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How Accurate Are the Anthropometry Equations in in Iranian Military Men in Predicting Body Composition?

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Abstract

Background: The body composition varies according to different life styles (i.e. intake calories and caloric expenditure). Therefore, it is wise to record military personnel's body composition periodically and encourage those who abide to the regulations. Different methods have been introduced for body composition assessment: invasive and non-invasive. Amongst them, the Jackson and Pollock equation is most popular.
Objectives: The recommended anthropometric prediction equations for assessing men's body composition were compared with dual-energy X-ray absorptiometry (DEXA) gold standard to develop a modified equation to assess body composition and obesity quantitatively among Iranian military men.
Patients and Methods: A total of 101 military men aged 23 - 52 years old with a mean age of 35.5 years were recruited and evaluated in the present study (average height, 173.9 cm and weight, 81.5 kg). The body-fat percentages of subjects were assessed both with anthropometric assessment and DEXA scan. The data obtained from these two methods were then compared using multiple regression analysis.
Results: The mean and standard deviation of body fat percentage of the DEXA assessment was 21.2 ± 4.3 and body fat percentage obtained from three Jackson and Pollock 3-, 4- and 7-site equations were 21.1 ± 5.8, 22.2 ± 6.0 and 20.9 ± 5.7, respectively. There was a strong correlation between these three equations and DEXA ($R^2 = 0.98$).
Conclusions: The mean percentage of body fat obtained from the three equations of Jackson and Pollock was very close to that of body fat obtained from DEXA; however, we suggest using a modified Jackson-Pollock 3-site equation for volunteer military men because the 3-site equation analysis method is simpler and faster than other methods.

Keywords: Anthropometry, DEXA Scan, Body Composition, Military, Obesity

1. Background

Fit military personnel guarantee the independence and sovereignty of every nation to a great extent. To study fitness needs a lot of commitment and a very tight control and supervision. Knowledge regarding health risks, potential metabolic diseases, nutritional diets, intake habits and even daily/weekly exercise regimens of military personnel can all be extracted off an index known as body fat percentage. To find out more about this very crucial quantity, the body composition as a broader term is under the spotlight of investigators. The body composition varies according to different life styles (i.e. intake of calories and caloric expenditure). Tight monitoring of body fat and an optimum muscle mass ensures longer service to the military system whilst happier in personal life. Therefore, it is wise to record military personnel body composition periodically and encourage those who abide to the regulations. Different methods have been introduced for body composition assessment: invasive and non-invasive. Amongst them, the Jackson and Pollock equation is most popular. Methods of body composition assessment should be valid and reliable. Anthropometry assessment has highly attracted researchers' attention because it is easy and inexpensive. Initially, anthropometry has originated from Hydrostatic Weighing (HW) and was only able to detect two components (2C) of body, fat mass (FM) and fat free mass (FFM). Later on, a four-component (4C) model evaluating FM, water, bone mineral content (BMC) and protein for anthropometric assessment was proposed (1). Although these two anthropometry assessment models (2C, 4C) were standard and precise models to assess body composition, they are not convenient to use in large military units due to practical reasons and maximal subject cooperation. Therefore, researchers began to think and used anthropometric equations to assess body composition in large communities. The two component model is still considered as a standard model (2) and can precisely estimate body density. Anthropometric equations are required to convert body density to fat percentage. An alternative method to be set as a gold standard method is Dual-energy X-ray absorptiometry (DEXA). DEXA is a standard method for body composition assessment estimating fat mass, fat free mass and bone mass (3-component model) simultaneously without needing to calculate density (3). Fat, bone mineral, and fat-free soft tissue have different absorption properties. Thus, DEXA can get estimates of body composition by scanning the entire body. DEXA is a safe and quick method (6 to 20 minutes) that requires minimal subject cooperation (4). Therefore, in many body composition laboratories, DEXA has been considered as a secure alternative to the 2C models of body composition assessment as a clinical reference model and as such, the anthropometric equations originated from HW should be compared with DEXA to determine probable discrepancies. Body composition determined from skin fold measurements correlates well with body composition determined by hydrodensitometry. Generalized skin fold equations developed in the 1970s are commonly used to estimate laboratory-measured fat percentage. The equations were developed on predominately white individuals using Siri's two-component percentage fat equation. The principle behind this technique is that the amount of subcutaneous fat is proportional to the total amount of body fat. It is assumed that close to one third of the total fat is located subcutaneously. The exact proportion of subcutaneous-to-total fat varies with sex, age, and ethnicity. Therefore, regression equations used to convert sum of skin folds to percent body fat must consider these variables for greatest accuracy (5). Jackson-Pollock 7-site (JP7) equation is mostly used in sport science and recommended by American College of Sports Medicine (ACSM's) (5). Comparing the estimations from these equations and DEXA in men, Ball and colleagues observed an underestimate of body fat percentage (%BF) in spite of finding a strong relationship between them (6). Evaluating 32 Estonian conscripts through anthropometric equations, Lintsi et al. (7) observed an overestimate in %BF compared to DEXA. Bottaro et al. (8) observed another skin fold equation with the underestimate of %BF compared to DEXA in Hispanic women. The rate of overweightness and obesity has become a major problem among military forces. In order to control obesity through scientific weight loss programs, we needed a precise and simple method to assess military forces' body composition to set as a platform to build our future program aiming to shed weight and yet to preserve the muscle mass. Due to racial differences and different lifestyles, an equation fitting the local military population should be designed (9, 10). To the best of our knowledge, there is no anthropometric equation emerging from DEXA for Iranian military men.

2. Objectives

The present investigation is meant to serve as a pilot study for greater and more comprehensive future studies at the national level. The present study is to investigate how correlative body fat percentage data, estimated from 3 most general anthropometric equations, are with that obtained from DEXA in a small sample of volunteered military combat forces based in Tehran suburbs.

3. Patients and Methods

3.1. Subjects

101 military men aged 23 - 52 were sampled randomly selected from three different categories of armor, ranger and staff. All of them participated in the study expressing full satisfaction in written form of consent.

3.2. Anthropometric Assessments

Anthropometric assessments were conducted according to recommended ACSM's regulations (5). Subjects were wearing minimal clothes (e.g. tight-fitting short or the likes). To measure skin folds, a Slim Guide skin fold caliper (Creative health products Plymouth MICH PATENT PEND) was utilized. In order to reduce the assessment error, every point of skin fold was assessed rotationally at least twice and the average of the two assessments was recorded. Evaluated skin folds included chest, midaxillary, triceps, thigh, subscapular, suprailiac, and abdomen (11). We tried not to change the caliper accuracy during assessment. According to ACSM's instruction, the body density and its conversion to %BF was estimated using Jackson and Pollock 3-site (JP3) and 7-site (JP7) equations (Table 1) and Siri equation (%BF = (495/Body Density) - 450), respectively (12). In addition, %BF was directly estimated using Jackson and Pollock 4-site (JP4) equation (11). All the assessments were performed by one same person and only 15 candidates were assessed for anthropometric evaluation every day. As recommended by Ball et al. (6), thirty subjects underwent anthropometric analysis in two stages to check the reliability before running the test. There was no significant difference between the two stages ($P = 0.60$), the correlation of which was $R = 0.96$ ($P < 0.001$).

3.3. Dual-Energy X-Ray Absorptiometry DEXA

%BF was assessed using DEXA (model QDR 4500A; Hologic-Delphi Systems, Bedford, MA, USA) through Fan Beam technology. Computer software of Hologic QDR Delphi W unit, (Apex software v 3.0.1) was used to compose the output of the machine as the body composition. The procedure was carried out according to the manufacturer's recommendations. Briefly, subjects lay on a certain place of DEXA table with the minimum coverage, tight shorts, without any metal objects. Before running the scans, DEXA machines and accessory equipment underwent quality control and calibration. In order to validate DEXA, %BF of 10 subjects were measured twice on the someday. Between tests each subject was removed from the DEXA table and repositioned (6). Correlation between the results of two stages was R = 0.98 (P < 0.001). All scans were technically performed and later analyzed and by the same operator.

3.4. Statistical Methods

Multiple regression analysis was used as the statistical method. Statistical package of SPSS (version 17) was used for off-line statistical analyses.

4. Results

Body fat Percentage of 101 military men aged 23-52 with a standard deviation and average age of 35.5 ± 8.4, height of 173.9 ± 6.5 cm, weight of 81.5 ± 11.7 kg and BMI of 26.9 ± 3.7 was obtained by methods of anthropometry and DEXA. Descriptive characteristics of studied factors are presented in Table 2. The average %BF obtained from DEXA and from JP7 was 21.19 and 21.1, respectively. There was no significant difference between the two methods' mean (-0.13) (P = 0.67). In addition, regression results show that the Coefficient of Determination between JP7 and DEXA was equal to $R^2 = 0.982$ (P < 0.0001), as presented in Table 3. The new equation is designed based on JP7 equation as follows:

BF% = 0.981 (1.112 - 0.00043499 (7SF) + 0.00000055 (7SF) 2 - 0.00028826 (age))

Figure 1 shows the scatter plot between DEXA and JP7. The average %BF obtained from JP4 equation (1985) was equal to 22.2. The mean value from JP4 was significantly different from that of DEXA (P = 0.002). Regression results also show that the Coefficient of Determination between JP4 and DEXA was $R^2 = 0.981$ (P < 0.0001), as presented in Table 4. The new equation is designed based on the JP4 equation as follows:

BF% = 0.931 (0.29288 (4SF) – 0.0005 (4SF) + (0.15845 × age) – 5.76377)

Figure 2 shows the scatter plot between DEXA and JP4.

The average %BF obtained in JP3 equation (1978) was 20.9, not significantly different from DEXA (P = 0.328). The Coefficient of Determination between JP3 and DEXA was equal to $R^2 = 0.981$ (P < 0.0001), Table 5. The new equation is designed based on the JP3 equation as follows:

BF% = 0.990 (1.10938 - 0.0008267 (3SF) + 0.0000016 (3SF) 2 - 0.0002574 (age)).

Table 1. Recommended generalizable Anthropometric Equations for Men[a]

Equation	Sites	Formula
7-Site (JP7)	Chest, midaxillary, triceps, thigh, subscapular, suprailiac, abdomen	Body density = 1.112-0.00043499 (∑7SF) + 0.00000055 $(∑7SF)^2$-0.00028826 (age)
3-Site (JP3)	Chest, abdomen, thigh	Body density = 1.10938-0.0008267 (∑3SF) + 0.0000016 $(∑3SF)^2$-0.0002574 (age)
4-Site (JP4)	Abdomen, thigh, triceps, suprailiac	% BF =(0.29288 × ∑4SF) – (0.0005 × (∑3SF)2) + (0.15845 × age)-5.76377

[a] Abbreviations: ∑7SF, sum of seven skinfold sites; ∑4SF, sum of four skinfold sites; ∑3SF, sum of three skinfold sites; JP7, 7 site equation by Jackson and Pollock (1978); JP4, 4-site skinfold equation by Jackson and Pollock (1985); JP3a, 3-site skinfold equation by Jackson and Pollock (1978).

Table 2. Descriptive Characteristics (N101) of Volunteers

Variable	Mean ± SD	Range
Age, y	35.8 ± 8.4	23 - 52
Height, m	173.9 ± 6.5	155.5 - 188
Weight, kg	81.5 ± 11. 7	47.5 - 109
BMI, kg/m²	26.9 ± 3.7	16.2 - 37.4
Body fat (JP7) [a]	21.1 ± 5.8	3.4 - 32.9
Body fat (JP4) [a]	22.2 ± 6.0	3.3 - 36.2
Body fat (JP3) [a]	20.9 ± 5.7	3.1 - 32.9
Body fat (DEXA) [a]	21.2 ± 4.3	9.9 - 29

[a] The values are presented as percent.

Table 3. Comparison of Dual-Energy X-Ray Absorptiometry and Jackson-Pollock 7[a]

Variable	Mean ± SD	SEM	Mean Diff	SD	SE	P Value	B	Standard Error	R²	P Value
Method			-0.13	2.98	0.3	0.67				
JP7	21.1 ± 5.8	0.57					0.981	0.013	0.982	< 0.0001
DEXA	21.2 ± 4.3	0.43								

[a] Abbreviations: JP, Jackson-Pollock; DEXA, Dual-energy X-ray absorptiometry.

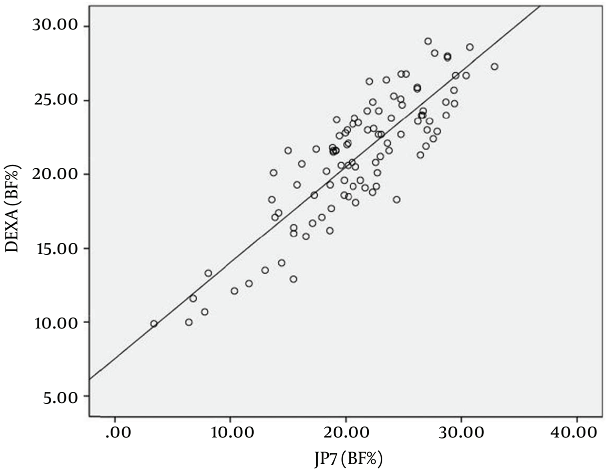

Figure 1. Scatter Plot Between Dual-Energy X-Ray Absorptiometry and Jackson-Pollock 7

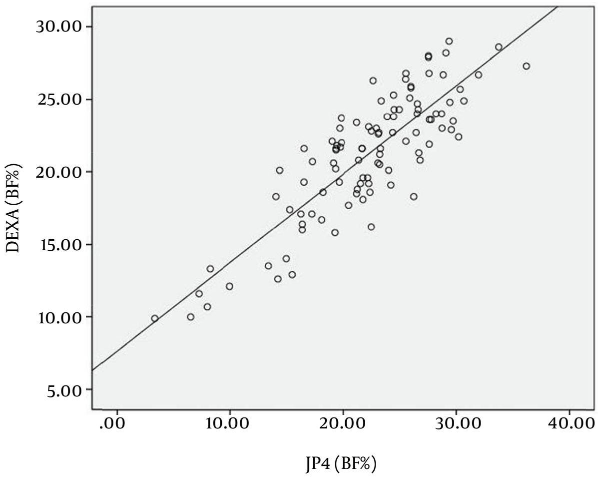

Figure 2. Shows the Scatter Plot Between Dual-Energy X-Ray Absorptiometry and Jackson and Pollock 4

Table 4. Comparison of Dual-Energy X-Ray Absorptiometry and Jackson-Pollock4[a]

Variable	Mean ± SD	SEM	Mean Diff	SD	SE	P Value	B	Standard error	R^2	P Value
Method			1.02	3.27	0.3	0.002				
JP4	22.2 ± 6.0	0.59					0.931	0.013	0.981	< 0.0001
DEXA	21.2 ± 4.3	0.43								

[a] Abbreviations: JP, Jackson-Pollock; DEXA, dual-energy X-ray absorptiometry.

Table 5. Comparison of Dual-Energy X-Ray Absorptiometry and Jackson-Pollock3[a]

Variable	Mean ± SD	SEM	Mean Diff	SD	SE	P Value	B	Standard Error	R^2	P Value
Method			-0.3	2.9	0.3	0.328				
JP3	20.9 ± 5.6	0.57					0.990	0.014	0.981	< 0.0001
DEXA	21.2 ± 4.3	0.43								

[a] Abbreviations: JP, Jackson-Pollock; DEXA, Dual-energy X-ray absorptiometry.

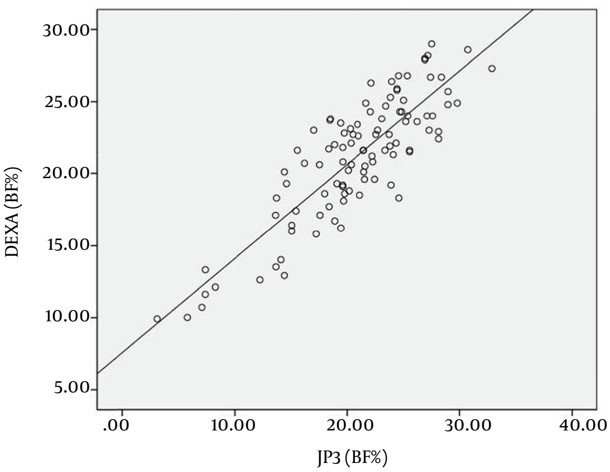

Figure 3. Scatter Plot of Dual-Energy X-Ray Absorptiometry Versus Jackson and Pollock 3

5. Discussion

In the present study, %BF in volunteer military men was measured by DEXA and compared with generalized Jackson and Pollock equations, the mean values of which were 21.1, 22.2 and 20.9 JP3, JP4 and JP7 respectively. Findings of this study show that the estimation of %BF in our volunteers follows Jackson and Pollock equations well. We can estimate %BF of volunteer military men using coefficients of 0.981, 0.931 and 0.990 for JP7, JP4 and JP3, respectively. According to searches conducted so far, no anthropometric equation is designed for Iranians assessed by DEXA and this is the first study in this field conducted on a few volunteer military men. Due to the importance of maintaining physical fitness, military forces are permanently monitored in terms of body composition. The present study aims to estimate %BF of military men using a cheap, quick, non-invasive and yet precise method to inform commanders and program planners of staff fitness maintenance as well as to decrease the occurrence of non-communicable diseases. Although DEXA is currently the best method of body composition assessment, it cannot be permanently used to assess body composition of military forces due to its high costs and problems with portability. Therefore, alternative anthropometric assessment methods cross-validated with a gold standard can be used to achieve this purpose. Since Ball and colleagues used the non-invasive and inexpensive method of Jackson and Pollock equations and proved its applicability, as compared to DEXA, we were inspired to follow them. Having different race and life styles in our sample population, how Jackson and Pollock equations could estimate %BF needed a thorough investigation. Considering high correlation of %BF assessments between Jackson and Pollock equations and our study, it is possible that Jackson and Pollock equations were precisely designed and could also be used for volunteer military men in the present study. Among more than one hundred anthropometric equations designed so far, generalized Jackson and Pollock equations are mostly used in sports and medicine for men. However, it is necessary to realize that Jackson and Pollock equations are developed from HW and need be updated with a new method such as DEXA in order to determine if their estimates are exact and not under- or overestimated. Therefore, equations will be modified for the society from which they are derived. In addition, any differences between the estimated (by Jackson and Pollock equations) and measured values (by DEXA) will be the underpinning of the modified equations. Beta regression can be used to design an appropriate equation, and by doing so, beta derived from JP7 and JP3 equations was 0.981 and 0.990 in our study, and 0.942 and 0.941 reported by Ball and Colleagues respectively (6). Ball and Colleagues concluded that JP7 equation is the best model for their studied population which seems consistent with the present study. However, in our study, JP4 equation shows a significant overestimation of DEXA ($P = 0.002$). Therefore, we suggest JP4 equation not to be used for future national studies. Since the Coefficient of Determination is almost identical in the JP7 and JP3 equations ($R^2 = 0.98$), it seems more appropriate to use JP3 equation (chest, abdomen, thigh), for it has less variables to measure and takes less time to complete. Time is of special importance for assessing a fairly large military unit, particularly when in military excercise or mission conditions. Our study indicates that other points used in JP7 equation have small effect on the assessment of %BF in our volunteered military men. Similar to the results reported by Ball and Colleagues (6), present data displayed an underestimate in JP3 and JP7 equations, though not significant. Yet some observable errors may be related to DEXA because DEXA and the relevant software base their function on an assumed value for soft tissues, and this assumption might lead to potential errors in the final results. Another limitation of DEXA is that it cannot directly estimate tissue density. In other words, DEXA may make an error in discriminating bone from other tissues, especially in the trunk of the fat people. It is therefore noteworthy to observe that DEXA is a device, which operates with its special software and may make errors in assessments. Comparing DEXA and anthropometry with computerized tomography (CT) in assessment of visceral adipose tissue (VAT), Micklesfield et al. (13) found that these two methods are unable to assess VAT as precise as CT and magnetic resonance imaging (MRI). Here, the difference is due to different types of fat; we did not remove hypodermic fat from VAT using DEXA and they assessed only VAT. However, they showed in another study that DEXA can act as an alternative to CT and MRI to assess VAT in clinical and research studies (14). Freedman et al. (15) used hip circumference divided by height 1.5 - 18 as an index to measure %BF while skin fold method was used in the present study. To validate noninvasive models, Kanellakis and Manios (16) also compared anthropometric and DEXA and reported their relationship, which our finding was consistent with. Despite a high correlation between %BF obtained from anthropometric equations and DEXA, Lintsi et al. (7) reported an overestimate in %BF obtained from skin fold equations compared to DEXA. It was consistent with our study and may be due to Lunar DEXA as well as the use of anthropometric equations of Durnin and Womersley (1974). Hart et al. (17), Bottaro et al. (8), and also ACSM's stated modified formulas to change body density to %BF for different ethnic groups such as native Americans, blacks, Spaniards, Japanese and caucasians (whites) separately (5). Lifestyle varies in different communities. In addition, there are various diet habits all over the world (18). Diets are directly associated with body composition. For example, several studies have compared obesity in different countries including Iran and have shown the differences. In addition, studies have shown that BMI has significantly increased in Iran during recent years (19) and even mean body mass index (BMI) is not similar amongst cities of Iran (20). Studies indicate the significant relationship between obesity and lifestyle indicators (21-24) and nutrition (25) in Iran. Therefore, the results of various studies show that regression equations of each community suit the very same community. This means that the equation presented in this study can be used for the entire military population in Iran. We require carrying out a comprehensive study on all ethnic groups in Iran to be able to create a generalized equation both appropriate and reliable for all Iranian military forces. Finally, an equation should be derived to study the entire population of Iran, if possible. The mean %BF obtained from the three equations of Jackson and Pollock was very close to that directly measured by DEXA in volunteered military combat forces based in Tehran. However, it is suggested to use the JP3 equation for the sample population for its simplicity and quickness.

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Footnotes

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