HUMAN MOVEMENT
2011, vol. 12 (1), 41 – 45

EVALUATION OF ACCURACY OF THE BODY COMPOSITION MEASUREMENTS BY THE BIA METHOD

doi: 10.2478/v10038-010-0027-x

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ABSTRACT
Purpose. The main purpose of this study is to verify the accuracy of body composition measurements by the BIA method, using TANITA 418 MA unit. **Basic procedures.** For purposes of our study we decided to use the type-A uncertainty evaluation method (statistical processing of measured data). To formulate diagnostic error for the BIA method we used typical (standard) error of measurement from differences between pairs of repeated measurements – which is in principle a mean error of the test. The research was carried out on a group of 10 students whose field of study is physical education and sport. These students were chosen from the total number of 74 students in such a way that they represent as wide range of fat fraction as possible. Representation of their fat fraction oscillated between 9.0 to 31.2% of body fat. Input value of body fat, which was the basic criterion for selection of students to the measurement etalon, was determined by the DEXA method. **Main findings.** We described the uncertainty (type A) in selected file of etalons by an average value and by a standard deviation in percentage of fat: 0.13 ± 0.05. A diagnostic error of the method expressed by means of typical (standard) error of measurement was 0.38% of body fat. **Conclusion.** Considering the detected values of uncertainty (type A) and of typical error of measurement, we can conclude that measurement of body composition by the BIA method using TANITA 418 MA unit is sufficiently accurate for requirements of practical use. The necessary condition for the above mentioned measurement accuracy is a strict observance of standard measurement conditions.

Key words: measurement uncertainty, method reliability, body composition

Introduction

Diagnostics of body composition is at present profusely used not only in the area of physical education process and sport training, but also in medicine. In sport training we can say that the most often monitored parameter is the value of body fat representation [1 – 4], because it is widely known that its exceedingly high values lead to a decrease in sport performance in a lot of sport disciplines. In medicine, data on body composition is used mainly in diabetology, obesitology and in osteoporosis treatment [5 – 8].

When detecting body composition, we always make estimations. And for these estimations we use a large scope of methods. These methods can be divided into laboratory methods and practical methods. Some selected laboratory methods serve simultaneously as reference methods (e.g. DEXA) [9, 10]. They are too demanding for practical use – not only in reference to technical equipment and demands for skilled operators, but also owing to high financial demands. Therefore, practical methods are mainly used in standard practice. Here we can include anthropometry and, in the first place, the method of bioelectric impedance (BIA) which is currently very widely used. This method operates on the base of different spreading of low-intensity electric current in various biological structures. It is based on the principle of differing electric characteristics of tissues, fat and especially body water. The current flows through water and electrolyte components in fatless matter and the output resistance is therefore proportional to its content [10, 11].

No measurement can determine the real value of measured quantity. In present technical measurement practice it is usual to use a concept of uncertainty, which is a parameter corresponding to the measurement result. This parameter characterizes the range of values, which can be rationally assigned to the measured value. Resultant uncertainty is expressed through the sum of squares of two basic types of uncertainties. Considering the fact that the methodology of determination of uncertainty – type B (type B = based on other than statistical processing of measured data) is quite complicated, it was not possible to detect it in our research due to the

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lack of necessary sources [12–14]. Our research is significantly limited by this situation, because one of the purposes of this study is to initiate discussion on the problem of technical measurements in kinanthropometry.

Classical theory of tests uses the reliability coefficient $r_{XX'}$ to express this method's diagnostic error. Hopkins [15] criticizes the practice where only correlation coefficient obtained by a stability method (test–retest) is used for reliability evaluation. He suggests using typical (standard) error of measurement for diagnostic error estimation.

The purpose of this study is to compare the accuracy of body composition measurement by the BIA method using TANITA 418 MA unit from the viewpoint of measurement uncertainty concept and from the viewpoint of classical theory of tests. The results obtained can help us in evaluation of body composition changes caused by external interventions (e.g. training programme, change in nutrition habits, etc.).

Material and methods

When expressing measurement deviations in the form of measurement uncertainty we use so-called etalon, which should be composed of at least 10 items [12]. The selected file of etalons for this study consisted of 10 students (5 men and 5 women) whose field of study is physical education and sport. They are people who regularly practice motor activities related to their field of study (physical education and sport) and to their sport activities. Considering this fact, it is possible to use obtained data for other diagnostics of people engaged in sports in various sport disciplines (and we also make this diagnostics). The average age of selected group was 20.85 years. These students were chosen from the total number of 74 students (45 men and 29 women) in such a way that they represent as wide range of fat fraction as possible. Representation of their fat fraction oscillated between 9.0 to 31.2% of body fat.

Input value of body fat was determined by a DEXA method (Densitometer Holgic QDR, 3rd generation) in all 74 students. We used tetrapolar bioimpedance weighing machine TANITA 418 MA for the BIA method in selected 10 students.

We tried to eliminate gross errors by a strict observance of standard measurement conditions. Reading errors were not taken into account owing to very easy manipulation of the equipment and to the long working experience of the measurement operator.

Equipment error was expressed by a standard uncertainty (type A) in absolute and relative values [12, 13]. The absolute value is expressed by standard deviation (SD) value and the relative value is expressed by a variation coefficient (V, calculated as SD/mean). Standard deviation values SD, mean M and variation coefficient V were calculated for each person from 10 subsequent measures. Diagnostic error of the method was expressed by means of typical (standard) error of measurement, which Hopkins [15] recommends especially for this type of measurements. Hopkins [15] presents this method of expressing reliability of measurements of 7 skinfolds for estimation of body composition. The extent of this error is expressed in percentage of body fat. The calculation was also done based on 10 subsequent repeated measurements. Statistical processing was performed by means of statistical program SPSS 17.0.

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

Results

Table 1 presents basic somatic characteristics of probands assigned to the research

Basic descriptive statistical characteristics and uncertainty values (type A) for single etalons are presented in Table 2.

Uncertainty (type A) of our technical measurements in absolute values of percentage of fat oscillated in the range of 0.02 to 0.19. Characteristics of selected file of etalons are described by the average value and by the standard deviation of single uncertainties: 0.13 ± 0.05.

Table 3 presents a diagnostic error of the method expressed by typical (standard) error of measurement for single pairs of repeated measurements. Resulting value of typical error is calculated from the root of scalar product of square power of typical errors (TE^2) of experiment pairs and degrees of freedom divided by a total sum of degrees of freedom [16].

Resulting typical error of measurement =

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

Typical error value oscillated in the range of 0.23% to 0.46% of body fat. Resulting value of typical error was 0.38% of body fat.

Discussion

Uncertainty of type A, which is presently used in technical measurement practice for expressing the quan-

Table 1. Input somatic characteristics of probands

	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10
BH (cm)	190.0	170.0	160.0	171.0	174.0	159.0	159.0	168.0	197.0	190.0
BW (kg)	78.3	66.1	58.0	60.0	78.1	51.6	60.3	59.7	88.7	83.5
BF (%)	9.0	26.8	11.2	27.4	14.6	22.8	23.4	31.2	18.3	16.4

P – person (no.), BH – body height, BW – body weight, BF – body fat measured by DEXA device

Table 2. Values of 10 measurements of body fat for each person measured by the BIA method and values of uncertainty (type A)

Trial	P 1 (%)	P 2 (%)	P 3 (%)	P 4 (%)	P 5 (%)	P 6 (%)	P 7 (%)	P 8 (%)	P 9 (%)	P 10 (%)
1.	11.0	27.3	17.0	20.6	23.1	26.7	18.7	13.9	8.1	11.3
2.	11.2	28.6	16.6	21.0	23.1	26.6	18.9	13.7	8.2	11.3
3.	10.9	27.4	16.3	19.4	22.5	26.5	18.7	13.5	8.8	11.2
4.	11.8	28.2	15.7	20.2	22.3	26.9	18.9	13.6	9.3	11.3
5.	11.6	27.8	15.4	21.4	22.5	26.8	19.0	14.0	8.7	11.1
6.	11.5	27.8	15.8	20.9	22.4	27.0	18.7	14.0	9.1	11.3
7.	11.8	27.8	15.5	20.2	22.5	27.2	19.6	15.7	9.4	11.3
8.	11.3	27.8	15.6	20.9	22.3	27.3	18.6	14.3	8.8	11.2
9.	11.5	27.9	15.3	19.9	22.3	27.6	18.9	14.3	9.1	11.3
10.	12.0	27.8	15.0	20.8	23.7	27.4	19.2	13.6	9.6	11.2
M	11.46	27.86	15.82	20.53	22.67	27.00	18.92	14.06	8.91	11.25
SD	0.34	0.34	0.59	0.56	0.44	0.34	0.28	0.60	0.46	0.06
Type A	0.11	0.11	0.19	0.18	0.14	0.11	0.09	0.19	0.15	0.02
V	0.029	0.012	0.037	0.027	0.019	0.012	0.014	0.043	0.052	0.005

P – person no., M – mean, SD – standard deviation, Type A – uncertainty (type A), V – variation coefficient

Table 3. Differences between experiments in tested persons given in percentage of fat and descriptive characteristics

Person	Trial								
	2 – 1	3 – 2	4 – 3	5 – 4	6 – 5	7 – 6	8 – 7	9–8	10 – 9
1	0.2	–0.3	0.9	–0.2	–0.1	0.3	–0.5	0.2	0.5
2	1.3	–0.6	–0.6	0.8	–0.4	0.0	0.0	0.1	–0.1
3	–0.4	–0.3	–0.6	–0.3	0.4	–0.3	0.1	–0.3	–0.3
4	0.4	–1.6	0.8	1.2	–0.5	–0.7	0.7	–1.0	0.9
5	0.0	–0.6	–0.2	0.2	–0.1	0.1	–0.2	0.0	1.4
6	–0.1	–0.1	0.4	–0.1	0.2	0.2	0.1	0.3	–0.2
7	0.2	–0.2	0.2	0.1	–0.3	0.9	–1.0	0.3	0.3
8	–0.2	–0.2	0.1	0.4	0.0	1.7	–1.4	0.0	–0.7
9	0.1	0.6	0.5	–0.6	0.4	0.3	–0.6	0.3	0.5
10	0.0	–0.1	0.1	–0.2	0.2	0.0	–0.1	0.1	–0.1
M	0.2	–0.3	0.2	0.1	0.0	0.3	–0.3	0.0	0.2
SD	0.46	0.55	0.51	0.54	0.31	0.65	0.60	0.39	0.62
TE	0.33	0.39	0.37	0.38	0.23	0.46	0.43	0.28	0.44

M – mean, SD – standard deviation, TE – typical (standard) error

titative indicator of measurement quality, is in monitored etalons relatively low. For more extensive discussion on the observed values we did not find any relevant data in the technical literature available. Observed values approach zero – this fact indicates high quality of the measurement performed using the above mentioned equipment. However, there is still the problem of impossibility to express uncertainty (type B), which naturally increases the detected uncertainty. The reason was the impossibility of obtaining the necessary data from the manufacturer (e.g. technical specifications of the equipment, equations used for calculation of single parameters, etc.). Therefore, we could not calculate the resulting – combined uncertainty, which would yet more precisely characterize the range of values that is possible to assign to the measured quantity. On the other hand, we assessed the uncertainty of measurement for various etalons covering a wide range of fat distribution in body composition of probands. At first sight it seems that portion of body fat distribution does not influence the value of uncertainty (type A). This opinion is only preliminary and it is necessary to perform more detailed research to verify it. Comparison of our results to results of other authors would be possible only in the area of technical measurements in other fields of study, e.g. in physics [16–20].

The obtained typical error of measurement corresponds to the results of other authors who present an interval of measurement accuracy at level $\alpha = 0.05$ in the range 1–3% of the resulting value (our result was 0.76%) [21–25, 10]. When making comparisons it is necessary to take into account the fact that authors used other equipment working on the base of BIA method and they also selected other procedures to obtain results. Resulting value of typical error in % of body fat was 0.38%. It is the value calculated from 10 repeated measurements in 10 persons. When we decreased the number of repeated measurements, this error decreased even more. The breaking point in the number of repetitions was 7 repetitions (from 7 to 4 repetitions the error was only 0.37% of body fat).

We are aware of the fact that our results can be influenced both by the range of our selected file and by diagnosed persons. When we generalize our results we have to proceed carefully. We realize that obtained results are valid especially for the given equipment on which we took our measurements.

Conclusion

Regarding the extent of the equipment error (for TANITA 418 MA) expressed by the uncertainty (type A) and the low diagnostic error expressed by typical error of measurement, we can conclude that body composition measurement (in this study represented by portion of body fat) is sufficiently accurate for the sphere of physical education and sport training. We are able to assess the extent of influence of external interventions to the changes in the sphere of body composition (represented by body fat) in monitored persons even at relatively low changes. The necessary requirement for the above mentioned measurement accuracy is a strict observance of standard measurement conditions. When using the BIA method it is especially important to observe the fundamentals regarding the hydratation, nutrition and motor activities of human body.

Acknowledgement

The submitted study is a part of the grant project promoting science and research in the "Moravskoslezský" Region. Both development of diagnostic methods to assess the quality of human movement and the study were financed from this project's sources.

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Paper received by the Editors: January 21, 2010.
Paper accepted for publication: July 1, 2010.

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