Original Article

Determination of new anthropometric cut-off values for obesity screening in Indonesian adults

Janatin Hastuti SSi, MKes, PhD[1], Masaharu Kagawa BSc(Hons), PhD[2], Nuala M Byrne MAppSc, PhD[3], Andrew P Hills MSc, PhD, FASMF[3]

[1]*Lab. of Bioanthropology and Paleoanthropology, Faculty of Medicine, Universitas Gadjah Mada, Yogyakarta, Indonesia*
[2]*Institute of Nutrition Sciences, Kagawa Nutrition University, Japan*
[3]*School of Health Sciences, University of Tasmania, Australia*

Background and Objectives: Body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR) have increasingly been used as screening tools for obesity. However, optimal cut-off values may be different between populations. The current study determined the optimum cut-off values for BMI, WC, WHR, and WSR for obesity screening in Indonesian adults using receiver-operating characteristic (ROC) analysis. **Methods and Study Design:** Stature, body weight, waist and hip circumferences were measured on 600 Indonesians aged 18-65 years (males, n=292; females, n=308) and BMI, WHR, and WSR calculated. Percentage of body fat (%BF) was determined using the deuterium isotope (D_2O) dilution technique. Some existing cut-off points for obesity determination were evaluated for sensitivity and specificity. **Results:** The existing cut-off values showed low sensitivity in our sample (between 18.4 and 71.1%) and new proposed cut-offs increased the sensitivity to reach 66.7 to 88.5%. The new cut-offs for BMI, WC, WHR, and WSR for determination of obesity were 21.9 (kg/m^2), 76.8 (cm), 0.86, and 0.48, respectively, for males and 23.6 (kg/m^2), 71.7 (cm), 0.77, and 0.47, respectively, for females. **Conclusions:** WC and WSR are the most predictive both for males and females, and therefore are considered as better screening tools for obesity in this population.

Key Words: anthropometric measures, cut-off values, obesity screening, percentage of body fat, Indonesian adults

INTRODUCTION

Body mass index (BMI) has been extensively used for the determination of obesity,[1] however, body fatness (regional and total), has been regarded as a better indicator of increased risk for obesity.[2] As the accurate measurement of body fat is challenging, anthropometry has commonly been used to determine both regional and total body fat.

Recent studies have indicated that central obesity presents a greater health risk than general obesity assessed with BMI.[3] Widely recognized as markers for central obesity, measurements of waist circumference (WC),[3,4] hip circumference (HC), waist-to-hip ratio (WHR),[5-8] and waist-to-stature ratio (WSR) or waist-to-height ratio (WHtR)[9] have increasingly been used to assess health risks associated with obesity. However, in some quarters there is controversy regarding the superiority of some obesity indicators in the discrimination of health risks associated with obesity.[10] A meta-analysis[10] involving 17 prospective and 35 cross-sectional studies showed that BMI, WC, WSR, and WHR were equally able to discriminate type 2 diabetes in prospective studies. In contrast, WC or WHR could discriminate type 2 diabetes risk in individuals in cross-sectional studies. A systematic review and meta-analysis which included more than 300,000 people from multi-ethnic backgrounds supported previous studies that measures of abdominal obesity using WHtR or WSR could better discriminate obesity-related cardiometabolic risk than BMI and WC.[9]

However, associations differ across age, gender and ethnicity which suggests the importance of age-, gender- and ethnic-specific cut-off points.[6,11-13] South Asians have been reported to be at higher risk of developing cardiometabolic conditions compared with Caucasians of a similar size and shape[14-16] suggesting the need to lower the optimal cut-off values for these populations. Determination of cut-off points for WC, WHR, and WSR for obesity indicators is critically important for research and clinical practice. To date, an increasing number of investigations have proposed optimal cut-off values in different populations, including Asians.[4,5,9,17] However, no studies to date have reported specific cut-off values for obesity determination in Indonesian populations, except by Guricci et al[18] using BMI only. This study aimed to examine the application of BMI, WC, WHR, and WSR for

Corresponding Author: Dr Janatin Hastuti, Lab. of Bioanthropology and Paleoanthropology, Faculty of Medicine, Universitas Gadjah Mada, Jalan Medika, Sekip, Yogyakarta, 55281, Indonesia.
Tel: +62 274 552577; Fax: +62 274 552577
Email: janatin.hastuti@ugm.ac.id
Manuscript received 03 February 2016. Initial review completed 10 March 2016. Revision accepted 18 March 2016.
doi: 10.6133/apjcn.072016.09

obesity determination in Indonesian adults and to evaluate the optimum cut-off values of indices as screening tools for obesity.

METHODS

Participants

Participants were 600 Javanese (292 men and 308 women) adults aged 18-65 years living in Yogyakarta Special District, Indonesia. The study was approved by the Human Research Ethics Committee of Queensland University of Technology, Australia and Universitas Gadjah Mada, Indonesia. Signed informed consents were obtained from the participants.

Anthropometric measures

Stature, body weight, minimum WC, and HC were measured. Stature was measured using a microtoise (Johnson and Johnson Co. Ltd.) to the nearest 0.1 cm. Body weight was measured with the participant wearing light clothing using a Seca weight scale (Seca803, Seca Deutschland) to the nearest 0.1 kg. Circumferences were measured using an anthropometric tape (Holtain Rinehart Co. Ltd.) at the level of the minimum waist circumference or at the midpoint between the lower costal (10th rib) border and the iliac crest if there was no obvious narrowing.[19] All measurements followed the standard protocol of the International Society for the Advancement of Kinanthropometry (ISAK)[19] and BMI, WHR, and WSR were calculated from those measures.

Percentage of body fat

Participants were instructed to fast overnight and avoid physical exercise and excessive sweating prior to the day of the measurement. Percentage of body fat (%BF) was obtained from the deuterium oxide (D_2O) dilution technique using an isotope ratio mass spectrometer (IRMS-Hydra 20-20 SerCon Mass Spectrometer) following the guidelines of Heyward and Wagner[20] and the International Atomic Energy Agency.[21] Details of the procedures have been described previously.[22] (Table 1)

Statistical methods

Obesity prevalence was defined from the overweight and obese categories on BMI, WC, WHR, WSR and %BF. Details of the classifications are presented in Table 1. The BMI cut-off points used were those recommended by the Ministry of Health, Republic of Indonesia, with a similar cut-off for determination of overweight to the WHO International BMI cut-off (BMI ≥25 kg/m^2).[23] The difference between these two categories is in the cut-off points for obese - the Indonesian Ministry of Health specifies a BMI ≥27.0 kg/m^2 and WHO specifies a BMI ≥30.0 kg/m.[24] Chi-square testing was performed to find differences in category distribution of the obesity classifications between males and females. Sensitivity and specificity were calculated to evaluate the accuracy of the BMI, WC, WHR, and WSR classifications in the determination of obesity based on %BF as the reference.

The cut-off points of the BMI, WC, WHR, and WSR were determined using receiver-operating characteristic (ROC) curve analysis as a screening tool for obesity defined by %BF. The ROC curve is a plot of the sensitivity (true positive rate) against 1-specificity (false positive rate) for each anthropometric index. The area under the curve (AUC) is an indicator of how precise an anthropometric index can distinguish a positive outcome. The AUC value can be between 0 and 1, with 0.5 (diagonal line) demonstrating that the anthropometric index has no

Table 1. Obesity classification

	Complete		Dichotomous	
	Category	Limit	Category	Limit
BMI[†]	Severe underweight	<17	Normal	<25
	Mild underweight	17.0–18.4	Obese	≥25
	Normal	18.5–24.9		
	Mild overweight	25.0–27.0		
	Severe overweight	>27		
%BF[‡]				
Men	Normal	<25.0	Normal	<25.0
	High	25.0–30.0	Obese	>25.0
	Very high	>30.0		
Women	Normal	>35.0	Normal	<35.0
	High	35.0–45.0	Obese	>35.0
	Very high	>45.0		
WC[§]				
Men	Obese	≥90.0		
Women	Obese	≥80.0		
WHR[‡]				
Men	Obese	>0.89		
Women	Obese	>0.81		
WSR[¶]				
Men	Obese	≥0.51		
Women	Obese	≥0.53		

%BF: percentage of body fat; WC: waist circumference; WHR: waist-to-hip ratio; WSR: waist-to-stature ratio.
[†]Cut-off points for Indonesians (Ministry of Health Republic of Indonesia, 1994).
[‡]Category defined by WHO.
[§]Category by International Diabetes Federation (IDF).
[¶]Category recommended for Asians (Liu et al., 2011).

predictive performance and 1 indicating ideal performance. The optimal cut-off value for each anthropometric index (BMI, WC, WHR, and WSR) was determined by the value of the largest sum of sensitivity and specificity. All statistical analyses were conducted using the SPSS program (version 20, SPSS Inc., 2011, Chicago, IL) and significance was determined with $p<0.05$.

RESULTS

Characteristics of participants are presented in Table 2. There was no difference in average age between males and females, however males were significantly ($p<0.01$) taller, heavier, and with greater WC. In contrast, HC, %BF, BMI and WSR were significantly greater in females, $p<0.05$ and $p<0.01$, respectively, for the latter two measures, whereas WHR was greater in males ($p<0.01$).

Differences in obesity prevalence among several obesity categories displayed in Table 3 showed all were significantly different between category and gender ($p<0.01$). In males, 30.0% were obese according to %BF category while only half (14.0%) were reported as obese in the BMI category. A higher proportion of females were classified as obese according to %BF category (46.4%), whereas using a BMI category about a quarter of the females were considered obese. Compared with the BMI category recommended by the Department of Health, Republic of Indonesia, BMI cut-offs for increased risk for Asian populations provided a greater prevalence of individuals who were obese. The lowest prevalence of obesity was obtained by the WC category - 5.8% of males and 17.9% of females.

Sensitivity and specificity of BMI and waist girth categories for obesity toward a %BF obesity category are detailed in Table 4. Regardless of gender, WC confirmed the highest specificity (99.5% and 97.0% in males and females, respectively). However, this classification showed low sensitivity i.e. 18.4% in males and 35.2% in females. BMI category for obesity as recommended by the Indonesian Health Department was able to correctly identify obese individuals at rates of 41.4% in males and 51.4% in females.

The ROC curves for BMI, WC, WHR, and WSR in males and females, as illustrated in Figure 1, showed that WC was the best indicator of %BF in both genders with WHR the poorest indicator (with the smallest area under the ROC curve). The values of the AUC for all anthropometric indices can be seen in Table 5. The optimal cut-offs for determination of overweight or obesity by %BF in males in the present study, therefore, were 21.9 kg/m^2, 76.8 cm, 0.86, and 0.48 for BMI, WC, WHR, and WSR, respectively; in females, the values were 23.6 kg/m^2, 71.7 cm, 0.77, and 0.47, respectively (Table 5). These new cut-off values increased the sensitivity of the BMI, WC, WHR, and WSR in males to reach 83.9%, 88.5%, 66.7%, and 79.3%, respectively. In females, the sensitivity of the anthropometric indices increased to 90.2%, 81.0%, 71.1%,

Table 2. Characteristics of participants

	Men (mean±SD)	Women (mean±SD)
N	292	308
Age (years)	38.8±11.8	39.3±11.0
Stature (cm)	165.2±6.5	153.1±5.3**
Body weight (kg)	59.1±10.6	52.5±9.6**
WC (cm)	75.7±8.6	72.0±8.8**
HC (cm)	90.8±6.9	92.7±7.5**
BMI (kg/m^2)	21.6±3.5	22.4±3.8*
WHR	0.84±0.05	0.78±0.06**
WSR	0.46±0.05	0.47±0.06**
%BF	21.4±7.0	33.3±7.7**

WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WSR: waist-to-stature ratio; %BF: percentage of body fat.
*$p<0.05$; **$p<0.01$.

Table 3. Comparison of obesity prevalence using %BF and different categories of BMI

	Men N (%)	Women N (%)	χ^2
%BF category†			
Normal	203 (70.0)	164 (53.6)	16.94**
Obese	87 (30.0)	142 (46.4)	
BMI‡			
Normal	251 (86.0)	229 (74.4)	12.62**
Obese	41 (14.0)	79 (25.6)	
WC§			
Normal	275 (94.2)	253 (82.1)	20.56**
Obese	17 (5.8)	55 (17.9)	
WHR†			
Normal	252 (86.3)	232 (75.3)	11.58**
Obese	40 (13.7)	76 (24.7)	
WSR¶			
Normal	236 (80.8)	251 (81.5)	0.04
Obese	56 (19.2)	57 (18.5)	

WC: waist circumference; WHR: waist-to-hip ratio; WSR: waist-to-stature ratio; %BF: percentage of body fat.
†Category defined by WHO.
‡Cut-off points for Indonesian (Ministry of Health Republic of Indonesia, 1994).
§Category by International Diabetes Federation (IDF).
¶Category recommended for Asians (Liu et al 2011).
**$p<0.01$.

Table 4. Sensitivity and specificity of some available categories for obesity

	Males		Females	
	Specificity %	Sensitivity%	Specificity%	Sensitivity%
BMI†	97.5	41.4	96.3	51.4
WC‡	99.5	18.4	97.0	35.2
WHR§	95.6	35.6	87.8	39.4
WSR¶	96.6	56.3	96.3	35.9

WC: waist circumference; WHR: waist-to-hip ratio; WSR: waist-to-stature ratio; %BF: percentage of body fat.
†Cut-off points for Indonesians (Ministry of Health Republic of Indonesia, 1994).
‡Category by International Diabetes Federation (IDF).

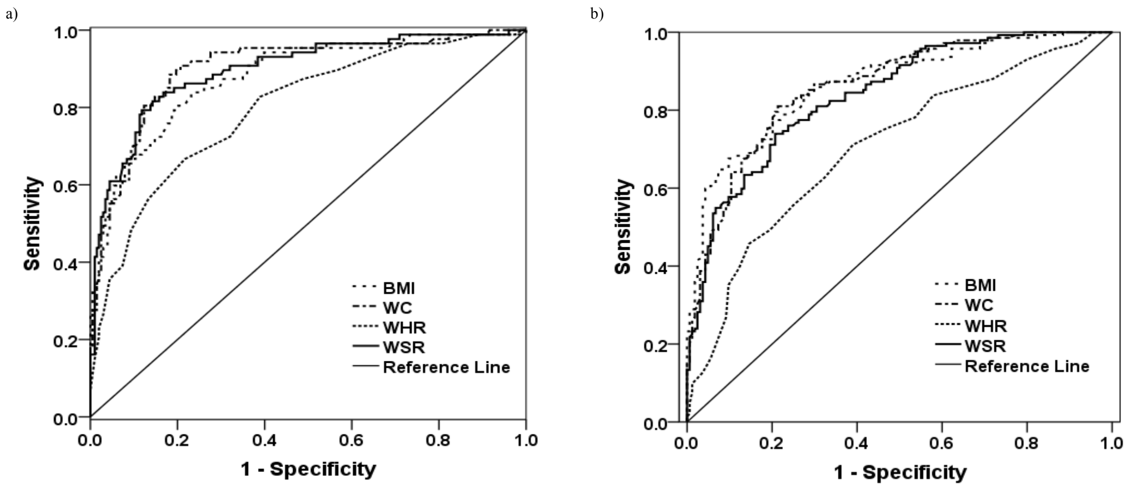

Figure 1. Receiver-operating characteristic (ROC) curves for body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-stature ratio (WSR) in males (a) and in females (b).

Table 5. Optimal cut-off, sensitivity, specificity, SEE, and area under the ROC curves for anthropometric indices in predicting %BF in males and females

	Cut-off	Sensitivity	Specificity	SEE	Area	95% CI
Men						
BMI	21.9	83.9	76.8	0.023	0.878	0.833–0.923
WC	76.8	88.5	81.8	0.021	0.902	0.861–0.943
WHR	0.86	66.7	78.3	0.029	0.797	0.741–0.854
WSR	0.48	79.3	88.2	0.021	0.896	0.854–0.938
Women						
BMI	23.6	67.6	90.2	0.021	0.866	0.826–0.906
WC	71.7	81.0	78.7	0.021	0.860	0.820–0.901
WHR	0.77	71.1	61.0	0.030	0.707	0.648–0.765
WSR	0.47	73.9	79.3	0.022	0.840	0.797–0.883

SEE: standard error of the estimate; WC: waist circumference; WHR: waist-to-hip ratio; WSR: waist-to-stature ratio.

and 73.3% for BMI, WC, WHR, and WSR, respectively. The most significant increase appears in WC by which the sensitivity is fourfold in males and more than twofold in females.

Table 6 indicates that by using the new cut-off points, the prevalence of obesity (including overweight) ranged from 30.8 to 41.1% in males and from 36.4 to 48.7% in females. The closest predicted obesity prevalence in both genders was obtained from WSR classifications (30.8 and 46.1% in males and females, respectively).

DISCUSSION

The present study showed that the available BMI, WC, WHR, and WSR cut-offs for defining obesity proposed by WHO, IDF, and some previous investigators, were not appropriate for Indonesian adults. We determined that cut-off values of 21.9 kg/m^2, 76.8 cm, 0.86, and 0.48 for BMI, WC, WHR, and WSR, respectively, were the optimum for obesity determination for Indonesian adult males and 23.6 kg/m^2, 71.7 cm, 0.77, and 0.47, respectively, for adult females. Of these, WC and WSR were the most predictive for both males and females. In addition, BMI should not be used in preference to other methods but always be used in conjunction with other anthropometric indicators for obesity such as WC, WHR, and WSR, as screening tools to classify individuals at risk of obesity.

Our findings indicated that approximately 20% males and 30% females who had normal weight according to BMI actually had high or very high body fat. On the other hand, approximately 10% of individuals with normal %BF were identified as obese by BMI. Both types of individuals may potentially have health risks. Those who were obese by BMI classification but with a normal %BF may engage in weight loss behaviours that put them at health risk. It might be that individuals with high BMI but low %BF have greater muscularity,[25] however participants in the present study were not specifically selected, and were not involved in high levels of physical activities, indeed, athletes were excluded. Similarly, normal weight individuals with a high %BF may be at risk of health problems pertaining to obesity.

The Indonesian and WHO international BMI classifications could only identify overweight or obese individuals in about 50% of the sample (41.4% of males and 51.4% females). The current study defined cut-off values of BMI for the obese category including overweight as has been used by the Ministry of Health, Republic of Indonesia.[23] Many studies have observed the sensitivity and specificity of the BMI category for obesity, however the use of different obesity cut-off values for BMI and %BF made comparisons difficult. For example, Chen et al[26] reported that the WHO BMI-obesity criterion (BMI ≥25 kg/m^2) showed good sensitivity (75% and 71%, respectively) compared with the %BF obesity cut-off (%BF ≥40%) in

Table 6. Prevalence of overweight/obesity based on the new cut-off values and reference %BF

Indicator	Men		Women	
	Normal-weight	Obese	Normal-weight	Obese
%BF	203 (70.0%)	87 (30.0%)	164 (53.6%)	142 (46.4%)
BMI	172 (58.9%)	120 (41.1%)	196 (63.6%)	112 (36.4%)
WC	178 (61.0%)	114 (39.0%)	158 (51.3%)	150 (48.7%)
WHR	189 (64.7%)	103 (35.3%)	143 (46.4%)	165 (53.6%)
WSR	202 (69.2%)	202 (30.8%)	166 (53.9%)	142 (46.1%)

%BF: percentage of body fat; WC: waist circumference; WHR: waist-to-hip ratio; WSR: waist-to-stature ratio.

Chinese females. Whereas, Dudeja et al[27] reported in an Indian population that the WHO BMI-obesity criterion (BMI ≥25 kg/m^2) resulted in a sensitivity of 34% and specificity of 97% when the %BF-obesity criterion of %BF used was ≥25% for males and ≥30% for females. Another study by Ko[28] in a Chinese population, using cut-offs for %BF similar to the present study (%BF ≥25% in males and ≥35% in females), reported a sensitivity of 90% and a specificity of 83.4% using the BMI cut-offs of ≥23.8 kg/m^2 in males and ≥24.2 kg/m^2 in females for obesity. This suggests that lowering the obesity criterion may improve the sensitivity and specificity.

Gurrici et al[18,29] have suggested lowering the BMI cut-off points for obesity in Indonesia from 30 kg/m^2 to 27 kg/m^2 for obesity and from 25 kg/m^2 to 22 kg/m^2 for overweight. The study however, did not differentiate males from females. The present study indicated that an application of the international BMI cut-off points recommended by WHO (BMI ≥25 kg/m^2) which have been adopted in Indonesia, was also not appropriate. Our study found that BMI ≥21.9 kg/m^2 and BMI ≥23.6 kg/m^2 were the optimum cut-off values for Indonesian males and females, respectively. These new cut-off values increased the sensitivity up to 42% in males (to reach 83.9%) and 16% in females (to reach 67.6%) compared with the WHO international BMI cut-off points.

The WC cut-offs for obesity as recommended by the IDF for Asians (WC ≥90 cm for males and WC ≥80 cm for females), which have also been applied in the National Health Survey in Indonesia, showed the poorest sensitivity (18.4% in males and 35.2% in females) among all the anthropometric indices. This is contrary to a study reported by Vasudevan et al[30] in South Asian Indians which found that the IDF WC cut-offs could identify approximately 75% of obese adults in that population. Similarly, Misra and Khurana[16] indicated that WC cut-offs for Asian Indians as low as 90 cm in males and 80 cm in females were the most appropriate. Some other studies have proposed different cut-off values for WC, however, the values vary across gender and ethnicity. Based on a large prospective cohort study involving more than 69 000 US adults, Flint et al[11] reported that WC cut-off values of 84.0 cm in males and 71.0 cm in females may be useful in identifying individuals at increased risk of developing coronary heart disease (CHD) in the US. Zaher et al[31] proposed that a WC cut-off value of 83 cm is appropriate for identifying increased risk of non-communicable disease (NCD) in Malaysian males and females. Liu et al[32] proposed WC cut-off values for the Chinese population were 91.3 cm for males and 87.1 cm for females.

Our data indicated that WC ≥76.8 cm in males and ≥71.7 cm in females were the optimum cut-offs for identifying obesity in Indonesian adults. These cut-off values were close to those generated by Misra et al[15] for Asian Indians, i.e. WC ≥78 cm for males and ≥72 cm for females. The results of the present study indicated that WC is a better indicator of obesity in both males and females in comparison with other anthropometric indices, as reflected in the largest AUC (Figure 1) and the high sensitivity (Table 5). The new proposed WC cut-offs can improve the sensitivity more than fourfold in males (to 88.5%) and more than twofold in females (to 81.0%). The specificity of this index, however, was slightly lower compared with other indices but still approximately 80%. This is consistent with other reports that WC may be a better indicator for obesity.[31,33] Individuals with high WC have been reported to have more than a fivefold increased likelihood of multiple cardiometabolic risk factors and over half the greater likelihood of having high CHD risk status, even after adjusting for BMI in a US population.[12] Research also indicated that those of South Asian origin have a higher risk of cardiovascular diseases than those of European origin at lower WC.[14] Our new WC cut-off values are of importance given that WC is regarded as highly related with abdominal obesity and that abdominal obesity is associated with cardiovascular risk factors. However, given that the association varies by ethnicity and is independently associated with high cardiovascular disease (CVD) risk status, further validation of its clinical significance is needed for its application to different ethnic groups.

Cut-off values for anthropometric indices of obesity may differ between countries. This may be partly due to different ethnicities having different relationships between anthropometric measures and body composition.[34,35] Flegal et al[36] demonstrated BMI, WC, and WSR perform similarly as indicators of body fatness measured with DXA in a large US population sample from the National Health and Nutrition Examination Survey (NHANES). Furthermore, evidence suggested that WHR was more strongly associated with the mortality index than BMI.[37] However, Taylor et al[38] demonstrated that central adiposity measurements were positively associated with all-cause mortality as was BMI, but only when those individuals with a BMI less than 22.5 kg/m^2 were removed from the analysis, indicating that those adiposity measures could not replace BMI in clinical or public health practice. Our findings indicated that previous WHR categories were better than WC categories but not as good as BMI or WSR categories. The new cut-offs for the WHR (WHR ≥0.86 for males and 0.77 for females) can improve the sensitivity by about 30% to become

66.7% in males and 71.1% in females. However, the AUC of this index in our study showed the poorest ability to determine obesity classified by %BF compared to other anthropometric indices.

The available WSR classifications showed a higher sensitivity compared with the WHO international BMI cut-off points but lower than the WHO BMI cut-offs modified for Asians. WSR cut-off points for Asians defined by Hsieh and colleagues[39,40] showed better results as compared to those defined by Liu et al[32] in our participants. However, our new WSR cut-off values (WSR ≥0.48 for males and ≥0.47 for females) can improve the sensitivity of the index up to 23% and 38% in males and females respectively to reach 79.3% in males and 73.9% in females. Findings of the current study are consistent with some previous reports that WSR could better predict obesity health risk than WHR and BMI in some populations.[41,42] However, our study indicated WSR as a better predictor than BMI in females only.

The importance of our findings is that our newly proposed cut-off values of selected anthropometric indices improve the sensitivity in determining obesity in Indonesian adults. The strength of our study is the use of a reference method for determination of body fatness. However, our study did not include assessment of disease risk factors associated with obesity, which may have different associations with each anthropometric measure or index. Further study regarding the role of central adiposity in disease outcomes is required to provide sufficient information regarding these indices as obesity indicators. This study also contributes to the empirical literature by filling the existing gaps on the comprehensive anthropometry and body composition data in Indonesian adults.[43] However, participants in our study were limited to those of Javanese ethnicity living in Yogyakarta Province; future studies involving other ethnicities and larger sample sizes are recommended to provide national representative data.

In conclusion, our study showed that obesity defined by %BF as a reference is likely to be under-diagnosed using the previously recommended cut-off anthropometric indices. This may indicate that these classifications may not be adequate for risk prediction. Our new cut-off values for anthropometric measures and indices were highly correlated with body fatness measured with D_2O and were able to be used to determine obesity more sensitively in the Indonesian population sampled. We recommend the use of WC or WSR cut-offs in the determination of overweight or obesity in Indonesians as they have higher sensitivity and low bias compared to other anthropometric categories for obesity.

ACKNOWLEDGEMENTS

The current study was supported by the Directorate General of Higher Education Republic of Indonesia, Universitas Gadjah Mada, Indonesia, and Queensland University of Technology, Australia. We are grateful to the participants in the current study and staff who assisted with data collection. For laboratory analyses, we would like to thank Ms Connie Wishart.

AUTHOR DISCLOSURES

None of the authors have any conflicts of interest.

REFERENCES

1. World Health Organization Expert Consultation. Appropriate body mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363:157-63.
2. Ricciardi R, Metter J, Cavanaugh EW, Ghambaryan A. Predicting cardiovascular risk using measures of regional and total body fat. Appl Nurs Res. 2009;22:2-9. doi: 10.1016/j.apnr.2007.01.011.
3. Goh LGH, Dhaliwal SS, Welborn TA, Lee AH, Della PR. Ethnicity and the association between anthropometric indices of obesity and cardiovascular risk in women: a cross-sectional study. BMJ Open. 2014;4:e00470. doi: 10.1136/bmjopen-2013-004702.
4. Wang Z, Ma J, Si D. Optimal cut-off values and population means of waist circumference in different populations. Nutr Res Rev. 2010;23:191-9. doi: 10.1017/S0954422410000120.
5. Lee SY, Kuk JL, Hannon TS, Arslanian SA. Race and gender differences in the relationships between anthropometrics and abdominal fat in youth. Obesity. 2008;16:1066-71. doi: 10.1038/oby.2008.13.
6. Lear SA, James PT, Ko GT, Kumanyika S. Appropriateness of waist circumference and waist-to-hip ratio cutoffs for different ethnic groups. Eur J Clin Nutr. 2010;64:42-61. doi: 10.1038/ejcn.2009.70.
7. Lee CMY, Huxley RR, Wildman RP, Woodward M. Indices of abdominal obesity are better discriminators of cardiovascular risk factors than BMI: a meta-analysis. J Clin Epidemiol. 2008;61:646-53.
8. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev. 2010;23:247-69. doi: 10.1016/j.jclinepi.2007.08.012.
9. Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: Systematic review and meta-analysis. Obes Rev. 2012;13:275-86. doi: 10.1111/j.1467-789X.2011.00952.x.
10. Qiao Q, Nyamdorj R. Is the association of type II diabetes with waist circumference or waist-to-hip ratio stronger than that with body mass index? Eur J Clin Nutr. 2010;64:30-4. doi: 10.1038/ejcn.2009.93.
11. Flint AJ, Rexrode KM, Hu FB, Glynn RJ, Caspard H, Manson JE,Willet WC, Rimm EB. Body mass index, waist circumference, and risk of coronary heart disease: a prospective study among men and women. Obes Res Clin Pract. 2010;4:e171-e181. doi: 10.1016/j.orcp.2010.01.001.
12. Ghandehari H, Le V, Kamal-Bahl S, Bassin S, Wong N. Abdominal obesity and the spectrum of global cardiometabolic risks in US adults. Int J Obes. 2009;33:239-48. doi: 10.1038/ijo.2008.252.
13. Hotchkiss JW, Leyland AH. The relationship between body size and mortality in the linked Scottish health surveys: Cross-sectional surveys with follow-up. Int J Obes. 2011;35:838-51. doi: 10.1038/ijo.2010.207.
14. Lear SA, Toma M, Birmingham CL, Frohlich JJ. Modification of the relationship between simple anthropometric indices and risk factors by ethnic background. Metabolism. 2003;52:1295-301. doi: 10.1016/s0026-0495(03)00196-3.
15. Misra A, Khurana L. Obesity-related non-communicable diseases: South Asians vs White Caucasians. Int J Obes. 2011;35:167-87.
16. Misra A, Vikram NK, Gupta R, Pandey RM, Wasir JS, Gupta VP. Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal

obesity. Int J Obes Relat Metab Disord. 2006;30:106-11. doi: 10.1038/ijo.2010.135.
17. Hsieh SD, Yoshinaga H, Muto T. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. Int J Obes. 2003;27:610-6. doi:10.1038/sj.ijo.0802259.
18. Gurrici S, Hartriyanti Y, Hautvast JGAJ, Deurenberg P. Relationship between body fat and body mass index: differences between Indonesians and Dutch Caucasians. Eur J Clin Nutr. 1998;52:779-83.
19. International Society for the Advancement of Kinanthropometry. International standards for anthropometric assessment. Canbera: ISAK; 2006.
20. Heyward V, Wagner D. Applied body composition assessment. Champaign, IL: Human Kinetics; 2004.
21. International Atomic Energy Agency Human Health Series No 3. Assessment of body composition and total energy expenditure in human using stable isotope techniques. Vienna: International Atomic Energy Agency; 2009.
22. Hastuti J, Kagawa M, Byrne NM, Hills AP. Development and validation of anthropometric prediction equations for estimation of body fat in Indonesian men. Asia Pac J Clin Nutr. 2013;22:522-9. doi: 10.6133/apjcn.2013.22.4.14.
23. Ministry of Health Republic of Indonesia. Practical guidance for nutritional status assessment of Indonesian adults. Jakarta: General Directorate of Health Efforts Development; 1994.
24. World Health Organization. Obesity, preventing and managing the global epidemic. in Report of a WHO Consultation on Obesity, 3-5 June. WHO/NUT/NCD/98.1 Geneva: World Health Organization; 1997.
25. Rush EC, Goedecke JH, Jennings C, Micklesfield L, Dugas L, Lambert EV, Plank LD. BMI, fat and muscle differences in urban women of five ethnicities from two countries. Int J Obes. 2007;31:1232-9. doi: 10.1038/sj.ijo.0803576.
26. Chen YM, Ho SC, Lam SSH, Chan SSG. Validity of body mass index and waist circumference in the classification of obesity as compared to percent body fat in Chinese middle-aged women. Int J Obes. 2006;30:918-25.
27. Dudeja V, Misra A, Pandey RM, Devina G, Kumar G, Vikram NK. BMI does not accurately predict overweight in Asian Indians in Northern India. Br J Nutr. 2001;86:105-12. doi: 10.1079/BJN2001382.
28. Ko GTC, Tang J, Chan JCN, Wu MMF, Wai HPS, Chen R. Lower bmi cut-off value to define obesity in Hong Kong Chinese: an analysis based on body fat assessment by bioelectrical impedance. Br J Nutr. 2001;85:239-42.
29. Gurrici S, Hartriyanti Y, Hautvast JGAJ, Deurenberg P. Differences in the relationship between body fat and body mass index between two different Indonesian ethnic groups: the effect of body build. Eur J Clin Nutr. 1999;53:468-72.
30. Vasudevan D, Stotts AL, Mandayam S, Omegie LA. Comparison of BMI and anthropometric measures among South Indians using standard and modified criteria. Public Health Nutr. 2011;14:809-16. doi: 10.1017/S136898001000 3307.
31. Zaher ZMMF, Zambari R, Pheng CSF, Muruga V, Ng B, Appannah G, Onn LT. Optimal cut-off levels to define obesity: Body mass index and waist circumference, and their relationship to cardiovascular disease, dyslipidaemia, hypertension and diabetes in Malaysia. Asia Pac J Clin Nutr. 2009;18:209-16.
32. Liu A, Byrne NM, Ma G, Nasreddine L, Trinidad TP, Kijboonchoo K, Ismail MN, Kagawa M, Poh BK, Hills AP. Validation of bioelectrical impedance analysis for total body water assessment against the deuterium dilution technique in Asian children. Eur J Clin Nutr. 2011;65:1321-7. doi: 10. 1038/ejcn.2011.122.
33. Xu F, Wang YFP, Lu L, Liang Y, Wang Z, Hong X,Lie J. Comparison of anthropometric indices of obesity in predicting subsequent risk of hyperglycemia among Chinese men and women in mainland China. Asia Pac J Clin Nutr. 2010;19:586-93.
34. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev. 2002; 3:141-6.
35. Flegal KM, Carroll MD, Ogden CL, Curtin RL. Prevalence and trends in obesity among US adults, 1999-2008. JAMA. 2010;303:235-41. doi: 10.1001/jama.2009.2014.
36. Flegal KM, Shepherd JA, Looker AC, Graubard BI, Borrud LG, Ogden CL, Harris TB, Everhart JE, Schenker N. Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. Am J Clin Nutr. 2009;89:500-8. doi: 10.3945/ajcn.2008.26847.
37. Yusuf S, Hawken S, Ounpuu S, Bautista L, Franzosi MG, Commerford P et al. Obesity and the risk of myocardial infarction in 27,000 participants from 52 countries: a case-control study. Lancet. 2005;366:1640-9. doi: 10.1016/S014 0-6736(05)67663-5.
38. Taylor AE, Ebrahim S, Ben-Shlomo Y, Martin RM, Whincup PH, Yarnell JW, Wannamethee, S G, Lawlor DA. Comparison of the associations of body mass index and measures of central adiposity and fat mass with coronary heart disease, diabetes, and all-cause mortality: A study using data from 4 UK cohorts. Am J Clin Nutr. 2010;91: 547-56. doi: 10.3945/ajcn.2009.28757.
39. Hsieh SD, Yoshinaga H. Waist/height ratio as a simple and useful predictor of coronary heart disease risk factors in women. Intern Med. 1995;34:1147-52. doi: 10.3945/ajcn.20 09.28757.
40. Hsieh SD, Yoshinaga H. Abdominal fat distribution and coronary heart disease risk factors in men: waist/height ratio as a simple and useful predictor. Int J Obes. 1995;19:585-9.
41. Xu L, Cheng X, Wang J, Cao Q, Sato T, Wang M, Zhao X, Liang W. Comparisons of body-composition prediction accuracy: a study of 2 bioelectric impedance consumer devices in healthy Chinese persons using DXA and MRI as criteria methods. J Clin Densitometry. 2011;14:458-64. doi: 10.1016/j.jocd.2011.04.001.
42. Li M, McDermott RA. Using anthropometric indices to predict cardio-metabolic risk factors in Australian indigenous populations. Diab Res Clin Pract. 2010;87:401-6. doi: 10.1016/j.diabres.2009.12.004
43. Hastuti J. Body composition in Javanese adults: Some anthropometric dimensions related to body fat. J Med Sci. 2009;41:63-73.