Medicina Sportiva
Med Sport 16 (4): 150-154, 2012
DOI: 10.5604/17342260.1024770

APPLICATION OF TYPICAL ERROR OF MEASUREMENT FOR ACCURACY OF MEASUREMENT OF BODY COMPOSITION IN ATHLETES USING THE BIA METHOD

Petr Kutáč (A,B,C,D,E,F)

Human Motion Diagnostics Center, University of Ostrava, Ostrava, Czech Republic

Abstract

Introduction: To ensure the interpretation of the measured results during repeated measuring, it is necessary to know the accuracy of measurement of the used method and device. One of the possibilities of expressing this error is to use typical error of measurement.

Objective: To determine the actual error of measurement of the monitored body composition parameters when applying the bioelectrical impedance method in soccer players using typical error of measurement.

Methods: The research included a group of 50 men whose average age was 20.35 ± 1.25 years; they were soccer players in the U21 age category. The measurement of the monitored parameters was carried out using the Tanita 418 MA device; the accuracy of measurement was determined using typical error of measurement and interclass correlation.

Results: The found mean values of the typical error of measurement were 0.11 kg in body weight, 0.39 kg and 0.44% in the representation of body fat, and 0.26 kg and 0.35% in total body water. The interclass correlation values ranged from 0.983 to 1.000.

Conclusion: The typical error of measurement allows us to determine actual errors of measurement expressed in the used measurement units. The measurement of body composition with the used device is sufficiently accurate for the needs of the practice of physical education.

***Key words**: accuracy of measurement, reliability, body weight, body fat, total body water, repeated trials, soccer players*

Introduction

Measurement of body composition is often used both in medicine [1-4] and sports training. In sports, the values of the found parameters are used for the evaluation of the morphological prerequisites of athletes for a particular discipline, readiness of athletes for the training load, and, during repeated measurements, the values allow for the assessment of the effects of the training programme on the bodies of the monitored athletes [5-9].

To measure body composition, there are many devices available that use various methods of measurement. Devices using the bioelectrical impedance method (BIA) are often used in sports. Such devices are used widely thanks to the promptness of measurement, unexacting organization of measurement, training of workers and also their financial availability. However, the practice has shown that no device is absolutely accurate. This means that no measurement results can be absolutely accurate; thus, it is necessary to work with errors. As for their effect, errors are classified as systematic and random [10]. Random errors are errors whose source the researcher is not able to control. Thus we can call them uncontrollable errors. Systematic errors are such errors that always distort the result in the same way, provided that the same conditions are observed in repeated measurements. Those errors include errors of the method, inaccuracy of gauges or measuring devices and errors made by the observer. We can restrict these types of errors by observing the set measuring procedures, conditions and principles of measurement (mostly provided in the user manuals), and by the alertness of the operators.

Thus, the effort to minimize errors is the condition for obtaining the most accurate results. To ensure a correct interpretation of the results obtained from repeated measurements we have to know the accuracy of the used method (device) that is most commonly expressed using reliability - the reliability coefficient is used to express it. There are several procedures for the calculation of this coefficient: repeated measurement (test – retest), measurement of parallel tests or halving tests (split-half reliability) [11, 12].

The problem is that we cannot determine the actual value of the error of measurement expressed in the used units of measure, for example, as in the study dealing with the effect of six-week training of soccer players on the body fat representation [13] or changes in the body composition of soccer players during the season [14]. The absence of knowledge of the actual error of measurement expressed in the used units of measure prevents us from evaluating the found changes objectively and thus decreases the evidential value of the obtained results as when interpreting the found changes we do not exactly know the level of the effect of the applied intervention on the change and the level of a device error. Therefore, we consider it to be more suitable to express the accuracy using typical error of measurement [13]. The author of the aforementioned study recommends this method of expressing the accuracy of measurement to biomedical fields. To ensure a sufficient accuracy of the estimate, at least 50 participants in three repeated trials measured immediately consecutively should be measured.

The aim of the study is to apply the typical error of measurement of the BIA method accuracy to estimate the body composition of soccer players.

Methods

Subjects

The research group consisted of soccer players in the U21 age category who were registered in the list of teams playing the highest junior competition in the Czech Republic (junior league). The total number of the tested persons was 50; their average age was 20.35 ± 1.25 years. According to the schedules provided by the clubs, the players train five times a week, each session takes 90 minutes, and they participate in one competitive match. The volume of the training load including the match is 9 hours per week.

The study protocol was approved by the Ethics and Research Committee of the University of Ostrava. All participants signed an informed consent form.

Procedures

The tetrapolar bio-impedance TANITA 418 MA scale (Tanita Corporation, Japan) was used for measurement via the bioelectric impedance method (BIA). With regard to the volume of the weekly physical activity of the monitored probands, we used the Standard mode of measurement according to the manual for the Tanita device. We tried to eliminate gross errors by observing the standard conditions of measurement, of which all the individuals in the research group were informed. We did not take into consideration the errors of the researcher in view of the very easy work with the device, and with regard to his experience.

The measurements were carried over the course of five days, always on the same day of the week (Tuesday), and at the same time (from 08:00 a.m.). 10 probands were measured on one day; each proband was measured three times consecutively.

Statistical Analysis

To numerically express the accuracy of measurement (reliability) of the used device, we used the typical error of measurement (TE) [15].

The typical error of measurement for the pairs of trials was calculated from the selected standard deviation differences between 2 trials of the monitored persons, and divided by the root of the number of trials. The resulting value of the typical error was calculated from the root of the scalar products of the square of typical errors (TE^2)of the pairs of trials and the degrees of freedom (Df = 49) divided by the total sum of the degrees of freedom [13].

The resulting typical error of measurement:

$$\frac{\sqrt{\sum_i TE_i^{\,2} \cdot Df_i}}{\sum_i Df_i}$$

To apply another level of reliability, we used the interclass correlation (ICC) determined by ANOVA [16]. Unlike the Pearson coefficient, ICC is created for correlating identical variables [16], which is the case of this study.

The values of the monitored parameters of the body composition from three immediately consecutive measurements of each proband were used for the calculation.

The statistical analysis was carried out using the SPSS 19.0 statistical programme.

Results

The basic anthropometric parameters of the monitored players are presented in Table 1. The body composition is characterized by total body weight, total body fat representation and by total body water. The mean values monitored in the individual trial are presented in Table 2.

Table 1. *Basic anthropometric parameters of the monitored athletes*

Parameter	M	SD
BH (cm)	180.40	7.01
BW (kg)	74.00	8.28
BMI (kg/m^2)	22.83	1.83

BH – body hight, BW – body weight, BMI – body mass index, M – mean, SD – standard deviation

The mean values of the somatic parameters determined in the monitored players fully correspond with the values that are presented in many studies dealing with the somatic parameters of soccer players [13, 14, 17-19]. The representation of total body water corresponds with the values that are defined as standard by the software of the used device. Therefore, we can consider the individuals involved in this study to be a model group representing soccer players.

The differences in the mean values of the monitored parameters between the individual trials are

Table 2. *Mean values of the monitored parameters of Trial 1 – 3*

Trial	BW (kg) M±SD	BF (%) M±SD	BF (kg) M±SD	TBW (%) M±SD	TBW (kg) M±SD
1. (*n*=50)	74.00±8.28	10.67±3.92	8.05±3.47	65.45±2.75	48.34±4.92
2. (*n*=50)	74.00±8.27	10.71±3.99	8.10±3.47	65.42±2.81	48.05±5.71
3. (*n*=50)	74.00±8.32	10.55±3.90	8.03±3.55	65.40±2.78	48.44±5.03

BW – body weight, BF – body fat, TBW – total body water, M – mean, SD – standard deviation

Table 3. *Differences in the mean values of monitored parameters between the individual trials and descriptive characteristics*

Parameter	Dch	Trial	
		2 - 1	3 - 2
BW (kg)	M	0.04	-0.02
	SD	0.16	0.13
	TE	0.12	0.09
	TE (M)	0.11	
	ICC	1.000	1.000
	ICC (M)	1.000	
BF(%)	M	0.05	-0.17
	SD	0.64	0.56
	TE	0.49	0.40
	TE (M)	0.44	
	ICC	0.984	0.990
	ICC (M)	0.987	
BF (kg)	M	0.05	-0.07
	SD	0.55	0.53
	TE	0.40	0.37
	TE (M)	0.39	
	ICC	0.987	0.989
	ICC (M)	0.988	
TBW (%)	M	-0.03	0.11
	SD	0.51	0.45
	TE	0.39	0.32
	TE (M)	0.35	
	ICC	0.980	0.987
	ICC (M)	0.983	
TBW (kg)	M	0.02	0.09
	SD	0.37	0.36
	TE	0.27	0.26
	TE (M)	0.26	
	ICC	0.997	0.997
	ICC (M)	0.997	

Dch – descriptive characteristic, TE – typical error, TE (M) – mean typical error, ICC – interclass correlation, ICC (M) – mean interclass correlation

very low. As for the values expressed in kilograms, the differences range from 0.02 to 0.09 kg; as for the values expressed in percents, the differences range from 0.05 to 0.17%. The low differences are also reflected in the values of the typical error of measurement (TE) and interclass correlation (ICC). The mean TE ranges from 0.11 to 0.39 kg in the values expressed in kilograms and from 0.35 to 0.44% in the values expressed in percents. The ICC values in all parameters exceed the limit of 0.98 (Table 3).

Discussion

The lowest mean TE in the parameters expressed in kilograms was found in the body weight. This fact corresponds with the used device as Tanita 418 MA is a scale. The mean TE value of 0.11 kg (110 g) corresponds with the accuracy of body weight measurement stated in literature [20]. The ICC values also predicate a high accuracy: they reached the value of 1.000 in all cases.

To compare the accuracy of measurement (the level of reliability) of the used device in the monitored body composition parameters with the results presented in other professional studies dealing with this issue, we can apply both the results of the typical error (TE) and interclass correlation (ICC). Using the ICC results provides for a comparison with a higher number of such studies as authors apply ICC much more often. However, the disadvantage is that it does not express the actual error of measurement, as stated above. The measured ICC values within the range from 0.983 to 0.997 are completely in accordance with the results presented in those studies. Authors most often state ICC values ranging from 0.932 to 1.000 for the BIA method in relation to the used device and the monitored group [21-28].

To compare the resulting TE values that we obtained for the monitored parameters, we will use studies in which authors also monitored the TE values in the body fat representation using Tanita devices. Those include UM-022, BF 350, TBF 410 and TBF 401 [26, 29]. The mean TE value we measured in the percentage body fat representation correspond with the mean TE values of the BF 350 and BF 410 devices; their values ranged from 0.45 to 0.48 % [26]. As for the UM-022 and TBF 401 devices, their values were higher (0.83 – 1.73 %) [26, 29]. When comparing the TE values we measured in the body fat mass (kg), we found that the mean TE value determined by our device was higher than the ones measured by the other devices. The mean TE values measured by the other devices ranged from 0.04 to 0.17 kg [26, 29]. The differences between the mean TE values we measured and the mean values in the comparative studies were not significant. They could have been caused by the used type of Tanita, by the scope of the tested groups and also by a different representation of body fat. The studies mentioned above did not include regularly trained individuals.

Limitations of the Study

We are aware of the fact that the results presented in this study may be affected by the selection of the diagnosed persons, as well as by their number; we need to be very cautious when generalising the results. We are aware that the obtained results apply namely to the used device and athletes (soccer players) whose body water representation is within the standard and whose body fat representation does not exceed the value of 11 %.

Conclusion

With regard to the found low values of the typical error and high values of the interclass correlation in the monitored body composition parameters, we can state that using Tanita 418 MA to measure the body composition for the needs of the physical education process and training is sufficiently accurate. We are able to evaluate the level of external intervention in the changes in the body composition of the monitored individual even when the change is relatively small. The accuracy is subject to strict observance of the standard conditions of measurement. As for the BIA method, this mainly includes observing the principles related to organism hydration.

As for the representation of body fat, which is a commonly monitored parameter in sports practice, it has been proven that when the determined change does not exceed the value of 0.50% or 0.40 kg, we can consider it to be a result of external intervention and not an error of measurement. Once again, the principles of measurement must be observed.

Acknowledgments

This work was supported by research projects SGS 6120.

Declaration of Interest

The author reports no conflicts of interest.

References

1. Pluijm SMF, Visser M, Smit JH, et al. Determinants of bone mineral density in older men and women: body composition as mediator. *J Bone Mineral Res* 2001; 16: 2142–51. DOI: 10.1359/jbmr.2001.16.11.2142.
2. Parikh SJ, Edelman M, Uwaifo GI, et al., The relationship between obesity and serum 1,25-dihydroxyvitamin D concentrations in healthy adults. *J Clin Endocrinol* Metab 2004; 89: 1196–9.
3. Bultink IEM, Lems WF, Kostense PJ, et al. Prevalence of and risk factors for low bone mineral density and vertebral fractures in patients with systemic lupus erythematosus. *Arthritis Rheum* 2005; 52: 2044-50.
4. McClung MR, Lewiecki EM, Cohen SB, et al. Denosumab in Postmenopausal Women with Low Bone Mineral Density. *N Engl J Med* 2006; 354: 821-1.
5. Roelants M, Delecluse C, Goris M, et al. Effects of 24 Weeks of Whole Body Vibration Training on Body Composition and Muscle Strength in Untrained Females. *Int J Sports Med* 2004; 25: 1-5. DOI: 10.1055/s-2003-45238.
6. Rahimi R. Effect of moderate and high intensity weight training on the body composition of overweight men. *Facta Universitatis: Series Physical Education & Sport* 2006; 4: 93–101.
7. Silvestre R, Kraemer WJ, West C, et al. Body Composition and Physical Performance During a National Collegiate Athletic Association Division I Men´s Soccer Season. *J Strength Cond Res* 2006; 20: 962–70.
8. Gil S, Ruiz F, Irazusta A, et al. Selection of young soccer players in terms of anthropometric and physiological factors. *J Sport Med Phys Fit* 2007; 47: 25-32.
9. Perez-Gomez J, Olmedillas H, Delgado-Guerra S, et al. Effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. *Appl Physiol Nutr Metab* 2008; 33: 501-10. DOI: 10.1139/H08-026.
10. Cohen J. Statistical power analysis for the behavioral sciences. New Jersey: Lawrence Erlbaum Associates, 1988.
11. Zvárová, J. The Basics of Statistics for Biomedical Fields. Praha: Karolinum, 2002.
12. Kutáč P, Gajda V. The Influence of Reliability in Measuring Skinfolds on the Reliability of Result of Endomorphic and Mesomorphic Components of Somatotyp. *Medicina Sportiva* 2008; 12: 36-40.
13. Hopkins WG. Measures of Reliability in Sports Medicine and Science. *Sports Med* 2000; 30: 1–15.
14. Heyward VH, Wagner DL. Applied body composition assessment. Champaihn, IL: Human Kinetics, 2004.
15. Jackson AS, Pollock ML, Graves JE, et al. Reliability and validity of bioelectrical impedance in determining body composition. *J Appl Physiol* 1988; 64: 529–34.
16. Wagner DR, Heyward VH. Techniques of body composition assessment: a review of laboratory and field methods. *Res Q Exercise Sport* 1999; 70: 135–49.
17. Malina RM,- Bouchard C, Or OB. Growth, maturation, and physical activity. Champaign, IL: Human Kinetics, 2004.
18. Heymsfield SB, Lohman TG, Wang Z, et al. Human body composition. Champaihn, IL: Human Kinetics, 2005.
19. Riegerová J, Přidalová M, Ulbrichová M. Application of physical anthropology in the physical education and sports. Olomouc: Hanex, 2006.
20. Chin MK, Kiew OF, Girandola RN. A Comparison of Body Fat Measurement by BodPod, Skinfolds, and Three Bioelectrical Impedance Analysis Techniques in Chinese College Student. *Int J Phys Educ* 2006; 43: 77–85.
21. Pribyl MI, Smith JD, Grimes GR. Accuracy of the Omron HBF-500 Body Composition Monitor in Male and Female College Students. *Int J Exer Sci* 2011; 4: 93–101.
22. Peterson JT, Repovich WES, Parascand CR. Accuracy of Consumer Grade Bioelectrical Impedance Analysis Devices Compared to Air Displacement Plethysmography. *Int J Exer Sci* 2011; 4: 176–84.
23. Rutherford WJ, Diemer GA, Scott ED. Comparison of Bioelectrical Impedance and Skinfolds with Hydrodensitometry in the Assessment of Body Composition in Healthy Young Adults. *J Res Health Phys Educ* 2011; 6: 56–60.

24. Kilduff LP, Lewis S, Kingsley MI. Reliability and Detecting Change Following Short-Term Kreatine Supplementation: Comparasion of Two-Component Body Composition Methods. *J Strength Cond Res* 2007; 21: 378-84.
25. Kettanech A, Heude B, Lomme A, et al. Reliability of bioimpedance analysis compared with other adiposity measurements in children: The FLVS II Study. *Diabetes & Metabolism* 2005; 31: 534-41.
26. Jesensky-Squires NE, Dieli-Conwright CHM, Rossuello A, et al. Validity and reliability of body composition analysers in children and adults. *Brit J Nutr* 2008; 100: 859-65.
27. Mohammadi E, Shakerian S. Comparison of body composition assessment in women using skinfold thickness equations, bioelectrical impedance analysis and underwater weighing. *Studies in Physical Culture & Tourism* 2010; 17: 223–9.
28. Lubans DR, Morgan P, Callister R, et al. Test-retest reliability of a battery of field-based health-related fitness measures for adolescents. *J Sport Sci* 2011; 29: 685–93.
29. Vicente-Rodríguez G, Rey-López JP, Mesana MI, et al. Reliability and Intermethod Agreement for Body Fat Assessment Among Two Field and Two Laboratory Methods in Adolescents. *Obesity* 2012; 20: 221–8.

Accepted: November 29, 2012
Published: December 21, 2012

Address for correspondence:
Petr Kutáč
Varenska 40a
Ostrava 1 702 00
Czech Republic
e-mail: petr.kutac@osu.cz

Authors' contribution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection