Discrimination of Different Body Structure Indexes of Elite Athletes in Combat Sports Measured by Multi Frequency Bioimpedance Method

Discriminación de Diferentes Índices de Estructura Corporal de Atletas de Elite en Deportes de Combate Medidos por el Método de Bioimpedancia de Múltiples Frecuencias

Milivoj Dopsaj1; Milan Markovic1; Goran Kasum2; Srecko Jovanovic3; Nenad Koropanovski4; Marko Vukovic5 & Milos Mudric6

DOPSJ, M.; MARKOVIC, M.; KASUM, G.; JOVANOVIC, S.; KOROPANOVSKI, N.; VUKOVIC, M. & MUDRIC, M.

INTRODUCTION

Organization of modern elite sport as a controlled system is based on multi annual practice. During this process, the athlete goes through various stages of basic and sports specific training, but also through the various stages of psychological, social, biological, morphological and competitive development. Constant control over the effects of the applied training facilities and methods must be used continuously during training, and it has essential importance for progress control and development of athlete’s competitive mastership (Issurin, 2008). As an athlete progresses in the relation to different elements of sport development i.e. sport mastership, raises professional need as well as practical possiblities for more specific studies of each element of athlete’s system, especially training effect individually (Sánchez-Puccini et al., 2014).

The main aim in sport is to achieve the best possible competitive result, that is why the training is used (technical,
tactical, physical, psychological and etc.) as a meaning to fulfill the same. For gaining top sports results sever factors should be completed. Among them very important part is training system and morphological factor (Dopsaj et al., 2013). Body structure is of great importance in a sport where its importance plays a main role due to sports’ achievements, still in certain groups of sports it is a limited performing factor related to technical propositions defined by weight categories (wrestling, boxing, judo, karate, rowing, etc).

Most experts and scientists engaged in the athlete’s morphology believe that there is a relationship between some sport characteristics and an athletes morphological characteristics. In fact in most cases, young athletes choose a sport which is appropriate to their morphology, as morphology of their bodies provide them advantage. On the other side, by training chosen sport, and considering adjustment phenomena over certain sports’ specificity, an athlete gains morphological characteristics typical for a certain sport. It is shown that top sports achievements are more often associated with body structure of an athlete (Cirkovic et al., 2010; Kim, et al., 2011). Therefore, in most sports significant focus is aimed to studying body structure status of and an active athlete and to those who consider getting engaged into some sport (Sánchez-Puccini et al.).

Group of combat sports, the object of this study consists of three most popular combats sports in Republic of Serbia, and those are: judo, Greco-Roman wrestling and karate (Cirkovic et al.). The first two belongs to Olympics group of sports (judo and wrestling) and all three are characteristic for sporting competitors by weight categories, specific for each sport.

Judo consists of 7 weight categories. For men those are: -60kg, -66kg, -73kg, -81kg, -90kg, -100kg i +100kg. Greco-Roman wrestling has characteristic match where the grips can be used performed from the waist to the top and it is consisted of the categories 59, 66, 71, 75, 80, 85, 98 i 130kg (71 i 80kg are not Olympics categories). While karate consists of only 5 weight categories which are: -60, -67, -75, -84 and +84kg.

A large number of morphological and body structure parameters to should be observed and analyzed may significantly affect the choice of techniques that are most commonly used in a fight (Kasum & Dopsaj, 2012). Firstly this is related to the longitudinal and transverse of the skeleton dimensions and diameter of joints, which are largely determined by inherited factors. The impact of specific multi annual training on some morphological parameters can be significant, but some may not significantly affect the planning. This is the case with the bone system, where under the influence of training stress, receives a high specific bone volume and density (Cirkovic et al.). Somatotype of elite male combat sports athletes are characterized by distinct mesomorphic characteristics (muscularity, low fat level), while women have a strong endomorphic characteristics that are often adjoin the mesomorphic. Ideal, judokas, wrestler, karate fighter should have a body fat level of 7-10 % built by optimal combination of training and adequate nutrition, with the exception of the top weight categories (Kasum & Dopsaj).

In combat sports control of body weight is one of the key issues during the training and competition. It is no surprise that athletes must take accelerated process of extenuation, which can cause negative health effects or negative competitive efficiency i.e. performance (Cirkovic et al.). That is why technological efficiency of sports training system is to be upgraded, even in relation to control processes of fighter body status by enhancement mechanisms of applied scientific methods by which athlete’s body status is controlled and managed toward optimum desirable structure (Sterkowicz-Przybycien, 2010; Kasum & Dopsaj). Therefore the studies in the field of defining innovative indicators of body structure one of the essential factor for updating knowledge of fighter’s body structure characteristics.

In the last few years bioelectrical impedance analysis is widely used in medical and sport practice and more and more present’s standard method for determination of complete body structure and body segments. Measuring procedure is simple and doesn’t take much time, method is noninvasive, relatively cheap, applicable for measuring large groups and can be applied regardless of age or sex (Gibson et al. 2008; Sillanpää et al. 2014).

Object of this research is analysis body composition characteristics of elite sport competitors in martial arts/combatsports – judo, Greco-roman wrestling and karate. Aim of this research is to define the most discriminative indicator of body structure indexes, by tracking body morphology change related to sports branch and kind of combat sport. All findings obtained in this research will be generally used due to sports training technologies, and in the terms of redefining morphological characteristics present models for examined fighters, as well as updating systems of sport nutrition effects and methodological control procedures of fighter’s body structure.

MATERIAL AND METHOD

In relation to the basic method, this study according to its character belongs to a scientific research category. In relation to form of research this study has characteristics of
fundamental and applied research, as it provides innovation of existing general knowledge in the area of elite athletes’ body structure, which can be used in combat sports. Basic method of finding in this study will be inductive conclusion as based on individual indicators of body structure will be explained procedures and processes in different examined combat sports.

**Subjects.** This research included 112 participants, male elite athletes, members of different Serbian national teams. Sample consists of high level athletes competitors in two Olympics sports, judo (N=62) and Greco-Roman wrestling (N=29) and one non Olympics sport, karate (N=21). Basic characteristics of total sample were: age – 23.26±3.85 yrs., training experience – 13.30±2.23 yrs., body mass – 83.29±13.63 kg, body height – 180.78±8.76 cm, BMI – 25.37±2.80 kg·m⁻². While the values for individual sports:

- **Judo:** age – 23.60±4.15 yrs., training experience – 13.13±4.79 yrs., body mass – 86.15±14.29 kg, body height – 183.00±8.72 cm, BMI – 25.60±2.80 kg·m⁻².
- **Wrestling:** age – 23.56±3.27 yrs., training experience – 12.65±3.13 yrs., body mass – 82.08±13.10 kg, body height – 175.68±8.58 cm, BMI – 26.44±2.34 kg·m⁻².
- **Karate:** age – 21.81±3.43 yrs., training experience – 14.62±3.88 yrs., body mass – 76.49±9.55 kg, body height – 181.3±6.10 cm, BMI – 23.23±2.26 kg·m⁻².

All examinees were informed about testing conditions and procedure and voluntarily participated in this research. Complete process of tracking this sample was carried out during the period 2011-2014, in scientific research laboratory in Faculty of Sport and Physical Education, University of Belgrade. The research was carried out in accordance with the conditions of Declaration of Helsinki: Recommendations Guiding Physicians in Biomedical Research Involving Human Subjects (http://www.cirp.org/library/ethics/helsinki/), and with the approval and consent of the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade.

**Testing.** Testing procedure of measuring body constitution was carried out by usage of bioelectrical impedance analysis (BIA), precisely InBody 720 Tetapolar 8 points by tactical electrodes system (Biospace Co, Ltd). Inbody 720 device (720 Inbody Biospace 2008) used the latest technology of measuring body structure by method DSM-BIA (Direct Segmental Multi frequency Bioelectrical Impedance Analysis). Bioelectrical impedance Inbody 720 showed high test – retest, reliability and accuracy (ICC 0.9995) (Gibson et al.). This kind of equipment is intensively used in sports health clinics and other health care improvement institutions.

All participants were measured in accordance with manufacturer’s suggestions. And prior to testing they got these instructions:

- Measuring was taken in the morning between 8:00 and 10:00am,
- Participants were asked to abstain from large meal after 9 am day before testing,
- Participants were asked to abstain from eating and drinking prior to testing on the measuring day,
- Participants were asked to refrain from extreme physical exertions 24 hours prior to measuring, and last training should have been performed at least 12 hours prior to measuring,
- Participants were asked to abstain from consuming any alcohol drinks 48 hours before measuring,
- Participants were asked to urinate and defecate at least 30 minutes prior to measuring,
- Participants were in the standing position at least 5 minutes prior to measuring due to normal fluid distribution in the body,
- Measuring was taken in the standing position, as it was suggested by manufacturer (hands aside placed 15 cm laterally from the body).

**Variables.** This study comprised 10 variables, 2 of which were primary and 8 were derived (index) variables, defining the morphology and composition of the body. The latter variables were:

1. **BH** – body height, expressed in cm;
2. **BM** – body mass, expressed in kg;
3. **BMI** – body mass index, expressed in kg·m⁻²;
4. **FFMI** – free fat mass index, calculated as: FFMI (free fat mass, in kg) · BH² (body height, in m), expressed in kg FFMI ·m⁻²;
5. **FMI** – fat mass index, calculated as: FMI (fat mass, in kg) · BH² (body height, in m), expressed in kg FMI ·m⁻²;
6. **PMI** – protein mass index, calculated as: PMI (protein mass, in kg) · BH² (body height, in m), expressed in kg PMI ·m⁻²;
7. **SMMI** – skeletal muscle mass index, calculated as: SMMI (skeletal muscle mass, in kg) · BH² (body height, in m), expressed in kg SMMI ·m⁻²;
8. **PBF** – percent of body fat, calculated as: PBF (body fat, in kg) / BM (body mass, in kg), expressed in %;
9. **PSMM** – percent of skeletal muscle mass, calculated as: PSMM (skeletal muscle mass, in kg) / BM (body mass, in kg), expressed in %;
10. **PFI** – protein fat index, calculated as relation between proteins (in kg) and body fat mass (in kg), expressed in kg.

**Statistics.** All raw results are, in the first step of statistical
analysis, submitted to calculation of basic descriptive statistics by measures of central tendency (MEAN), measure of statistical dispersion (SD, cV%, Std. Error absolutely and relatively, lower and higher 95% confidence interval bound). Regularity of variables distribution is tested by Kolmogorov-Smirnov nonparametric test. To determine differences between of participants subsamples MANOVA is used in general meaning, while ANOVA is used in partial meaning. Difference between pairs of individual variables of examined subsamples is tested by Bonferroni criterion. To define the most important factor of morphological variables difference in function of subsamples we used Discriminative analysis. All statistical analysis were accomplished by statistical softwares SPSS 19.0, while the level of statistical significance is defined by 95% and the probability values of a p < 0.05 (Hair et al., 1998).

RESULTS

In Tables I and II all descriptive indicators of tested morphological index are shown in the relation to total sample of participants, as well as a single martial arts sport. Table III shows results of body structure index differences (MANOVA and ANOVA) with regard to type of analyzed martial arts sport.

The figure 1 shows centroid positions of athletes in relation to a combat sport and tested body structure index. In relation to the first isolated factor (discriminative factor) judokas were allocated on 0.38, wrestlers – 1.55, a karatekas on 1.01 centroid position, while considering the second factor position for the judokas was 0.30, -0.16 for wrestlers and -0.67 for karatekas.

Table IV and V display result of discriminative analysis with results of defined canonic discriminant function.

DISCUSSION

Researches of body structure are very important in the relation to the general population as well as population of different level competitive athletes and different sport branches (Janssen et al., 2000; Andreaoli et al., 2001; Dopsaj et al., 2010; Sillanpää et al.; Sánchez-Puccini et al.). Related to the general population the phenomenon of body structure is studied to research the connection with non-infectious diseases, i.e health status, as well as in relation to the measuring methods and body structure modeling with different races (Wang et al., 1994; Janssen et al.; Sillanpää et al.), while with population of athlete research is aimed at the phenomenon of body structure adaptation on training.

Table I. Basic descriptive statistics of whole combat sport subject sample.

<table>
<thead>
<tr>
<th>Variables</th>
<th>MEAN</th>
<th>SD</th>
<th>cV%</th>
<th>Std. Error (Aps)</th>
<th>Std. Error (%)</th>
<th>Confidence Interval 95</th>
<th>K-S Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH (cm)</td>
<td>180.78</td>
<td>8.76</td>
<td>4.85</td>
<td>0.83</td>
<td>0.46</td>
<td>179.95</td>
<td>181.61</td>
</tr>
<tr>
<td>BM (kg)</td>
<td>83.29</td>
<td>13.63</td>
<td>16.36</td>
<td>1.29</td>
<td>1.55</td>
<td>79.00</td>
<td>81.58</td>
</tr>
<tr>
<td>BMI (kg•m⁻²)</td>
<td>25.37</td>
<td>2.80</td>
<td>11.04</td>
<td>0.26</td>
<td>1.02</td>
<td>25.11</td>
<td>25.63</td>
</tr>
<tr>
<td>FFMI (kg•m⁻²)</td>
<td>22.62</td>
<td>2.24</td>
<td>9.90</td>
<td>0.21</td>
<td>0.93</td>
<td>22.41</td>
<td>22.83</td>
</tr>
<tr>
<td>FMI (kg•m⁻²)</td>
<td>2.74</td>
<td>1.22</td>
<td>44.53</td>
<td>0.12</td>
<td>4.38</td>
<td>2.62</td>
<td>2.86</td>
</tr>
<tr>
<td>PMI (kg•m⁻²)</td>
<td>4.51</td>
<td>0.46</td>
<td>10.20</td>
<td>0.04</td>
<td>0.89</td>
<td>4.47</td>
<td>4.55</td>
</tr>
<tr>
<td>SMMI (kg•m⁻²)</td>
<td>13.00</td>
<td>1.39</td>
<td>10.69</td>
<td>0.13</td>
<td>1.00</td>
<td>12.87</td>
<td>13.13</td>
</tr>
<tr>
<td>PBF (%)</td>
<td>10.62</td>
<td>3.84</td>
<td>36.16</td>
<td>0.36</td>
<td>3.93</td>
<td>10.26</td>
<td>10.98</td>
</tr>
<tr>
<td>PSMM (%)</td>
<td>51.31</td>
<td>2.30</td>
<td>4.56</td>
<td>0.22</td>
<td>0.43</td>
<td>51.09</td>
<td>51.53</td>
</tr>
<tr>
<td>PFI (kg)</td>
<td>2.02</td>
<td>1.13</td>
<td>55.94</td>
<td>0.11</td>
<td>5.45</td>
<td>1.91</td>
<td>2.13</td>
</tr>
</tbody>
</table>
Table II. Basic descriptive statistics of combat sport subject subsample.

<table>
<thead>
<tr>
<th>Variables</th>
<th>MEAN</th>
<th>SD</th>
<th>cV%</th>
<th>Std. Error (Aps)</th>
<th>Std. Error (%)</th>
<th>Confidence Interval 95 %</th>
<th>K-S Z (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH (cm)</td>
<td>183.00</td>
<td>8.72</td>
<td>4.77</td>
<td>1.11</td>
<td>0.61</td>
<td>181.89 - 184.11</td>
<td>0.930</td>
</tr>
<tr>
<td>BM (kg)</td>
<td>86.15</td>
<td>14.29</td>
<td>16.59</td>
<td>1.82</td>
<td>2.11</td>
<td>82.82 - 89.49</td>
<td>0.671</td>
</tr>
<tr>
<td>BMI (kg.m⁻²)</td>
<td>25.60</td>
<td>2.80</td>
<td>10.94</td>
<td>0.36</td>
<td>1.41</td>
<td>24.94 - 26.25</td>
<td>0.765</td>
</tr>
<tr>
<td>FFMI (kg.m⁻²)</td>
<td>22.62</td>
<td>2.01</td>
<td>8.89</td>
<td>0.26</td>
<td>1.15</td>
<td>22.13 - 23.11</td>
<td>0.857</td>
</tr>
<tr>
<td>FMI (kg.m⁻²)</td>
<td>2.96</td>
<td>1.34</td>
<td>45.27</td>
<td>0.17</td>
<td>5.74</td>
<td>2.65 - 3.26</td>
<td>1.045</td>
</tr>
<tr>
<td>PMI (kg.m⁻²)</td>
<td>4.51</td>
<td>0.41</td>
<td>9.09</td>
<td>0.05</td>
<td>1.11</td>
<td>4.41 - 4.61</td>
<td>0.793</td>
</tr>
<tr>
<td>SMII (kg.m⁻²)</td>
<td>13.01</td>
<td>1.25</td>
<td>9.61</td>
<td>0.16</td>
<td>1.23</td>
<td>12.71 - 13.32</td>
<td>0.844</td>
</tr>
<tr>
<td>PBF (%)</td>
<td>11.32</td>
<td>3.96</td>
<td>34.98</td>
<td>0.50</td>
<td>4.42</td>
<td>10.39 - 12.26</td>
<td>0.673</td>
</tr>
<tr>
<td>PSMM (%)</td>
<td>50.94</td>
<td>2.36</td>
<td>4.63</td>
<td>0.30</td>
<td>0.59</td>
<td>50.38 - 51.50</td>
<td>0.804</td>
</tr>
<tr>
<td>PFI (kg)</td>
<td>1.83</td>
<td>0.96</td>
<td>52.46</td>
<td>0.12</td>
<td>6.56</td>
<td>1.55 - 2.11</td>
<td>1.477</td>
</tr>
</tbody>
</table>

Table III. Results of morphological index differences in relation to type of analyzed combat sport (MANOVA & ANOVA).

### Multivariate Tests - MANOVA

| Wilks' lambda  | 0.435 | 5.78 | 18.00 | 202.00 | 0.000 | 104.10 | 1.00 |

### Univariate Tests - ANOVA

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Noncent. Parameter</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW</td>
<td>1521.69</td>
<td>2</td>
<td>760.85</td>
<td>4.34</td>
<td>0.02</td>
<td>8.69</td>
<td>0.74</td>
</tr>
<tr>
<td>BMI</td>
<td>132.76</td>
<td>2</td>
<td>66.38</td>
<td>9.85</td>
<td>0.00</td>
<td>19.70</td>
<td>0.98</td>
</tr>
<tr>
<td>FFMI</td>
<td>145.68</td>
<td>2</td>
<td>72.84</td>
<td>19.25</td>
<td>0.00</td>
<td>38.50</td>
<td>1.00</td>
</tr>
<tr>
<td>FMI</td>
<td>7.51</td>
<td>2</td>
<td>3.75</td>
<td>2.58</td>
<td>0.08</td>
<td>5.16</td>
<td>0.51</td>
</tr>
<tr>
<td>PMI</td>
<td>6.32</td>
<td>2</td>
<td>3.16</td>
<td>20.44</td>
<td>0.00</td>
<td>40.89</td>
<td>1.00</td>
</tr>
<tr>
<td>SMII</td>
<td>55.35</td>
<td>2</td>
<td>27.67</td>
<td>19.04</td>
<td>0.00</td>
<td>38.08</td>
<td>1.00</td>
</tr>
<tr>
<td>PBF</td>
<td>125.70</td>
<td>2</td>
<td>62.85</td>
<td>4.53</td>
<td>0.01</td>
<td>9.06</td>
<td>0.76</td>
</tr>
<tr>
<td>PSMM</td>
<td>60.77</td>
<td>2</td>
<td>30.39</td>
<td>6.07</td>
<td>0.00</td>
<td>12.14</td>
<td>0.88</td>
</tr>
<tr>
<td>PFI</td>
<td>9.44</td>
<td>2</td>
<td>4.72</td>
<td>3.89</td>
<td>0.02</td>
<td>7.78</td>
<td>0.69</td>
</tr>
</tbody>
</table>
Table IV. Results of discriminative analysis with results of defined canonical functions.

<table>
<thead>
<tr>
<th>Function</th>
<th>Eigenvalue</th>
<th>% of Variance</th>
<th>Cumulative %</th>
<th>Canonical</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.92*</td>
<td>86.30</td>
<td>86.30</td>
<td>0.69</td>
</tr>
<tr>
<td>2</td>
<td>0.15*</td>
<td>13.70</td>
<td>100.00</td>
<td>0.36</td>
</tr>
</tbody>
</table>

a. First 2 canonical discriminant functions were used in the analysis.

Wilks’ Lambda

<table>
<thead>
<tr>
<th>Test of Function(s)</th>
<th>Wilks’ Lambda</th>
<th>Chi-square</th>
<th>df</th>
<th>S i g.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 through 2</td>
<td>0.45</td>
<td>83.82</td>
<td>14</td>
<td>0.000</td>
</tr>
<tr>
<td>2</td>
<td>0.87</td>
<td>14.47</td>
<td>6</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Table V. Results of defined structure matrix in the most significant difference factor of body structure index.

Structure Matrix

<table>
<thead>
<tr>
<th>Function</th>
<th>PSMM*</th>
<th>PBF</th>
<th>PFI</th>
<th>BW</th>
<th>SMMI*</th>
<th>PMI</th>
<th>BMI</th>
<th>FFMI</th>
<th>FMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.34*</td>
<td>0.28*</td>
<td>-0.26*</td>
<td>-0.02</td>
<td>-0.54*</td>
<td>-0.57</td>
<td>-0.34*</td>
<td>-0.55</td>
<td>-0.16</td>
</tr>
<tr>
<td>2</td>
<td>-0.11</td>
<td>0.27</td>
<td>-0.23</td>
<td>0.74*</td>
<td>0.73*</td>
<td>0.72*</td>
<td>0.72*</td>
<td>0.70*</td>
<td>0.40*</td>
</tr>
</tbody>
</table>

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions. Variables ordered by absolute size of correlation within function.

* Largest absolute correlation between each variable and any discriminant function.

a. This variable not used in the analysis.

By individual comparison of average body mass within analyzed sports we noticed the highest average value with judokas 86.15±14.29 kg, then wrestlers 82.08±13.11 kg, and then karate athletes 76.49±9.55 kg (Table II). Results of univariate test showed that body mass (BM) among subsamples are statistically significantly different on level F=4.34 and p=0.015, but between variable pairs BM is statistically different only between karate athletes and judokas on level p=0.014. Related to standards BM of healthy and young people in Republic of Serbia it can be asserted that wrestlers and karate athletes belong to a group of average BM (74.19 - 83.96 kg), while judokas has BM above average level (83.97 - 88.82 kg). Related to distribution of percentiles judokas are on 80 % (percentile), wrestlers on 65 % and karate athletes on 42 % of population body mass (Dopsaj et al., 2010).

By comparison of combat sports individually with foreigners’ results, we noticed that body mass of Brazilian judokas is 90.6±23.8 kg (Franchini et al.). Iranian national wrestling team has similar values like encompassed sample of this research 81.5±20.2 kg (Mirzaei & Akbarnezhad), while wrestler of Turkish national team has lower average value BM 77.88±18.84 kg (Arslanoglu et al.). In comparison with Croatian karate athletes BM results are slightly lower 75.38±9.90 kg (Katic et al.), while research sample of elite Polish karate athletes shows great difference in BM 86.1±8.25 kg. By comparison of average Caucasian body mass BM 77.0±11 kg, i.e. Asians race 68.0±10 kg (Wang et al.), generally the fact is that by training process an athletes’ muscle mass in examined combat sports increases, probably as a result of training and diet.
Related to examined subsamples we can assert that average BMI value of wrestlers is 26.44±2.34 kg/m², judokas 25.60±2.80 kg/m² and karate athletes 23.23±2.26 kg/m² (Table II). In comparison with Italian judokas, where in average value of BMI is 24.7±2.1 kg/m² (Andreoli et al.) our sample has 3.64 % higher kg/m². By observing values BMI of our wrestlers and Korean wrestlers where average BMI value is from 22.9±1.8 kg/m² (Lee et al., 2009), also we can assert that our sample has even 15.46 % more kg/m². However in comparison with BMI values of karate athletes from our sample within elite Polish karate athletes average value of BMI is from 26.8±2.0 kg/m² (Sterkowicz-Przybycien), which means that Serbian karate athletes has 15.37 % less kg/m².

Related to standards for BMI in population of healthy Serbian persons it can be stated that only karate athletes belongs to a group of people with average BMI (22.76 - 25.18 kg/m²), while judokas belongs to a group of above average value BMI (25.19 - 26.40 kg/m²), and wrestlers to a group of people with high BMI (26.41 - 28.82 kg/m²). Related to distribution of percentiles, wrestlers are on 86‰ (percentile), judokas on 77‰, and karate athletes on 40‰ of BMI value of population (Dopsaj et al., 2010).

Average values of the fat and muscle percentage in the body in relation to the entire sample examined athletes in analyzed sports is 10.62±3.84 % for BF and 51.31±2.34 % for SMM (Table II). By individual combat sports judo athletes had %BF at the level of 11.32±3.96 % and % SMM at the level of 50.94±2.36, wrestler’s had a %BF at 8.84±3.22 and 52.55±2.04 of % SMM and karate athletes had a %BF 10.99±3.64 and 50.71±2.10 of % SMM. Compared to the healthy and non-trained population of Caucasians and Asians found to have a value of %BF of 19.3±6.4 % and 21.4±6.3, respectively (Wang et al.), tested athletes have nearly twice lower percentage of body fat. In relation to standards %SMM defined by multichannel bioelectrical impedance for adults, health and recreation trained men whose average value is asserted % SMM at the level of 47.59±4.34 % (Rakic et al., 2013), the value of %SMM with the whole test sample of athletes by 8.01±2.11 % higher (Judo - 7.04%, the wrestlers - 10.42 % and karate athletes - 6.56 %).

Related to the index variables, among whom were some are newly introduced for martial arts elite athletes, and for more precisely information can be used to define the body structure of combat sports in different weight categories, the highest level for discrimination due to the tested athletes in the function of the sports branches has been established with the following variables: percent of skeletal muscle mass (0.34), percent of body fat (0.28) and protein fat index (0.26), first isolated factor (p = 0.000), which explained 86.30 % of variance measurement, and skeletal muscle mass index (0.73), protein mass index (0.72), body mass index (0.72) and fat free mass index (0.70), as a second factor (p = 0.030), which explains the remaining 13.70 % of measurements variance (Table IV).

Considering the fact that martial art sports have characteristic weight categories, athletes strive for the optimal or ideal body composition, where strategy is aimed to favoring muscle compared to fat tissue, because by this way the contractile potential of fighters is increased in relation to the potential manifestations of strength, power and speed, and consequently minimize the presence of fat in the body (Mirzaei & Akbarnezhad; Kim et al.). Also, defined structure of body structure differences, and set of influence of individual variables in relation to the tested morphological space is given guidelines for tested sports for redefining the morphological model, i.e. form which athletes should aim, through training and proper nutrition. Also, by monitoring the value of the most sensitive body structure index a valid means i.e. tool may be provided for the process of body weight correction in the acute phase and accelerated changes of body category, and in order to prevent the loss of desirable physical element, or sports performances (Artioli et al.; Kasum & Dopsaj).

CONCLUSION

For achieving top sport results it is necessary to provide adequate status of an athlete considering several factors. Related to combat sports, where weight categories are determined by rules, morphological space as well as body structure presents one of the most significant factor of success.

Subject of this research is analysis body structure characteristics of elite athletes competitors in combat sports – judo, Greco-roman wrestling and karate, while the aim is defining the most discriminative indicator of body structure, i.e. morphological index by which we can track specific changes of body constitution in relation to a sport branch and type of combat sport. Examined variables present combination of classic (standard) and recently projected index provided by measuring technology with multichannel segmental bioimpedance method (device InBody 720). Examinees sample in research included 112 elite senior athletes, male sex, members of national Serbian teams, consists of 62 judokas, 29 Greco-roman wrestlers and 21 karate athletes.

Discriminative analysis showed that subsamples of
the athletes were statistically significantly different by body structure on level Wilks’ lambda - 0.435, (p = 0.000), that next variables are the most discriminative in relation to tested athletes in the sport function: percent of skeletal muscle mass (0.34), percent of body fat index (0.28), as the first isolated factor (p = 0.000) which explains 86.3 %, respectively, and body weight (0.74), skeletal muscle mass index (0.73), protein mass index (0.72), body mass index (0.72), and free fat mass index (0.70), as second factor (p= 0.030) which explains 13.7 % variability of measuring space.

By establishing body structure models of judokas, wrestlers and karate athletes for tested variables and by using latest technological measuring methods (InBody 720) new information are obtained that characterize the sport’s specificity, which all contribute to development and improvement of existing knowledge in this area. By tracking given variables, particularly changes in their structure, which all provides the new index value, such as PFI, SMMI, FFMI and FMI may enable accurate control of the system in determining body structure and impact of training type process on the quality of the same.

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Corresponding author: Milivoj Dopsaj
Department of Analysis and Diagnosis in Sport
Faculty of Sport and Physical Education
Blagoja Parovica 156 Str,
11030 Belgrade
SERBIA

Telephone: +381 11 3531 000
Fax: +381 11 3531 001

Email: milivoj@eunet.rs

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