Journal of Public Health and Epidemiology Vol. 5(1), pp. 15-19, January 2013
Available online at http://www.academicjournals.org/JPHE
DOI: 10.5897/JPHE12.050
ISSN 2141-2316 ©2013 Academic Journals

Full Length Research Paper

Validation of percent body fat using skinfold-thickness, bioelectrical impedance analysis and standard hydrostatic method in male wrestlers

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Accepted 17 August, 2012

The aim of this present study was to determine and validate the percent body fat through skinfold-thickness and bioelectrical impedance analysis (BIA) using hydrostatic (standard method) among male wrestlers in Ahvaz city. To do so, 25 male wrestlers were selected randomly (N = 60). Statistical analysis was done using Pearson correlation coefficient, paired T-test, standard error estimation (SEE) and total error (TE). The statistical analysis shows that the skinfold-thickness method used by Lohman for wrestlers has a significant difference with hydrostatic method (standard method). Also, there was no significant difference between wrestlers in terms of bioelectrical impedance and standard method results (TE = 0.0078, SEE = 0.0071, R = 0.871, P = 0.297). Findings suggest that using BIA is a more suitable method to measure wrestlers' percent body fat.

Key words: Percent body fat, skinfold-thickness, bioelectrical impedance, hydrostatic.

INTRODUCTION

Finding the ratio of fat-free mass (FFM) to fat mass (FM) in athletes is very important; so that the little changes in body composition determines health and performance of the athletes (Houtkooper and Going, 1994). And in some competitions like wrestling and weight lifting, an appropriate body composition influences the competition result (Heyward and Stolarczyk, 1996). Especially, those who are involved in weight measuring for their sports category (like wrestling), weight of the body should be observed and it needs a regular program. There are several methods for determining the body composition of different groups, which differ in terms of cost, time period, and measurement problems (Claros et al., 2005). Amongst many methods to measure body composition, the underwater weighing method is known as a standard method (Katch, 1969). Air-displacement plethysmography and dual-energy X-ray absorptiometry (DXA) are two new reference techniques (Dempster and Aitkens, 1995; Salamone et al, 2000). However, these techniques have some limitations, like the unavailability or expensiveness of the equipment for measurement. Therefore, the simpler techniques like bioelectrical impedance analysis (BIA) and skinfold-thickness are used and they are still useful in field studies (Mírza et al., 2004). Underwater weighing is a gold standard technique for researchers, athletes and physicians, but it has some limitations such as being time-consuming (it takes 30 to 60 min), subjects should stay for a long time under the water and it also requires us to measure the remaining volume of the lung (Lippincott and Williams, 2005). Skinfold-thickness is a field technique which requires a long and careful fat measurement using the caliper and the skillfulness of the investigator will influence the result; thus, this technique requires the investigator to undergo some special training before conducting the test (Jackson and Pollock, 1985). Skinfold-thickness limitations has led researchers to go after some other techniques like BIA which is less time consuming, easier for investigator to conduct it, does not need to train the investigator and is non-invasive (Cable et al., 2003). Willa et al., (1999) in her study on reliability and validity of body composition measures in female athlete students of Michigan State

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University showed that bioelectrical impedance has the most reliability and validity than other techniques. Craig et al. (1998) in "Bias and limits of agreement between hydro densitometry, bioelectrical impedance and skinfold calipers measures of percentage body fat" found that there are some differences between the standard technique and both the field techniques; however, they suggested that by meeting some criteria, these techniques could be used for athletes. Coolville et al. (1989) have compared methods for estimation of body fat in body builders. They tested Jackson-Pollock's seven-point subcutaneous fat and bioelectrical impedance on 21 athletes (including 9 men and 12 women) and then these two methods were compared to underwater weighing. Results suggest that there is a weak correlation between bioelectrical impedance and underwater weighing methods (R = 0.36), but the Jackson-Pollock's seven-point subcutaneous fat method has a relatively good correlation with under water weighing (R = 0.84). This study suggested that instead of underwater weighing method we can use Jackson-Pollock's seven-point subcutaneous fat method. Researchers use different methods to estimate percentage of body fat in athletes and still there is no established method for that, which in turn makes researchers confused. The most important aim of the present study is to determine the percentage of body fat using skinfold-thickness, BIA and underwater weighing (hydrostatic) methods, in male wrestlers. The second important matter is to figure out, whether there is a difference between skinfold- thickness and bioelectrical analysis on one hand and underwater weighing method on the other, in terms of percentage of body fat for male wrestlers. And considering the fact that skinfold-thickness and bioelectrical impedance methods are less expensive and more available and also the limitation of hydrostatic method in terms of cost, time consumption and location, therefore, what is the best and most suitable method(s) for determining the percentage of body fat in male wrestlers? The aim of the present study is to determine the percent body fat through skinfold-thickness, BIA using hydrostatic (standard method) among male wrestlers in Ahvaz.

METHODOLOGY

The population for statistics in the present study was all male wrestlers (60 persons). Out of these subjects who have been selected via a questionnaire, we selected randomly, 25 wrestlers from active clubs (Folad and corporation oil) in Iran. Because the total wrestlers were unavailable, the participant had at least 4 years of professional experience in wrestling. The participant's background exercises were included at least 2 h per day, 6 days exercise per week and they were in fitness period for competitions.

Measuring devices

The measuring devices were Harpenden caliper for measuring the skinfold-thickness, Seca medical scale (Germany) for weighing the subjects, stand height measuring device (Digital vertical jumping tester, Japon), bioelectrical impedance device (Olympia 3.3, Jawon of Core), Digital hydrostatic scale (Rengit, Poya electric of Iran) and pool in dimension $1.2 \times 1.2 \times 1.5$ m^2, Spirometer for estimate of the remained volume of lung (Ganshorn, Germany). All the subjects took all the tests [hydrostatic weighing (HW), BIA and SKF] in a single day and 12 h prior to the test, the subjects were asked to neither have any food nor do any exercise. For young male wrestlers (18 to 26), we used the skinfold-thickness method through Lohman three-point equation (Lohman, 1982) as follows:

Y = (Abdominal + sub-scapular + triceps) BD = 1.0982 - 0.000815 (Y) + 0.00000084 (Z) 2, and the remaining volume of the lung was measured by Spirometer. BIA was measured using Body composition analysis device (Olympia 3.3); and to convert it into percent body fat, we used Siri equation (Siri, 1956).

$$\%BF = [4.95 / BD - 4.5] \times 100$$

Measuring subcutaneous fat using a caliper

Skin thickness includes epidermis and dermis layers. Skinfold measurement was done using Harpenden skinfold caliper under a pressure of 10 gm/mm^2. In order to consider validation criteria, we did all measurements on the right side of the body, using Lohman's method (1982). After marking the desired spot, we take the caliper in our right hand and then we can measure thickness of the subcutaneous fat by pinching the fat.

Measuring body fat using bioelectrical impedance

We asked participants to stand on the foot plates of the device with command of the tester. Then we asked them to hold the handhold and keep it beside their body with an angle of 30°. Then they were supposed to squeeze the handholds for 10 s. After some seconds, the details of their body compositions were displayed on the monitor.

Measuring body fat using hydrostatic weighing

Required equipments to measure the body density includes a specialized tank of water with dimensions of 1.2 × 1.2 × 1.5 m, a seat out of polyvinyl chloride (PVC) which is hanging from the ceiling and it is connected to a digital hydrostatic scale. Before testing, we measured the °C water temperature and controlled its temperature in an appropriate level (30 to 34). All participants were asked not to eat any food (except for drinking water) 12 h prior to the test and refrain from every sporting activity. After observing the stated criteria, we explained to participants how to perform HW and the potential risks especially when exhaling inside the water tank; then we asked them to enter the water tank gently and sit on the seat. In the following stage of the test, they were asked to inhale deeply for 4 to 5 times and then take a complete and slow exhale, in such a way that 90% of exhale is outside the water and the remaining 10% is followed by submerging the head in water. Then in these conditions, they stayed submerged for 4 to 5 s in the water and the tester recorded the figures displayed on digital scale up to three decimal places. We repeated this process for 5 times for each participant. Eventually, we measured mean of two lower amounts in order to determine the hydrostatic weight.

RESULTS

Tables 1 and 2 show statistical findings related to the

Table 1. Descriptive findings about wrestlers.

Statistics variable	Mean (SD)	Maximum value	Minimum value
Age (year)	22.20 ± 2.58	26	18
Height (cm)	172.24 ± 6.92	192	160
Weight (kg)	68.37 ± 7.55	83	55
BMI (kg/m^2)	24.63 ± 4.06	33.54	18.59

Table 2. Results of Pearson correlation coefficient test between variables through Lohman three-point equation.

Variable statistics	R	R^2	TE	SEE	t	P-value	M ± SD	Range
%BF - HW % bf	0 / 821	0 / 756	3 / 87	2 / 64	-5 / 42	0 / 001	16.45 ± 8.75	9.56 - 22.15
BD - HW bd	0 / 871	0 / 780	0 / 0078	0 / 0071	-5 / 71	0 / 001	1.0671 ± 0.0127	1.0512 - 1.0790
BIA - HW % bf	0 / 736	0 / 722	2 / 61	2 / 03	1 / 81	0 / 297	14.65 ± 6.01	8.74 - 21.01
HW % bf							14.04 ± 6.07	7.3 - 20.8
HW bd							1.0640 ± 0.002	1.0451 - 1.0681

TE, Total error; SEE, standard error; BD, body density.

body density and fat percentage tests. Internal reliability of groups in the first and second phases tests showed that the correlation was R = 0.87 to 1.0 and the errors were negligible and the tolerance for all tests was normal.

External reliability of groups in terms of percent body fat in first and second phases of the test showed a correlation of R = 0.88 to 1.0 and the negligible errors confirm the reliability and accuracy of the test. We found the following results:

1) There is a difference between Lohman equation and standard method, in terms of measuring the body density for male wrestlers (Table 2) (P = 0.001). The mean value of subcutaneous fat was measured by Lohman three-point equation and standard method (16.45 and 14.04, respectively). These two means have a significant difference (P = 0.001).
2) There is correlation between Lohman equation and standard method in terms of measuring body density of male wrestlers (Table 2) [R^2 = 0.780, R = 0.871, standard error estimation (SEE) = 0.0071, total error (TE) = 0.0078]. Also, there is a significant correlation between Lohman three-point equation and standard method in terms of percent body fat (R^2 = 0.756, R=0.821, SEE = 2.64, TE = 3.87).
3) There was no difference between bioelectrical impedance and standard method in terms of body density in male wrestlers. In other words, considering Table 2, the percent body fat determined through bioelectrical impedance and standard method are the same; that is, there is no significant difference between the two methods (P = 0.297).
4) There was a significant correlation between bioelectrical impedance and standard method in terms of body density in male wrestlers (TE = 2.61, SEE = 2.03, R = 0.0763, R^2 = 0.0722) (Table 2).

DISCUSSION

The average density of body was 1.0671 g/ml according to Lohman's three-point equation and the same value determined by standard method was 1.0640 g/ml (Table 2) for male wrestlers. These two averages have a significant difference.

This means that the determined density of body through Lohman's three-point equation (BD) is more than the value determined by standard method (HW).

Also, the average subcutaneous fat determined by Lohman's three-point equation was 16.45% and 14.04% in standard method. These two averages have a significant difference.

This result corresponds with previous results by wellborn (2000) and Guang et al. (2005), and it is not consistent with results of Housh et al. (2004), Andreoli et al. (2006) and DE Lorenzo (2004). The correlation coefficient of body density for wrestlers was R = 0.871, using Lohman equation and standard method.

Comparison of this correlation coefficient against the possibility (P ≥ 0.05) shows that there is a significant correlation between both BD methods and coefficient of determination (R^2 = 0.780) shows that there is an appropriate linear relation between the two mentioned methods.

It should be noted that the SEE was 0.0071 g/cc and TE was 0.0078 g/cc. The correlation coefficient of percent body fat using Lohman's three- pint equation and standard method for wrestling was R = 0.821. With regard to the level of probability ($P \leq 0.05$) for percent body fat of subjects between Lohman's three-point equation and standard method, there is a significant correlation.

This result is somehow consistent with previous results by Utter et al. (2001), Dixon et al. (2005) and Williams and Bale (1988), but it is not consistent with results by Covington (1990) and Andreoli et al. (2004).

Findings show that there is a significant difference between Lohman's three-point skinfold-thickness method and standard method in terms of average value (P = 0.001) and also, there is a very high correlation between them through the standard method which shows the accuracy of these equations; however, we can rely on these equations, for the coefficients used are appropriate for non-Iranian population and they are not suitable for Iranian community.

Jeffrey and Johansson (1995) found out in their study that we cannot use the same equation in every population to measure the subcutaneous fat (Bruzuck et al., 1963). Also, they suggested some special equations by Heyward and Stolarczyk (1996) for different populations (Heyward and Stolarczyk, 1996). Lohman suggests that some errors related to BD predictions might be as the following:

A) Technical errors are due to the difference between calipers or experience and skill of the examiners.
B) Biological differences of subjects, including difference in terms of percent body fat, will affect the BD estimation (Lohman, 1992).

The average value of percent body fat was 14.65 through bioelectrical impedance and it was 14.04 through standard method for wrestlers and the existing difference between the two methods is not significant and the results of our study are consistent with results by Williams and Bale (1988), but the results are not consistent with results of Charke (1989), Coolville et al. (1989), Dixon et al. (2005), Huygens (2002), Clark et al. (2004) and de Lorenzo (2004).

Correlation coefficient for percent fat in wrestling, determined by bioelectrical impedance and standard method was R = 0.763. With regard to the level of probability ($P \leq 0.05$) for percent body fat of subjects between bioelectrical impedance and standard method, there is a significant correlation.

The resulted coefficient of determination ($R^2 = 0.722$) shows that there is a good linear relation between the two test methods. This result is somehow consistent with results by Dixon et al. (2005), Clark et al. (1994), Charke (1989) and Clark et al. (2004) but it is not consistent with results by Coolville et al. (1989), Andreoli (2004) and Welborn and Knuiman (2000). Segal (1996) in his evaluation study suggested that bioelectrical impedance in sports and exercise is a method to evaluate the athletes' body composition.

There are several problems in using BIA in sports and exercise and some issues should be taken into consideration for the future studies. There are generally two problems; physiological factors change and the limitation in predicting equations which brings about the statistical problems.

Some physiological factors should be considered when using BIA, to control the conditions of the test; for example, we should consider the amount of body water, body temperature, time of the last exercise, glycogen storage and chemical maturity in young athletes. Accuracy and validity of BIA method will be achieved only when the experimental conditions are controlled exactly (Segal, 1996).

Considering the average value of studied methods and standard method for wrestlers, we have found results that can be significantly different for implication of validated predicting equation in ethnic, genetic and tribal groups. According to this theory, only bioelectrical impedance method had the admissible P-value (TE = 2.61, SEE = 2.03, R = 0.763, p = 0.297).

This shows that despite the high correlation between bioelectrical impedance and standard method and in spite of negligible errors (SEE, TE), there is no significant difference between the elite methods, and the bioelectrical impedance method has a higher level of validity and reliability. Thus, we suggest that it can be used for athletes. And Lohman's skinfold-thickness method is not valid and there is a significant difference between several averages of Lohman's three-point method in wrestlers and we should not use it for male wrestlers.

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