Original Article

Anthropometry to assess body fat in Indonesian adults

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Background and Objectives: Anthropometric equations are widely used to estimate body composition however, are only appropriate for use in populations in which they have been developed and validated. The present study developed anthropometric prediction equations for Indonesian adults and cross-validated them with selected equations used in this population. **Methods and Study Design:** Six hundred Indonesian adults aged between 18–65 years (292 males and 308 females) were divided equally into development and validation groups. Stature, body weight, skinfold thickness at eight sites, girth at five sites, and bone breadth at four sites were measured. Stepwise multiple regression analysis was used to propose percentage body fat (%BF) prediction equations using measured variables and %BF from the deuterium oxide dilution technique as the reference. The proposed prediction equations were then cross-validated using the validation group and %BF estimated from several existing equations. **Results:** Proposed prediction equations showed *r* ranged from 0.82 to 0.86 and Standard Error of the Estimate (SEE) from 4.7 to 5.4%. Cross-validation analysis showed bias with the reference %BF between 0.2 and 3.3% and Pure Error (PE) between 2.8 and 4.0%. Among the existing equations, the Durnin and Womersley equation was applicable in females whilst the equation by Davidson et al. underestimated %BF by 6.3–6.6% and the equation by Gurrici et al overestimated by 2.0–3.4% in both genders ($p<0.01$). **Conclusion:** The proposed prediction equations provide better options for accurate prediction of %BF in Indonesian adults.

Key Words: body composition, percentage body fat, prediction equation, anthropometry, Indonesian adults

INTRODUCTION

Anthropometry is widely used in health assessments in both clinical and field settings because the instruments are portable, inexpensive, and relatively simple and non-invasive. Anthropometry has been utilized to identify the health risks[1,2] of individuals and populations and to predict body composition.[3,4] A number of studies have reported relationships between anthropometric measures and body composition[2,5-7] with studies among Asian populations indicating a higher percentage body fat (%BF) at any given body mass index (BMI) when compared to Caucasians.[8,9] Based on studies using young Japanese and Caucasian Australians, Kagawa and colleagues[10,11] reported that race or ethnicity may contribute to the difference in the relationships between %BF and anthropometric indices. For the Indonesian population, Gurrici et al[9,12] reported on the BMI-%BF relationship however, associations between other anthropometric indices and %BF were not described.

Numerous techniques are available to determine body composition accurately and precisely. However the application of these techniques in both clinical and field research is limited due to cost, lack of portability plus skill and license to operate.[13-16] Even though anthropometry is one of the viable techniques with minimum subject burden, prediction equations to estimate body composition from anthropometry are known to be ethnic-, gender-, and age-specific.[3,5,17] To date, a number of prediction equations have been developed to estimate body density (BD) or %BF using anthropometric variables.[5,18-21] However, most were generated from Caucasian populations with only a few developed from Asians, including Indonesians. To our knowledge, the only prediction equation developed from Indonesians was proposed by Gurrici et al[9] using BMI however, it has not been cross-validated. Moreover, despite the widespread use of the BMI to determine obesity, the index has several limitations including inability to differentiate body composition and the influence of body proportions. Different BMI-%BF relationships in various ethnic groups[17,22,23] points to the need to propose %BF prediction equations using other anthropometric variables to estimate body composition of Asian populations.

In addition, accuracy and precision of anthropometric approaches to estimate body composition are influenced by measurement skill, equipment, biological factors of

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participants and choice of prediction equations. The current study therefore aimed to develop and validate %BF prediction equations using anthropometry and deuterium dilution technique and also to evaluate the applicability of commonly used existing %BF prediction equations for Indonesian adults.

PARTICIPANTS AND METHODS

Participants

Indonesian adults of Javanese ethnicity living in Yogyakarta Special District Province were recruited for the present study. Apparently healthy males and females aged 18-65 years and were selected among the potential participants, whilst those who had physical or mental disabilities, under medical treatment, or involved in weight-reducing programs, were excluded. Written informed consent was obtained from all potential participants prior to their participation. Prior to the day of the measurement, participants were reminded to fast overnight and avoid vigorous physical exercise and excessive sweating. A total of 600 participants (292 males and 308 females) were included and the study was approved by the Human Research Ethics Committee of Queensland University of Technology in Australia and Universitas Gadjah Mada in Indonesia.

Anthropometry

All participants underwent measurements of stature, body weight, eight skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, and medial calf), five girth measures (arm relaxed, arm flexed and tensed, minimum waist, gluteal, and maximum calf), and four breadth measures (biacromial, biiliocristal, humerus, and femur). All measurements were conducted using standardized equipment and measurement protocol proposed by the International Society for the Advancement of Kinanthropometry (ISAK).[24] All measurements were conducted by an accredited ISAK level 1 anthropometrist and intra-tester technical error of measurements (TEM) calculated from the first 20 participants was within the recommended standard by ISAK.[24] BMI, waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR) were calculated.

Body composition assessment

Deuterium oxide dilution was used as the reference technique to predict %BF from the measurement of total body water (TBW). Methods for the measurement of isotope concentration and TBW have been described in detail previously.[25] Based on the measured TBW, fat mass (FM) and fat-free mass (FFM) were estimated using the hydration coefficient of 0.732 as proposed by Pace and Rathburn.[26]

Statistical analysis

Participants were randomized into development and cross-validation groups of the same sample size (n=300; 146 males and 154 females). Between-group differences in the physical characteristics and %BF were evaluated using independent sample *t*-test analysis. In the development group, stepwise multiple regression analyses were used to develop prediction equations using %BF estimated from deuterium dilution as the dependent variable and anthropometric variables and calculated indices as well as age, body weight and stature as independent variables. Anthropometric variables were grouped into skinfold site, sum of four skinfolds (triceps, biceps, subscapular, and iliac crest), BMI, girths (arm relaxed, arm flexed and tensed, minimum waist, gluteal, and maximum calf), and breadths (biacromial, biiliocristal, humerus, and femur). The precision of the prediction equation was evaluated by the coefficient of correlation (r), coefficient of determination (r^2), standard error of the estimate (SEE), and the Akaike Information Criterion (AIC). The most optimal prediction equations were determined from those which had the highest r and r^2, but the smallest SEE and AIC values.

Performance of the proposed equations was evaluated using the validation group and the bias between the %BF from deuterium dilution and the prediction equation was assessed by correlation and difference using paired *t*-tests. The pure error (PE) was calculated with a smaller pure error value indicating greater accuracy of the equation. Predicted and measured %BF values were also regressed and Bland and Altman plots used to examine agreement between %BF from the two methods.[27] Limits of agreement were decided as mean ±1.96 x standard deviation (SD).

In addition, existing %BF estimation equations were evaluated and compared with the values obtained from deuterium dilution technique. Equations evaluated in the present study included Durnin and Womersley,[18] Davidson et al[19] and Gurrici et al.[9] Values were compared using paired t-test analysis and Bland and Altman plots.[27] All statistical analyses were conducted using the SPSS program (version 20, SPSS Inc., 2011, Chicago, IL) with a significant level of 0.05.

RESULTS

There were no significant differences in age, body weight, stature, BMI, and %BF between the development and validation groups in males and females, as well as in total samples (Table 1).

From the analyses, prediction equations using each skinfold site, sum of four skinfolds, BMI, girth and breadth measures, and other anthropometric indices were proposed. All prediction equations showed comparable correlation coefficients with the highest correlation from the equation using individual skinfolds (Table 2). Due to reduced participant burden, the equation using the sum of four skinfolds was preferred because equation using the sum of eight skinfolds showed only a slightly higher r^2. In this model, skinfolds at triceps and iliac crest sites showed significant contributions in estimation of %BF. In comparison, equations from girth and breadth measurements indicated that gluteal and waist girths as well as humerus breadth were significant predictors with r ranged from 0.82 to 0.86. The precision of the proposed prediction equations as shown in the SEE values were from 4.7 to 5.4% and the AIC values from 942 to 1,006.

Cross-validation analyses showed that the proposed prediction equations were significantly correlated (p<0.01) with $\%BF_{2HO}$ with r ranging between 0.83 and 0.89 in males and between 0.69 and 0.75 in females. However, significant differences were observed between the

Table 1. Characteristics of the study groups

	Males		Females		Total samples	
	Group 1 (n=146)	Group 2 (n= 46)	Group 1 (n=154)	Group 2 (n=146)	Group 1 (n=300)	Group 2 (n=300)
Age (years)	39.0±11.6	38.7±12.0	39.3±10.9	39.5±11.2	39.1±11.2	39.1±11.6
Body weight (kg)	58.2±10.0	59.8±11.2	52.2±9.4	52.6±9.4	55.1±10.1	56.1±10.9
Stature (cm)	165±7.0	165±5.9	154±5.2	153±5.4	159±8.4	159±8.5
BMI (kg/m^2)	21.4±3.3	21.8±3.8	22.1±3.7	22.6±3.9	21.8±3.5	22.3±3.8
%BF$_{D2O}$	21.1±6.6	21.7± 7.5	32.6±7.8	33.9± 7.4	27.0±9.3	27.9± 9.6

Group 1: development group; Group 2: cross-validation group; there were no significant differences between the mean values of group 1 and 2 in males, females, and total sample.

Table 2. Percentage body fat prediction equations developed using anthropometric variables

Dependent variables	Regression equation	r	r^2	SEE	AIC
Skinfold sites	%BF = 17.026 + 0.509 (triceps) + 0.342 (iliac crest) - 5.594 (G)	0.864	0.746	4.69	926
Sum 4 skinfolds†	%BF = 17.858 + 0.215 (sum of 4 skinfolds) - 6.448 (G)	0.857	0.734	4.80	942
BMI	%BF = 1.938 - 10.509 (G) + 1.388 (BMI)	0.817	0.668	5.36	1,006
Girth and breadth measures	%BF = -8.545 - 4.830 (G) + 0.420 (waist girth) + 0.439 (gluteal girth) - 4.830 (humerus breadth)	0.848	0.719	4.94	959
Anthropometric index	%BF = -5.032 - 12.712 (G) + 0.294 (body weight) + 0.477 (WSR)	0.821	0.675	5.31	997

G: gender (1 for males, 0 for females); BMI: body mass index; WSR: waist-to-stature ratio.
†Sum of skinfold thicknesses at triceps, biceps, subscapular, and iliac crest; r: coefficient of correlation; r^2: coefficient of determination; SEE: standard error of the estimate; AIC: the Akaike Information Criterion.

%BF$_{2HO}$ and the equation from both girth and breadth measures in males (p<0.01) and the equation from skinfolds in females (p<0.05) as presented in Table 3. Mean differences of %BF estimated from the proposed equations and the reference %BF ranged between -3.3 and -0.6% with PE between 2.8 and 4.0% in males. In females, these differences were between 0.7 and 1.0% of %BF and between 3.6 and 3.8% of PE. Bland and Altman analysis indicated that the limits of agreement of both methods ranged between ±7.5 and 8.8% (Figure 1) in males and between ±9.6 and 10.6% in females (Figure 2). There was a tendency to underestimate %BF in lower body fat and overestimate %BF in higher body fat in both genders, however males showed more clearly.

Estimated %BF from equations of Durnin and Womersley,[18] Davidson et al[19] and Gurrici et al[9] are presented in Table 4. The results indicated significant differences (p<0.01) between the reference %BF and %BF estimated from these equations, except for the Durnin and Womersley[18] for females (bias of 0.5%). The equation of Davidson et al[19] significantly (p<0.01) underestimated %BF by 6.6% and 6.3% in the validation groups in males and females respectively, whereas the Gurrici et al[9] equation overestimated %BF by 3.4% and 2.0% in males and females respectively (p<0.01).

DISCUSSION

The present study developed and evaluated anthropometric prediction equations applicable for Indonesian adults and demonstrated that %BF can be predicted across a

Table 3. Comparison of %BF reference and anthropometric equations in the validation groups

	Reference‡	Prediction equation			Paired sample test	
	Mean±SD	Mean±SD	Bias±SD	PE±SD	r	t
Males						
Skinfold sites	21.6±7.4	22.0±5.7	-0.4±3.7	2.8±2.3	0.875**	-1.23
Sum of 4 skf†	21.6±7.4	22.1±5.7	-0.6±3.5	2.8±2.2	0.886**	-1.94
BMI	21.6±7.4	21.8±5.2	-0.2±4.3	3.4±2.4	0.825**	-0.68
Girth & breadth	21.5±7.4	24.8±5.9	-3.3±3.6	4.0±2.8	0.855**	-10.55
Index	21.6±7.4	22.0±5.7	-0.4±4.1	3.2±2.4	0.834**	-1.15
Females						
Skinfold sites	33.9±7.4	32.9±5.9	1.0±4.9	3.7±3.3	0.751**	2.56*
Sum of 4 skf†	33.9±7.4	33.1±6.0	0.8±5.0	3.6±3.4	0.745**	2.01*
BMI	33.9±7.4	33.4±5.4	0.4±5.4	3.6±3.5	0.685**	1.02
Girth & breadth	33.9±7.4	33.2±5.6	0.7±5.1	3.8±3.6	0.730**	1.62
Index	33.8±7.4	33.0±5.3	0.7±5.2	3.8±3.6	0.707**	1.75

*p<0.05; **p<0.01; skf: skinfold; BMI: body mass index; SD: standard deviation; PE: pure error.
†Sum of skinfold thicknesses at triceps, biceps, subscapular, and iliac crest.
‡The reference values may different from each variable due to the different dropped outliers; r: coefficient correlation; t: t values.

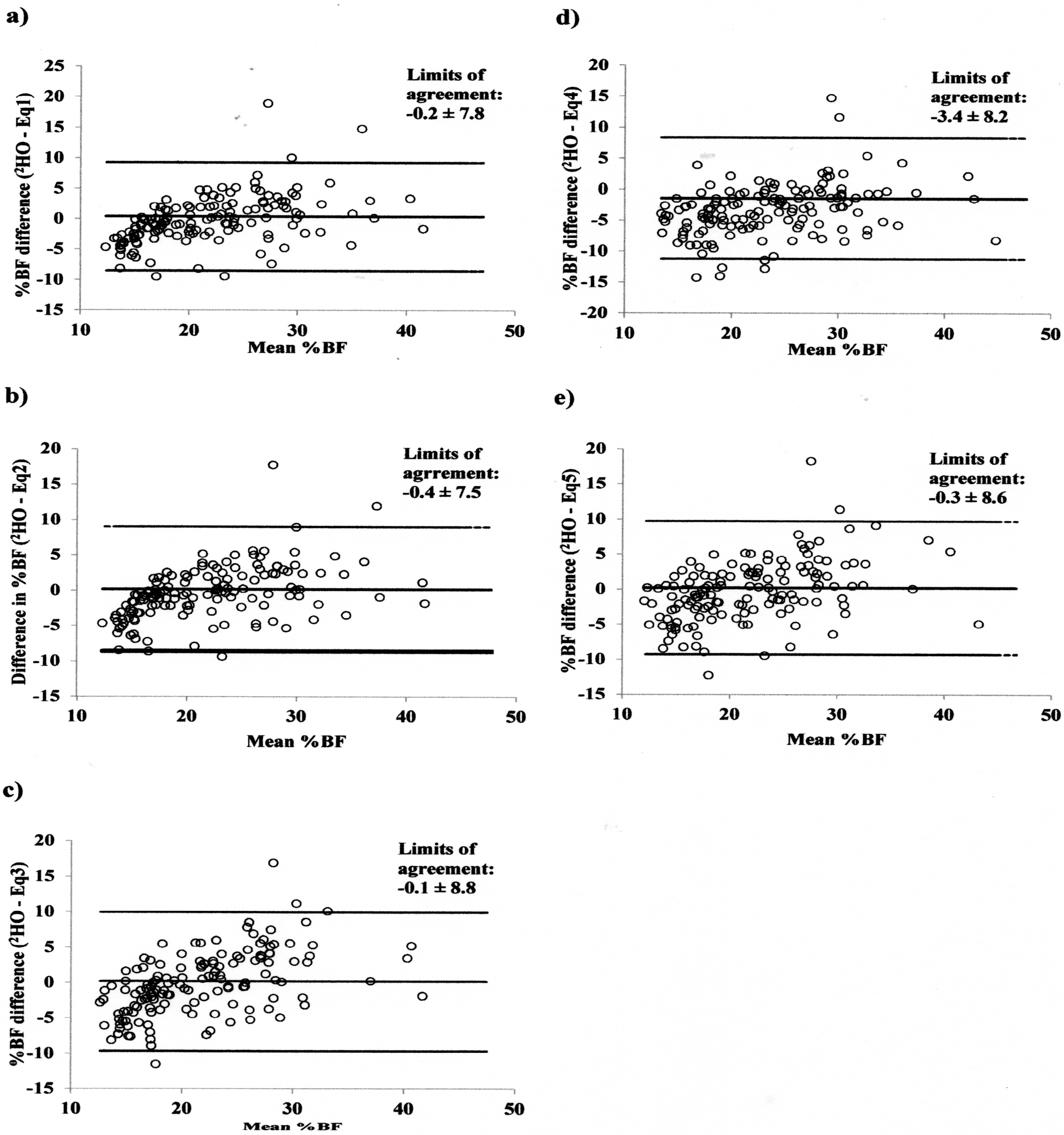

Figure 1. Agreement between %BF from deuterium oxide dilution methodas the reference method and %BF estimated using prediction equations in males, prediction equations is plotted against mean %BF;a: the difference between %BF obtained from the reference and %BF predicted from skinfold site; b: %BF predicted from sum of four skinfold; c: %BF predicted from BMI, d: %BF predicted from girth and breadth measures; and e: %BF predicted from anthropometric index; D_2O: deuterium oxide dilution method; Eq1: prediction equation from skinfold site; Eq2: prediction equation from sum of skinfold thicknesses at triceps, biceps, subscapular, and iliac crest; Eq3: prediction equation from BMI; Eq4: prediction equation from girth and breadth measures; Eq5: prediction equation from anthropometric index prediction equations.

broad age range of males and females when laboratory-based body composition assessment techniques are not available. Examination on a separate group of samples indicated that the proposed equations also showed good performance.

The inclusion of gender improved the equation's performance which may be due to the larger sample size, however age did not significantly contribute to this model. This finding is not consistent with previous studies by van der Ploeg et al[28] and Kagawa et al.[10,32] Age may influence body composition and the relationship between BMI and %BF since older adults may experience loss of lean mass, loss of weight and decrease in BMI but retention of fat mass.[29] Particularly in the prediction equation using skinfold thickness, van der Ploeg et al[28] found that skinfold thickness better predicted %BF in the younger age group (<30 y) and predicted %BF increased as the greater skinfold thickness was more evident in the older age group (>30 y).

In the present study, skinfold thickness at triceps and iliac crest selected from eight skinfold sites accounted for 74.6% of the variance, greater than the variance from the sum of four skinfolds (biceps, triceps, subscapular, and iliac crest) (73.4%). Using a four-compartment model to develop an equation to predict %BF, van der Ploeg and colleagues[28] reported that subscapular, biceps, abdominal, thigh, calf, and mid-axilla sites resulted in an SEE of 2.2% BF (r^2=0.91). Difference in fat distribution and fat mass among ethnicities are often regarded as potential sources of inapplicability of prediction equations.[9,23,30] Moreover, differences in defined sites of chosen skinfolds, even as small as one centimeter away produced signifi-

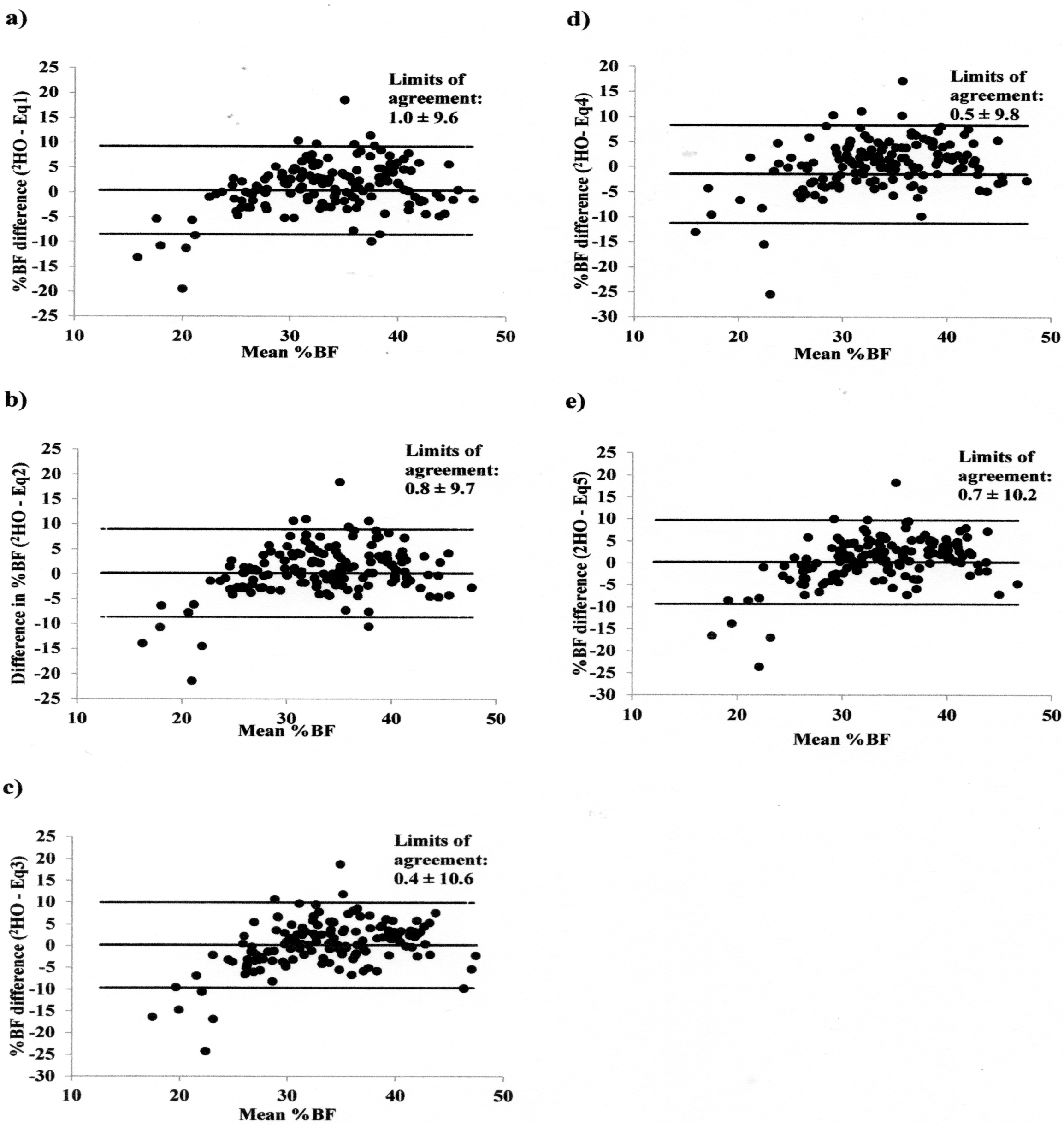

Figure 2. Agreement between %BF from deuterium oxide dilution methodas the reference method and %BF estimated using prediction equations in females, prediction equations is plotted against mean %BF;a: the difference between %BF obtained from the reference and %BF predicted from skinfold site; b: %BF predicted from sum of four skinfold; c: %BF predicted from BMI, d: %BF predicted from girth and breadth measures; and e: %BF predicted from anthropometric index; D_2O: deuterium oxide dilution method; Eq1: prediction equation from skinfold site; Eq2: prediction equation from sum of skinfold thicknesses at triceps, biceps, subscapular, and iliac crest; Eq3: prediction equation from BMI; Eq4: prediction equation from girth and breadth measures; Eq5: prediction equation from anthropometric index prediction equations.

cant differences in the majority of skinfold measurements.[31] In the present study, although the prediction equation from skinfolds showed the best performance and was highly correlated with the reference %BF in the cross-validation analysis in males, a significant (p<0.05) bias was evident in females. This may be due to gender differences in subcutaneous fat distribution. Kagawa et al.[11] also reported gender differences - abdominal and medial calf skinfolds had a better correlation with %BF obtained from DXA in males, whereas triceps, iliac crest, biceps, medial calf, and abdominal sites gave the highest correlation value and the lowest SEE in females.[32]

The skinfold prediction equation of Durnin and Womersley[18] has been widely used to estimate %BF, including to underestimate %BF in Indonesian populations.[9,12,30] However, the current study found the equation had no significant bias with %BF obtained from deuterium dilution technique, particularly for females. In the current study, the only difference was that we replaced the suprailiac skinfold used in the Durnin and Womersley[18] equation with the iliac crest skinfold taken at the centre of the skinfold raised immediately above the marked iliocristale.[24] In contrast, despite being updated specific to sex and ethnicity and using the original Durnin and Womersley[18] skinfold sites, the Davidson et al. equation[19] showed the highest bias with measured %BF in our samples. This might be explained by possible differences in body composition and anthropometric measurement techniques used in the equation development.[19]

Although the performance of the prediction equation

Table 4. Differences between %BF obtained from D_2O and various prediction equations

	Reference†	Prediction equation	Paired sample test	
	Mean±SD	Mean±SD	r	Mean diff±SD‡
Males				
%BF from DW	21.7±7.5	20.9±7.1	0.857**	0.8±3.9*
%BF from D	21.6±7.4	15.0±6.3	0.896**	6.6±3.3**
%BF from Gurrici	21.7±7.5	25.1±4.9	0.807**	-3.4±4.6**
Females				
%BF from DW	33.9±7.4	33.4±6.1	0.726**	0.5±5.4
%BF from D	33.9±7.4	27.6±6.5	0.768**	6.3±4.8**
%BF from Gurrici	33.9±7.4	35.9±5.1	0.685**	-2.0±5.4**

*p<0.05; **p<0.01; SD: standard deviation; mean diff: mean difference.
DW: %BF predicted using BD formula of Durnin and Womersley (1974) and %BF formula of Siri (1961); D: %BF predicted using formula of Davidson et al (2011); Gurrici: %BF predicted using formula of Gurrici et al (1998).
†The reference values may different from each variable due to the different dropped outliers.
‡Significant difference between %BF and predicted from the equations.

from BMI was not as good as others it represented the lowest bias with %BF obtained from the reference technique in cross-validation analysis indicating that this equation is also applicable to this population. The magnitude of the BMI equation was comparable with a study using 2C model by Kagawa and colleagues[33] in Japanese females and males with r^2 values of 0.61 and 0.44 respectively. It was suggested that the use of a multi-compartment model resulted in a higher correlation as reported by van der Ploeg et al[28] using a 4C body composition model with r^2 values of 0.84 to 0.94.

The BMI prediction equation of Gurrici et al[9] was specifically designed for the Indonesian population yet overestimated %BF in our validation samples by about 3% with greater overestimation at higher %BF in both genders. Moreover, a wide range agreement limits in the Bland and Altman plots (males: between -12.4 and 5.6%, females: between -12.6 and 8.6%) may have resulted in a high variation. Consequently, this equation should be used with careful since factors such as physical activity[34] and body build[8,34,35] may influence the results.

The strength of the current study lies in its sampling and validity assessment of the proposed equation. The large sample size allows a stable estimation of the relationship between measured %BF and the predictor variables. Moreover, participants were randomly selected across a large age and BMI range, and representative of the largest ethnic group in the Indonesian populations. Nevertheless, generalization to other populations should be interpreted with care since differences in %BF may exist among Indonesian sub-populations.[12] The reference %BF in the current study was obtained from the deuterium oxide dilution technique considered one of the gold standard methods for the assessment of body composition[16,36] which can be used in the absence of the availability of a four-compartment model. Norgan[37] indicated that laboratory-based estimates of body composition are best performed by multi-compartment methods or by two-compartment methods adjusted for populations under investigation. In addition, the cross-validation study of the proposed prediction equations allows advanced evaluation for the precision of the equations.[37]

To summarize, the present study proposed new %BF prediction equations and based on cross-validation, equations were found to be applicable for use in Indonesian adults. These equations may assist in both clinical and field research settings when more complex instruments for the assessment of %BF are not available. Limitations of the present study include the lack of heterogeneity of the samples in terms of ethnicity and socio-economic level and the use of a two-compartment model for the assessment of %BF. Further studies involving multiple ethnicities are important to ensure precise prediction of %BF.

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AUTHOR DISCLOSURES

The authors declare that this manuscript is original and there is no conflict of interests among the authors.

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