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CROSS-VALIDATION OF ANTHROPOMETRIC MEASURES AGAINST BODY MASS INDEX FOR THE ASSESSMENT OF OBESITY IN CHILDREN

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ABSTRACT

Background: It goes without saying that central or upper body adiposity leads to increased risks of obesity-associated metabolic complications. Direct methods of measurement of central obesity are not practical for field studies due to technical difficulties and cost. Thus, the urge to depend on anthropometry is going larger. The purposes of the study were to evaluate the relations between different anthropometry and to predict and cross-validate these measures.

Methods: Subjects participating in the study included only 71 boys from different grades (aged 6-12 years). The following anthropometric measurements were measured and calculated: body mass index(BMI), waist circumference(WC), waist to hip ratio(WHR), and waist to height ratio(WHtR).

Results: WC was the best single predictor of obesity, explaining 67.4% (r=0.67)of its variance while WHR explained 0.6% (r=0.006)and WHtR explained 7.3%.(r=0.07) Following quadratic regression and cross-validation techniques, it was obvious that WC better explained 77.3%(r=0.77) with p<0.05 of the variance of BMI, while WHtR explained 11.5% (r=0.11)with p<0.961, and WHR explained 16.7% (r=0.16)with p<0.546.

Conclusion: Collinearity between body mass index(BMI) and waist circumference (WC) does exist, but it is recommended to use Waist circumference associated with body mass index at a young age due to the period of intense growth.

Keywords: Anthropometric measures, visceral adiposity, subcutaneous adiposity, cross-validation.

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INTRODUCTION

One of the most common chronic health problems is obesity. This may be due to the correlated morbidity and overall mortality [1]. Low-income countries showed an increased prevalence of obesity that may exceed that of developed countries [2]. Obesity is a global concern, and it has substantial burden particularly in the developing countries comprises Saudi Arabia [3,4]. It has been also showed that obesity is associated with many health problems including, high blood pressure, diabetes, hyperlipidemia [5].

In Saudi Arabia, the prevalence of obesity has much increased recently in the age range of 5-12 years. The prevalence in girls was 11.0 and boys was 7.8 as reported by Musaiger (2011) [6] and El-Mouzan et al. 2010 [7].

As the prevalence of childhood obesity is growing fast, the urges to develop prevention strategies increases [8]. Physical therapy prevention strategies can include many strategies ranging from changing lifestyle early in life to identifying obese children with increased risk for targeted interventions including regular exercise performance [9].

Traditional measurement of childhood obesity involves the use of anthropometry, and recently the use of magnetic resonating imaging(MRI) and computed tomography(CT) provides an accurate estimate of adiposity Goran et al. [10]. However, the use of these modern technologies may be limited due to availability, cost, and radiation exposure. So there is an urge to depend on anthropometry.

The gold standard anthropometric measure is body mass index(BMI). Many studies have related High BMI to increased risk to cardiovascular diseases [11], but Body mass index has many disadvantages when used in children: 1) body mass index involves both fat masses and free of fat masses 2) body mass index cannot outline body fat distribution. A need to find alternatives to BMI increased rapidly.

A second popularly known anthropometric measure is the circumference of waist to height ratio (WHtR) which is used commonly to evaluate potential risks of diseases related to centralized adiposity [12]. However, many studies suggested that using Waist circumference alone(WC) is more useful in both adults and children [8]. Although the relationship between BMI and WC is not firmly established, it is often suggested that an individual with high BMI and high WC is at risk of developing metabolic complications in addition to increased abdominal obesity accumulation [1].

Thus, the purposes of the study were: 1) to identify the relation between WC, WHtR, and WHR to BMI in healthy Saudi male children; and 2) to cross-validate and derive the predicted equations of these surrogates in identifying obesity which was measured by BMI.

Materials and methods

Study subjects

Participants of the study included 71 school aged children (only boys) from different grades (aged 6-12 years) in Al Madinah Al Menwwarah city during 2016. The legal guardian of each child participating in the study signed an informed consent that is consistent with the guidelines outlined in the Declaration of Helsinki. This study was ethically approved by the committee of the college of Medical Rehabilitation Sciences, Taibah University.(Ref CMR-PT-2017-020)

Anthropometric measurement

The researcher took anthropometric measurements. Weight and height were both taken from standing position and without shoes or heavy cloth. Waist circumference in this study was defined as WHO definition [13] which is a round measurement taken at umbilical level (belly button), and it was taken from standing position. Similarly, hip circumference in this study was taken from standing position and was defined as WHO [13] which is a round measurement taken around the widest portions of the buttocks. BMI was measured by dividing the weight of the body by the height squared (kg/m2). WHR was measured by dividing girth of waist by girth of the hip. WHtR was measured by dividing girth of waist by height.

Statistical Analysis

Pearson correlation coefficients examined the relationships between WC, WHtR, and WHR to BMI. Predictive equations between the variables of interest and BMI were developed using linear regression. The predictors considered in the model were: WC, WHtR, and WHR. Quadratic regression was used to find curves of best fit for each variable with R-squared was used to test goodness of fit. Each model was validated using the jack-knifing procedure. Due to the inter-relation of the variables of interest, stepwise multiple regression was used to determine that each one has significance above and beyond the others. The accuracy of Predictive equations is stated if the relationship between predicted and measured BMI was significantly strong. Scatter plots were chosen to evaluate bias by assessing measured and predicted BMI. SPSS 20.0 was used for data analysis, and level of significance was determined to $P<0.05$ for all tests.

RESULTS

Group Characteristics

A group of 71 boys was used to develop the predictive equations was all Saudi male children, and the physical characteristics are given in table 1.

Table 1: Physical characteristics and body anthropometry of the studied population

Physical characteristics	$\overline{X}$ ±SD	p
N (number)	71	
Age(years)	9±2.5	0.086
weight (Kg)	27.92±9.58	0.003*
Height (cm)	121±4	0.073
BMI (Kg(/m^2)	40.05±35.81	0.002
WC (cm)	56.12±9.35	0.543
WtHR (cm/cm)	1.57±6.77	0.444
WHR (cm/cm)	24.92±37.58	0.514

p: level of significance; BMI =body mass index; WC =waist circumference; WHtR =waist to height ratio; WHR =waist to hip ratio.

Correlations between BMI and other measures of anthropometry are shown in Table 2. BMI correlates strongly with WC and weight where $r(69) = 0.67$, $p< 0.01$ and $r(69) = 0.65$, $p<0.01$. respectively.

Table 2: Pearson's correlation coefficients for body density with body anthropometry

Body anthropometry	r	*p*
WC	0.674	0.000*
WHR	-0.006	0.961
WHtR	0.073	0.546

P, level of significance; $\overline{X}$, Mean; SD, standard deviation; r, correlation coefficient

*p <0.01

Table 4: Summary of cross-validation to determine accuracy and precision of prediction equations

variable selected		Regression equation	R^2	*SEE*	t^a	sig.
WC	BMIP	52.463 - 0.230× WC	0.773	6.022	-0.988	0.317
	BMIP**2	52.463+ 0.OO4×WC			0.962	0.332
WHR	BMIP	21.083+ 0.489×WHR	0.06	37.854	0.915	0.363
	BMIP**2	21.083- 0.005×WHR			-0.954	0.344
WHtR	BMIP	0.050+0.131× WHtR	0.167	6.781	1.365	0.177
	BMIP**2	0.050- 0.001× WHtR			-1.257	0.213

BMIP= predicted body mass index; BMIP**2= Predicted body mass index after jackknifing procedures; t^a, paired t-test; R^2, root mean square; SEE, standard estimation error

Development of prediction equations

A linear regression model was used to identify how much each of the anthropometric measures contributes to BMI. Each of the variances of BMI explained by each anthropometry, and predictive equations are given in Table 3. WC was the best predictor of obesity, explaining 67.4% (see fig. 1) of its variance while WHR explained 0.6% (see fig. 2) and WHtR explained 7.3% (see fig. 3). Quadratic regression was performed to find curves of best fit. The results showed that WC better explained 77.3% of the variance of BMI (see fig. 1), while WHtR explained 11.5% (see fig. 2), and WHR explained 16.7%. (see fig. 3) this proved that higher order curves could follow the actual data points more closely for WC relationship but rarely succeeded to follow more points of the real data for WHR and WHtR.

Table 3: Simple linear regression analysis for the determinant of obesity as measured by BMI

variable selected	Regression equation	R^2	*SEE*
WC	49.074 +0.176×WC	0.773	6.022
WHR	25.178-0.006×WHR	0.06	37.854
WHtR	1.027+0.14×WHtR	0.73	6.809

R^2, root mean square; SEE, standard estimation error

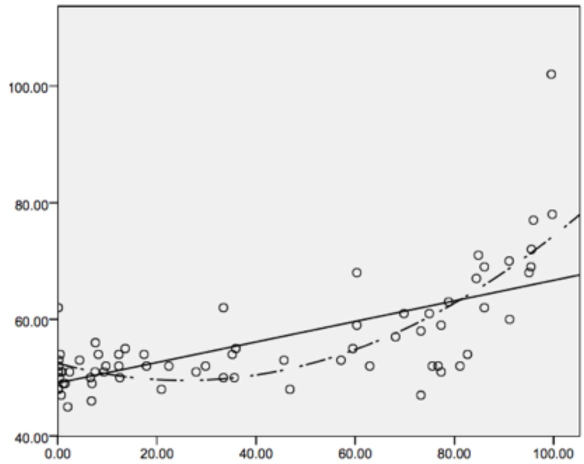

Figure 1: Relationship between waist circumference and body mass index (o=observed; ----=linear; = = quadratic)

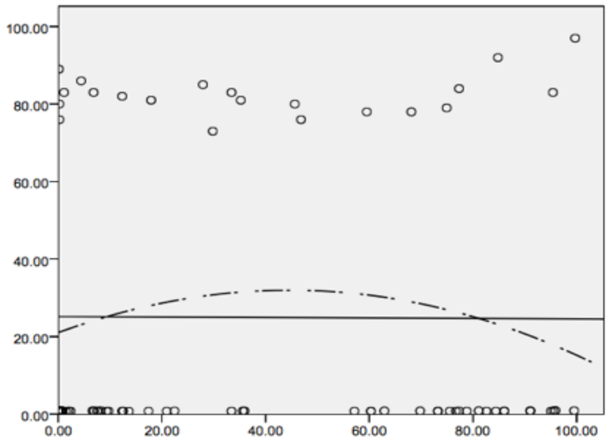

Figure 2: Relationship between waist to hip ratio and body mass index index (o=observed; -----=linear; = = quadratic)

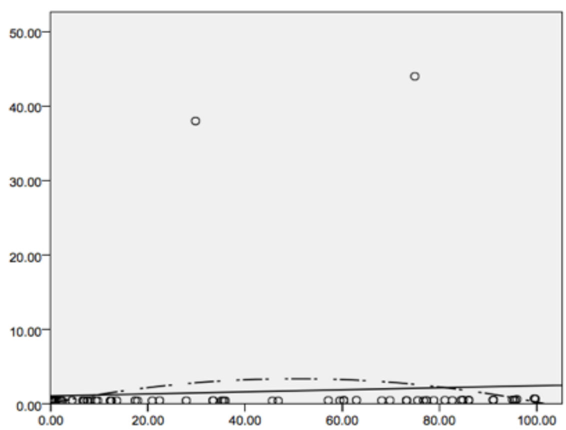

Figure 3: Relationship between waist to height ratio and body mass index index (o=observed; -----=linear; = = quadratic)

Stepwise regression was calculated to predict BMI based on WC, WHtR, and WHR. A regression equation was found ($F(3, 68) = 14.894$, $p < 0.000$) with an R2 of 0.658. Predicted BMI is equal to -81.467+ 1.673×WC+ 0.246×WHtR-0.28×WHR.

Cross-validation of equations

The precision and accuracy of the predictive equations were evaluated by testing regression between originally predicted BMI and jackknifed BMI developed in Table 4. paired *t*-test showed no significant difference for all variables.

DISCUSSION

As much as we know, this is the first study that attempts to validate different anthropometric measures for predicting obesity in children in Saudi Arabia. The current study is limited to the use of anthropometric measurements against body mass index although they may not accurately estimate the percentage of fat as indicated by computed tomography [14,15]. The use of anthropometry in this study is appropriate regarding cost and age of population included in the study.

Our study correlates with the study of Wang et al. (1994) who found that although, Asian population who have shorter stature and subsequently have lower body mass index values, they have higher fat percentages. The predictive equations using BMI only revealed high standardized estimation of error ranging from 4.4% to 5.7% [16].

On the contrary, Pietrobelli et al. (1998) stated in a study in which they use dual-energy x-ray absorptiometry against BMI that BMI is a good indicator of total body fat, but they referred to be used with cautious when used among different age groups [17].

The primary finding is that circumference of waist is a good predictor of obesity in school children. Our study showed that WC explained only 77.3% of variations of obesity as measured by BMI, and this may be due to the limited adequacy of BMI to explain adiposity. Periera et al. (2015) showed in their study that adolescents were considered as having normal body weight, measured by BMI, although having excess body weight as expressed by WC [18].

Regarding WC, it has been shown that it has a moderate correlation with BMI (r= 0.67, P= 0.01). Janseen et al. (2004) found a better high correlation of BMI and WC in a study of 2,597 children aged 5-18 years [19]. This may be due to the altered association between total fat of the body and abdominal fat during puberty [20].

WHR reflects the skeletal structure, and it is highly dependent on age, so great variations may be present if it is used alone as an anthropometric indicator of obesity [18,21-23]. Our study showed that BMI correlates poorly with WHR (r= -0.006, p= 0.961). The previous study on adolescents, with normal and excess weight, also showed a poor correlation with different values in different groups indicating less sensitivity of WHR in identifying central obesity due to body changes during puberty [20].

WHtR is one of the popular indices for evaluating central obesity [24]. However, its use may be globally limited due to its variation between women and men and among different ethnic group [25-27]. Our results shows poor correlation between BMI and WHtR (r= 0.073, P= 0.546). This may be due to wide differences in the growth's velocities in WC and height with age. This goes in line with results of McCarth et al. on children in British study aged 5-16.9 years showing a decrease in mean values of WHtR, and also that WHtR plateaued around 18 years [28]. This explains the effect of height on WC throughout growth, especially during puberty. As proposed in the literature, many anthropometric measures have been used as predictors of obesity such as WC and WHR [10,21,29-31]. On the contrary, this study succeeded only to validate the use of WC in predicting obesity as measured by BMI. However, limitations that restrict recommendations may include: 1) small study population (n= 71) and 2) the study involved only male children with a limited age range (6-12 years).

CONCLUSION

It can be concluded that increase in abdominal fat correlates with an increase in BMI indicating collinearity between WC and BMI. The presence of a weak correlation between height and circumference measures is accepted especially in the period of intense growth. It is recommended to use WC associated at least with BMI in the obesity assessment in school-aged children to prevent height from concealing the real association with adiposity.

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