.
HA 2. There are significant mean differences in the effects of varied packages of plyometric training on speed.
HA 3. There is a significant effect of varied packages of plyometric training on leg explosive power.
HA 4. There are significant mean differences in the effects of varied packages of plyometric training on leg explosive power.
HA 5. There is a significant effect of varied packages of plyometric training on muscular endurance.
HA 6. There are significant mean differences in the effects of varied packages of plyometric training on muscular endurance.

Material and Methods
Participants
The participants of this research comprised of Sixty (n=60) healthy undergraduate university male students of Gomal University, Dera Ismail Khan. The students (age= 21.37±1.40) were divided into two groups namely, Control Group (CG, n=15) and Experimental Group (EG, n=45). The EG was further divided into three different groups based on the different training packages such as Low, Medium, and High-Intensity plyometric training. Plyometric training for a period of eight weeks offered to the participants of the Experimental Group.

Inclusion Criteria
The subjects included in the study by adopting the following inclusion criteria:
1. All male students included in the study;
2. The healthy student included in the study;
3. The student aging 20-23 years included in the study.

The study was conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Research Design
The study contains a single-dimensional design consisted of four portions by giving various sets of exercise. In order to assist the investigation, sixty unskilled healthy undergraduate university male students at the age of 20 to 23 were selected as subjects through random sampling. The subjects of the study distributed into four equal groups namely Experimental Group (EG) A. (First Package of Plyometric training) Group B. (Second Package of Plyometric training) Group C. (Third Package of Plyometric training) and Group D. (Control Group) did not involve in any training. The selected student was evaluated through different tests before administering plyometric training. Plyometric training for a period of eight weeks in the direction of the researcher offered to the selected group of individuals. At the end of eight weeks, the post-test was taken.

Test Protocol
We used a modified test protocol. A Pilot Study was conducted for the purpose of finalizing and deciding up upon the intensity and duration of the various packages of a plyometric training program. The Pilot Study was conducted with twenty (n=10) subjects to know the suitability of varied packages of plyometric training and to find out the difficulties and shortcomings of the study.

Collection of Data
Low, Medium and High Intensity of plyometric training were given as per the training schedule. The pre and post check records on the chosen criterion variables were accumulated by way of administering the test as in step with the standardized procedures before and after the eight weeks of the program.

Experimental Procedure (Fig. 1.).
Selection of the Tests
The study in hand examined the effects of assorted programs of plyometric training, (Low, Medium & High intensity) on selected motor ability components such as Speed, Leg explosive power, and Muscular endurance among college male students. On the base of the present literature, the given test was conducted to gather associated information on the dependent variables which are given below (table 1).

Criterion Measures
1. Speed. The Speed of the subjects was measured by using a 50 yards’ dash test. The measurement will be recorded 1/100 of the seconds.
2. Leg Explosive Power. For measuring Leg Explosive Power, standing broad jump test was used and
the unit of measurement were taken in meters.  
3. **Muscular Endurance.** For measuring Muscular Endurance, sit ups test was used and the unit of measurement were taken in counts.

**Equipment used**

The following equipment was used during the conduction of the test:  
1. Paint;  
2. Table;  
3. Rope;  

**Result**

*Effects of varied packages of plyometric training on speed*

The analysis of covariance in the perspective of the effects of varied packages of plyometric training on the speed of the pre and post score of experimental groups and control group have been presented in the table mentioned below (table 2).

The above table depicts the pre-test mean score of speed regarding the effects of low intensity, medium intensity, high intensity, and control group. According to the analysed data, the mean scores were obtained 7.116, 7.114, 7.116, and 7.117 respectively for low intensity, medium intensity, high intensity, and control group.

According to the table, the obtained ‘f’ ratio of 0.012 is less than the table value of 2.684.

Likewise, the post-test results in terms of different groups like low intensity, medium intensity, high intensity, and control groups were recorded as 7.064, 7.046, 7.011, and 7.115. Similarly, the ‘f’ ratio was recorded greater than the table value (12.982 > 2.684).

The adjusted mean scores of the post-test were noticed as 7.004, 7.047, 7.011, and 7.114 respectively for low intensity, medium intensity, high intensity, and control group. The analysed data have shown that the ‘f’ value was found greater than the table value (18.672 > 2.684).

Based on the data analysis, the study revealed that there existed significant differences in the mean scores of adjusted post-test with reference to the effect of varied packages of plyometric training such as low intensity, medium intensity, and high intensity upon speed.

As there found a significant difference in the ‘f’ ratio of adjusted post-test. Therefore, the researcher applied Scheffe’s test to analyze the paired mean differences (table 3).

The above table depicts the mean differences among different plyometric training groups including low intensity, medium intensity, high intensity, and control group of the participants upon speed. Accordingly,

---

![Diagram showing experimental procedure and test results](image)

**Fig. 1.** Showing the experimental procedure used in the study

**Table 1.** Showing the description of selection of the tests

<table>
<thead>
<tr>
<th>S. No</th>
<th>Variables</th>
<th>Tests applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Speed</td>
<td>50 Yards Dash</td>
</tr>
<tr>
<td>2</td>
<td>Leg Explosive Power</td>
<td>Standing Broad Jump</td>
</tr>
<tr>
<td>3</td>
<td>Muscular Endurance</td>
<td>Sit-ups</td>
</tr>
</tbody>
</table>
the mean differences 0.056, 0.052, 0.665, and 0.102 respectively for low intensity, medium intensity, high intensity, and control group were found greater than the required confidence interval value (CIV) at a confidence level of 0.05. Therefore, it can be said that the above comparison was insignificant.

The table has shown the comparison between (LI) plyometric training group and (MI) plyometric training group and (HI) plyometric training group. Accordingly, the results were found at 0.016 and 0.034 for the above comparison respectively. These scores were found lesser than the required confidence interval at a significant level (0.016, 0.034 <0.04). Therefore, these two comparisons were found significant.

**Effects of varied packages of plyometric training on leg explosive power**

The table has shown the comparison between (LI) plyometric training group and (MI) plyometric training group and (HI) plyometric training group. Accordingly, the results were found at 0.023 and 0.035 for the above comparison respectively. These scores were found lesser than the required confidence interval at a significant level (0.023, 0.035<0.05). Therefore, these two comparisons were found significant.

**Table 2.** Showing the analysis of covariance of pre-test, post-test, and Adjusted post-test on the speed of experimental and control groups

<table>
<thead>
<tr>
<th>Test</th>
<th>LI</th>
<th>MI</th>
<th>HI</th>
<th>CG</th>
<th>Df</th>
<th>O’f’ R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test Mean</td>
<td>7.116</td>
<td>7.114</td>
<td>7.116</td>
<td>7.117</td>
<td></td>
<td>0.012</td>
</tr>
<tr>
<td>Post-test Mean</td>
<td>7.064</td>
<td>7.046</td>
<td>7.011</td>
<td>7.115</td>
<td>(3,57)</td>
<td>12.982*</td>
</tr>
<tr>
<td>Adjusted Post-test Mean</td>
<td>7.004</td>
<td>7.047</td>
<td>7.011</td>
<td>7.114</td>
<td></td>
<td>18.6726*</td>
</tr>
</tbody>
</table>

**NOTE:** *Significant at 0.05 level of confidence, LI= low intensity, MI=medium intensity, HI= high intensity, CG= control group, df= degree of freedom & OFR=obtained ‘f’ ratio.

**Table 3.** Cheffe’s Test showing the differences between paired means of different groups on speed

<table>
<thead>
<tr>
<th>LI</th>
<th>MI</th>
<th>HI</th>
<th>CG</th>
<th>MD</th>
<th>CIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.056</td>
<td>7.039</td>
<td></td>
<td></td>
<td>0.016</td>
<td>0.04</td>
</tr>
<tr>
<td>7.056</td>
<td>7.011</td>
<td>7.114</td>
<td>0.052*</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>7.056</td>
<td>7.011</td>
<td>7.114</td>
<td>0.034</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>7.039</td>
<td>7.011</td>
<td>7.114</td>
<td>0.665*</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>7.011</td>
<td>7.114</td>
<td>0.102*</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** *Significant at 0.05 level of confidence, LI= low intensity, MI=medium intensity, HI= high intensity, CG= control group, MD= mean differences, CIV= confidence interval value.
found significant.  

Effects of varied packages of plyometric training on muscular endurance

The analysis of covariance in the perspective of the effects of varied packages of plyometric training on muscular endurance of the pre and post score of experimental groups and control group have been presented in the table below (table 6).

The sketched table represents the pre-test mean score of muscular endurance regarding the effects of low intensity, medium intensity, high intensity, and control group. According to the analysed data, the mean scores were obtained 27.433, 27.522, 27.498, and 27.565 respectively for low intensity, medium intensity, high intensity, and control group. According to the table, the obtained ‘f’ ratio of 0.030 is lesser than the table value of 2.684 required for significance at the 0.05 level.

Likewise, the post-test results in terms of different groups like low intensity, medium intensity, high intensity, and control groups were recorded as 30.798, 31.865, 33.423, and 27.764. Similarly, the ‘f’ ratio was recorded greater than the table value (35.10>2.684) required for significance at the 0.05 level.

The adjusted mean scores of the post-test were noticed as 30.858, 31.845, 33.438, and 27.718 respectively for low intensity, medium intensity, high intensity, and control group. The analysed data have shown that the ‘f’ value was found greater than the table value (97.288> 2.684).

The study showed significant differences in the mean scores of adjusted post-test with reference to the effect of varied packages of plyometric training upon the muscular endurance of the participants included in the study.

As there found a significant difference in the ‘f’ ratio of adjusted post-test, therefore; the researcher applied Scheffe’s test to analyse the paired mean differences (table 7).

The above table depicts the mean differences among different plyometric training groups including low intensity, medium intensity, high intensity, and control group of the participants upon muscular endurance. Accordingly, the mean differences 0.985, 2.578, 3.137, 1.591, 4.124, and 5.718 respectively for low intensity, medium intensity, high intensity, and control group were found greater than the required confidence interval value.

---

**Table 4.** Showing the analysis of covariance of pre-test, post-test and Adjusted post-test on leg explosive power of experimental and control groups

<table>
<thead>
<tr>
<th>Test</th>
<th>LI</th>
<th>MI</th>
<th>HI</th>
<th>CG</th>
<th>df</th>
<th>OFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test Mean</td>
<td>2.223</td>
<td>2.223</td>
<td>2.229</td>
<td>2.228</td>
<td></td>
<td>0.542</td>
</tr>
<tr>
<td>Post-test Mean</td>
<td>2.247</td>
<td>2.281</td>
<td>2.323</td>
<td>2.229</td>
<td>(3,57)</td>
<td>53.951</td>
</tr>
<tr>
<td>Adjusted Post-test Mean</td>
<td>2.260</td>
<td>2.284</td>
<td>2.320</td>
<td>2.227</td>
<td></td>
<td>128.915</td>
</tr>
</tbody>
</table>

NOTE: *Significant at 0.05 level of confidence, LI= low intensity, MI=medium intensity, HI= high intensity, CG= control group, df= degree of freedom & OFR=obtained ‘f’ ratio.

**Table 5.** Scheffe’s Test showing the differences between paired means of different groups on leg explosive power

<table>
<thead>
<tr>
<th>LI</th>
<th>MI</th>
<th>HI</th>
<th>CG</th>
<th>MD</th>
<th>CIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.252</td>
<td>2.276</td>
<td></td>
<td></td>
<td>0.023</td>
<td>0.014</td>
</tr>
<tr>
<td>2.252</td>
<td></td>
<td>2.32</td>
<td></td>
<td>0.059*</td>
<td>0.014</td>
</tr>
<tr>
<td>2.252</td>
<td></td>
<td></td>
<td>2.227</td>
<td>0.062*</td>
<td>0.014</td>
</tr>
<tr>
<td>2.276</td>
<td>2.32</td>
<td></td>
<td></td>
<td>0.035</td>
<td>0.014</td>
</tr>
<tr>
<td>2.276</td>
<td></td>
<td></td>
<td>2.227</td>
<td>0.056*</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>2.32</td>
<td>2.227</td>
<td></td>
<td>0.092*</td>
<td>0.014</td>
</tr>
</tbody>
</table>

NOTE: *Significant at 0.05 level of confidence, LI= low intensity, MI=medium intensity, HI= high intensity, CG= control group, MD= mean differences, CIV= confidence interval value.

**Table 6.** Showing the analysis of covariance of pre-test, post-test, and Adjusted post-test on muscular endurance of experimental and control groups

<table>
<thead>
<tr>
<th>Test</th>
<th>LI</th>
<th>MI</th>
<th>HI</th>
<th>CG</th>
<th>df</th>
<th>OFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test Mean</td>
<td>27.433</td>
<td>27.522</td>
<td>27.498</td>
<td>27.565</td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>Post-test Mean</td>
<td>30.798</td>
<td>31.865</td>
<td>33.423</td>
<td>27.764</td>
<td>(3,57)</td>
<td>35.10*</td>
</tr>
<tr>
<td>Adjusted Post-test Mean</td>
<td>30.858</td>
<td>31.845</td>
<td>33.438</td>
<td>27.718</td>
<td></td>
<td>97.288*</td>
</tr>
</tbody>
</table>

NOTE: *Significant at 0.05 level of confidence, LI= low intensity, MI=medium intensity, HI= high intensity, CG= control group, df= degree of freedom & OFR=obtained ‘f’ ratio.
(CIV) at a confidence level of 0.05. Therefore, it can be said that the above comparison was insignificant.

Discussion

The study was conducted to assess the Effects of Varied Packages of Plyometric Training on Selected Motor Ability Components among undergraduate university students aging 20-23. The researcher collected data from the participants of four different groups such as low-intensity plyometric training, medium intensity plyometric training, high-intensity plyometric training, and control groups. The measurements were collected in perspectives of selected motor ability components including speed, leg explosive power, and muscular endurance.

In response to the first hypothesis that there would significant effects of varied packages of plyometric training on the speed of the college boys, the data revealed a significant difference in the mean score of pre and posttests of various plyometric training in respect of the speed of subjects. According to the analysed data, the mean scores were obtained 7.116, 7.114, 7.116, and 7.117 respectively for low intensity, medium intensity, high intensity, and control group. Likewise, the post-test results in terms of different groups like low intensity, medium intensity, high intensity, and control groups were recorded as 7.064, 7.046, 7.011, and 7.115.

The above significant statistical difference of the pre and post-tests in terms of average speed time showed a clear indication of the type of advantages of low intensity, medium intensity, high-intensity plyometric training aging 18-20 years. These findings are supported by the findings of [16-18]. It is evident by their findings that experimental groups had produced positive results after 6 weeks plyometric training program. Whereas, some research’s findings [19, 20] did not match the results of the present study.

In respect of the hypothesis that there would significant effects of varied packages of plyometric training on leg explosive power of the college boys, the analysed data indicated, the mean scores were obtained 2.223, 2.223, 2.229, and 2.228 respectively for low intensity, medium intensity, high intensity, and control group. Likewise, the post-test results in terms of different groups like low intensity, medium intensity, high intensity, and control groups were recorded as 2.247, 2.281, 2.323, and 2.229.

When compared to the mean score of different groups, the results exhibited significant statistical differences. The differences in the pre and post-tests showed a clear indication of the type of advantages of low intensity, medium intensity, high-intensity plyometric training holds for college boys. Similar results have been indicated by the researcher [21] as their findings revealed that concurrent endurance and circuit resistance training have produced positive effects on muscular strength and power development. Likewise, researchers [22] conducted a study and found that plyometric training has a positive effect on the perspective of the overall fitness and particularly the leg explosive power of the participants.

The hypotheses that there would significant effects of varied packages of plyometric training on muscular endurance of the college boys, the analysed inferences have shown significant mean differences in perspective of the effects of varied packages of plyometric training on muscular endurance of the pre and post score of experimental groups and control group.

These differences indicated that various plyometric training programs such as low intensity, medium intensity, high intensity have produced significant development in improving the muscular endurance of college male students. The findings of the present study are supported by the findings of [23] who found positive improvement of plyometric training on muscle functioning and athletic performance of college students. Marques et al. [24] indicated significant improvement in strength, endurance, and power performance in elite senior professional volleyball players after 6 weeks of plyometric training programs. Whereas, some other researchers [25] have found acute effects of plyometric exercise on maximum squat performance in male athletes.

Main findings of the Study

The researcher obtained the following findings after careful analysis of the collected measurements from the perspective of the effects of varied packages of plyometric training on selected motor ability components among undergraduate students aging 20-23 of Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan.

1. The results of the study revealed that there are

### Table 7. Scheffe’s Test showing the differences between paired means of different groups on muscular endurance

<table>
<thead>
<tr>
<th>LI</th>
<th>MI</th>
<th>HI</th>
<th>CG</th>
<th>MD</th>
<th>CIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.858</td>
<td>31.845</td>
<td>0.985</td>
<td>0.982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.858</td>
<td>33.438</td>
<td>2.578</td>
<td>0.982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.858</td>
<td>31.845</td>
<td>27.718</td>
<td>3.137</td>
<td>0.982</td>
<td></td>
</tr>
<tr>
<td>31.845</td>
<td>33.438</td>
<td>1.591</td>
<td>0.982</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.845</td>
<td>33.438</td>
<td>27.718</td>
<td>4.124</td>
<td>0.982</td>
<td></td>
</tr>
<tr>
<td>33.438</td>
<td>27.718</td>
<td>5.718</td>
<td>0.982</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: *Significant at 0.05 level of confidence, LI= low intensity, MI=medium intensity, HI= high intensity, CG= control group, MD= mean differences, CIV= confidence interval value.

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significant differences in the mean scores of adjusted post-test with reference to the effect of varied packages of plyometric training such as low intensity, medium intensity, and high intensity upon the speed of the subjects.

2. The study indicated that high-intensity plyometric training has produced a positive effect on the speed of the subjects.

3. Based on the analysed data, significant differences were noticed in the perspective of the adjusted mean scores of post-test for low intensity, medium intensity, high intensity, and control group. Therefore, it is found that plyometric training has produced a significant effect in empowering the leg explosive power among the subjects.

4. According to the analysed data, high-intensity plyometric training was noticed as superior then low and medium intensity plyometric training in the perspective of the effect on leg explosive power among the study participants.

5. Based on the significant differences in the adjusted mean scores of the post-test, the results indicated that plyometric has produced a positive effect on the muscular strength of the subjects.

6. The study has shown significant differences regarding the effect of varied packages of plyometric training upon muscular endurance as the results indicated that high-intensity plyometric training has produced a comparatively better effect upon the muscular endurance of the participants.

**Conclusion**

The results of the study revealed that various plyometric training programs have produced significantly the components of motor ability components such as speed, leg explosive power, and muscular endurance of the participants. The study has shown significant differences among different training packages including low-intensity plyometric training, medium intensity plyometric training, high-intensity plyometric training, and control groups with reference to their effects on speed, leg explosive power, and muscular endurance. Based on the data analyses, the results indicated that high-intensity plyometric training was noticed as superior then low and medium intensity plyometric training in the perspective of the effect of varied packages of plyometric on selected motor ability components among college students.

**Recommendations**

Keeping into consideration the results of the study, the researcher recommended that:

1. The results of the study revealed that high-intensity plyometric training has produced a comparatively better effect on the research variables. Therefore, it is recommended that the coaches, trainers, and physical educationists may use high-intensity plyometric training to improve the components of motor ability components such as speed, power, and leg explosive power.

2. The researchers also recommend that the exercise protocol used in this study may help to adopt for the development and improvement of such components (Speed, Leg explosive power, and Muscle endurance) to get peak performance in sports.

**Conflicts of interest**

The authors declare no conflicts of interest.

**References**


https://doi.org/10.15561/20755279.2020.004

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Cite this article as:


https://doi.org/10.15561/20755279.2020.00504

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Received: 15.08.2020
Accepted: 03.10.2020; Published: 30.10.2020

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Ratio and interconnections of functional fitness structure key components of elite combat athletes at the stage of maximum realization of individual capabilities

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2 Gdansk University of Physical Education and Sport, Gdaiisk, Poland
4 State University of Telecommunications, Kyiv, Ukraine
5State University of Applied Sciences in Kalysz, Poland
6National Pedagogical Dragomanov University, Kyiv, Ukraine

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

Abstract

Purpose: The objective of the work consisted in studying the ratio and interconnections of functional fitness structure key components of elite combat athletes in the process of adaptation to physical loads at the stage of individual capacity maximum realization.

Material: 55 highly skilled wrestlers aged 19-27 years old, members of the national teams of Ukraine in different styles of wrestling - freestyle, Greco-Roman, judo were examined. The assessment of wrestlers’ functional fitness structure was made according to a complex of indices of physiological systems activity at rest and during performance of a block of testing physical loads on a bicycle ergometer.

Results: The components of functional fitness structure of male combat athletes of three wrestling styles (Greco-Roman, freestyle and judo) were studied according to the manifestations of the respiratory and circulatory functions during testing loads performance, and achieved indices of work capacity. It has been revealed that the key integrative components of the general structure of wrestlers’ fitness include: the level of special work capacity, general level of functional fitness, mobility of physiological processes, economy, anaerobic power. Greco-Roman wrestlers are superior to freestyle wrestlers and judokas in anaerobic power, mobility and economy. The greatest differences are manifested in the values of anaerobic power, mobility and general level of functional fitness, whereas the least - in indices of economy. The key criteria for the functional fitness of wrestlers in the manifestation of a high level of physical work capacity include: economy of functioning at rest and during muscular activity of anaerobic-aerobic nature, high reactivity of the cardiovascular system to physical load, power of the anaerobic energy supply system, the rate of recovery processes, the state of cardiac activity regulatory mechanisms, the level of metabolic processes and excitability of the heart muscle. The level of development and the ratio of the components of functional fitness structure of elite combat athletes may be used as the reference models for development of differentiated scales for estimation of the key constituents of physical state of wrestlers specialized in freestyle, Greco-Roman wrestling and judo. Complex application of different methods of testing athletes provides more efficient approach to the problem of monitoring and managing functional fitness and special work capacity of wrestlers at the stage of maximum realization of individual capacities.

Conclusions: An increase in the proportion of key integrative functional indices in special work capacity of athletes specialized in various wrestling styles - Greco-Roman, freestyle and judo represent the most significant criterion for improving their functional fitness structure.

Keywords: wrestlers of different styles, structure, functional fitness, criteria, work capacity.

Introduction

Efficient studying functional fitness structure (FFS) of combat athletes, the variety of geno- and phenotypic factors that determine its formation in the process of long-term adaptation to physical loads, is possible on the basis of complex research methods and principles of a systematic approach [1-4].

The main provisions and principles of systematic approach envisage the study of the ratios of physiological parameter development levels and the interconnections of mechanisms determining special fitness of athletes at different stages of the training process [5-8].

Despite the fact that many researchers used complex research methods to study the integral activity of the body of combat athletes, the structure of athletes ‘fitness was analyzed without account for the ratio of development levels and interconnections of its key components to ensure the athletes’ special work capacity [9-11].

Most authors analyzed the general structure of combat athlete fitness, mainly according to its individual components, factors, or few indices without taking into account their ratio and interconnections in the process.
of ensuring specific activity of wrestlers [12-15]. Few complex studies failed to observe the main principle of the systematic approach - the relationships and ratios of the constituents of structural and functional components in the general fitness structure of athletes were incompletely taken into account in connection with ensuring a high level of special work capacity or competitive activity [16-18].

Insufficient coverage of functional fitness structure of combat athletes from systemic positions prevented the authors from substantiating a differentiated approach to its assessment in wrestlers of different weight categories, age, skill level, gender, style of wrestling [19, 20].

This made it difficult to assess the structure of combat athlete functional fitness as one of the key components of their general fitness structure, along with physical, technical, psychological and moral-volitional fitness. In addition, it also reduced the effectiveness of methodological approaches aimed at the formation and improvement of athlete fitness structure in the process of long-term adaptation to physical loads.

The study of physiological systems interconnected activity in the structure of functional and general fitness of athletes is necessary for substantiated and efficient managing adaptation reorganizations, increasing the level of special work capacity, reliability of performing motor actions and the growth of sports results in wrestling [8, 21, 22].

The importance of this problem for the theory and practice of wrestling, system physiology, physiology of physical education and sport, and its insufficient coverage in the literature have determined the choice of direction and subject of study.

The objective of this work is to study the ratio and interconnections of functional fitness structure key components of elite combat athletes in the process of adaptation to physical loads at the stage of individual capacity maximum realization.

Material and methods

Participants. 55 highly skilled wrestlers aged 19-27 years old, members of the national teams of Ukraine in different styles of wrestling - freestyle, Greco-Roman, judo were examined. The 31 of Ukrainian National Team athletes, participated in this study, were at the student’s age (19-24 years old) during championships and 24 of them were currently students.

Study protocol was approved by Ethic Committee University. The research was fulfilled in compliance with WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects [23].

Procedure. The studies were carried out at different stages of the annual preparation cycle and performed as a natural open experiment.

To assess the functional fitness (FF) structure of combat athletes, instrumental research methods as well as methods of mathematical statistics, mathematical modeling and forecasting were used.

The structure of athlete functional fitness was examined in a state of a relative rest and during responses to testing physical loads.

Vegetative and somatic indices were recorded in a state of a relative rest by electrocardiography and variational pulsography methods [24], tremometry, computer-based testing [6, 22], wrist and torso dynamometry, methods for recording the maximum, relative and explosive strength of the lower extremity muscles [6], etc.

Parameters of the electrocardiogram, time of simple and complex motor responses, accuracy of visual information processing, frequency of movements in the tapping test, speed-strength manifestations of the lower extremity muscles, and other indices were recorded at rest under basal conditions. AsCARD MrGrey v.07.205 electrocardiograph of ASPEL S.A (Poland) company was used to record temporal and amplitude characteristics of the electrocardiogram.

The assessment of wrestler functional fitness structure during muscular activity was made according to the indices of the activity of the muscular, respiratory and cardiovascular systems and the achieved work capacity indices while performing the block of testing loads on the bicycle ergometer. Various test conditions allowed to evaluate the general level of athlete functional fitness by the degree of development of its key structural properties, such as anaerobic and aerobic power, mobility and economy [21, 25]. This structuration of the body functional capacities enabled to outline the most generalized properties of FFS, which are subjected to targeted improvement through the use of specially selected training effects [25].

The “Oxycon Pro” high-speed automatic gas analyzer of “Jeager” company (Germany) was used to examine the body functional manifestations. In the process of performing loads, the following initial indices were determined: respiratory minute volume (l · min⁻¹) concentration of oxygen and carbon dioxide in exhaled air (%), heart rate [beats · min⁻¹] and the corresponding indices of the power of performed load [W]. According to the results of performing the battery of testing loads, a complex of 9 indices was calculated, based on which such key factors of functional fitness structure as anaerobic power, mobility, economy was differentiated in accordance with specially designed algorithm [5, 25, 26]. General level of functional fitness and the degree of development of the studied structural properties were determined on the basis of a system of formalized hallmark assessment of indices [5].

The examinations were carried out on a “Monark” bicycle ergometer [Sweden]. The following types of testing loads were used: 1) State of rest - 3 minutes; 2) Load of standard [moderate] power - 6 min [2 W per kg of weight]; 3) Anaerobic power load lasting 30 seconds; 4) Anaerobic power load lasting 60 seconds.

Recovery pauses between testing loads were filled with unloaded pedaling.

Statistical analysis. STATISTICA 13,5 statistical package was used for statistical processing of experimental material [27].
Results

As a result of conducted studies, it was found that in a state of relative rest, under basal conditions (in the morning, lying down after waking up), the characteristic signs of a high level of the body functional state of elite combat athletes include: according to electrocardiography and variational pulsography - bradycardia (heart rate (HR)) from 38 to 52 beats \( \cdot \) min \(^{-1} \), increase in QRS complex duration without signs of blockade, increased voltage of the T wave in leads V3 - V5, an upward 1-2 mm shift of the ST segment in leads V1, V2, increase in duration and variability of the R-R interval, respiratory-type arrhythmia, decrease in Baevsky myocardial stress index (SI) [24].

These characteristic signs of athlete’s heart are most apparent among lightweight wrestlers. They reflect a more pronounced economy of their heart and the body functioning.

In wrestlers of higher weight categories, heart rate and SI are higher than those of lightweight athletes. They also have the greatest increase in heart rate and SI when performing an orthostatic test.

Statistical processing of vegetative and somatic indices recorded under basal conditions, as well as while performing a number of tests in a state of relative rest, allowed to determine the key generalized factors and indices of wrestlers’ FFS: 1) factor of the optimal ratio and interconnections of physiological mechanisms determining the general level of wrestlers’ physical state (46.7% of the total variance of the studied indices); 2) factor of economy and differentiation of regulatory mechanisms during manifestation of muscle speed-strength capacities (36.0% of the total variance) 3) factor of interconnections between the components of vegetative support and central-nervous coordination in controlling local movements (14.7% of the total variance).

The following vegetative indices were determined as the key ones: heart rate, myocardial SI, arterial pressure (AP), hemoglobin (Hb) content. The key somatic indices include: the tremor amplitude, frequency of movements in the tapping test, strength of the right and left hands, strength and ratio of excitation and inhibition processes in the central nervous system, static endurance, maximum, relative and explosive strength of the lower extremity muscles, the time of simple and complex motor responses, accuracy of visual information processing.

The use of analysis-of-variance methods allowed to show that, in a state of relative rest, the variability of FFS vegetative and somatic indices is more determined by the body weight of athletes than their skill level.

Higher weight categories are associated with increased activity of cardiovascular system, higher tension of functioning of cardiac activity regulatory mechanisms (according to SI), elevated diastolic (P<0,01) and decreased pulse (P<0,01) BP, improved absolute strength capacities of athletes (P<0,01), reduced relative strength of trunk extensor muscles (P<0,01), decreased strength of inhibitory process in CNS (P<0,01).

Of the somatic parameters, the most variable at rest is the tremor amplitude reflecting the state of the neuromuscular system and regulatory mechanisms that coordinate the extremity micromotions while controlling the wrestler vertical posture stability.

Evaluation of the structure of wrestler functional fitness general level by manifestations of respiratory and circulatory functions in response to ongoing testing loads and achieved work capacity indices [5; 21] allowed to determine the level of development and the ratio of the key components of FFS of combat athletes, such as anaerobic and aerobic power, mobility and economy.

Table 1 shows statistical expression of the factors of functional fitness structure of combat athletes for the manifestation of their athletic work capacity (table 1).

The following ratios of the key factors in the general structure of combat athlete functional fitness were revealed without account for their specialization: anaerobic power – 53,0\(\pm\)2,1\%, aerobic power – 53,5\(\pm\)1,8\%, mobility – 80,4\(\pm\)2,8\%, economy – 45,3\(\pm\)2,5\%. The results are indicative of high mobility level and relatively low economy of physiological processes in combat athletes. The level of anaerobic and aerobic power is characterized by average values.

The most integral index - the general level of functional fitness (FF), determined by mobility, economy, anaerobic and aerobic power, is at an average level of 55 \(\pm\) 2.0\% in the combined group of combat athletes (Table 1).

Below are presented mathematical models of the general level of wrestlers’ functional fitness dependence on the level of development and the interconnections of the integral components of FF structure (Table 2).

<table>
<thead>
<tr>
<th>Statistical parameters</th>
<th>Factors of functional fitness structure</th>
<th>Mobility, %</th>
<th>Economy, %</th>
<th>General level of FF, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\bar{x})</td>
<td>53,0</td>
<td>53,5</td>
<td>80,4</td>
<td>45,3</td>
</tr>
<tr>
<td>(\pm m)</td>
<td>2,1</td>
<td>1,8</td>
<td>2,8</td>
<td>2,5</td>
</tr>
<tr>
<td>(S)</td>
<td>15</td>
<td>13</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>(V, %)</td>
<td>28,5</td>
<td>24,6</td>
<td>24,9</td>
<td>39,3</td>
</tr>
<tr>
<td>(n)</td>
<td>53</td>
<td>52</td>
<td>51</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1. Factors of functional fitness structure of combat athletes according to manifestations of respiratory and circulatory functions during testing loads
Regression models reflect the share contribution of individual integral indices of the functional fitness structure of Greco-Roman, freestyle, and judo wrestlers to the general structure of their functional state.

Revealed models are the basis for development of a system for assessing and predicting the wrestlers’ FFS, differentiated according to the level of development of its key integral components: anaerobic power, economy, aerobic power, mobility. Both in the combined group of highly skilled combat athletes and in each separate group of subjects: Greco-Roman, freestyle, and judo wrestlers.

Figure 1 shows the components of functional fitness structure of male combat athletes representing three styles of wrestling (Greco-Roman, freestyle and judo) according to the manifestations of respiratory and circulatory functions under testing loads and achieved indices of work capacity.

Comparative analysis of FFS of highly skilled representatives of different wrestling styles indicates that Greco-Roman wrestlers are superior to freestyle wrestlers and judokas in the following components of functional fitness: anaerobic power, mobility and economy. The greatest differences are manifested in the values of anaerobic power and mobility.

Statistically significant differences reflect more expressed ability of the body of Greco-Roman wrestlers to faster restore functions after physical load, (mobility), and to achieve the highest levels of work capacity under short-term physical load (anaerobic power).

The least differences between three groups of wrestlers were manifested in indices of economy, reflecting the ability of athletes to perform physical loads with a minimum level of function strain and minimal energy expenditures.

Figure 2 illustrates the general level of functional fitness of highly skilled freestyle and Greco-Roman wrestlers and judokas.

Average values of functional fitness general level, as an integral index determined by mobility, economy, anaerobic and aerobic power, are higher in Greco-Roman wrestlers (60.1 ± 3.2%). Freestyle wrestlers and judokas are inferior to Greco-Roman wrestlers in terms of functional fitness level (40.2 ± 2.8% and 39.0 ± 2.9%, respectively), which probably reflects the specifics of

Table 2. Mathematical models of the general level of wrestlers’ functional fitness dependence on the levels of development and ratio of its integral components

<table>
<thead>
<tr>
<th>Groups of subjects</th>
<th>Regression models</th>
<th>Correlation coefficients (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined group of</td>
<td>Y=((0.295x₁+0.248x₂+0.280x₃+0.046x₄)-0.749)±6.11</td>
<td>R=0.938, p&lt;0.0000..</td>
</tr>
<tr>
<td>combat athletes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greco-Roman wrestling</td>
<td>Y=(16.26+0.281x₁+0.337x₂+0.044x₃+0.055x₄)±6.2</td>
<td>R=0.903, p&lt;0.00000..</td>
</tr>
<tr>
<td>Freestyle wrestling</td>
<td>Y=(21.6+0.019x₁+1.11x₂-0.253x₃-0.533x₄)±0.92</td>
<td>R=0.993, p&lt;0.00000..</td>
</tr>
<tr>
<td>Judo</td>
<td>Y=(21.1+0.271x₁+0.366x₂+0.082x₃-0.208x₄)±4.7</td>
<td>R=0.943, p&lt;0.00000..</td>
</tr>
</tbody>
</table>

Notes: Y – general level of FF, %; x₁ – aerobic power; x₂ – anaerobic power, %; x₃ – mobility; x₄ – economy.

Fig. 1. Ratio of the components of functional fitness structure in athletes specialized in judo, freestyle and Greco-Roman wrestling

Fig. 2. General level of functional fitness in freestyle and Greco-Roman wrestlers and judokas
adaptive morphofunctional alterations associated with distinctive peculiarities of technical and competitive preparation of combat athletes of various specializations. Verification of this assumption may become the subject of further in-depth studies.

The results indicate that Greco-Roman wrestlers are most functionally prepared as compared to freestyle wrestlers and judokas, according to the outlined criteria. Therefore, elite athletes of the analyzed groups differ both in the general level of functional fitness and in the level of development of the studied structural properties. The greatest differences are manifested in the parameters of anaerobic power, mobility and integral index - the general level of functional fitness.

**Discussion**

The dominance of the analytical approach in studying the structure of combat athlete fitness allowed researchers to uncover different aspects of athletes’ physical state in the process of long-term adaptation to physical loads [10, 12, 28-30]. This approach, however, prevented them from examining the mechanisms of athlete body integration systems in the process of providing the high level of their fitness at different stages of training process. Application of the system approach methods in various sports events enabled some researchers to analyze the specifics of several body system integration in the process of ensuring a high level of physical work capacity [6, 25].

This approach permitted to evaluate not only the level of development, but also the ratio and interconnections of the components of athletes’ fitness general structure in the process of modeling different modes of muscular activity energy supply [7, 18, 25].

However, most of the similar studies dealt with the analysis of functional fitness structure of athletes specialized mainly in cyclic sports events [25, 26]. At the same time, FFS of combat athletes is reflected in special literature on wrestling without account for the variety of interdependent factors affecting its formation: weight category, gender, age, skill level and other factors [6, 8].

Conducted studies resulted in obtaining experimental material that characterizes the structure of combat athlete functional fitness according to complex of vegetative and somatic indices in various physiological states: before and under different physical loads, which show the role of various energy systems in ensuring physical performance of combat athletes specialized in different wrestling styles - judo, freestyle and Greco-Roman.

The use of complex research methods, including the cyclic test block, allowed us to carry out complex registration of physiological indices at rest, as well as under different modes of muscular activity, with accurate recording parameters of load, respiration, cardiac activity and work capacity [22, 31].

Complex registration of the parameters of combat athlete FFS provided the framework for developing appropriate models of systemic support for the muscular activity of highly skilled wrestlers. Previously developed models [6, 8, 31, 32], supplemented by the results of the given study, allow to differentiate the assessment of functional fitness structure of wrestlers according to different criteria and in various physiological states of their body (rest, muscular activity).

At the same time, while evaluating and interpreting the findings, one should take into account the fact that, according to the structure of movements, the cyclic load is not specific to acyclic activity of combat athletes.

In the studies of various authors, as well as in our earlier works, combat athletes were also tested using exercises that model their specific activity. This allowed to make indirect quantitative [in terms of time and number of movements performed in the test] and qualitative [in terms of quality of specialized movements technique] assessment of the level of their special work capacity and fitness [6, 31]. However, the degree of precision of the estimates of FFS, the ratio of its components, and the level of physical work capacity during such test execution is lower than during performing a block of cyclic loads.

The use of a block of physical loads of varying intensity and duration with registration of cardiac activity and respiration parameters provides high-precision determination of the level of development and the ratio

**Fig. 2. General level of functional fitness (%) in highly skilled wrestlers of different specialization (freestyle and Greco-Roman wrestling, judo)**

![General level of functional fitness (%) in highly skilled wrestlers of different specialization](image)
of the components of athletes’ functional fitness structure, the character of energy supply, as well as the level of their non-specific work capacity [4, 6, 31].

High mobility of the body functional manifestations of highly skilled wrestlers reflects its ability to restore functions as soon as possible after physical load [25, 26].

Differenciation of the estimates of the various FFS components of highly skilled combat athletes of different weight categories during performance of the testing load block allows high-precision assessment of their functional reserves, manifested differently in responses to physical load at various stages of annual training cycle [31]. It also permits to differentiate monitoring of physical state and fitness control of wrestlers of light and heavy weight categories according to key indices of cardiac activity of gas analysis and special work capacity [31-34].

Conclusions.

Generalization of the findings allows to believe that the key criteria for the functional fitness of highly skilled wrestlers providing a high level of physical work capacity include: economy of physiological systems functioning at rest and during muscular activity of anaerobic-aerobic nature, high reactivity of the cardiovascular system to physical load, power of the anaerobic energy supply system, rate of recovery processes, state of cardiac activity regulatory mechanisms, level of metabolic processes and excitability of the heart muscle.

The level of development and the ratio of the components of functional fitness structure of highly skilled combat athletes may be used as the reference models for development of differentiated scales for estimation of the key constituents of physical state of wrestlers specialized in freestyle, Greco-Roman wrestling and judo. Complex application of different methods of testing athletes provides more efficient approach to the problem of monitoring and managing functional fitness and special work capacity of wrestlers at the stage of maximum realization of individual capacities.

Conflict of interests.

The authors declare that there is no conflict of interest.

References


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Received: 09.09.2020
Accepted: 14.10.2020; Published: 30.10.2020
Parameters of lipid and oxidative-antioxidant status in persons aged 18-23 from radiation-contaminated areas under conditions of moderate physical activity

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Bohdan Khmelnytsky National University of Cherkasy, Cherkasy, Ukraine

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

Abstract

Purpose: There is a significant amount of data on the stressful effects of exercise, which contain conflicting results. Some publications testify to the adaptive processes and the benefits of optimized exercise for various physiological systems, some deny such an effect. Much controversial is the question of combination the physical exercises of different intensity with other stressors. The purpose of the study: to analyze the parameters of lipid metabolism and oxidative-antioxidant system in persons aged 18-23 who lived in territories with different radioecological status, under conditions of moderate physical activity during exercise.

Material: There were examined 50 students from relatively ecologically clean areas (control group) and 50 students from the IV radiation zone (experimental group). The radiation zone is selected by the dosimetry of soil contamination with \textsuperscript{137}Cs isopes after the Chornobyl catastrophe. Age of the examined is 18-23 years. Within the framework of the experimental group there were formed two subgroups: the main group for physical training classes (without signs of morphological-functional disorders) and the group for therapeutic physical training classes (TPTC, persons with signs of vegetative-vascular dystonia syndrome). For the control and experimental main group, classes contained all the planned exercises due to the standard curriculum. The program included a combination of aerobic and strength exercises of moderate intensity. For students with signs of vegetative-vascular dystonia, teachers used specially designed therapeutic exercise complexes. The first analysis of parameters was carried out the day before physical training classes, the second one – immediately after the class.

Results: Higher levels of total cholesterol and its lipoprotein fractions (LDL-C and HDL-C), triglycerides, oxidative stress index are detected in the experimental group compared to the control group. At the same time lower levels of sulfhydryl groups (SH) were marked. The absence of statistically significant changes in the analyzed parameters in the control group and the experimental therapeutic group after physical exercises is shown in the study. There were evident tendencies of ceruloplasmin level increase in the control along with the absence of such trends in persons with signs of vegetative-vascular dystonia syndrome. This led to the formation of a significant difference between groups for this antioxidant. There is a significant increase in cortisol level and oxidative stress index in the main group of students from radiation contaminated areas.

Conclusions: Potentiation of various stress factors in persons who experienced the prolonged exposure to Chornobyl accident reduces the adaptive potential of homeostatic systems. This eliminates the optimization of lipid metabolism and oxidative-antioxidant system through moderate exercise. Exercise therapy does not cause a pronounced stress effect.

Keywords: physical training, Chornobyl accident, adaptive reactions, malondialdehyde, oxidative stress index

Glossary

Adaptive reactions are body reactions to the change of environmental conditions. They are especially expressed at extreme influences of environmental factors and controlled by homeostasis systems.

Aerobic exercise is a type of physical activity characterized by the aerobic nature of energy supply (walking, running, swimming, etc.). Usually aerobic exercises are cyclic and performed for a relatively long time. Aerobic exercise is considered an effective type of health-improving physical activity.

Antioxidants are biologically active protein and low-molecular components. They can prevent or slow down the oxidation processes in the cell by interacting with free radicals and prooxidants.

Chornobyl accident is a radiation catastrophe at the Chornobyl nuclear power plant in 1986 caused a number of fundamental and applied radiobiological problems in the areas of radionuclide contamination.

High-density lipoprotein cholesterol (HDL-C) is a transport form of cholesterol that carries it back to the liver. It is a high-molecular easily soluble form that does not precipitate. HDL-C plays a protective role against lipid deposition in atherosclerotic plaques

Hypercortisolemia is a condition of elevated cortisol level due to stressful situation.

Low-density lipoprotein cholesterol (LDL-C) is a transport form of cholesterol and desaturated fatty acids from the liver to organs and tissues. LDL-C is poorly soluble and prone to the formation of atherosclerotic plaques in blood vessels, due to the increased ability to lose cholesterol during transportation.

Malondialdehyde (MDA) is a product of lipid peroxidation, a marker of oxidative stress, widely used in the assessment of oxidative status in various biological
samples.

**Oxidative stress (OS)** is oxidative processes mobilization, qualitatively different from spontaneous cellular processes. It is characterized by ROS production or inactivation imbalance, as well as oxidants/antioxidants imbalance (in favor of oxidants). Oxidative stress can cause destructive and pathogenic effects in the body.

**Oxidative-antioxidant status** is the balance between complexes of oxidants and antioxidants in the body.

**Physical training** is a system of physical exercises increasing the general physical activity of different social groups that is the factor of good health and physical condition maintenance.

** Reactive oxygen species (ROS)** are free radical components, oxygen ions and peroxides. Their sources are mitochondrial, microsomal, phagocytic electron transport chains of oxidation, etc. They have a high reactivity and a short life span. ROS levels may increase in response to certain endogenous and exogenous factors.

**Stress** is any change in the homeostasis due to the action of real or potentially dangerous factors characterized by activation of the axis «hypothalamus-pituitary-adrenal». The phase of physiological parameters recovery to homeostatic values is an important component of a normal response to stress. Stress exposure when regulatory systems are unable to restore indicators to optimal values, is called an allostatic load.

**Therapeutic physical training classes (TPTC)** are a set of strictly dosed physical exercise specially created for treating diseases and injuries, preventing disease recurrence or complications, restoring the health and working ability of patients or disabled people.

**Triglycerides** are the main lipid component of ultra-low density lipoproteins containing little cholesterol. It is a leading transporter of cholesterol from the liver to the blood.

**Vegetative-vascular dystonia** is a complex multifactorial syndrome. Its development is caused mostly by genetic factors. It is characterized by impaired neurohumoral and endocrine regulation of tone, mainly at the level of the cardiovascular system.

**Introduction**

Proper physical activity is considered an important factor in maintaining optimal health of the human. It affects the intensity of aging, development and progression of chronic diseases associated with age [1, 2]. Regular exercise can reduce the destructive manifestations of aging in the elderly at the level of immune status. It can indirectly reduce the impact of negative psychosocial factors and prevent the formation of depressive states [3, 4]. The mechanisms of the following effect at the molecular level are still being discussed. Perhaps the leading factor is adaptive response in the form of metabolic changes focused on forming a new dynamic balance in the body [5]. The result may be influenced by other factors of individual life: diet, smoking, alcohol and medication. It is believed that an important factor of exercise positive effect is inducing changes in the level of cholesterol, low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C), triglycerides. In other words the effect is manifested in the lipid and lipoprotein metabolism and catabolism. Although a similar result can be obtained through the normal physical work, the value of special training in maintaining a proper lipid profile is more important [6, 7]. The question of the exercise expedition, duration, intensity, frequency in the implementation of the mechanisms of dynamics of the lipids and lipoproteins level always attracted the attention of scientists [8, 9]. Here it is recommended to take into consideration the difference between the concepts of “physical activity” and “physical exercise”. Also we should mind the lack of clear recommendations for the selection of exercises to improve lipid status [10].

Previous research suggests that physical activity has a positive effect on metabolic status not only by increasing energy expenditure. It also alleviates the psychosocial stress caused by metabolic syndrome and obesity. On the other hand, exercise itself is a stressor. Chronic activation of the hypothalamus-pituitary-adrenal axis, associated with stress, forms a state of hypercortisolemia [11]. Increased stress reactivity may be a prerequisite for the formation of metabolic syndrome [12].

One of the possible factors of physical activity influence on age-related changes in the body is the intensification of oxidative processes. They can cause the destruction of muscle fibers and the suppression of the antioxidant defense [13, 14]. On the one hand, it is believed that the positive effects of exercise are mostly realized due to the active forms of oxygen. Active forms of oxygen are required for mitochondrial biogenesis and effective muscle contraction [15]. On the other hand, an increase in the concentration of reactive oxygen species is a sign of the oxidative processes mobilization. They, in turn, are realized by lipid peroxidation, in other words, it is the manifestation of oxidative stress [16].

Oxidative stress (OS), in particular during intense physical activity, is characterized by an imbalance between the production/inactivation of reactive oxygen. There is an imbalance between oxidants and antioxidants (in favor of oxidants). This can cause destructive and pathogenic effects in the body [5, 17]. Oxidative stress manifestations vary depending on the type of exercise. High-intensity exercise increases oxidative stress, and medium-intensity exercise is usually associated with decreased OS level [18]. Accordingly, the exercise intensity can be considered the factor of health benefits [19].

However, there were described the cases when long-term exposure to medium-intensity aerobic exercise has led to increased levels of malondialdehyde (MDA, a marker of oxidative stress) in laboratory animals [20]. Periodic increase in training load with weight reduced lipid peroxidation and, accordingly, had a positive effect on the development of oxidative stress [21].

In previous years, a significant amount of data has been accumulated on the stressful effects of physical activity with rather contradictory results. Some studies propose the hypothesis of adaptation to cross-stress. It
finds the benefits of optimized exercise for the formation of adaptive processes to strong social stressors. Other researches deny this effect. Many publications indicate that the positive or negative effect of training exercise on the human body depends on the various factors. It includes the type, intensity, frequency and duration of exercise, the rate of body parameters returning to its original level. The conclusions could be influenced by the methodological difference of conducting experiments that indicates the need to continue the scientific research in this direction [4, 11, 22].

It should be taken into account that a strongly pronounced increase in the level of reactive oxygen species (ROS) with subsequent cell damage is observed under conditions of environmental pollution of varying nature [17]. In our previous studies, we have found an increase in oxidative stress in people who have lived for a long time in radiation-contaminated areas. Also the signs of lipid status disorders were discovered [23-25]. However, in the same cohort, dosed physical exercise during physical training classes led to short-term changes in the immune system within the homeostatic norm. It indicated a low level of physical stress and effective recovery [26].

Purpose of study: to analyze the parameters of lipid metabolism and oxidative-antioxidant system in persons aged 18-23 who lived in areas with various radioecological status, under conditions of moderate physical activity during exercise.

Materials and methods

Participants.

The control group includes 50 students of Bohdan Khmelnitsky National University of Cherkasy (Ukraine) from radiation-free areas, without signs of acute or chronic diseases. The experimental group includes 50 students from the territory of enhanced radioecological control (zone IV, the status was granted by dosimetric assessment after the Chornobyl accident in 1986). Within the experimental group there are two subgroups formed: 25 healthy people (the main group) and 25 people with signs of vegetative-vascular dystonia (the therapeutic group). Age of students is 18-23 years. The conclusion about the state of health of the examined students was made by the doctors of the sanatorium “Edem” of Cherkasy National University. The study was conducted in compliance with the ethical principles of the European Convention and the Helsinki Declaration (ethics principles regarding human experimentation). It was confirmed by the Bioethics Commission of the University. Examined provided written approvals for analysis and subsequent disclosure.

Procedure.

Biomaterial collection techniques, used in the study reagents and methods for assessing the level of cortisol, lipid and oxidative-antioxidant status are described in detail in previous publications [23-25]. To assess the intensity of oxidative processes used the method developed by Korol and Myhal [27].

The research was conducted in late September, early October, after the adaptation period due to the beginning of studies. First-year students were not involved in the research. Physical activity in physical training classes was supervised by the teachers. Class duration is 80 minutes. For the control and experimental main groups, classes contained all the planned exercises due to the standard curriculum. The aerobic and strength exercises of moderate intensity were combined [28]. For people with signs of vegetative-vascular dystonia, teachers used specially designed therapeutic exercise complexes. They include breathing exercises, stretching exercises and coordination exercises, time-limited action games [29].

The first analysis of parameters was carried out the day before physical training classes, the second one immediately after the class.

Statistical Analysis.

The calculated statistical parameters are presented in the table in the form of average values and standard error (M ± m). Student’s t-test was used to compare data between groups and parameters before and after exercising. In the case where the data did not show a normal distribution, the Mann–Whitney U test was used. Statistical significance of the parameter’s difference is reflected in three levels (P < 0.05; P < 0.01; P < 0.001).

Results

It was found that in the control group the concentration of cortisol was within homeostatic norm. Physical training caused a tendency to increase in the concentration of cortisol, but the changes were not statistically significant. Examined from areas of radiation contamination (both main and therapeutic group) showed the initial concentration of cortisol significantly higher than the control values (P < 0.001). The index was at the upper values of the homeostatic norm. Physical training caused a tendency to increase in the therapeutic group and a significant increase in the main group (P < 0.05). The rate after exercise is significantly higher than the control under the same conditions (P < 0.001) in both groups of students from radiation-contaminated areas (Table 1).

Prior to physical training, total cholesterol concentration was shifted to the upper values of the homeostatic norm in the main group from radiation-contaminated areas. The index exceeded the upper values of the norm in the therapeutic group (with signs of vegetative-vascular dystonia) The index in both groups from radiation-contaminated areas is significantly higher than the control (P < 0.001). After physical activity any significant changes were not detected in either the control or experimental groups (Table 1).

Similar features were observed for triglyceride concentration and high-density lipoprotein cholesterol. In both experimental groups from radiation-contaminated areas, the rates were significantly higher than the control both before and after exercise (P < 0.001). Under conditions of physical activity any significant changes are absent in all the groups of examined students. Although some tendencies to increase (in average) in the level of HDL-C and decrease in the level of triglycerides were observed in all the groups (Table 1).
Before physical activity a significantly higher rate of low-density lipoprotein cholesterol was found compared to the control. The effect is marked in both main (P < 0.01) and therapeutic (P < 0.001) groups of students from radiation-contaminated areas. In the therapeutic group the rate is significantly higher than in the main group (P < 0.05). There are no statistically significant changes under conditions of physical exercise in all the groups. However, students from radiation-contaminated areas, especially in the therapeutic group, have a tendency to the rate decrease. After exercise, the rate in the main group is significantly higher than in the control under the same conditions (P < 0.05). In the therapeutic group it is significantly higher than in the control (P < 0.001) and in the main group (P < 0.01) (Table 1).

There are no significant differences between the analyzed groups before physical exercise in the concentration of malondialdehyde, ceruloplasmin and transferrin. There are no significant changes in exercise conditions as well (Table 1). There are pronounced trends to increase in ceruloplasmin concentration on the average value in the control group. The same trends are absent in the group of people with the signs of vegetative-vascular dystonia. This led to the fact that the rate became significantly lower in the therapeutic group than in the control group after exercise (P < 0.01) (Table 1).

Before exercise, SH-groups concentration in the examined from the main group was significantly lower than in the control (P < 0.001). In the therapeutic group it is lower than both in the control (P < 0.001) and in the main group (P < 0.01). No significant changes were found for all the groups. After exercise, there was a significant difference in the rate compared to the control. The effect was marked both in the main group of students from contaminated areas (P < 0.001) and in the therapeutic group (P < 0.001). In the therapeutic group index remained significantly lower than in the main group (P < 0.001) (Table 1).

The oxidative stress index was significantly higher in both experimental groups than in the control, both before and after exercise (P < 0.001). Under conditions of physical activity, the rate significantly increased only in the main

### Table 1. Physical activity influence caused by physical training lessons on cortisol parameters, lipid profile and oxidative-antioxidant status of the examined (M ± m)

<table>
<thead>
<tr>
<th>Components</th>
<th>Control, n=50 before exercise</th>
<th>After exercise</th>
<th>The main group, n=25 before exercise</th>
<th>After exercise</th>
<th>The therapeutic group, n=25 before exercise</th>
<th>After exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortisol, nmol /l</td>
<td>349.1±10.12</td>
<td>387±18.44</td>
<td>627.2±21.10</td>
<td>693.1±15.9</td>
<td>620.2±24.31</td>
<td>641.1±19.02</td>
</tr>
<tr>
<td>Total cholesterol, mmol /l</td>
<td>3.06±0.28</td>
<td>2.81±0.16</td>
<td>5.35±0.51</td>
<td>5.32±0.85</td>
<td>6.63±0.84</td>
<td>6.65±0.61</td>
</tr>
<tr>
<td>Triglycerides, mmol /l</td>
<td>0.52±0.08</td>
<td>0.50±0.07</td>
<td>0.93±0.08</td>
<td>0.90±0.06</td>
<td>0.97±0.04</td>
<td>0.96±0.06</td>
</tr>
<tr>
<td>High density lipoprotein cholesterol, mmol /l</td>
<td>1.07±0.07</td>
<td>1.16±0.07</td>
<td>1.64±0.09</td>
<td>1.69±0.08</td>
<td>1.47±0.07</td>
<td>1.56±0.07</td>
</tr>
<tr>
<td>Low density lipoprotein cholesterol, mmol /l</td>
<td>1.82±0.11</td>
<td>2.05±0.13</td>
<td>3.15±0.41</td>
<td>2.92±0.40</td>
<td>4.92±0.58</td>
<td>4.25±0.39</td>
</tr>
<tr>
<td>Malondialdehyde, mmol /l</td>
<td>125.4±27.51</td>
<td>132.1±23.14</td>
<td>130.3±10.01</td>
<td>142.2±10.99</td>
<td>141.2±9.99</td>
<td>143.1±8.11</td>
</tr>
<tr>
<td>Ceruloplasmin, g /l</td>
<td>0.24±0.02</td>
<td>0.28±0.02</td>
<td>0.22±0.01</td>
<td>0.26±0.02</td>
<td>0.21±0.02</td>
<td>0.21±0.02</td>
</tr>
<tr>
<td>Transferrin, cond. un.</td>
<td>5.33±1.01</td>
<td>5.36±1.08</td>
<td>4.52±0.63</td>
<td>4.63±0.87</td>
<td>4.25±0.85</td>
<td>4.32±0.96</td>
</tr>
<tr>
<td>SH-groups, mmol /l</td>
<td>2.52±0.03</td>
<td>2.62±0.05</td>
<td>1.84±0.04</td>
<td>1.99±0.06</td>
<td>1.63±0.06</td>
<td>1.67±0.04</td>
</tr>
<tr>
<td>Oxidative stress index, un.</td>
<td>1.03±0.04</td>
<td>1.05±0.06</td>
<td>1.37±0.04</td>
<td>1.52±0.05</td>
<td>1.43±0.05</td>
<td>1.44±0.05</td>
</tr>
</tbody>
</table>

Notes: * – P < 0.05; ** – P < 0.01; *** – P < 0.001 compared to the control under the same conditions; # – P < 0.05 compared to the index before exercise; $ – P < 0.05; $$ – P < 0.01; $$$ – P < 0.001 compared to the index in the main group under the same conditions.
Discussion

Cortisol level remains the leading biomarker of the hypothalamus-pituitary-adrenal activity and the reactions of the physiological response of the body to acute or prolonged stress [30]. Increased cortisol level in the examined from radiation-contaminated areas before exercise indicated the chronic stress. Ionizing radiation is a stressor for the human body. Moreover, it acts both as a physical and psychological factor, in particular, with a long-term awareness of the constant potential health risk [31-33]. Under conditions of physical activity during physical training lessons, cortisol level significantly increased only in the main group of students from the IV radiation zone (Table 1). However, cortisol rate did not reach such high values as in the period of intensified psycho-emotional load caused by the examination session. This effect, when cortisol level also increased in the control group, was observed in our previous studies [24, 25]. Thus, we can distinguish the lack of the evident stress effect of physical activity. Cortisol level increase in the main group of students could be a sign of potentiation of previous chronic radiation exposure and exercise. The important factor is no increase in cortisol levels in the therapeutic group. The positive aspects of this effect can be assessed in comparison with the analysis of other analyzed parameters.

Hypercortisolemia is associated with metabolic syndrome, accumulation of total cholesterol and low-density lipoprotein cholesterol, as well as decrease in the level of high-density lipoprotein cholesterol [34, 35]. Lipoprotein lipase (LPL) activity increases that, in turn, leads to an increase in triglycerides. Such processes are mobilized in individuals with dysregulated or hyperactive stress response [11, 36, 37]. Correction of elevated cortisol level usually improves the state of hyperlipidemia [38]. Our previous studies have shown associative relations between cortisol level and lipid profile in individuals from the areas of enhanced radioecological control. Strongly pronounced lipid parameters imbalance was observed in persons with signs of vegetative-vascular dystonia and dysfunctions of thyroid status [23].

Taking into consideration the initial elevated level of cortisol in the experimental groups, its further increase during physical exercise could be characterized as an unfavorable factor. However, it is necessary to take into account the possible positive effect of exercise on the lipid profile. There are studies conducted for Australian farmers who have experienced severe emotional stress and were inclined to metabolic disorders. It was shown that a set of physical exercises caused a significant reduction in obesity. However, it had little effect on cortisol concentrations, anxiety, depression and stress [39].

There are data indicating on elevated levels of total cholesterol and LDL-C in individuals of different sexes who had a high level of physical activity during the life [40]. However, a significant number of publications indicate a positive effect of exercise on the lipoprotein profile of examined. It applies to people of different ages, starting from childhood and ending with the old age [41, 42]. Usually, the ratio of low and high density lipoproteins cholesterol, as well as the level of triglycerides, is analyzed when assessing the lipid profile. Elevated LDL-C indicates an excess of lipids in the blood. Along with triglyceride excess, it causes a risk of cardiovascular dysfunction. In particular, it is a marker of atherosclerotic diseases [10, 43, 44]. In contrast, HDL-C, transporting lipids to the liver for further utilization is considered to be protective for cardiovascular system. However, a significant increase in this parameter can also create the preconditions for the pathologies development [45, 46]. Hypertriglyceridemia has received less attention in clinical practice, although it is clearly associated with diabetic conditions and pancreatitis [47, 48].

Thus, in our case, a group of people with signs of vegetative-vascular dystonia can be considered a risk group. This is the risk of metabolic syndrome formation and the development of cardiovascular disorders complications. They are caused by a significantly elevated LDL-C level. Under conditions of physical activity, no statistically significant changes in the lipid profile parameters of the examined were detected. However, there are signs of positive effect of physical exercises, especially pronounced in people from the therapeutic group. Here belong the tendency to decrease in the level of LDL-C against the background of LDL-C increase and triglycerides decrease (Table 1).

Lipid profile changes during exercise can be influenced by several factors. First of all, it’s exercise intensity. Analysis of publications shows that low and medium intensity aerobic exercises lead to a significant reduction in the level of LDL-C. It is believed such exercises determine the effective use of lipids as a source of energy, supporting the activity of the cardiovascular system [49, 50]. Moderate-intensity exercises keep the level of LDL-C and triglycerides lower than high-intensity exercises. Under the same conditions HDL-C level is contrarily higher. At the same time no difference in the level of total cholesterol between the groups of physical activity of different intensity may be observed. Such tendencies are representative not only for aerobic, but also for strength training [10, 51].

The second effectiveness factor is exercise type. Aerobic exercises (running, cycling) are considered more favorable for lipid profile improving. However, the result is mostly determined by the intensity [10, 52]. The combination of aerobic and strength exercises usually gives a result similar to individual aerobic. Moreover, the statistical significance of lipid profile changes is noted for the elderly people. In young ones there were only trends in the same direction [53].

The next effectiveness factor is the age of the examined, although the results are contradictory in this regard. There are reports of the absence of a clear correlation between physical activity and lipoprotein profile in the elderly.
There is evidence that at the beginning of the training period the level of low-density lipoprotein cholesterol was observed after 2-6 months of training [42, 55, 58]. There are data on a certain racial and gender variability of the signs of obesity or overweight showed certain trends. At the same time, a study of college students with the signs of obesity or overweight showed certain trends. An increase in HDL-C and decrease in triglyceride level during regular fitness is observed. It is especially evident in females [54]. Fitness also improved the lipid profile of obese adult women [55].

Another important factor is previous physical form. Usually the concentrations of total cholesterol and LDL-C are significantly higher in groups that did not have regular exercise. The concentration of high-density lipoprotein cholesterol is higher in the group of trained individuals [56]. It was reported that untrained young males showed the ratio of low/high density lipoproteins higher than in the trained group. The effect appeared both before and after exercise. However, cortisol level (also elevated) in this group was optimized after exercise [57]. In general, people previously having low physical activity, showed a correlation of its growth with an improvement in triglycerides and HDL-C. Moreover, taking into account the data variability, the main effect of exercise is suggested to be an increase in HDL-C [10].

The duration of the physical training course should not be neglected either. In particular, a significant decrease in the level of low-density lipoprotein cholesterol was observed after 2-6 months of training [42, 55, 58]. There are data on a certain racial and gender variability of the lipid profile response to exercise [59]. Metabolic changes being formed in the body of athletes during intense physical and emotional load are characterized by specific features. On the one hand, physical activity helps to increase overall physical efficiency, energy supply, optimization of maximum oxygen consumption [60]. On the other hand, it leads to the body deconditioning and the oxidative stress formation. There is evidence that at the beginning of the training period the level of malondialdehyde in the group of athletes is higher than in the control group [56]. The rate increased even more by the end of the training period that indicates the body deconditioning and the oxidative stress formation. In the middle of the training period, the rate declining tendency was observed, that was characterized as the oxidative processes hierarchy change [61, 62].

Intensification of lipid peroxidation was observed in middle-aged and elderly men during long training with combined strength and exercise tolerance circuit. This gave the reason to talk about the importance of the time factor in the response of oxidative and antioxidant systems to physical stress [63]. However, even short-term intense exercise (running, swimming) can cause the MDA level increase and the effect lasts at least 24 hours [64, 65]. In particular, the MDA concentration increase after intense exercise was found in young people of different sexes in the postpubertal period. This indicates the mobilization of oxidative stress [66]. Intensification of oxidative processes in trained individuals during exercise was less pronounced than in untrained group [67]. There are data demonstrating the absence of pronounced changes in the level of malondialdehyde during 12-week training [68].

Malondialdehyde (MDA), as a product of lipid peroxidation, is its reliable marker. It is widely used in the assessment of oxidative status in various biological samples [16, 69, 70]. The MDA level assessment under conditions of exogenous influences should be performed in combination with the antioxidant status assessment. However, even in this case, contradictory results are often obtained. Some studies have described the absence of a significant increase in the level of MDA, in others its presence is marked [71, 72]. Obviously, in addition to the time factor, the training intensity is essential for the effect manifestation. This is confirmed by the positive correlations between exercise intensity, antioxidant and malondialdehyde concentration [56].

There is comparison of the groups of students who had standard training and balanced physical therapy classes. It showed no difference in the level of MDA both at the beginning of the 8-week training period and at the end. Moreover, at the beginning of the training period there was a tendency to the MDA level increase after classes. At the end of training period a fairly stable level was marked. There was a tendency to gradually reduce the level of MDA during the training period [73].

There is an analysis of 8-week classes of various types in a group of men aged 60-80 years. Aerobic, strength or combined classes three times a week for 1 hour. We marked a decrease in the level of MDA, regardless of the type of exercise. The effect was characterized as the oxidative stress reduction. Antioxidant protection parameters also improved, however, the value depended on the type of exercise performed. This indicated the variability of the antioxidant protection mechanisms depending on the type of exercise [4].

Ceruloplasmin, transferrin and sulfhydryl groups are recognized antioxidants [75-77]. Particular attention is paid to ceruloplasmin. It is a regulator of copper and iron ions homeostasis in the body and free radicals formation protector [78]. Antioxidant status is usually higher in trained individuals before exercise and it was improved in untrained individuals after exercise [57]. In our studies, there is no significant difference between the analyzed groups in the initial concentration of malondialdehyde. It relates to the most parameters of antioxidant status. Only SH-groups concentration in the main group of students from radiation-contaminated areas is significantly lower than in the control. In the therapeutic group it is significantly lower than in the other two groups (Table 1). After physical training, there were no significant changes in the parameters. However, different tendencies led to a significant increase in the index of oxidative stress in the examined of the main experimental group (Table 1). Thus, they showed a tendency of increase in the levels of ceruloplasmin and sulfhydryl groups that did not compensate the tendencies of increase in the levels of malondialdehyde. In general, the oxidative stress index is significantly higher in all experimental groups than the control both before and after exercise. It is clear that in
conditions of environmental pollution of various nature, the level of ROS increases [17]. Obviously, the effect is caused by long-term living in the territories of the IV radiation zone. It happened in the periods of ontogenesis that is important for the formation of physiological homeostatic systems. As a result, it created the tension of the antioxidant system with the following specific response to exogenous influence. On the other hand, there is the lack of the oxidative stress index increase in the therapeutic group. It indicates the optimal selection of exercises for therapeutic training course.

Vegetative-vascular dystonia syndrome is a complex of dysfunctions at the level of autonomic regulation and vascular insufficiency. This requires careful physiotherapeutic rehabilitation, in particular, through exercise [79]. Regular exercise is considered an important physiological stimulus for adaptive responses. They improve the regulation of vascular tone and, consequently, vascular endothelial function [80]. In addition, there are data on the associated nature of neurodegenerative diseases with increased oxidative stress. Under such conditions regular exercise can increase the activity of antioxidant system and the system of oxidative damage repair [81, 82].

When assessing any stress response as the cause of allostatic load, it is recommended to take into consideration various parameters. They are the value (intensity) of stress, its frequency, duration, rate of parameters’ return to the initial level, etc. [11]. ROS are the important signal molecules for adaptive response. Detoxification and normalization of ROS parameters due to exercise depends on various factors. These are age, sex, level of physical activity, environmental conditions, genetic characteristics of the individual, lifestyle, nutrition quality. Increased as a result of metabolic processes, ROS production leads to oxidative damage. However, it also stimulates the antioxidant protection that eliminates much of the damage [83].

Thus, we considered the age of the examined, the lack of trained individuals, low and medium intensity of the exercise. Accordingly, we expected more pronounced changes in lipid status and improved parameters of antioxidant status. Perhaps a significant factor was the study period. The analysis was performed almost at the beginning of the semester. Any significant changes could be expected at the end of the school year.

It is believed the benefit of regular short-term exercise is connected with the stimulation of oxidative processes. ROS level increase continues to the values causing significant but acceptable damage. This, in turn, stimulates adaptive responses. According to the theory of hormesis, they protect against stress effects of greater intensity or strength. The following effect, being realized at the molecular level, can serve as a protective factor against diseases associated with ROS. In particular, age-related changes [18, 84]. However, the examined from radiation-contaminated areas have some specifics. The adaptive reactions realization could be affected by failures in the regulation of lipid and oxidative-antioxidant profile. The failure probability is described in our previous publications [23-25]. When selecting exercise for this cohort, it is important to consider the risk of all stressors’ potentiation. A special attention should be paid to the social anxiety as a factor of significant hypercortisolemia [85].

Conclusions
Students from the control group did show statistically significant changes of the analyzed parameters during physical activity. The group of exercise therapy was formed by the people from radiation-contaminated areas with signs of vegetative-vascular dystonia syndrome. There are no significant changes in lipid metabolism and oxidative-antioxidant status in the group. This indicates the absence of a pronounced stress effect of specially selected exercises. People from the radiation-contaminated areas performed the standard set of aerobic and strength exercises. There is a significant increase in cortisol level and oxidative stress index in the group. This effect may indicate the potentiation of various stressors. The group from the IV radiation zone has the lack of positive dynamics of the analyzed parameters after physical education. This may be a sign of a short period of training and failure of adaptive homeostatic systems.

Acknowledgements
The authors express their sincere gratitude to the chief physician of the “Edem” sanatorium at the Bohdan Khmelnytsky National University of Cherkasy Pinkovska L. O. for the examination of the experimental group and control group of students and assessment of their health status, and to the medical staff of the sanatorium for blood sampling.

Conflict of interest
The authors state that there is no conflict of interest.
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**Cite this article as:**


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Received: 15.09.2020
Accepted: 15.10.2020; Published: 30.10.2020
SUBMISSION OF MANUSCRIPTS
(For more detailed information see http://www.sportedu.org.ua/index.php/PES/pages/view/trebovaniya-e)

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Information:
Sponsors, Partners, Sponsorship:
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SCIENTIFIC EDITION (journal)

Physical Education of Students, 2020;24(5)

Editorial to the publisher department KSPU:
certificate DK №860 20.03.2002.

designer - Iermakov S.
editing - Yermakova T.
administrator of sites - Iermakov S.
designer cover - Bogoslavets A.

passed for printing 30.10.2020
Format A4.
PRINTHOUSE (B02 № 248 750, 13.09.2007).
61002, Kharkov, Girshman, 16a.