Original Article

Predictability and implications of anthropometric indices for metabolic abnormalities in children: nutrition and health survey in Taiwan elementary children, 2001-2002

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Background: To determine whether separate anthropometric screening tools are needed for obesity and the metabolic syndrome in children, we compared the predictability of several anthropometric indices, including waist circumference (WC) and body mass index (BMI), with regard to metabolic disorders. Study design: The Nutrition and Health Survey in Taiwan Elementary School Children (2000-2001) collected data from 2,215 children. Logistic regression analysis was used to study the association between anthropometric indices and metabolic abnormalities, which was defined as two or more of the following conditions: high fasting triglycerides, high fasting glucose levels, high blood pressure and low high-density lipoprotein-cholesterol. The receiver operating characteristic curve was used to study the sensitivity and specificity of these anthropometric indices. Results: predictability was the ranked highest for WC (R^2 = 10.69%), followed by BMI (R^2 = 9.80%), arm girth (R^2 = 9.75%), hip circumference (R^2 = 9.43%), scapular skinfold thickness (R^2 = 9.28%) and waist-to-height ratio (R^2 = 9.25%). Waist circumference or BMI cut-offs for maximal balanced sensitivity and specificity were close to the 60th percentile for each age and gender group. Values were greater in boys than in girls and increased with age. Conclusion: It is justifiable to use the WC criteria to define the metabolic syndrome in children. Due to its practicality, BMI remains the most suitable index for defining overweight/obesity. Only moderate levels of sensitivity and specificity were achieved with these two popular obesity indices with regard to metabolic abnormalities.

Key Words: anthropometric index, children, the metabolic syndrome, waist circumference, body mass index

INTRODUCTION

The Metabolic syndrome, an independent risk factor for cardiovascular disease,[1] is becoming increasingly common worldwide.[2-4] Among the different components of the metabolic syndrome, obesity[5] and insulin resistance are generally recognized as critical underlying conditions necessary for developing this condition. The prevalence of obesity in children is steadily increasing.[6] One longitudinal study[7] has shown that metabolic abnormalities in children predict the metabolic syndrome in adults. Therefore, it is crucial to screen children with a predisposition for the metabolic syndrome to avoid disease progression and cardiovascular disease in adults.

Body mass index (BMI) is a well-recognized general obesity index, whereas waist circumference (WC) is an index of abdominal adiposity. Obesity and overweight in children are defined as a BMI ≥ 95th percentile and a BMI between the 85th and 94th percentile, respectively with gender and age specific cut-off points. Age- and gender-specific WC cut-off points are not customary for defining metabolic disorders in children. Although studies have shown that obese/overweight children have higher levels of blood pressure, triglyceride, fasting glucose, but lower level of high-density lipoprotein (HDL)-cholesterol,[8,9] it is not clear how BMI compares to WC for predicting these metabolic abnormalities.[10] In this study, we compare the predictive power of various anthropometric indices for metabolic abnormalities, as well as the sensitivity and specificity of these indices. Our findings may help to shed light on how to apply these anthropometric indices when defining obesity and the metabolic syndrome in children.

MATERIALS AND METHODS

Study population

The Nutritional and Health Survey in Taiwan Elementary School Children (NAHSIT Children 2001-2002) was supported by the Department of Health. The NAHSIT

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Manuscript received 1 October 2009. Initial review completed 27 April 2009. Revision accepted 8 June 2009.

Children is a national representative sample that was collected using a multi-staged probability sampling scheme.[11]

A total of 2215 children (1189 boys and 1026 girls) with complete anthropometric and blood examination data were included in this study. The ages of the children ranged from 6 to 12 years old. Informed content was signed by a parent on behalf of the child. Reviewers from the Department of Health in Taiwan deemed the study ethical.

Measurements

Anthropometric indices included body height,body weight, WC, hip circumference, waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), arm girth, tricep skinfold thickness, scapular skinfold thickness and wrist girth.[11] Waist circumference was measured horizontally at the level of the natural waist, which was identified as the level at the hollow molding of the trunk when the trunk was laterally concave. Hip circumference was measured horizontally at the level of the greater trochanters. Arm circumference was measured midway between the acromion and the olecranon with the arm held naturally parallel to the trunk. Tricep skinfold thickness was measured midway between the acromion and the olecranon at the marked midline of the posterior surface of the right upper arm. Subscapular skinfold thickness was measured at a marked point one centimeter below the tip of the right scapula, with the arm positioned parallel to the trunk. Wrist circumference was measured at the distal wrist crease using a soft tape measure with an accuracy of 0.1 mm. All measurements were carried out at least twice. BMI was calculated by dividing weight (kg) by the square of height (m). Blood pressure was measured after the subjects had rested for at least 5 minutes, using the Omega 1400 Non-Invasive Blood Pressure Monitor with appropriately sized cuffs. The average of three blood pressure measurements was used for analysis. All children were asked to fast overnight for at least 8 hours before blood samples were drawn for biochemical measurements. Complete blood counts were measured on site immediately after the blood draw using a Beckman Coulter AcT 8 analyzer (USA). Serum glucose, cholesterol, triglycerides and HDL-cholesterol were measured within a month of blood collection using an automatic analyzer (Hitachi 747, Japan) in the clinical laboratory of the National Taiwan University Hospital.

Definition of abnormal metabolic or cardiovascular disease risk factors

Elevated fasting glucose was defined as fasting glucose ≥ 100 mg/dL.[12,13] However, the proportion of children with glucose ≥ 110 mg/dL is also provided for comparison with other populations. When the systolic or diastolic blood pressure value was above the 90^{th} percentile for the age- and gender-specific population, blood pressure was considered high. A triglyceride value above 110 mg/dL was defined as high.[13] A low HDL-cholesterol level was defined as less than 40 mg/dL for both genders.[13] Metabolic abnormality was defined as two or more metabolic risk factors above the specified cut-off points.

Statistical methods

Data from male and female children are presented as mean ± standard deviation. Student t-test or chi-square tests was used, depending on the data type, for comparing the characteristics between boys and girls. Age- and gender-adjusted means and standard error were also estimated by metabolic abnormality status, using the general linear model.

We used partial correlation to estimate the association between anthropometric indices and metabolic risk factors, independent of age and gender. The age- and sex-adjusted partial correlation 0.3 between two variables means that there is 0.3 standard deviation change of one variable given one standard deviation change of the other, after removing the age and sex effects. The higher the partial correlation coefficients, the higher the degree of

Table 1. Characteristics of the subjects

Variables	Boys (n = 1189) Mean ± SD	Girls (n = 1026) Mean ± SD	*p*-value
Age (years)	9.0 ± 1.8	9.1 ± 1.8	0.183
Metabolic parameters			
Triglycerides (mg/dL)	68.4 ± 33.7	73.1 ± 34.0	0.001
HDL-C (mg/dL)	59.5 ± 12.8	57.9 ± 12.8	0.003
Total cholesterol (mg/dL)	175.7 ± 31.6	174.4 ± 32.9	0.324
Systolic BP (mm Hg)	98.0 ± 10.2	96.2 ± 9.3	<0.001
Diastolic BP (mm Hg)	57.0 ± 7.2	57.4 ± 7.0	0.259
Glucose (mg/dL)	97.0 ± 8.3	95.1 ± 7.7	<0.001
High triglycerides (≥ 110 mg/dL)	10.0%	12.5%	0.066
Low HDL-C (<40 mg/dL)	4.0%	4.6%	0.465
High blood pressure (≥ 90^{th})	16.0%	15.8%	0.903
High glucose (≥ 100 mg/dL)	35.0%	27.3%	<0.001
Metabolic Abnormality	12.2%	21.6%	0.788
Anthropometric index			
BMI (kg/m^2)	18.3 ± 3.7	17.5 ± 3.2	<0.001
Waist circumference (cm)	60.2 ± 9.1	57.1 ± 7.7	<0.001
Hip circumference (cm)	74.8 ± 9.9	74.9 ± 9.6	0.777
Waist-to-Hip Ratio	0.80 ± 0.05	0.76 ± 0.05	<0.001
Waist-to-Height Ratio	0.44 ± 0.05	0.42 ± 0.05	<0.001
Arm girth (cm)	21.0 ± 3.9	20.4 ± 3.4	<0.001
Scapular skinfold thickness (mm)	9.7 ± 5.9	10.0 ± 5.3	0.314
Tricep skinfold thickness (mm)	13.2 ± 6.7	13.4 ± 5.6	0.416
Wrist girth (cm)	14.0 ± 1.5	13.5 ± 1.3	<0.001

HDL-C: high-density lipoprotein cholesterol; BP: blood pressure; BMI: body mass index.

Table 2. Age- and gender-adjusted anthropometric indices (mean ± standard error) in children with elevated metabolic risk factors and their counterparts

	Triglycerides		*p* value	HDL-Cholesterol		*p* value	Systolic/diastolic BP		*p* value	Fasting plasma glucose		*p* value
	< 110mg/dl	≥ 110 mg/dl		≥ 40 mg/dl	< 40 mg/dl		< 90th†	≥ 90th†		<100 mg/dl	≥ 100 mg/dl	
n (prevalence)	1968	247 (11.2%)		2121	94 (4.2%)		1863	352 (15.9%)		1519	696 (31.4%)	
BMI (kg/m^2)	17.7 ± 0.1	20.3 ± 0.2	<0.001	17.8 ± 0.1	20.3 ± 0.3	<0.001	17.5 ± 0.1	20.3 ± 0.2	<0.001	17.8 ± 0.1	18.3 ± 0.1	<0.001
Waist circumference (cm)	58.0 ± 0.2	64.8 ± 0.5	<0.001	58.5 ± 0.2	64.9 ± 0.8	<0.001	57.8 ± 0.2	64.1 ± 0.4	<0.001	58.3 ± 0.2	59.7 ± 0.3	<0.001
Hip circumference (cm)	74.2 ± 0.2	79.8 ± 0.5	<0.001	74.6 ± 0.2	79.6 ± 0.8	<0.001	73.8 ± 0.2	80.1 ± 0.4	<0.001	74.4 ± 0.2	75.8 ± 0.3	<0.001
WHR	0.78 ± 0.00	0.81 ± 0.00	<0.001	0.78 ± 0.00	0.81 ± 0.00	<0.001	0.78 ± 0.00	0.80 ± 0.00	<0.001	0.78 ± 0.00	0.79 ± 0.00	0.099
WHtR	0.43 ± 0.00	0.47 ± 0.00	<0.001	0.43 ± 0.00	0.47 ± 0.00	<0.001	0.43 ± 0.00	0.46 ± 0.00	<0.001	0.43 ± 0.00	0.44 ± 0.00	0.002
Arm circumference (cm)	20.4 ± 0.1	23.0 ± 0.2	<0.001	20.6 ± 0.1	23.0 ± 0.3	<0.001	20.3 ± 0.1	22.9 ± 0.2	<0.001	20.5 ± 0.1	21.2 ± 0.1	<0.001
Scapular skinfold thickness (mm)	9.4 ± 0.1	13.5 ± 0.3	<0.001	9.7 ± 0.1	13.8 ± 0.6	<0.001	9.1 ± 0.1	13.6 ± 0.3	<0.001	9.6 ± 0.1	10.5 ± 0.2	<0.001
Tricep skinfold thickness (mm)	12.7 ± 0.1	17.6 ± 0.4	<0.001	13.1 ± 0.1	17.3 ± 0.6	<0.001	12.6 ± 0.1	16.9 ± 0.3	<0.001	12.9 ± 0.2	14.0 ± 0.2	<0.001
Wrist circumference (cm)	13.6 ± 0.0	14.4 ± 0.1	<0.001	13.7 ± 0.0	14.4 ± 0.1	<0.001	13.6 ± 0.0	14.4 ± 0.1	<0.001	13.7 ± 0.0	13.9 ± 0.0	<0.001

HDL-Cholesterol: high-density lipoprotein cholesterol; BP: blood pressure; BMI: body mass index; WHR: Waist-to-Hip ratio; WHtR: Waist-to-Height ratio.
† Age- and gender-specific 90th percentile value.

Table 3. Association between anthropometric indices and metabolic risk factors

	n	Partial correlation coefficients†					Partial† R^2				
		TG	HDL-C	Systolic BP	Diastolic BP	GLU	High TG	Low HDL-C	High BP	High GLU	≥ 2 MA‡
Body Mass Index (kg/m^2)	2215	0.320	-0.309	0.469	0.237	0.099	7.39	5.15	9.47	0.43	9.80
Waist circumference (cm)	2215	0.346§	-0.342§	0.476	0.261	0.101	9.30§	6.49§	9.42	0.48	10.69§
Hip circumference (cm)	2215	0.302	-0.284	0.479§	0.272§	0.110	6.88	4.34	9.66§	0.51	9.43
Waist-to-Hip Ratio	2215	0.227	-0.264	0.204	0.087	0.030NS	5.18	4.89	1.93	0.09	3.90
Waist-to-Height Ratio	2215	0.332	-0.334	0.393	0.195	0.079	8.84	6.43	7.05	0.33	9.25
Arm circumference (cm)	2215	0.316	-0.308	0.475	0.238	0.111	7.37	5.10	8.85	0.60	9.75
Scapular skinfold thickness (mm)	2215	0.295	-0.296	0.431	0.249	0.105	6.57	5.02	8.82	0.46	9.28
Tricep skinfold thickness (mm)	2215	0.320	-0.267	0.406	0.219	0.105	7.97	4.82	7.22	0.46	8.88
Wrist circumference (cm)	2215	0.264	-0.269	0.459	0.221	0.113§	5.86	4.77	8.05	0.64§	8.17

$p < 0.001$ for all correlation coefficients. NS: not significant ($p > 0.05$). † Adjusted for age and gender. ‡ Metabolic abnormalities (MAs) included elevated triglycerides (TG), low high-density lipoprotein cholesterol (HDL-C), high blood pressure (BP) and high fasting glucose (GLU). §: the highest correlation coefficients or highest partial R^2 of likelihood.

association between two variables. Partial R^2 of likelihood obtained from the logistic regression analysis was used to show the degree of association between elevated anthropometric indices and metabolic abnormalities. Partial R^2 of likelihood in logistic regression had a similar property with partial R^2 in linear regression. The higher the R^2 of likelihood, the higher degree of association between two conditions. The comparison between two correlation coefficients from paired measurements was carried out using the formula created by Olkin.[14] The receiver operating characteristic curve approach was used to estimate sensitivity and specificity of these anthropometric indices.

RESULTS

Table 1 shows the metabolic characteristics and anthropometric indices of the male and female children included in this study. Boys had significantly lower triglyceride levels, but higher levels of HDL-cholesterol, systolic blood pressure, fasting glucose, WC, BMI, WHR, WHtR, arm girth and wrist girth.

The prevalence of elevated triglyceride levels (≥ 110 mg/dL), low HDL-cholesterol (<40 mg/dL), elevated blood pressure (≥ 90th percentile for age- and gender-specific populations) and high fasting glucose (≥ 100 mg/dL) were 11.2%, 4.2%, 15.9% and 31.4%, respectively. Only 4% of the children had fasting glucose values greater than 110 mg/dL. Anthropometric indices were greater in children with any of the above metabolic abnormalities than in those without (Table 2). Age- and gender-adjusted WHR levels were the exception and did not differ significantly between children with and without elevated glucose.

The association between anthropometric indices and metabolic abnormalities is shown in Table 3. Partial correlation coefficients, which control for age and gender, were calculated when metabolic abnormality were analyzed as a continuous variable, the total number of abnormalities, whereas the partial R^2 of log likelihood (adjusting for age and gender) was estimated from the logistic regression when metabolic abnormality were analyzed as a categorical variable. All anthropometric indices were significantly associated with metabolic abnormality, except WHR, which was not associated with fasting glucose. The association between WC and triglyceride levels had the highest partial correlation coefficient and partial R^2 (partial r = 0.346; partial R^2 = 9.30%), followed by the association between WC and HDL-cholesterol levels (partial r = -0.342; partial R^2 = 6.49%).

The partial R^2 associated with metabolic disorders was ranked the highest for WC (partial R^2 =10.69%), followed by BMI (partial R^2 = 9.80%), arm girth (partial R^2 = 9.75%), hip circumference (partial R^2 = 9.43%), scapular skinfold thickness (partial R^2 = 9.28%), WHtR (partial R^2 = 9.25%), tricep skinfold thickness (partial R^2 = 8.88%), wrist circumference (partial R^2 = 8.17%) and WHR (partial R^2 = 3.90%).

We compared the partial correlation coefficients between WC and BMI with regard to metabolic risk factors. The partial correlation coefficients with WC and with BMI was 0.346 and 0.320 for TG, respectively (p value = 0.0760), and -0.342 and -0.309 for HDL-C, respectively

Table 4. Waist circumference cut-off values and corresponding percentile for sensitivity and specificity balanced and maximized in relation to metabolic abnormalities (≥ 2 MAs†)

Age	Boys						Girls					
	n	≥ 2 MAs†	WC Cut-off (cm)	Percentile	Se	Sp	n	≥ 2 MAs†	WC Cut-off (cm)	Percentile	Se	Sp
6	96	6.3%	53.2	50th	50%	50%	78	9.0%	50.1	55th	57%	57%
7	207	8.7%	57.6	73rd	78%	78%	156	9.0%	52.0	52nd	50%	52%
8	193	12.4%	58.5	67th	74%	73%	170	11.2%	54.3	58th	61%	61%
9	194	12.4%	63.1	70th	75%	77%	172	12.2%	57.7	62nd	65%	66%
10	202	15.8%	62.5	62nd	65%	65%	186	16.1%	58.2	61st	67%	66%
11	217	11.5%	66.8	62nd	65%	65%	176	14.2%	60.0	60th	61%	64%
12	80	20.0%	65.3	61st	69%	69%	88	14.8%	63.5	57th	62%	60%

WC: waist circumference; Se: sensitivity; Sp: specificity. † Metabolic abnormalities (MAs) included elevated triglycerides, low high-density lipoprotein cholesterol, high blood pressure and high fasting glucose.

Table 5. Body Mass Index cut-off values and corresponding percentile for sensitivity and specificity balanced and maximized in relation to metabolic abnormalities (≥ 2 MAs†)

Age	Boys						Girls					
	n	≥ 2 MAs†	BMI Cut-off (kg/m^2)	Percentile	Se	Sp	n	≥ 2 MAs†	BMI Cut-off (kg/m^2)	Percentile	Se	Sp
6	96	6.3%	15.8	50th	50%	50%	78	9.0%	15.4	53rd	57%	54%
7	207	8.7%	16.8	63rd	67%	66%	156	9.0%	16.2	56th	57%	57%
8	193	12.4%	17.9	68th	74%	74%	170	11.2%	16.3	58th	61%	61%
9	194	12.4%	20.0	71st	79%	79%	172	12.2%	18.2	65th	70%	69%
10	202	15.8%	19.5	65th	72%	73%	186	16.1%	17.2	56th	60%	60%
11	217	11.5%	20.7	63rd	65%	66%	176	14.2%	18.6	60th	65%	64%
12	80	20.0%	20.9	59th	63%	64%	88	14.8%	19.1	52nd	54%	53%

BMI: body mass index; Se: sensitivity; Sp: specificity. † Metabolic abnormalities (MAs) included elevated triglycerides, low high-density lipoprotein cholesterol, high blood pressure and high fasting glucose.

(p value = 0.0466). The partial correlation coefficients with WC and with BMI were not significantly differential for Systolic BP (p value=0.3345), for Diastolic BP (p value=0.1152) and for fasting glucose (p value=0.4705) (table 3). We used logistic regression with stepwise selection option after controlling the effects of age and sex to assess the impact of WC and BMI on abnormal metabolic risk factors. We found that WC had higher explained variance than BMI for all abnormal metabolic risk factors. Moreover, WC and BMI were independently associated with high blood pressure.

We estimated the optimal cut-off value for each anthropometric parameter as the balancing point with the closest sensitivity and specificity. Table 4 shows that WC cut-offs were higher in boys than in girls for all age groups. Values increased with age for both genders. At these WC cut-off points, sensitivity and specificity approximated the 60th percentile for most age and gender groups, with some exceptions. Similar information for BMI is presented in Table 5. In each age group, boys had higher BMI cut-off values than girls, and cut-off values increased with age for both genders. These BMI cut-off points also corresponded to sensitivity and specificity levels approximating the 60th percentile, again with a few exceptions.

DISCUSSION

In this nationally representative sample of Taiwanese children aged 6-12 years old, we found that among all the anthropometric indices we studied, WC was the best predictor of metabolic abnormalities. Although BMI was not as good, its predictive power approached that of WC. We tried to maximize and balance the sensitivity and specificity of diagnosing children with metabolic disorders using these two anthropometric parameters. The identified so-called "optimal" cut-off values for both WC and BMI were near the 60th percentile for age- and gender-specific distributions. The cut-off values increased with age irrespective of gender and were higher for boys than girls. The sensitivity and specificity of these cut-off values ranged from 50 to 79% for various age-gender groups and was slightly higher for WC than BMI.

Our findings suggest that WC can be used to define the metabolic syndrome in Taiwanese children. The superiority of WC for defining metabolic syndrome has also been observed in other studies.[15-19] The CASPIAN study in Iran reported that among WC, BMI, WHR and WHtR, WC had the strongest association with the metabolic syndrome in 4811 students aged 6- to 11-years-old[16]. The correlation between WC and cardiovascular risk factors is also slightly better than that found with BMI in 2593 Chinese children in Hong Kong.[15] In children of Greek-Cypriot origin,[20] WC is the most significant predictor for all cardiovascular disease risk factors. Waist circumference is also a significantly better index of trunk fat mass than WHR.[21] Thus WC, which is an indicator of truncal and visceral adiposity in children,[21] is also useful for screening early stage metabolic aberrations.

Abdominal obesity is a central element[22] and a strong predictor[23] of the metabolic syndrome. Adults with the metabolic syndrome have approximately a two-fold greater risk for cardiovascular disease[1] than those without. We now understand that obese children with high metabolic risk factor values are susceptible to large artery conditions, such as carotid artery stiffness.[24] Furthermore, high metabolic risk factor levels in childhood predict adult cardiovascular disease.[7] Screening children who are predisposed to the metabolic syndrome and managing them should diminish the progression of the metabolic syndrome and reduce the risk of cardiovascular disease in adulthood.

In this study, we have demonstrated that BMI predicts early stage aberrations in metabolic parameters almost as well as WC. Given the difficulty and the lack of uniformity for measuring WC, we feel that it is justifiable to use BMI percentile cut-off points to define overweight and obesity. Body mass index is easily measured and well connected to the definition of obesity in adults. In children, overweight is generally defined as a BMI between the age- and gender-specific 85th and 95th percentiles, whereas obesity is defined as a BMI greater than the 95th percentile.[25-27] However, the Bogalusa Heart Study[10] found that using the international obesity cut-offs[28] and the Center of Disease Control 95th percentile to diagnose the metabolic syndrome in children and adolescents yields low sensitivity and high specificity. Our data is in agreement; the 60th percentile value represents maximal sensitivity and specificity. Nonetheless, determining WC cut-off points for defining obesity and overweight is complex. Available resource and social implications require consideration when doing so.

The cut-off values of waist circumference that corre-

Table 6. The optimal cut-points of waist circumference for predicting cardiovascular risk factors in various studies

Age	Boys				Girls			
	Our study	Bogalusa Heart Study[10]†		Hong Kong Study[15]†	Our study	Bogalusa Heart Study[10]†		Hong Kong Study[15]†
		White	Black			White	Black	
6	53.2	54.1	53.5	55.3	50.1	52.7	53.3	54.8
7	57.6	56.0	55.4	57.0	52.0	55.0	55.1	56.5
8	58.5	58.3	57.4	58.9	54.3	57.6	57.3	58.2
9	63.1	61.1	59.4	61.3	57.7	60.5	59.6	59.9
10	62.5	64.4	61.6	64.3	58.2	63.3	62.0	61.8
11	66.8	67.8	63.9	66.8	60.0	65.8	64.4	64.2
12	65.3	71.3	66.4	69.2	63.5	68.0	66.6	66.4

†: Three or more of the six cardiovascular risk factors (high blood pressure, high low-density lipoprotein cholesterol, high triglycerides, high fasting insulin, low high-density lipoprotein cholesterol, high glucose)

spond to balanced, maximized sensitivity and specificity in terms of percentile values varied by ethnic group and country. Waist circumference cut-off points were located around the 75th percentile for age and gender in adolescents residing in the US[10,29] as well as children in Argentina.[27] Percentile cut-offs of WC for predicting the metabolic syndrome were both at the 70th percentile in 140 Spanish children.[18] In Spanish boys, the point on the optimal ROC curve corresponded to the 70th percentile for BMI, to the 75th percentile for triceps skinfold, and to the 70th percentile for waist circumference.[30] The cut-offs for waist circumference were found to be located at the 60th percentile in our current study. The different criteria for central obesity among different ethnic populations may reflect different prevalence of central obesity. If we removed the children with the metabolic syndrome, the cut-points were pushed nearer to the 65th percentile. Therefore, we suggest to use the cut-off values not the percentile values for comparison between populations.

Waist circumference cut-off values increase with age and are greater in boys than in girls in general (Table 6).[10 15,16] The comparable and so-called "optimal" WC thresholds in the Bogalusa Heart Study[10] ranged from 54.1 to 71.3 cm in white boys, 52.7 to 68.0 cm in white girls, 53.5 to 66.4 cm in African-American boys and 53.3 to 66.6 cm in African-American girls. A study of children in Hong Kong[15] showed that WC cut-off values for predicting modified ATP III metabolic syndrome ranged from 57 to 74 cm in boys and 55 to 67 cm in girls. The WC cut-offs in our study were comparable to most of the above studies, but slightly lower (53.2 to 66.1 cm in boys; 50.2 to 63.6 cm in girls) than in the Hong Kong study.[15] The underlying cause behind this discrepancy is not clear. Differential optimal WC cut-offs for central obesity in different ethnic groups may be caused by either life-style or genetic factors, or an interplay between the two.

In adults, WHR is generally considered as a better screening measure for cardiovascular risk factors than many other anthropometric indicators[31] despite a few studies that show inconsistent results.[32,33] However, as observed previously,[16,34] our study shows that WHR has poor predictability in children. Skinfold thickness measurements directly assess subcutaneous fat with a calliper,[35] but in the current study, skinfold thickness had poorer predictive power than BMI, perhaps due to poorer precision.

Our study examined cross-sectionally the relationship between anthropometric indices and early signs of metabolic abnormalities. Our results may be strengthened if linkage can be made with the development of the metabolic syndrome in adulthood.

CONCLUSIONS

Waist circumference is the best predictor of metabolic abnormalities in Taiwanese children, thus supporting the inclusion of WC as a component for defining the metabolic syndrome in children. Body mass index performed reasonably well in predicting metabolic risk. Due to the difficulties associated with measuring WC, it is practical to define childhood obesity with BMI. However, the relatively low to moderate levels of sensitivity and specificity of WC and BMI indicate that employing these anthropometric indices in managing obesity and metabolic risk remains less than ideal. The information derived from our study may be useful not only in Taiwan but also for Chinese children living in similar urban settings.

ACKNOWLEDGMENTS

This study was supported by a grant (DOH-1999-3) from the Department of Health (DOH). Data analyzed in this paper were collected by the research project "Nation and Health Survey in Taiwan (NAHSIT)" sponsored by the Department of Health in Taiwan (DOH-88-FS, DOH89-88shu-717, DOH90-FS-5-4, DOH91-FS-5-4). This research project was carried out by the Institute of Biomedical Sciences of Academia Sinica and the Research Center for Humanities and Social Sciences, Center for Survey Research, Academia Sinica, directed by Dr. Wen-Harn Pan and Dr. Su-Hao Tu. The Center for Survey Research of Academia Sinica was responsible for data management. The assistance provided by the Institutes and aforementioned individuals is greatly appreciated. The views expressed herein are solely those of the authors.

AUTHOR DISCLOSURES

The authors report no conflicts of interest.

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Original Article

Predictability and implications of anthropometric indices for metabolic abnormalities in children: nutrition and health survey in Taiwan elementary children, 2001-2002

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學童體位測量指標對代謝異常疾病的預測力與涵義：臺灣地區國小學童營養健康狀況調查, 2001-2002

背景：探討在學童中，對於肥胖與代謝異常症候群的篩檢，個別的體位測量篩檢工具是否需要。我們比較各項體位測量指標對代謝異常疾病的預測力，包括腰圍與身體質量指數。研究設計：臺灣地區國小學童營養健康狀況調查(2000 - 2001 年)，共計收集 2,215 位學童的資料。羅吉斯回歸被用來評估體位測量指標與代謝異常的關係，代謝異常定義為具兩個或兩個以上的下列危險因子：偏高的空腹三酸甘油脂、偏高的空腹血糖、高血壓與偏低的高密度脂蛋白膽固醇。接受器操作特性曲線(ROC curves)被用來研究各項體位測量指標的敏感度與精確度。結果：預測力最高是腰圍(R^2 =10.69%)、依次為身體質量指數(R^2=9.80%)、上臂周長(R^2=9.75%)、臀圍(R^2=9.43%)、肩胛皮下脂肪厚度(R^2=9.28%)、腰圍-身高比值(R^2=9.25%)。以年齡與性別分層之腰圍或身體質量指數，其理想切點靠近 60 百分位。切點的數值會隨著年齡而增加，且男孩有較高的切點值。結論：以腰圍的切點標準來定義兒童代謝症候群是合理的。考量實用性，身體質量指數仍然是最適合定義過重或肥胖的指標。對預測代謝異常疾病而言，這兩個常用肥胖指標的敏感度與精確度僅在中等。

關鍵字：體位測量指標、兒童、代謝症候群、腰圍、身體質量指數