New Percentage Body Fat Prediction Equations for Japanese Males

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Abstract Anthropometry is simple, cheap, portable and non-invasive method for the assessment of body composition. While the Nagamine and Suzuki body density prediction equation has been frequently used to estimate %BF of Japanese, the equation was developed more than 40 years ago and its applicability to the current Japanese population has not been studied. This study aimed to compare %BF results estimated from anthropometry and dual energy X-ray absorptiometry (DXA) in order to examine applicability of the Nagamine and Suzuki equation. Body composition of 45 Japanese males (age: 24.3±5.5 years, stature: 171.6±5.8 cm, body mass: 62.6±7.1 kg, %BF: 15.7±5.6%) were assessed using whole-body DXA (Hologic® QDR-2000) scan and anthropometry using the protocol of the International Society for the Advancement of Kinanthropometry (ISAK). From anthropometric measurements %BF was calculated using the Nagamine and Suzuki equation. The results showed that the Nagamine and Suzuki equation significantly (p<0.05) underestimated %BF of Japanese males compared to the DXA results. There was a trend towards greater underestimation as the estimated %BF values using DXA increased. New %BF prediction equations were proposed from the DXA and anthropometry results. Application of the proposed equations may assist in more accurate assessment of body fatness in Japanese males living today. J Physiol Anthropol 25(4): 275–279, 2006 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.25.275]

Keywords: body composition, anthropometry, DXA, prediction equation, Japanese males

Introduction

The estimation of body composition, including fat mass (FM), fat free mass (FFM) and percentage body fat (%BF), is essential in order to assess the health status of individuals. Among the many methods available, anthropometry that includes measurements of skinfolds and girths is a convenient, cost-efficient and non-invasive method to assess human body composition. Because of its portability and simplicity, anthropometry has frequently been used in field settings. Anthropometry is based on the two-compartment model that divides the human body into FM and FFM and predicts the %BF of individuals using a prediction equation. The equation was derived from a regression analysis using body density or %BF obtained from underwater weighing and other advanced methods (Brozek and Keys, 1951; Durnin and Womersley, 1974; Lohman, 1981). As body composition alters by gender, age and lifestyle, prediction equations are considered as “population-specific” (Norton, 1996) and only applicable to the group whose characteristics are similar to the group that the equation was originally established from.

Dual energy X-ray absorptiometry (DXA) is considered as one of the more accurate methods for determining human body composition (Heymsfield et al., 1990; Wellens et al., 1994; Van Loan, 1998). This method is able to differentiate the body into three components, lean body mass, FM and bone minerals. In comparison to anthropometry, DXA has limitations compared to other methods with portability, convenience, cost and radiation exposure, even though the latter is at a very low level. Among the range of prediction equations developed during 1960–1980’s (Nakadomo, 1991; Komiya and Nakao, 2002), the Nagamine and Suzuki body density prediction equation (1964) is the most commonly used body density prediction equation in body composition research in Japan. The equation for adult males was based on data obtained from 96 Japanese males using water displacement and anthropometric methods and it uses the sum of two skinfolds (triceps and subscapular). After 40 years of use, changes in body size, including stature and body mass, and body proportion in Japanese have been reported and the validity of the Nagamine and Suzuki equation to predict %BF accurately has been questioned (Komiya and Nakao, 2002). However there has been no reported study that

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compared %BF values estimated from the Nagamine and Suzuki equation and the results obtained from advanced methods such as DXA. Furthermore, while there are studies that proposed body composition prediction equations (Tahara et al., 1995; Tahara et al., 2002), a number of studies that proposed an equation that directly predicts %BF of Japanese males using the results obtained from DXA are limited.

The aim of the current study was to compare %BF values estimated from whole-body DXA scanning and anthropometry using the Nagamine and Suzuki equation. From the results, new %BF prediction equations for this particular group were also proposed.

Subjects

A convenient sample of 45 healthy Japanese males (aged between 18 and 40 years old, median age: 22 years old) were recruited through the Japanese community in Perth, Western Australia. Inclusion criteria for the Japanese subjects were holding Japanese nationality and self-recognition as “Asian”. Mean age, height and body mass of the study group were 24.3±5.5 years old, 171.6±5.8 cm and 62.6±9.6 kg respectively. Recruitment was mainly conducted at education institutions, including universities and language schools. Most of the Japanese males (64%) had spent less than 6 months in Australia at the time of their participation.

Method

The study was approved by the Human Research Ethics Committee of Curtin University of Technology and adhered to the principles of medical research established by the National Health and Medical Research Council (NHMRC, 1999). Written information was provided to each subject and consent was obtained before his participation. Each subject underwent comprehensive anthropometric assessment and a whole-body DXA scan.

1) Dual Energy X-ray Absorptiometry (DXA)

The whole-body DXA scans were conducted using the Hologic® QDR-2000 (version 5.73) instrument to obtain %BF and total bone density (TBD). More than half of the subjects completed the DXA scan within two weeks of the anthropometric examination and all had their DXA scan within four weeks. All subjects had their stature and body mass re-measured prior to the scan and another set of skinfold values were taken if their body mass was different by more than a kilogram between the measurement sessions.

2) Anthropometry

Stature, body mass, eight skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, and medial calf), 12 girths, seven bone lengths and seven bone breadths of each subject were measured using the International Society for the Advancement of Kinanthropometry (ISAK) protocol (ISAK, 2001). All measurements were conducted by a Level 3 (instructor) anthropometrist who was accredited by ISAK (MK). All subjects were asked to wear light clothing, such as shorts and T-shirt, and stature and body mass were measured without shoes and socks. Technical Error of Measurement (TEM) of anthropometric measurements was within the range of intra-tester error for a Level 3 anthropometrist (within 5% for skinfolds and within 1% for other measurements) as recommended by ISAK (Gore et al., 1996).

Body density and %BF of Japanese males were calculated prior to a comparison with the results obtained from DXA. Body density was estimated using the Nagamine and Suzuki equation (1964) [body density=1.0913−0.00116 (X1); where X1=a sum of triceps and subscapular skinfolds in mm]. Estimated body density was then converted into %BF values using the equations by Siri (1961) [%BF=495/BD−450]. From anthropometric measurements, body mass index (BMI; body mass (kg)/stature² (m)), sum of eight (ΣSF; triceps+subscapular+biceps+supraspinale+iliac crest+abdominal+front thigh+medial calf), and sum of two skinfolds (ΣSF2; triceps+subscapular) were calculated.

The SPSS® statistical package for Windows (version 10.0, 1999, Chicago) was used for statistical analysis. Differences in estimated %BF from DXA and anthropometry were determined and the limit of agreement was calculated (Bland and Altman, 1986). A stepwise multiple regression analysis was also conducted to develop a %BF prediction equation from anthropometric measurements.

Results

Physical characteristics of the study groups are shown in Table 1. While the %BF values estimated from anthropometry were highly correlated to the DXA results (r=0.827), the mean value was significantly (p<0.05) smaller than the DXA value (Table 1). The Bland and Altman plot (Fig. 1) clearly showed that %BF values estimated by the Nagamine and Suzuki equation tend to underestimate %BF of individuals who were estimated to have a large amount of body fat deposition as measured by the DXA.

The results indicate that the Nagamine and Suzuki equation is not applicable for predicting %BF of Japanese males, even though the equation was developed using Japanese males.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years)</td>
<td>24.3±5.5</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>171.6±5.8</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>62.6±9.6</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>21.3±2.3</td>
</tr>
<tr>
<td>Sum of eight skinfolds (mm)</td>
<td>73.5±28.2</td>
</tr>
<tr>
<td>Total Bone Density (TBD) (g/cm²)</td>
<td>1.10±0.08</td>
</tr>
<tr>
<td>% Body Fat by DXA (%)</td>
<td>15.7±5.6</td>
</tr>
<tr>
<td>% Body Fat by anthropometry (%)</td>
<td>13.3±3.1</td>
</tr>
</tbody>
</table>

* Significantly different from %BF by DXA at the 0.05 level.
Fig. 1 Inter-method differences in estimated %BF between DXA and anthropometry using Nagamine and Suzuki prediction equation.

A Bland and Altman plot showed that the Nagamine and Suzuki equation underestimates %BF of Japanese males in comparison to DXA results by 2.4% in average. In addition, Japanese males with large amount of body fat as measured by DXA were likely to be underestimated by much as 9.4%.

Table 2 Correlations between percentage body fat estimated from DXA and selected anthropometric variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Correlation with DXA result (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triceps skinfold</td>
<td>0.702**</td>
</tr>
<tr>
<td>Subscapular skinfold</td>
<td>0.756**</td>
</tr>
<tr>
<td>Biceps skinfold</td>
<td>0.586**</td>
</tr>
<tr>
<td>Iliac crest skinfold</td>
<td>0.744**</td>
</tr>
<tr>
<td>Supraspinale skinfold</td>
<td>0.744**</td>
</tr>
<tr>
<td>Abdominal skinfolds</td>
<td>0.767**</td>
</tr>
<tr>
<td>Front thigh skinfold</td>
<td>0.560**</td>
</tr>
<tr>
<td>Medial calf skinfold</td>
<td>0.572**</td>
</tr>
<tr>
<td>Sum of eight skinfolds</td>
<td>0.741**</td>
</tr>
<tr>
<td>Arm (relaxed)</td>
<td>0.529**</td>
</tr>
<tr>
<td>Arm (flexed and tensed)</td>
<td>0.476**</td>
</tr>
<tr>
<td>Waist girth</td>
<td>0.513**</td>
</tr>
<tr>
<td>Gluteal girth</td>
<td>0.400**</td>
</tr>
<tr>
<td>Calf girth</td>
<td>0.255</td>
</tr>
</tbody>
</table>

** Spearman’s correlation is significant at the 0.01 level.

Therefore it may be useful to seek alternative equations or cut-off point for the assessment of body fatness in Japanese males. Table 2 shows correlation coefficients between %BF and anthropometric measurements. Among the skinfold measurements, abdominal skinfold correlated highly with %BF (r=0.767), followed by subscapular skinfold (r=0.756). Sum of eight skinfolds (ΣSF) was also highly correlated with %BF estimated from DXA (r=0.741). For girth measurements, relaxed arm girth was correlated well with %BF obtained from the DXA (r=0.529) followed by waist girth (r=0.513).

Stepwise regression analyses were conducted using %BF obtained from DXA as a dependent variable and age and 1) individual skinfold and girth sites, 2) ΣSF, 3) ΣSF2 and 4) waist girth as independent variables. The analyses yielded the following equations:

1. %BF = 0.376 + 0.402* (abdominal skinfold) + 0.772* (medial calf skinfold) + 0.217* (age) (r² = 0.86, SEE = 2.37),
2. %BF = −1.268 + 0.142* (Sum of eight skinfolds) + 0.270* (age) (r² = 0.71, SEE = 3.07),
3. %BF = −3.915 + 0.676* (Sum of two skinfolds) + 0.257* (age) (r² = 0.74, SEE = 2.94),
4. %BF = −26.762 + 0.481* (waist girth) + 0.293* (age) (r² = 0.42, SEE = 4.37).

Discussion

The Nagamine and Suzuki (1964) body density equation has been the most commonly used equation to estimate %BF in Japanese populations. Although the estimated %BF values were highly correlated with the values obtained from DXA, the current study showed that the equation significantly underestimated %BF of Japanese males. The magnitude of underestimation was as high as 9% and the results clearly showed a trend of greater underestimation in individuals with large amount of body fat deposition as estimated by DXA. The current findings therefore confirmed a concern raised by other Japanese researchers (Komiya and Nakao, 2002).

There are several possible reasons for underestimation using the Nagamine and Suzuki equation. The equation was proposed as a linear regression equation, but a later study (Jackson and Pollock, 1978) suggested that a relationship between skinfolds and body density is quadratic rather than linear. Hence the application of linear regression to estimate body density could introduce an error in prediction of individuals, particularly for those who were located at the extremities of the distribution. The other contributing factor for underestimation is a secular trend in Japanese physique, including body size and body proportions since the proposal of the equation in 1964. The average height of young Japanese males has increased by more than 5 cm and weight has increased by about 9 kg in the last 40 years (The Society for the Study of Health and Nutritional Information, The Japan Dietic Association, 1998; The Society for the Study of Health and Nutritional Information, 2004). Although there have been no reported studies that have examined body composition changes over this time period, the increasingly energy-dense diet and increasing proportion of overweight and obesity in Japan indicate the likelihood of differences in body composition from the time the equation was initially proposed.

In the current study triceps and subscapular skinfolds showed correlations of 0.702 and 0.756 respectively with %BF estimated from DXA. In addition, a %BF prediction equation using sum of two skinfolds (i.e., triceps + subscapular) has showed r² of 0.74 and SEE of 2.94 respectively. This indicates that both triceps and subscapular skinfolds may remain good predictors of %BF for Japanese males. However, using two skinfolds as prediction variables, the current study indicated that a prediction equation using
abdominal and medial calf skinfolds has a better correlation with the DXA results ($r^2=0.86$, SEE=2.37). This may indicate that Japanese males have increased more fat deposition in abdominal region compared to the time the Nagamine and Suzuki equation was first proposed and consequently it may be inappropriate to keep using triceps and subscapular skinfolds to predict body density or %BF of Japanese males accurately.

Application of body density and body fat prediction equations always involves with prediction errors and also difficult to select appropriate equations when comparing groups of different characteristics such as gender, age and ethnic backgrounds. Because sum of skinfolds and certain skinfold sites were highly correlated with the estimated %BF using DXA, using these variables to directly estimate total fatness of Japanese males may be an option to avoid unnecessary prediction errors. The current study established regression equations using abdominal and medial calf skinfolds, sum of eight skinfolds, sum of two skinfolds and waist girth. Using these equations, it is possible to estimate approximate skinfolds or waist girth that are equivalent to excessive level of total body fat deposition (such as %BF of 20) for Japanese males of this specific age range (18–40 years old). Although the proposed equations require further validation, using estimated skinfolds or waist girth values may reduce prediction errors that could be introduced in %BF calculation. In addition, calculated skinfold and waist values may be satisfactory to be used as a guideline to indicate a level of body fatness of Japanese males and also to maintain their health.

The current study used Japanese males living in Australia. The subjects of the current study had stature and body mass consistent to the values of the most recent national nutrition survey in Japan (171.2±5.6 cm and 64.1±8.4 kg for 24 years old) (Kenkou Eiyou Jouhou Kenkyukai, 2004). On the other hand, the current study showed a greater %BF compared to the 20–24.99 age group (n=57, mean age=21.6 years old) reported by Tahara et al. (2002) (170.6±4.8 cm, 63.2±7.3 kg, 12.97%). Although more than 60% of them have spend less than six months in Australia and the difference in %BF from the previous study may be because of a difference in a methodology (DXA vs. underwater weighing) as well as age distribution and a sample size of subjects, it is recommended to replicate the study in Japan to clarify any environmental impact on their body composition. It is also recommended that the future study to be conducted with a larger sample size and also to include a wider age range.

Conclusion

In comparison with the DXA results, the Nagamine and Suzuki equation underestimates %BF of Japanese males living today. The study also showed that individuals with large fat deposition as measured by DXA were more likely to be underestimated. The study proposed %BF prediction equations for Japanese from the results obtained from DXA and anthropometry assessments. Although further validation of proposed equation is required, using these equations to assist frequent application of measured values may be useful in body fat assessment compared to application of the Nagamine and Suzuki equation.

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