Original Article

Relationship between anthropometric and dual energy X-ray absorptiometry measures to assess total and regional adiposity in Malaysian adolescents

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The main objective of this paper was to determine the utility of various anthropometric measures to assess total and regional body fatness using dual-energy X-ray absorptiometry (DXA) as the criterion in 454 adolescent boys and girls aged 12-19 years. Multivariable regression analyses of gender-specific and gender-combined models were used to determine anthropometric measures on DXA-derived body fatness models, after adjusting for known confounding biological factors. Partial correlation analyses, after adjusting for age, pubertal growth status and ethnicity in boys and girls, showed that body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), and waist-height ratio (WhtR) were significantly correlated with total body fat (TBF), percent body fat (%BF), android region fat (ARF) and trunk fat (TF) (all $p<0.0001$). BMI was the greatest independent determinant, contributing 43.8%-80.9% of the total variance for DXA-derived body fatness models. Results confirmed that a simple anthropometric index such as the BMI is a good surrogate indicator of body fat levels in Malay and Chinese adolescents.

Key Words: anthropometric measures, body fatness, dual-energy X-ray absorptiometry, ethnicity, adolescents

INTRODUCTION

The prevalence of childhood obesity has increased dramatically over the past three decades in Malaysia and worldwide such that the condition is recognized as one of the most serious public health challenges of the 21st century.[1] A growing body of evidence indicates that childhood obesity, as determined by an excess accumulation of body fat, exerts a wide range of health risks in childhood and increased likelihood of developing chronic diseases such as cardiovascular diseases, type 2 diabetes, and certain types of cancers in later life.[2,3] Hence, the identification of valid body fat assessment techniques in children and adolescents is important to assist in the determination of those at risk of obesity during the growing years.

Numerous body composition assessment approaches have been used to predict body fatness in children and adolescents in both clinical and epidemiological settings. Techniques include magnetic resonance imaging (MRI), computed tomography (CT), dual energy χ-ray absorptiometry (DXA), air-displacement plethysmography, bioelectrical impedance analysis, skinfolds and numerous anthropometric measures. Each technique has advantages and limitations[4,5], however DXA provides an accurate, precise and practical approach to assess body fat mass. The technique is relatively inexpensive, easier to undertake, and has low radiation exposure compared to MRT and CT procedures.[6] Several studies have indicated that adiposity levels assessed by DXA were strongly correlated with CT measures of body fatness.[7,8] In contrast, BMI, an indicator of relative fatness, is widely used in epidemiological studies to classify risk of obesity in children and adolescents.[2,9] However, the validity of BMI as a surrogate indicator of body fatness among children and adolescents has been questioned, due to its inability to differentiate fat mass and fat-free mass (FFM), which could result in large errors in the estimation of total body fatness.[10] Other anthropometric indicators such as waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WhtR) have been used to quantity abdominal fat in adults[11-14] and have been proposed as

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proxy indices of abdominal obesity.

Body fat assessment in children and adolescents may be more challenging than in adults[5] due to marked changes in body composition distribution during the pubertal growth period, including the establishment of gender differences.[15,16] Validation of simple and non-invasive anthropometric indicators of body fatness is increasingly important, particularly to help identify high-risk children and adolescents. To date, studies comparing anthropometric measurements of total and regional adiposity compared with CT, DXA, and MRI have provided disparate findings.[4,17-21] Several studies in children and adolescents have indicated a strong relationship between i) BMI and DXA-derived total body fat[17,18] and ii) BMI and MRI-derived body fatness.[19] Other studies, however, have suggested that WC has a stronger independent effect on DXA-derived trunk fat and CT-derived abdominal visceral fat than BMI.[20,21] Importantly, most studies have focused on children and adolescents of Caucasian origin, with only one study to date performed on Chinese children,[22] despite recognition that body composition may vary according to ethnicity, age and gender. For instance, a higher percentage of body adiposity at a lower BMI level has been found in Asian compared with Caucasian populations.[23,24] To the best of our knowledge, there is still limited data on the utility of anthropometry to assess body fatness of children and adolescents from diverse Asian ethnicities. Therefore, the main objective of the present study was to examine the usefulness of BMI, WC, WHR, WhtR on DXA-derived adiposity indices of total body fat (TBF), percent body fat (%BF), android region fat (ARF) and trunk fat (TF) in 454 Malaysian adolescent boys and girls aged 12 to 19 years. This study also examined the combination of BMI and other anthropometric measures to determine whether such combinations would improve body fat estimates compared to the commonly used single anthropometric measures.

PARTICIPANTS AND METHODS

Study design

The study was undertaken in Kota Bharu, Kelantan, Malaysia. A total of 456 adolescent boys and girls were recruited from a representative sample of school-aged adolescents, ranging from 12 to 19 years. Recruitment was undertaken using advertisements, school and community announcements, and peer-to-peer referral in the community areas. Eligible participants were selected if they were healthy and physically active, had no clinical signs of bone-related disorder that could prevent them from being physically active, and not taking medications known to influence bone metabolism. Complete data were available for 454 adolescents, comprising 204 boys and 250 girls of Malay and Chinese origin. The study was approved by the Research Human Ethics Committee of the Universiti Sains Malaysia (USM) and written informed consent was obtained from both participants and parents or guardians prior to the study.

Anthropometric measurements

Body weight, height, and waist and hip circumferences were assessed according to standard procedures.[25] Each participant was required to wear light clothing and no shoes during the assessments. Body weight and height were measured using an electronic scale with attached stadiometer (SECA 220, Germany) to the nearest 0.1 kg and 0.1 cm, respectively. BMI was calculated as weight (kg) divided by height (m) squared and BMI classified based on the revised WHO reference chart for BMI-for-age.[26] Waist and hip circumference were measured with a flexible plastic tape to the nearest 0.1 cm. WC was measured at the narrowest point between the lower costal border and the iliac crest at the end of expiration, while hip circumference was measured at the maximum circumference of the buttocks in a horizontal plane when the participant was in a standing position. All measurements were taken twice, however if measurements differed by more than 1.0 cm or 1.0 kg, a third measurement was taken. The mean of the two closest measurements was recorded. Waist-to-hip circumference (WHR) and waist-to-height (WhtR) were calculated by dividing WC by HC, and WC by height, respectively.

Assessment of dual energy x-ray absorptionmetry (DXA)

Body fatness was assessed using DXA (GE Lunar Prodigy, DPX; Lunar Corp, Madison, WI, USA) at the Department of Medical Radiology, Hospital Universiti Sains Malaysia. All bone and body scans were analysed using software provided by the manufacturer (enCORE software version 12.2). Participants were required to wear specific clothing for the DXA scan and remove all metal objects prior to scanning. Measurements were taken with participants positioned supine and motionless on the scanning table while the arm of the DXA machine passed over the body, beginning at the top of the head moving down to the feet.

Total body fat (kg) and regional fat mass were obtained from total body scans. Percent body fat (%BF) was calculated as the total body fat divided by total body mass (multiplying by 100). Regional fat distribution such as trunk fat (kg) and android region fat (kg) were also obtained from the manufacturer's software of regions of interest (ROI) analysis. This employs an algorithm that divides total body measurements into areas corresponding to head, trunk, arms and legs. For trunk fat mass, the trunk region was defined by the vertical borders lateral to the ribs and a lower border by the iliac crest, with an upper horizontal border below the chin (neck cut). The abdominal fat distribution of the "android" and gynoid" regions were also calculated using the software provided by the manufacturer as described in detail in a previous study using the same DXA device.[27] "The android region" was defined as a lower boundary at the pelvis cut and the upper boundary above the pelvis cut by 20% of the distance between the pelvis and the neck cuts. The lateral boundaries are the arm cuts. The "gynoid region" was defined as the boundary of umbilicus ROI to a distance equal to twice the height of the android fat region. However, only android region fat was used as an outcome variable in the present analysis because it was strongly correlated with visceral adipose tissue measured by CT.[8,28] In addition, it is well established that individuals with an android fat pattern with excess fat in the upper (central) body region of the abdomen as compared with the gynoid fat pattern have increased risk of metabolic and cardiovascular complications in adolescence[29] and adulthood.[8] All body scans were performed by one of the two trained radiological technicians throughout the study. Body and bone scan data were analysed by the same person, in order to minimize technical variation. All assessments were performed under the supervision of a qualified radiologist with quality assurance performed daily. Prior to each body scan, the densitometer was calibrated according to the manufacturer's recommendations with the precision of repeated measurements (CVs) using a manufacturer-supplied phantom being 0.4%. Less than 1% is indicative of satisfactory long-term stability of the instrument with no sign of drift. Additionally, a short-term precision measurement was made each day using the same phantom, which gave a coefficient of variation of 0.4% (Department of Radiology, unpublished data). In addition, *in vivo* precision for body composition measurements using DXA was excellent, with inter-observer CV of <2.5% for body fat mass, android region fat and gynoid region fat using a similar DXA model in the present study.[30]

Other covariate assessment- pubertal Tanner stage assessments

Pubertal growth status was determined by self-reported assessment of breast and pubic hair development for girls and genital hair development for boys according to the Tanner pubertal stage classifications.[31] Participants selected the stage that most accurately reflected their current appearance, based on the questionnaire containing illustrations and written description of 5 different Tanner pubertal stages. A random subsample of 20% of participants (40 male and 40 female) was further examined by trained personnel of the same gender to determine the validity of the self-reported assessment. There was a high correlation between self-reports and direct physical examination (r=0.971; P<0.001), indicating that the self-report tool provides accurate and reliable information regarding sexual maturation.

Statistical analysis

Descriptive statistics are reported as mean±SD values for numerical variables, and frequency and percentage for categorical variables (unless otherwise indicated). An independent Student's t-test was used to assess gender differences for continuous variables, and chi-square tests were used for categorical variables. Partial correlation coefficients of gender-specific models were used to examine the association of anthropometric measures on DXA-derived body fatness indices in boys and girls, respectively, after adjusting for age, pubertal growth and ethnicity. Multiple linear stepwise regression analyses for gender-specific and gender-combined models were used to assess the relative strength of these anthropometric indicators on each body fatness models measured by DXA. This was made after adjusting for age, pubertal growth status and ethnicity in the gender-specific model, whereas in gender-combined models, gender was further adjusted in the final model. The coefficient of determination for each anthropometric measurement as independent variable on each body fatness model was calculated. Subsequently, BMI was combined with WC, WHR or WhtR in the multiple linear stepwise regression models to assess the most effective predictive anthropometric measure. Multicollinearity between BMI and each anthropometric indicator used in the model was determined using the tolerance and variance inflation factor (VIF). The stability of estimated parameters was not influenced by multicollinearity. Data analyses were performed using SPSS for Windows version 18.0 (SPSS Inc. Chicago, IL) with a p value of less than 0.05 was considered to be significant.

RESULTS

Table 1 shows the general characteristics and body composition profiles of participants according to ethnicity. The mean age of participants was 15.3±1.9 years with the majority (72.5%) within the normal weight BMI range based on the recently revised WHO classification.[26] As expected, both Malay and Chinese girls had significantly higher DXA-derived body adiposity (TBF, %BF, trunk fat, android and gynoid region fat) than male participants (all at least p<0.01). In contrast, boys had significantly higher levels of body weight, WC and WHR than girls, regardless of ethnicity. In general, there was no statistically significant difference in age, pubertal growth, and body composition observed between Malays and Chinese of similar gender (the exception being height in girls).

Gender-specific correlation coefficients for anthropometric measures with DXA-body fatness indices are presented in Table 2. All anthropometric measurements were strongly correlated with DXA-derived body fatness measurements (all with p<0.0001), after adjusting for age, pubertal growth and ethnicity. BMI displayed the strongest correlation for each DXA-derived body fatness index, ranging from 0.851 to 0.958 in both boys and girls, whereas the weakest relationships were found for WHR, especially in adolescent girls with r values ranging from 0.306 to 0.460. Overall, there were no consistent differences in r values between anthropometric indicators and DXA-derived body fatness indices examined between adolescent boys and girls.

Linear regression analyses of gender-specific and gender-combined models were undertaken to examine the significant determinant of each anthropometric indicator on total and regional body fat assessed by DXA. In gender-specific regression models, the total variance for each DXA-derived body fatness model was consistent between boys and girls, except for the WHR model (data not shown), in which adolescent girls had the lowest determinant that only contributed 11.3% to 17.8% of the total variance of each DXA-derived body fatness model compared to their male counterparts. Table 3 shows the univariate and multivariable regression analyses of gender-combined models. BMI remained the strongest independent determinant for all DXA-derived body fatness models examined in both boys and girls, after further adjustment for age, gender, pubertal growth and ethnicity. The total variance for each TBF, %BF, ARF and TF model attributed to BMI ranged from 43.8% to 80.9% of the total variance, which was higher than for other anthropometric measures examined. In contrast, the total variance explained by WHR of between 11.0% and 22.3% was the lowest. Moreover, there were no consistent differences found in the total variance attributed to WC and WhtR

Table 1. General characteristics of adolescent boys and girls (n=454)

	Boys (n=204)		Girls (n=250)		Total (n=454)
	Malays (n=104)	Chinese (n=100)	Malays (n=132)	Chinese (n=118)	
Age (years)	15.4±1.9	15.2±1.9	15.2±1.9	15.4 ± 1.9	15.3±1.9
Height (m)	1.6±0.1	1.6±0.1	1.5±0.1††***	1.6 ± 0.1§***	1.6±0.1
Weight (kg)	52.5±14.1	55.9±15.0	48.6±13.4††*	51.2 ± 10.2††**	51.8±13.4
BMI (kg/m^2)	20.4±4.3	20.7±4.2	20.6±4.8	21.1 ± 3.8	20.7±4.3
Underweight†	9.6 (10)	6.0 (6)	10.6 (14)	4.2 (5)	7.9 (36)
Normal	70.2 (73)	75.0 (75)	72.0 (95)	79.7 (94)	72.5 (329)
Overweight and obese	20.2 (21)	19.0 (19)	17.4 (23)	16.1 (19)	19.6 (89)
Pubertal Tanner stage status					
Prepubertal	5.8 (6)	13.0 (13)	0.8 (1)	0	4.4 (20)
Pubertal	78.8 (82)	71.0 (71)	67.4 (89)	78.8 (93)	73.8 (335)
Postpubertal	15.4 (16)	16.0 (16)	31.8 (42)	21.2 (25)	21.8 (99)
Waist circumference (cm)	68.0±11.3	69.6±12.6	65.1±10.3††*	65.7±8.7††**	66.9±10.8
Hip circumference (cm)	85.2±10.2	85.1±10.6	87.8±10.4	88.5±8.5††*	86.8±10.0
Waist to hip ratio (WHR)	0.8±0.1	0.8±0.1	0.7±0.1††***	0.7±0.1††***	0.8±0.1
Waist to height ratio (WhtR)	42.7±6.6	42.5±6.8	42.5 ± 6.2	42.2±5.4	42.5±6.2
Body fatness indices					
Total body fat (TBF), (kg)	9.9±8.7	11.3±8.4	16.3 ± 8.9††***	17.4±6.9††***	14.0±8.8
Percent body fat (%BF) (%)	17.1±10.0	18.8±9.4	31.7 ± 8.4††***	32.8±7.1††***	25.8±11.2
Android region fat (ARF) (kg)	0.8±0.8	0.9±0.8	1.0 ± 0.7††**	1.3±0.6††**	1.0±0.7
Gynoid region fat (kg)	2.0±1.4	2.3±1.4	3.4 ± 1.5††***	3.7±1.2††***	2.9±1.5
Trunk fat (TF) (kg)	4.6±4.3	5.5±4.6	7.5 ± 4.7††***	8.3±3.5††***	6.7±4.5

†BMI for age for category of underweight, normal and overweight and obese was based on new revised WHO Growth Chart [26].
††Significantly different from boys of similar ethnicity at $^{*}p$<0.05; $^{**}p$<0.01 and $^{***}p$<0.001
§Significantly different from Malays adolescents at $^{***}p$<0.001

Table 2. Relationships of anthropometric measures and body fat indices distribution assessed by dual-energy *X*-ray absorptiometry in adolescent boys and girls of Malay and Chinese-origins aged 12 to 19 years†

	BMI	WC	WHR	WHtR
Boys (n=204)				
Total body fat (kg)	0.939***††	0.890***	0.650***	0.892***
% BF (%)	0.866***††	0.803***	0.619***	0.851***
Android region fat (kg)	0.930***††	0.892***	0.670***	0.892***
Trunk fat (kg)	0.934***††	0.889***	0.663***	0.886***
Girls (n=250)				
Total body fat (kg)	0.958***††	0.883***	0.403***	0.837***
% BF (%)	0.851***††	0.775***	0.345***	0.770***
Android region fat (kg)	0.935***††	0.887***	0.460***	0.852***
Trunk fat (kg)	0.940***††	0.876***	0.418***	0.830***

†Adjusting for age, race and pubertal Tanner stage status
Significant correlation at $^{***}p$<0.001
††The strongest correlation for each DXA-derived body fatness measure.

across each body fatness model assessed. We further compared whether the combination of BMI with WC, WHR and WhtR, as markers of central obesity, could improve the accuracy of the prediction of total and regional body fatness measured by DXA in the multiple regression analyses (Table 4). In the BMI models, WC, WHR or WhtR contribute less than an additional 2% of the total variance explained in each model of DXA-derived body fat examined. However, BMI emerged as the strongest determinant, contributing about 80.2% to 82.8% of the total variance for total body fat, android region fat and trunk fat, after adjusting for other potential confounding biological factors such as age, gender and ethnicity.

DISCUSSION

The main finding of the present study was that after adjusting for age, gender, pubertal growth status and ethnicity, BMI was the strongest anthropometric predictor of total and regional body fat. This highlights that BMI is a good surrogate indicator of body fatness in adolescent boys and girls of Malay and Chinese origin, a finding

Table 3. Crude and adjusted multivariable linear regression analyses of anthropometry measurement indices on total and regional body adiposity assessed by dual-energy *X*-ray absorptiometry in gender combined model

	Crude			Adjusted†		
	β ± SEM	R^2	*p* value	*β* ± SEM	R^2	*p* value
Model 1: TBF (kg)						
BMI	1.826 ± 0.043	80.2	$p<0.0001$	1.804 ± 0.029	80.2	$p<0.0001$
WC	0.623 ± 0.025	58.3	$p<0.0001$	0.683 ± 0.017	58.3	$p<0.0001$
WHR	31.437 ± 6.070	5.4	$p<0.0001$	74.772 ± 5.625	11.0	$p<0.0001$
WhtR	1.128 ± 0.041	63.0	$p<0.0001$	1.137 ± 0.031	63.0	$p<0.0001$
Model 2: %BF (%)						
BMI	1.721 ± 0.092	43.8	$p<0.0001$	1.735 ± 0.053	43.8	$p<0.0001$
WC	0.512 ± 0.043	24.1	$p<0.0001$	0.640 ± 0.025	35.7	$p<0.0001$
WHR	5.512 ± 7.926		0.487	73.692 ± 6.202	13.1	0.487
WhtR	1.115 ± 0.067	37.8	$p<0.0001$	1.137 ± 0.038	39.4	$p<0.0001$
Model 3: ARF (kg)						
BMI	0.156 ± 0.003	82.8	$p<0.0001$	0.156 ± 0.003	82.8	$p<0.0001$
WC	0.057 ± 0.002	68.1	$p<0.0001$	0.060 ± 0.001	68.1	$p<0.0001$
WHR	4.027 ± 0.490	12.8	$p<0.0001$	7.063 ± 0.477	12.8	$p<0.0001$
WhtR	0.100 ± 0.003	69.7	$p<0.0001$	0.100 ± 0.003	69.7	$p<0.0001$
Model 4: TF(kg)						
BMI	0.934 ± 0.022	80.9	$p<0.0001$	0.923 ± 0.016	80.9	$p<0.0001$
WC	0.328 ± 0.013	60.3	$p<0.0001$	0.359 ± 0.009	60.3	$p<0.0001$
WHR	19.361 ± 3.245	7.5	$p<0.0001$	39.128 ± 3.008	22.3	$p<0.0001$
WhtR	0.582 ± 0.021	63.4	$p<0.0001$	0.579 ± 0.017	63.4	$p<0.0001$

Abbreviations: TBF, total body fat; %BF, percent body fat; ARF, android region fat; TF, trunk fat; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WhtR, waist-to-height ratio.
†Adjusting for age, gender, pubertal Tanner stage status and ethnicity.

Table 4. Combination of BMI and other anthropometric measurements on total and regional body adiposity assessed by dual-energy *X*-ray absorptiometry in gender combined multiple regression models†

	TBF model			%BF model			ARF model			TF model		
	β ± SEM	R^2	*p* value	*β* ± SEM	R^2	*p* value	*β* ± SEM	R^2	*p* value	*β* ± SEM	R^2	*p* value
BMI + WC												
BMI	1.481±0.062	80.2	$p<0.0001$	1.488±0.116	43.8	$p<0.0001$	0.110±0.006	82.8	$p<0.0001$	0.724±0.035	80.9	$p<0.0001$
WC	0.146±0.025	0.6	$p<0.0001$	0.112±0.046	0.2	$p<0.0001$	0.021±0.002	1.8	$p<0.0001$	0.092±0.014	0.9	$p<0.0001$
BMI + WHR												
BMI	1.770±0.033	80.2	$p<0.0001$	1.735±0.053	43.8	$p<0.0001$	0.145±0.003	82.8	$p<0.0001$	0.902±0.018	80.9	$p<0.0001$
WHR	5.061±2.440	0.1	$p=0.039$			NS	1.397±0.238	6.9	$p<0.0001$	3.328±1.398	0.1	$p=0.018$
BMI + WhtR												
BMI	1.698±0.060	80.2	$p<0.0001$	1.111±0.111	43.8	$p<0.0001$	0.122±0.006	82.8	$p<0.0001$	0.842±0.034	80.9	$p<0.0001$
WhtR	0.146±0.042	0.1	$p<0.0001$	0.464±0.076	1.6	$p<0.0001$	0.026±0.004	0.8	$p<0.0001$	0.064±0.024	0.1	$p<0.0001$

Abbreviations: TBF, total body fat; %BF, percent body fat; ARF, android region fat; TF, trunk fat; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WhtR, waist-to-height ratio.
†Adjusting for age, gender, pubertal stage status and ethnicity

with important implications for nutrition research, especially in resource poor settings. This finding is consistent with several previous studies using the same reference densitometry method in Caucasian children and adolescents.[18,32] A study of 985 Pima Indian children and adolescents[17] aged 5-20 years also indicated that regardless of age group and gender, BMI was a strong predictor of total body fat with correlation *r* values between 0.96 and 0.98. Moreover, a study of 198 healthy Caucasian children and adolescents from 5 to 19 years, also showed that BMI was a strong predictor of total body fat, compared to other anthropometric measures where the total variation in boys and girls was 85% and 89%, respectively.[33] In addition, BMI was also found to be the best indicator of total body fat assessed by the MRI in Chinese adolescents.[22]

Significant differences in body fatness profiles were found in adolescent boys and girls consistent with sexual dimorphism during pubertal growth when girls deposit greater amounts and proportions of their weight as fat.[5,15] As a consequence, girls of both ethnicities had significantly higher levels of total and regional body fat compared to boys however boys had higher mean WC and WHR. This finding is consistent with a study undertaken in adults and the greater propensity to accumulate excess fat within the abdominal region as compared to the gluteal-femoral region in men.[33] There were no significant differences in age, anthropometry and body fatness profiles between Malay and Chinese participants. Gender-specific models of multivariable regression analyses were used to determine the relationships between anthropometry and total and regional body fatness indices. Relationships between measures of body fatness measured by DXA and anthropometry were fairly consistent between boys and girls.

Despite being strongly correlated with abdominal fatness assessed using DXA and CT in adults,[12,13] WC, WHR and WhtR were not stronger than BMI in predicting android region fat and trunk fat and consistent with finding in a study of Caucasian boys and girls aged 11-13 years using MRI.[15] Similar results were observed in studies of adults[34] and the elderly.[8] In contrast to the present findings, in a study of Caucasian and Hispanic children and adolescents aged 7-16 years, WC had significantly higher correlations than measures of BMI with abdominal visceral adipose tissue, as measured by MRI.[21] The majority of participants were obese (73%) compared with only 19.6% in the present study which may account for the discrepancy.

Separate studies of children and adults have suggested that a combination of BMI and WC could further improve the prediction of total body fatness, assessed by skinfolds[36] and MRI.[34] In a study of 341 Caucasian adult men and women, the combination substantially increased the prediction of non-abdominal and abdominal subcutaneous and visceral fat, assessed by MRI.[34] This was not the case in the present study with less than 2% of the total variance contributed by the addition of WC, WHR or WhtR into the regression models. WHR is a reliable proxy marker of central obesity and higher risk of adverse health in adults. However, the utility of WHR in estimating body fatness among children and adolescents is still unclear, especially from Asian populations. In the present study, WHR was not a useful predictor of total and regional body fat, consistent with findings from several studies of Caucasian children and adolescents.[15,20,37]

A number of limitations of the present study need to be acknowledged. Due to its cross-sectional nature, we cannot establish the direction of associations between anthropometric measures and body fatness assessed by DXA. Secondly, the use of DXA to assess body fatness may not be regarded as optimal, particularly with regard to abdominal body fat distribution as DXA is unable to differentiate visceral and subcutaneous fat from intra-abdominal adipose tissue.[4] Despite this limitation, we believe that the use of DXA-trunk fat and abdominal subregion (such as android region) fat provides a reliable indicator of abdominal fatness. Both DXA measures were comparable in predicting visceral fat when assessed by CT and MRI in children[19,37] and adults,[7-8] suggesting that the use of DXA to measure total abdominal fat may be useful in children and adolescents. Finally, as the present study only included Malay and Chinese adolescents, findings may not be generalised to other ethnic groups. However, the present study has several strengths, including the large sample size of adolescents of both genders across a wide age range, incorporating comprehensive anthropometric measurements, pubertal growth status assessments and adjusted potential confounding variables such as age and pubertal maturation.

Conclusion

In conclusion, the present findings indicate that BMI is more reliable than WC, WhtR and WHR in estimating total and regional body fat assessed by DXA, independent of age, pubertal growth status, gender and ethnicity. This suggests that BMI is a good surrogate indicator of body fatness in adolescent boys and girls of Malay and Chinese origin. Further population-based studies are needed to compare the utility of various anthropometric measures that reflect the full range of health-related outcomes associated with childhood obesity.

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AUTHOR DISCLOSURES

The authors declare that they have no competing interests.

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Original Article

Relationship between anthropometric and dual energy X-ray absorptiometry measures to assess total and regional adiposity in Malaysian adolescents

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體位測量和雙能量 X 光吸收儀測量法評估馬來西亞青少年總體及局部肥胖的相關性

本篇文章主要目的是以雙能量 X 光吸收儀(DXA)當作標準，評量各種體位測量法對估測 454 名 12-19 歲的青春期男孩和女孩其整體及局部體脂肪的效用。在校正已知的生物學干擾因子後，利用 DXA 衍生的體脂肪模式，以性別分層及合併模式的多元回歸分析評估各體位測量值的預測性。在校正男女性的年齡、青春期生長狀況與種族後，淨相關分析顯示身體質量指數(BMI)、腰圍(WC)、腰臀圍比(WHR)及腰圍身高比(WhtR)與總體脂肪(TBF)、體脂肪百分比(%BF)、腰腹部脂肪(ARF)及軀幹脂肪(TF)具有顯著相關性(全部 $p<0.0001$)。BMI 為最佳的獨立預測因子，占 DXA 衍生體脂肪模式的總變異 43.8%-80.9%。此研究結果證實簡單的體位測量指標如 BMI，為馬來及華裔青少年良好的體脂肪測量替代指標。

關鍵字：體位測量、體脂肪、雙能量 X 光吸收儀、種族、青少年