COMPARISON OF METHODS FOR DETERMINING PERCENTAGE OF BODY FAT ON A SAMPLE OF KAYAKERS AND CANOEISTS – IN SLALOM

KOMPARACIJA METODA UTVRĐIVANJA POSTOTKA MASNOG TKIVA NA UZORKU KAJAKAŠA I KANUISTA SLALOMAŠA

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ORIGINAL SCIENTIFIC PAPER

doi: 10.5550/sgia.201601.en.pgt
UDC: 797.122
Received: 07.11.2020.
Approved: 12.11.2020.
Sportlogia 2020, 16 (1), 91-109.
E-ISSN 1986-6119

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ABSTRACT

Determining body structure in physical culture, sports, but also in sports recreation is one of the ways to check effectiveness of certain training programs and their impact on a percentage of subcutaneous fat and fat-free components. This study was conducted on a sample of 49 kayakers and slalom canoeists (aged 19.9 ± 1.7 years), and the aim was to compare validity of methods for estimating percentage of body fat based on the skinfold measurement method in relation to the bioelectrical impedance method for application in diagnostics within a training process of slalom kayakers and slalom canoeists. The percentage of body fat was determined by methods of determining the percentage of body fat according to Siri (1961), Brozek et al. (1963), Jackson, & Pollock, (1985) and the BIA bioelectrical impedance method. After statistical procedures, correlation analysis revealed a high correlation between the methods: anthropometric methods according to Siri and Brozek, both methods with the Jackson Pollock method, while all three methods have a high level of correlation with the BIA method, while the Wilcoxon test showed that the bioelectrical impedance method had statistically significantly higher values than the method of determining the percentage of body fat according to Siri & Brozek ($p < 0.001$), and significantly lower than the method of determining the percentage of body fat according to Jackson Pollock ($p = 0.005$). The research showed that in the observed sample of respondents, when it comes to one respondent, a group of respondents, respondents within one sport or an uneven sample of non-athletes, if it is not possible to use some of the more sophisticated BIA methods, a satisfactory method could be the skinfold measurement method.

Keywords: *skinfold measurement method, bioelectrical impedance, body fat, kayak canoe slalom*

INTRODUCTION

Kayak canoe slalom is an Olympic sport regulated by the rules of the International Canoe Federation (ICF). Competitors race on a course a maximum of 400m long with natural or artificial obstacles to the water flow (ICF, 2019). An experienced competitor usually needs 75-95 seconds to master the course, the fastest overall time. (Macdermid, et al., 2019).

Slalom racers use a combination of technically demanding movement structures associated with short accelerations and high-intensity rowing, which requires resynthesis of energy through anaerobic metabolism. (Messias et al., 2014).

According to Zamparo et al. (2006) aerobic energy source accounts for about 50% (aerobic - 45.2%; anaerobic alactic - 24.9; anaerobic lactic - 29.0%) of the total metabolic energy turnover in a slalom race. The importance of aerobic metabolism in slalom skiers has been shown in other studies (Ferrari et al., 2017; Manchado-Gobatto et al., 2014; Messias et al. 2015). Bielik et al. (2019) conclude that slalom skiers may benefit from the oxidative system during rest in or interval training. The role of fat in the oxidative system as an energy source is significant (Gollnick, 1985; Achten, & Jeukendrup, 2004), and as slalom training is on average 1.5-2 hours long, the importance of mass as an energy source is not negligible.

Excess of fat percentage negatively affects the performance of slalom racers. The increased weight of the rowers causes boats to sink deeper into water, increasing a contact area, ie. total frictional resistance and wave resistance, thus increasing the resistance that the rower must overcome in order to push the boat forward. (Lundström, Borgen, & McKenzie, 2019).

Data from anthropometric measurements in recent decades, at competitors in kayaking and canoeing, show a lower percentage of body fat and increased musculature of the upper body and arms, which is associated with performance and more successful rowing. (Lundström, Borgen, & McKenzie, 2019; Hagner-Derengowska et al., 2014). Previous studies have shown that there is no significant difference between canoeists and kayakers in the percentage of body fat, and the authors explain that this is caused by both groups having identical track sections and training aimed at improving strength and speed, resulting in increased muscle mass. (Kameyama et al., 1999; Hamano et al., 2015).

Determination of body structure, and especially the percentage of body fat, is done in order to control the training of athletes to assess health status, possible risks, as well as control health status during diets (Malina, 2007; Ackland et al., 2012), and Wells & Fewtrell (2006) point out that the measurement of body structure in vivo is an imperfect process and that it is subject to various limitations, but that it has significant clinical value in pediatric practice.

The validity of BIA bioelectric impedance method has been investigated in numerous studies. The validity of this method in relation to hydrodensiometry, skinfold measurement method, ADP (plethysmography of whole body volume) was confirmed and a large correlation was found between the total conductivity of the human body and the fat-free component (Keller & Katch, 1985; , Graves, & Mahar, 1988; Macias, Alemán-Mateo, Esparza-Romero, & Valencia, 2007).

Wang, Zhang et al. (2013) comparing four different systems on the principle of bioelectric impedance with DEXA and MRI methods obtained a high level of correlation r=0.71-0.89 to estimate the percentage of body fat. They conclude that the devices are accurate in assessing body composition, especially skeletal muscle mass and fat-free component. A high degree of correlation of the BIA method with the DEXA method was also established by Fornetti, Pivarnik, Foley & Fiechtner (1999), as well as Company & Ball (2010).

Wells & Fewtrell (2006) believe that it is less accurate than DEXA, that there are limitations to estimating whole body composition using the skinfold measurement method and BIA, and state that applying a combination of both methods can reduce the probability of error, which should be borne in mind because the data obtained by determining the structure of the body provide insight into the current state and represent the starting point for planning and programming training and exercise to achieve or maintain optimal and desirable relations of different tissue types.Incorrect assessment of the thickness of subcutaneous body fat, and thus the total fat content using the skinfold measurement method, with the main problems being the impossibility of palpation of fat-muscle demarcation and the impossibility of reliable measurement in obese people, has been documented in previous studies (Brozek, & Kinsey, 1960; Himes, Roche, & Siervogel, 1979). Disadvantages of this method include compression of subcutaneous body fat during measurement and the possibility of measurement only at certain points (Lohman, 1981; Burkinshaw, Jones, & Krupowics, 1973). The skinfold measurement method is simple, fast and informative, but there are limitations in very obese people as well as in significant deviation of regional tissue distribution in relation to average people, therefore standardized equations have been developed which based on skin folds, according to gender, age and other population nature (physical activity, specific disease, race) calculate the percentage of body fat: special equations for adults (Jackson & Pollock, 1982), special equations for men (Jackson & Pollock, 1978), for the female population (Jackson, Pollock & Ward 1980), special formulas for male athletes (Sinning, Dolney, & Little, 1985; Forsyth & Sinning, 1973; Sinning, 1974; Pollock, Gettman, Jackson, Ayres, Ward, & Linnerud, 1977), and special formulas for female athletes (Sinning, 1978; Meleski, Shoup, & Raspberry, 1982; Sinning & Wilson, 1984 and Mayhew, Clark, McKeown, & Montaldi, 1985). Since the equations developed for one sample cannot always be applied with great reliability to another sample, special formulas have been developed for certain sports: for long-distance runners (Pollock, Gettman, Jackson, Ayres, Ward, & Linnerud, 1977), wrestlers (Sinning, 1974), gymnasts (Sinning, 1978), swimmers (Meleski, Shoup, & Malina, 1982), etc.This research was conducted in order to determine the validity of the method of calculating the percentage of body fat based on the skinfold measurement method in relation to the bioelectrical impedance method in slalom kayakers and slalom canoeists, to select and apply the appropriate method, its accuracy and precision in their training process.

RESEARCH METHODS

The sample of respondents consisted of athletes - 49 male kayakers and canoeists, aged 19.9 ± 1.7 years, participants in the European Kayak Canoe Slalom Championship in the category of juniors and younger seniors. The respondents were representatives of Germany, Poland, Slovakia, Slovenia and Croatia and were of normal health status and voluntarily joined the survey. Since the respondents are top kayakers and canoeists who secured a place in the national selections through election races, and that these teams represent the most competitive teams, this is a sample that has been included in the training process for many years.

The research was conducted in the morning three days before the start of the championship in the cabinet for anthropomotorics at the Faculty of Physical Education and Sports in Banja Luka. The instruments were of standard workmanship and calibrated. Due to the way the data were taken, the respondents were dressed in underwear and without socks, did not consume alcohol for at least 72 hours, food and fluids for at least 4 hours, did not exercise for at least 12 hours before the measurement, nor were they diuretic users.

A Martin anthropometer was used to collect data on the height of the respondents, according to the protocol and methods of measuring anthropometric dimensions according to IBP. Anthropometric estimation of body density and fat content in the structure of body composition and upper extremities was determined using bioelectrical impedance method and body composition analyzer of brand Tanita model BC 418-MA III (Tanita, Tokyo, Japan) by passing a low current of 800 μamp through body of a respondent. The measurement was performed in the protocol provided conditions (room temperature 22 - 24°C in a quiet environment) according to the protocol of preparation for the measurement. Since the percentage of body fat according to Siri, Brozek and Jackson and Pollock is determined by equations, before determining the percentage of body fat it was necessary to determine the values of skin folds (triceps, pectoral, midaxillary, abdominal, suprailiac, suprascapular and thigh) and body density on the basis of equations with skin folds. The skinfold measurement method was done using a Harpenden caliper with a measuring range from 0 to 40 mm according to the IBP standard.

The bioelectrical impedance method and the skinfold measurement method were used to determine the percentage of body fat of the respondents. The specificity of the skinfold measurement method is that there are different formulas of different authors for estimating the percentage of body fat, which are all based on the same formula for calculating body density and for the purposes of this research the following formulas were used:

a) Fat (%) = (4.95/BD-4.5)*100 men (Siri, 1957; according to: Sudarov & Fratic 2010)
b) Fat (%) = (4.57/BD-4.142)*100 (Brozek et al.1963)
c) Fat (%) = 0.29288 *Σ4 – 0.0005 * (Σ4)2+ 0.15845 x A – 5.76377, (Jason & Pollock, 1985)

For the Siri and Brozek formulas, it was necessary to determine the value of seven skin folds: triceps, pectoral, midaxillary, abdominal, suprailiac, suprascapular and patellar skin fold, while for the Jason and Pollock formula it was necessary to determine the values of four skin folds (mm): abdominal, triceps, patellar, and suprailial skin folds.

From the envlosed it can be seen that all three formulas when calculating the percentage of fat use A (age of the subjects) and BD - body density calculated using the equation for men from 18 to 29 years according Jason i Pollock (1978):

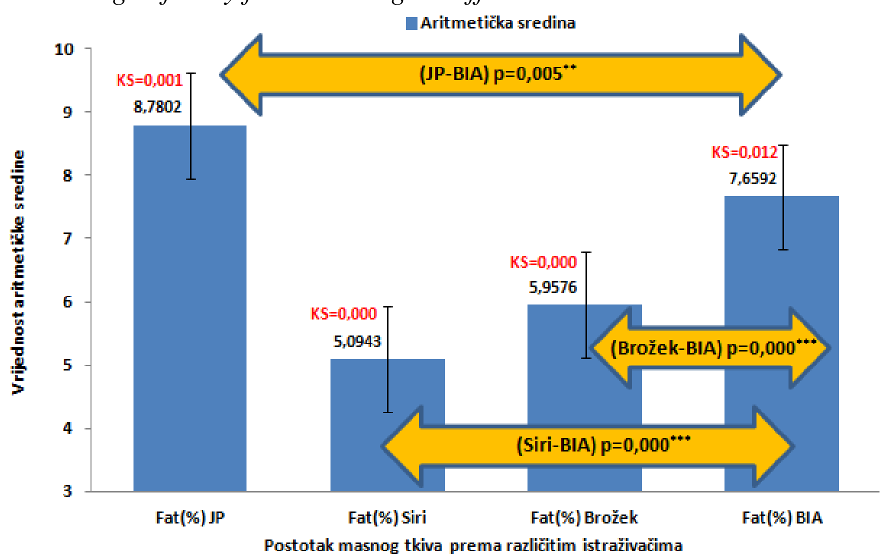
BD = 1.12 - 0.00043499*Σ7 + 0.00000055*(Σ7)2 - 0.00028826*A.

Statistical analysis

Descriptive statistics methods were used for statistical data processing, Kolmogorov-Smirnov test for determining normality of distribution, correlation between skinfold measurement method and BIA method were determined by Spearman correlation coefficient, and Wilcoxon test was used to compare body fat percentage values obtained by anthropometric and BIA method. Values in which p <0.05 were taken as statistically significant. All experimental data were analyzed using SPSS version 20.0 statistical software (SPSS Inc, IBM-Company, Chicago, IL, USA).

RESULTS

Chart 1. *Percentage of body fat according to different methods*



Legend: Y axis arithmetic mean ± standard deviation; KS - Kologorov-Smirnov test (statistical significance); p - Statistical significance of Wilcoxon test for paired samples; Fat (%) JP - percentage of body fat according to Jackson and Pollock; Fat (%) Siri - percentage of body fat according to Siri; Fat (%) Brozek - percentage of body fat according to Brozek; Fat (%) BIA- percentage of body fat according to BIA

The difference between the arithmetic means measured on the basis of the methods according to Siri and Brozek (5.09; 5.96) is significantly smaller than the results obtained by the BIA bioelectrical impedance technique (7.66), while the highest values of the percentage of body fat were shown by the Jackson Pollock method (8.78). The largest error of the arithmetic mean is shown by the BIA method (0.63) followed by the Jackson Pollock method (0.57), while the standard errors of the arithmetic mean of the methods according to Siri and Brozek have lower values (0.50) and (0.46), respectively. The normality of the distribution was tested (Chart 1) by the Kolmogorov-Smirnov test of normality, which showed that none of the observed methods had a normal distribution, which was expected considering the selected group of kayakers and canoeists.

Verification of the degree of correlation of methods for determining the percentage of body fat was performed by Spearman correlation analysis. The obtained result indicates that the coefficient has a statistically significant value at the level of significance p=0.01, ie. 99%. The correlation coefficient of the BIA method (MT (%) BIA) with the methods according to Siri and Brozek (MT (%) Siri and MT (%) Brozek) is 0.667, which is a very high correlation, while with the method according to Jackson Pollock (MT (%)) JP) is slightly lower 0.636. The values obtained by the Siri and Brozek equations are completely correlated, while the Spearman coefficient of both methods is in relation to the method of the Jackson Pollock equation r = 0.975.

Thus, after the analysis of the correlation coefficient of the percentage of body fat determined by applying three different methods, it can be concluded that a high statistical correlation of variables was observed.

The Wilcoxon test showed the existence of significant differences in the obtained values by anthropometric methods in relation to the bioelectrical impedance of BIA. Comparing the medians MT(%) JP and MT(%) BIA (7.50 and 6.80, respectively) showed that the BIA method shows statistically significantly (p = 0.005) lower values of the percentage of body fat compared to the Jackson Pollock method. On the other hand, comparing the median MT(%) Siri (4.20) and MT(%) Brozek (5.13) with MT(%) BIA (6.80) showed that there was a statistically significant difference (p <0.001). The BIA method shows statistically significantly higher values of the percentage of body fat compared to the two methods based on seven skin folds. (Chart 1).

DISCUSSION

In this study, four methods for estimating the percentage of body fat in body structure were compared: three based on the skinfold measurement method and the method of bioelectrical impedance. Their common features are that they are non-invasive, simple, fast and relatively cheap.

According to the correlation analysis, a high correlation of the methods was observed: anthropometric methods according to Siri and Brozek are completely correlated (1.000), both methods with the Jackson Pollock method have a slightly lower coefficient $\rho=0.975$, while all three methods have a high level of correlation with the BIA method, which indicates that it is possible to predict one variable based on another. The obtained results are in line with previous research (Jackson, Pollock, Graves & Mahar 1988; Bascevan, Vucetić, & Rodic, 2011; Utter et al. 2001; Ostojic, 2006).

The Wilcoxon test showed significant differences in the values obtained by anthropometric methods compared to the BIA method. The measurement methods according to Siri and Brozek have statistically significantly lower values of the percentage of body fat, while the method according to Jackson Pollock showed statistically significantly higher values compared to BIA. Similar results have been found in other studies (Knechtle, B., Knechtle, P., & Rosemann, 2011; Michailidis, Methenitis, & Michailidis, 2013). The basic question that arises is which of these methods is more precise and valid?

Numerous studies have confirmed the reliability of bioelectrical impedance with respect to hydrodensiometry, Keller & Katch (1985); Lukaski et al. (1985); Jackson, Pollock, Graves, & Mahar, (1988). The precision and validity of bioelectrical impedance relative to ADP whole-body volume platysmography have been established by Macias, Alemán-Mateo, Esparza-Romero, & Valencia (2007). The accuracy of the BIA system in relation to DEXA has been established in many studies (Wang, Zhang et al. 2013; Fornetti, Pivarnik, Foley & Fiechtner 1999; Company & Ball (2010)). When it comes to anthropometric methods based on equations based on which the percentage of body fat is calculated over skin folds, numerous studies also show consistency and that they correlate with the DEXA method (Lintsi, Kaarma & Kull, 2004; Bowden et al. 2005). It has been shown here that skinfold measurement methods have a significantly higher correlation coefficient with the DEXA method than the BIA method. This can be partly explained by the development of a number of equations for calculating the percentage of body fat across skin folds, which are specialized for a specific population by sex (Jackson & Pollock, 1982), especially for men (Jackson & Pollock, 1978) and especially for women (Jackson & Pollock, 1980) or by activity (Sinning, Dolney, & Little 1985; Forsyth & Sinning, 1973; Sinning, 1974; Pollock, et al. 1977). On the other hand, some studies have indicated the inaccuracy of these equations compared to the DEXA and ADP method (Silva, Fields, Quitério, & Sardinha, 2009) where it was concluded that these anthropometric methods are not valid for estimating and monitoring changes in fat and fat-free percentage with highly trained judokas before and after the competition. Brodie, Moscrip, & Hutcheon (1998) extensive research of a large number of papers dealing with various body composition assessment systems including chemical, electrical, physical and anthropometric, concludes that sophisticated body structure assessment devices such as computerized tomography scanners are available mainly to large institutes with high budgets. However, they find that the clinical experience of many nutritionists has shown that it is possible to very successfully apply low-budget methods which are fast and non-invasive.

In this study, although the methods according to Siri and Brozek are highly correlated with the method according to Jackson Pollock, on the other hand, statistically significantly higher and lower values compared to the BIA were measured. This research showed that in the case of top slalom kayakers and slalom canoeists who participated in the research, not all equations show the same value. Of course, it is necessary to look at possible factors that may have contributed to such results. The value of the percentage of body fat for the results obtained by the skinfold measurement method according to Siri, Brozek and Jackson and Polok could be influenced by the method of measurement in which there was a possibility of error even though performed by the same measurer, and uneven distribution of tissue in proportion to the specifics of the sport, while the results obtained by the BIA method could be affected by insufficient preparation of athletes to perform measurements (measurement was performed three days before the competition and each athlete has special preparations for the competition that should not be affected - supplementation, nutrition and hydration regime, training schedule, etc.). Also, it should be taken into account that this was a transversal type study and the specificity of the sample on which the study was conducted, because they were athletes who underwent training for many years, and to get more valid results of such studies it would be desirable such measurements spend significantly more often on the same population of athletes. The research showed that in this sample of respondents, if it is not possible to use one of the more sophisticated methods of the BIA method type, the satisfactory method could be any of the three observed methods of measuring skin folds. It is important to always use the same method. Of course, this claim cannot be generalized.

CONCLUSION

Today, there are specific equations for calculating the percentage of fat by anthropometric methods for individual sports. Developing a special equation for kayakers and canoeists would help determine the percentage of fat more precisely with this cheapest and most mobile method.

Also, it has been shown that in sports training of kayakers and canoeists, depending on financial possibilities, if one wants to constantly monitor the percentage of body fat of athletes, there is a choice between two methods of determining the percentage of body fat - using Body composition analyser or measuring skin folds with a caliper and then determining the percentage of body fat via a formula according to Jackson Pollock and Siri and Brozek. From a practical point of view, it is clear that due to the practicality and simplicity of measurement and the speed of data acquisition, the method of bioelectrical impedance is preferred. However, when you look at the economic situation in sports, and that the price of a device for measuring bioelectrical impedance, for our circumstances, is not so low, measuring body structure by methods through skin folds is certainly valid enough and more affordable. If we are talking about smaller groups of athletes and if the measurements are performed by the same measurer with the same caliper, the possibility of error is further reduced.

In order to be able to say with certainty which of the measured methods is the most valid for assessing body composition in the kayak canoe sport, it would be necessary to include a much larger sample and compare the processed methods with the most accurate methods such as DEXA, ADP or hydrodensiometry.

REFERENCE

1. Achten, J., & Jeukendrup, A. E. (2004). Optimizing fat oxidation through exercise and diet. Nutrition (Burbank, Los Angeles County, Calif.), 20(7-8), 716-727.
https://doi.org/10.1016/j.nut.2004.04.005
PMid:15212756

2. Ackland, T. R., Lohman, T. G., Sundgot-Borgen, J., Maughan, R. J., Meyer, N. L., Stewart, A. D., & Müller, W. (2012). Current status of body composition assessment in sport: review and position statement on behalf of the ad hoc research working group on body composition health and performance, under the auspices of the I.O.C. Medical Commission. Sports medicine (Auckland, N.Z.), 42(3), 227-249.
https://doi.org/10.2165/11597140-000000000-00000
PMid:22303996

3. Baščvan, S., Vučetič, V., & Rodić, S. (2011). Comparison of different methods for assessment body composition. U: S. Simović (Ur.), 2nd international scientific congress"Anthropological aspects of sport, physical education and recreation". 2, str. 165-169. Banja Luka: Faculty of Physical Education and Sport

4. Bielik, V., Messias, L.H., Vajda, M., Lopata, P., Chudý, J., & Manchado-Gobatto, F. (2019). Is the aerobic power a delimitating factor for performance on canoe slalom?: An analysis of Olympic Slovak canoe slalom medalists and non-Olympics since Beijing 2008 to Rio 2016. Journal of Human Sport and Exercise, 14, 876-892.
https://doi.org/10.14198/jhse.2019.144.16

5. Bowden, R. G., Lanning, B. A., Doyle, E. I., Johnston, H. M., Nassar, E. I., Slonaker, B., Scanes, G., & Rasmussen, C. (2005). Comparison of body composition measures to dual-energy x-ray absorptiometry. Journal of Exercise Physiology Online, 8(2), 1-9.

6. Brodie, D., Moscrip, V., & Hutcheon, R. (1998). Body composition measurement: a review of hydrodensitometry, anthropometry, and impedance methods. Nutrition (Burbank, Los Angeles County, Calif.), 14(3), 296-310.
https://doi.org/10.1016/S0899-9007(97)00474-7

7. Brozek, J., & Kinsey, W.(1960). Age changes in skinfold compressibility. Journal of Gerontology, 15 (1), 45-51. https://doi.org/10.1093/geronj/15.1.45
https://doi.org/10.1093/geronj/15.1.45
PMid:13805108

8. Brozek, J., Grande, F., & Anderson, J.T.(1963). Densiometric analysis of body composition: revision of some quantitative assumptions. Annals of the New York Academy of Sciences, 110, 113-140.

https://doi.org/10.1111/j.1749-6632.1963.tb17079.x
PMid:14062375

9. Burkinshaw, L., Jones, P., & Krupowicz, D. (1973). Observer Error in Skinfold Thickness Measurements. Human Biology, 45(2), 273-279. Retrieved November 6, 2020, from http://www.jstor.org/stable/41459867

10. Company, J. & Ball, S. (2010). Body Composition Comparison: Bioelectric Impedance Analysis with Dual-Energy X-Ray Absorptiometry in Adult Athletes, Measurement in Physical Education and Exercise Science, 14(3), 186-201
https://doi.org/10.1080/1091367X.2010.497449

11. Ferrari, H. G., Messias, L., Reis, I., Gobatto, C. A., Sousa, F., Serra, C., & Manchado-Gobatto, F. B. (2017). Aerobic Evaluation in Elite Slalom Kayakers Using a Tethered Canoe System: A New Proposal. International journal of sports physiology and performance, 12(7), 864-871.
https://doi.org/10.1123/ijspp.2016-0272
PMid:27918656

12. Fornetti, W. C., Pivarnik, J. M., Foley, J. M., & Fiechtner, J.J.(1999). Reliability and validity of body composition measures in female athletes. Journal of Applied Physiology, (Bethesda, Md.: 1985), 87(3), 1114-1122.
https://doi.org/10.1152/jappl.1999.87.3.1114
PMid:10484585

13. Forsyth, H. L., & Sinning, W. E.(1973). The anthropometric estimation of body density and lean body weight of male athletes. Medicine and science in sports, 5(3), 174-180.
https://doi.org/10.1249/00005768-197323000-00015
PMid:4747639

14. Gollnick P. D. (1985). Metabolism of substrates: energy substrate metabolism during exercise and as modified by training. Federation proceedings, 44(2), 353-357.

15. Hagner-Derengowska, M., Hagner, W., Zubrzycki, I., Krakowiak, H., Słomko, W., Dzierżanowski, M., Rakowski, A., & Wiącek-Zubrzycka, M. (2014). Body structure and composition of canoeists and kayakers: analysis of junior and teenage polish national canoeing team. Biology of sport, 31(4), 323-326.
https://doi.org/10.5604/20831862.1133937
PMid:25609891 PMCid:PMC4296839

16. Hamano, S., Ochi, E., Tsuchiya, Y., Muramatsu, E., Suzukawa, K., & Igawa, S. (2015). Relationship between performance test and body composition/physical strength characteristic in sprint canoe and kayak paddlers. Open access journal of sports medicine, 6, 191-199.
https://doi.org/10.2147/OAJSM.S82295
PMid:26150737 PMCid:PMC4480586

17. Himes, J. H., Roche, A. F., & Siervogel, R. M. (1979). Compressibility of skinfolds and the measurement of subcutaneous fatness. The American journal of clinical nutrition, 32(8), 1734-1740.
https://doi.org/10.1093/ajcn/32.8.1734
PMid:463811

18. Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. British Journal of Nutrition, 40(3), 497-504.
https://doi.org/10.1079/BJN19780152
PMid:718832

19. Jackson, A. S., Pollock, M. L., & Ward, A. (1980). Generalized equations for predicting body density of women. Medicine and Science in Sports and Exercise, 12(3), 175-181.
https://doi.org/10.1249/00005768-198023000-00009
PMid:7402053

20. Jackson, A. S., & Pollock, M. L. (1982). Steps towards the development of generalised equations for predicting body composition of adults. Canadian Journal of Applied Sport Science, 7(3), 189-196.

21. Jackson, A. S., & Pollock, M. L. (1985). Practical Assessment of Body Composition. The Physician and Sportsmedicine.,13(5),76-90.
https://doi.org/10.1080/00913847.1985.11708790
PMid:27463295

22. Jackson, A. S., Pollock, M. L., Graves, J. E., & Mahar, M. T. (1988). Reliability and validity of bioelectrical impedance in determining body composition. Journal of Applied Physiology (Bethesda, Md.:1985), 64(2), 529-534.
https://doi.org/10.1152/jappl.1988.64.2.529
PMid:3372410

23. Kameyama, O., Shibano, K., Kawakita, H., Ogawa, R., & Kumamoto, M. (1999). Medical check of competitive canoeists. Journal of Orthopaedic Science, 4(4), 243-249.
https://doi.org/10.1007/s007760050099
PMid:10436270

24. Keller, B., & Katch, F.I. (1985). Validity of bioelectrical resistive impedanse forestimation of body fat in lean males. Medicine & Science in Sports & Exercise, 17 (2), 272.
https://doi.org/10.1249/00005768-198504000-00404

25. Knechtle, B., Knechtle, P., & Rosemann, T. (2011). Upper body skinfold thickness is related to race performance in male Ironman triathletes. International Journal of Sports Medicine, 32(1), 20-27.
https://doi.org/10.1055/s-0030-1268435
PMid:21110283

26. Lintsi, M., Kaarma, H., & Kull, I. (2004). Comparison of hand-to-hand bioimpedanse and anthropometry equations versus dual-energy X-ray absorptiometry for the assessment of body fat percentage in 17-18-year-old conscripts. Clinical Physiology and Functional Imaging, 24(2), 85-90.
https://doi.org/10.1111/j.1475-097X.2004.00534.x
PMid:15056180

27. Lohman T. G. (1981). Skinfolds and body density and their relation to body fatness: a review. Human Biology, 53(2), 181-225.

28. Lukaski, H. C., Johnson, P. E., Bolonchuk, W. W., & Lykken, G. I. (1985). Assessment of fat-free mass using bioelectrical impedance measurements of the human body. The American journal of clinical nutrition, 41(4), 810-817.
https://doi.org/10.1093/ajcn/41.4.810
PMid:3984933

29. Lundström, P., Borgen, J. S., & McKenzie, D. (2019). The canoe/kayak athlete. In D. McKenzie, & B. Berglund, Handbook of Sports Medicine and Science Canoeing (pp. 40-46). Hoboken, NJ : Wiley-Blackwell.
https://doi.org/10.1002/9781119097198.ch3

30. Macias, N., Alemán-Mateo, H., Esparza-Romero, J., & Valencia, M.E. (2007). Body fat measurement by bioelectrical impedanse and air displacement plethysmography: a cross-validation study to design bioelectrical impedanse equations in Mexican adults. Nutrition Journal, 6, 18.
https://doi.org/10.1186/1475-2891-6-18
PMid:17697388 PMCid:PMC2020472

31. Macdermid, P. W., Osborne, A., & Stannard, S. R. (2019). Mechanical Work and Physiological Responses to Simulated Flat Water Slalom Kayaking. Frontiers in physiology, 10, 260.
https://doi.org/10.3389/fphys.2019.00260
PMid:30949065 PMCid:PMC6436605

32. Malina R. M. (2007). Body composition in athletes: assessment and estimated fatness. Clinics in sports medicine, 26(1), 37-68.
https://doi.org/10.1016/j.csm.2006.11.004
PMid:17241914

33. Manchado-Gobatto, F. B., Arnosti Vieira, N., Dalcheco Messias, L. H., Ferrari, H. G., Borin, J. P., de Carvalho Andrade, V., & Terezani, D. R. (2014). Anaerobic threshold and critical velocity parameters determined by specific tests of canoe slalom: Effects of monitored training. Science & Sports, 29(4), pp. e55-e58.
https://doi.org/10.1016/j.scispo.2014.04.006

34. Mayhew, J. L., Clark, B. A., McKeown, B. C., & Montaldi, D. H. (1985). Accuracy of anthropometric equations for estimating body composition in female athletes. The Journal of sports medicine and physical fitness, 25(3), 120-126.

35. Meleski, B. W., Shoup, R. F., & Malina, R. M. (1982). Size, physique, and body composition of competitive female swimmers 11 through 20 years of age. Human biology, 54(3), 609-625.

36. Messias, L. H. D., dos Reis, I. G. M., Ferrari, H. G., & de Barros Manchado-Gobatto, F. (2014). Physiological, psychological and biomechanical parameters applied in canoe slalom training: a review. International Journal of Performance Analysis in Sport, 14(1), 24-41.
https://doi.org/10.1080/24748668.2014.11868700

37. Messias, L. H., Ferrari, H. G., Sousa, F. A., Dos Reis, I. G., Serra, C. C., Gobatto, C. A., & Manchado-Gobatto, F. B. (2015). All-out Test in Tethered Canoe System can Determine Anaerobic Parameters of Elite Kayakers. International journal of sports medicine, 36(10), 803-808.
https://doi.org/10.1055/s-0035-1548766
PMid:26038882

38. Michailidis, Y., Methenitis, S., & Michailidis, C. (2013). A comparison of arm to leg bioelectrical impedanse and skinfolds in assessing body fat in professional soccer players. Journal of Sport and Human Performance, 1(4):8-13.
https://doi.org/10.12922/18

39. Ostojic, S.M. (2006). Estimation of body fat in athletes: skinfolds vs bioelectrical impedanse. Journal of Sports Medicine and Physical Fitness, 46, 442-446.

40. Pollock, M. L., Gettman, L. R., Jackson, A., Ayres, J., Ward, A., & Linnerud, A. C. (1977). Body composition of elite class distance runners. Annals of the New York Academy of Sciences, 301, 361-370.
https://doi.org/10.1111/j.1749-6632.1977.tb38213.x
PMid:270927

41. Silva, A.M, Fields, D.A., Quitério, A.L, & Sardinha, L.B. (2009). Are Skinfold-Based Models Accurate and Suitable for Assessing Changes in Body Composition in Highly Trained Athletes? Journal of Strength & Conditioning Research, 23(6), 1688-1696.
https://doi.org/10.1519/JSC.0b013e3181b3f0e4
PMid:19675495

42. Sinning, W.E. (1974). Body composition assessment of college wrestlers. Medicine & Science in Sports & Exercise ,6(2), 139-145
https://doi.org/10.1249/00005768-197400620-00026

43. Sinning, W.E. (1978). Anthropometric estimation of body density, fat and lean body weight in women gymnast. Medicine & Science in Sports & Exercise, 10(4), 243-249

44. Sinning, W.E., Dolney, D.G., & Little, K.D. (1985). Validity of "generalized" equations for body composition analysis in male athlete. Medicine & Science in Sports & Exercise, 17(1), 124-130.
https://doi.org/10.1249/00005768-198502000-00020

45. Sinning, W.E., & Wilson, J.W. (1984). Validity of "generalized" equations for body composition analysis in women athletes. Research Quarterly for Exercise and Sport, 55:2, 153-160. https://doi.org/10.1080/02701367.1984.10608392

46. Siri, W. E. (1961). Body composition from fluid space and density. In J. Brozek & A. Hanschel (Eds.1961), Techniques for measuring body composition (pp. 223-244). Washington, DC: National Academy of Science.

47. Sudarov, N & Fratrić, F. (2010). *Dijagnostika treniranosti sportista* [Diagnostic of athletes]. Novi Sad, RS: Pokrajinski zavod za sport.

48. Utter, A.C., Scott, J.R, Oppliger, R.A., Visich, P.S., Goss, F.L., Marks, B.L., Nieman, D.C., & Smith, B.W. (2001). A comparison of leg-to-leg bioelectrical impedanse and skinfolds in assessing body fat in collegiate wrestlers. Journal of Strength and Conditioning Research, 15(2), 157-160.
https://doi.org/10.1519/1533-4287(2001)015<0157:ACOLTL>2.0.CO;2
https://doi.org/10.1519/00124278-200105000-00001
PMid:11710398

49. Zamparo, P., Tomadini, S., Didone, F., Grazzina, F., Rejc, E., & Capelli, C. (2006). Bioenergetics of a slalom kayak (K1) competition. International journal of sports medicine, 27(07), 546-552.
https://doi.org/10.1055/s-2005-865922
PMid:16802250

50. Wang, J. G., Zhang, Y., Chen, H. E., Li, Y., Cheng, X. G., Xu, L., Guo, Z., Zhao, X. S., Sato, T., Cao, Q. Y., Chen, K. M., & Li, B. (2013). Comparison of two bioelectrical impedance analysis devices with dual energy X-ray absorptiometry and magnetic resonance imaging in the estimation of body composition. Journal of strength and conditioning research, 27(1), 236-243.
https://doi.org/10.1519/JSC.0b013e31824f2040
PMid:22344056

51. Wells, J. C., & Fewtrell, M. S. (2006). Measuring body composition. Archives of disease in childhood, 91(7), 612-617.
https://doi.org/10.1136/adc.2005.085522
PMid:16790722 PMCid:PMC2082845

COMPARISON OF METHODS FOR DETERMINING PERCENTAGE OF BODY FAT ON A SAMPLE OF KAYAKERS AND CANOEISTS – IN SLALOM

SAŽETAK

Određivanje tjelesne strukture u fizičkoj kulturi, sportu, ali i u sportskoj rekreaciji jedan je od načina za provjeru efikasnosti određenih trenažnih programa i njihovog uticaja na postotak potkožnog masnog tkiva i nemasne komponente. Ovo istraživanje provedeno je na uzorku od 49 kajakaša i kanuista slalomaša (starosti 19,9 ±1,7 godina), sa ciljem upoređivanja validnosti metoda procjene postotka masnog tkiva koje se baziraju na metodi mjerenja kožnih nabora u odnosu na metodu bioelektrične impendance radi primjene u dijagnostici trenažnog procesa kod kajakaša i kanuista slalomaša. Postotak masnog tkiva utvrđen je metodama utvrđivanja postotka masnog tkiva prema Siriju (1961), Brožeku i sar. (1963), Jackson, i Pollock, (1985) i metodom bioelektrične impedanse BIA. Nakon provedenih statističkih procedura, korelacionom analizom utvrđena je visoka povezanost metoda: antropometrijskih metoda po Siriju i Brožeku, obje metode sa metodom po Džekson Poloku, dok sve tri metode imaju visok nivo korelacije sa metodom BIA, dok je Wilcoxon test pokazao da metoda bioelektrične impedance ima statistički značajno veće vrijednosti od metoda utvrđivanja postotka masnog tkiva prema Siriju i Brožeku ($p<0.001$), a značajno manje u odnosu na metodu utvrđivanja postotka masnog tkiva prema Džekson Poloku ($p=0.005$). Istraživanje je pokazalo da bi na posmatranom uzorku ispitanika, kada je u pitanju jedan ispitanik, grupa ispitanika, ispitanici u okviru jednog sporta ili neujednačeni uzorak nesportista, ukoliko nema mogućnosti za korištenje neke od sofisticiranijih metoda tipa BIA, zadovoljavajuća metoda mogla biti metoda mjerenja kožnih nabora.

Ključne riječi: *metod kožnih nabora, bioelektrična impedanca, kajak kanu slalom*

Received: 07.11.2020.
Approved: 12.11.2020.

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