ORIGINAL ARTICLE

Predictive Utility of Anthropometric Based Cut-offs in Assessing Excess Adiposity among Preschool Children in a Multiethnic Population

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ABSTRACT

Objective: *Screening for childhood obesity is a necessary step in developing appropriate and effective interventions. We evaluated the diagnostic performance of various recommended international anthropometric cut-offs based on body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), triceps skinfold (TSF), and mid-upper arm circumference (MUAC) in predicting excess adiposity (body fat ≥ 25%) in a random sample of Trinidadian preschoolers.*

Methods: *After obtaining written parental consent, weight, height, WC, TSF, and MUAC were measured in 596 children using standard procedures. These were used to calculate BMI for age, WHtR, TSF-for-age z-scores, and MUAC-for-age z-scores. Percentage body fat was measured using a Tanita-531 foot-to-foot bioelectrical impedance analyser (BIA). Sensitivities, specificities and area under the receiver-operating curve analysis and predictive values were then computed* in reference to BIA estimates.

Results: *The prevalence of excess adiposity was 12.2% and 5.1% among males and females, respectively. Sensitivities for the various cut-offs ranged from 20.0% to 75.0% and 57.1% to 96.9% among males and females, respectively. WHO-BMI recommended cut-offs and those based on MUAC z-scores had significantly higher sensitivities in females than in males. TSF z-scores had significantly lower sensitivities compared to those based on BMI and WHtR among males. Similarly, specificities ranged from 81.3% to 99.9% and 79.8% to 99.9% among males and females, respectively. In girls, cut-offs based on TSF z-scores had a higher likelihood ratio than cut-offs from Centers for Disease Control, International Obesity Task Force and WHtR. Diagnostic performance was not associated with ethnicity.*

Conclusion: *Our results suggest that diagnostic performance was associated with gender and the cut-offs used; however, it was not associated with ethnicity.*

Keywords: Cut-offs, diagnostics, obesity, preschooler.

INTRODUCTION

The nutrition-related chronic non-communicable diseases have become a major public health challenge for Caribbean governments. Approximately half of all annual visits to health facilities locally are due to hypertension, diabetes and their co-morbidities (1). These diseases originate early in life and are not confined to adulthood (2, 3). Obese children also have an increased prevalence of hyperlipidaemia, insulin resistance and diabetes mellitus (4). Overweight and obesity appear to be strong and consistent risk factors for the development of these conditions (5).

Globally, childhood obesity has increased with great alacrity during the past three decades (6, 7). This seems to have been driven by the early adoption of 'obesogenic' lifestyles characterized by sedentary behaviours and poor eating habits (8, 9). Data from the Caribbean suggest that up to a quarter of children between the age

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of 5 and 18 years may be obese (10). However, there is little available data for children between the age of 2 and 5 years. While we have gained much knowledge in our understanding of the biological aspects of obesity, we have been much less successful in our attempts at prevention and reduction (11–13).

The ability to identify and monitor children at increased risk for obesity is crucial to the development of relevant interventions (14). Successful identification and monitoring (15) requires identifying children at an increased risk of obesity and ruling out those with normal fat levels. This will allow better targeting of at-risk groups and more effective use of resources (14). Body mass index (BMI) has been recommended as the main measure for survey purposes (16), and it remains the most commonly used and inexpensive tool for assessing body composition (16, 17). Other criteria are based on waist circumference (WC), triceps skinfold (TSF), mid upper arm circumference (MUAC), and waist-to-height ratio (WHtR) (18).

This article evaluates the diagnostic performance of various established recommended anthropometric-based cut-offs in identifying excess adiposity among Trinidadian preschool children. Preschool years are formative years where children develop habits which may be beneficial or detrimental to health later in life (19). Identification of children at risk in this population is therefore a key strategy for targeting the development of interventions aimed at fostering healthy lifestyle habits (20).

SUBJECTS AND METHODS

Population

In this cross-sectional study, 17 Government Early Childhood Care and Education (ECCE) centres were randomly selected from each of the seven educational districts in Trinidad: St. George East, North Eastern, Victoria, South Eastern, Caroni, Port of Spain and Environs, and St. Patrick. The sampling frame was obtained from the Ministry of Education, Trinidad and Tobago website (21). This represented approximately 11% of the sampling frame for Government schools. Government schools are partially or fully government funded, while private schools do not receive government funding. Each of the 17 public schools was then matched to its nearest non-governmental ECCE centre, giving a total of 34 participating schools. Prior to commencement of the study, permission was obtained from the ECCE Unit of the Ministry of Education Trinidad and Tobago, the SERVOL Board and the principals of the participating schools. Parents were asked to complete a consent form to demonstrate their willingness to have their child participate in the study. Only those pupils whose parents gave written consent were enrolled. Children were categorized based on self-identified race from school records. The sample size calculation assumed a worst-case scenario where 50% of all participants were at increased risk for excess adiposity, with a 5% margin of error at the 5% level of significance. Results suggested a minimum of 384 preschool children to be included in the study. A total of 596 children participated fully.

Procedures

Standardized approved protocols were used throughout this investigation (22). All measurements were taken at the respective schools with children in school uniforms and barefoot. Measurements were done during the morning period in a non-fasting state between 8:30 am and 11:30 am from June 2008 to July 2009. The details of all procedures have been published elsewhere (23).

Statistical analyses

All analyses were conducted using SPSS version 15 for Windows (SPSS, Chicago, IL, USA). Results were expressed as means ± standard deviations and percentages. Kolmogorov–Smirnov tests for normality were performed on all variables prior to analysis. Continuous variables that were non-normal were log-transformed. *t*-tests and Mann–Whitney *U*-tests were used to determine gender differences in variables of interest. Similarly, Kruskal–Wallis tests and ANOVA were used to evaluate ethnic differences in variables of interest. *Post-hoc* procedures (Bonferroni and Tukey tests) were used to determine which groups had significant differences in anthropometric and body composition measures by ethnicity. The Chi-square test (χ^2) was used to analyse the association of excess adiposity for categorical variables.

The performance of the various classification systems was therefore tested by comparing their respective diagnostic accuracy indices—sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and positive likelihood ratio (LR+) in reference to BIA estimates. Sensitivity (true positive rate) is the probability of classifying a child as obese when he/she is truly obese, while specificity (true negative rate) is the probability of classifying a child as non-obese when he/she is truly non-obese. Positive predictive value is the probability of being truly obese when a subject is classified as such by the screening method, while NPV is the probability of being non-obese when a subject is classified as such. The likelihood ratio is the ratio of true positives (sensitivity) to false positives (1 – specificity) (24, 25). Receiver operating characteristic analyses were also performed to determine the percentages of area under the curve (AUC) for all classification systems. Area under the curve is a measure of the diagnostic power of a test. A value of 100% indicates that the test is perfect, while 50% or less means that the test is no better than chance at identifying those at increased risk of excess adiposity (18, 26). All diagnostics were run by gender and ethnicity.

RESULTS

Table 1 gives a background of the anthropometric characteristics of participants by gender, and has been published elsewhere (23). Males were significantly taller, heavier and had a higher percentage body fat as obtained by bioelectrical impedance analysis (BIA), while females had a significantly higher mean TSF and BSF thickness. The prevalence of excess adiposity (≥ 25%) as determined by BIA was 12.2% for boys and 5.1% for girls [(χ^2 (1) = 9.468, $p = 0.002$)]. The overall prevalence of overweight and obesity using the International Obesity Task Force (IOTF)-BMI criteria was 9.3% and 4.7% among boys and 8.5% and 6.8% in girls, respectively. The Centers for Disease Control (CDC)-BMI criteria identified 19.6% and 17.6% of boys and girls to be overweight and obese, respectively.

Table 1: Anthropometric characteristics of participants by gender

Anthropometric characteristics	Meanh (SD)		*p*-value
	Boys (n = 301)	Girls (n = 295)	
Age (months)	53.58 (7.41)	52.94 (6.97)	0.258
Height (cm)	107.03 (8.47)	105.79 (5.82)	0.038*
Weight (kg)	18.03 (3.94)	17.38 (3.94)	0.009*
Body mass index (kg/m^2)	15.51 (2.25)	15.39 (2.28)	0.295
Percent body fat: BIA (%)	19.02 (5.79)	14.51 (5.92)	< 0.001**
Waist circumference (cm)	50.93 (5.54)	50.23 (5.89)	0.016*
Mid-upper arm circumference (cm)	16.82 (2.06)	16.77 (2.02)	0.609
Triceps skinfold (mm)	7.26 (2.52)	7.92 (2.83)	< 0.001**
Biceps skinfold (mm)	4.34 (1.56)	4.68 (1.73)	< 0.001**
BMI-for-age: *z*-score	0.02 (1.57)	–0.05 (1.36)	0.577
MUAC: *z*-score	0.24 (1.28)	0.15 (1.19)	0.266
TSF: *z*-score	–0.45 (1.17)	–0.50 (1.13)	0.208

BIA = bioelectrical impedance analysis; BMI = body mass index; MUAC = mid-upper arm circumference; TSF = triceps skinfold.
*Significance at the 0.05 level.
**Significance at the 0.001 level.

Preschoolers of African descent were significantly taller and heavier ($p < 0.001$) and had significantly higher BMI, WC and MUAC than their East Indian and mixed descent counterparts. On the other hand, preschoolers of East Indian descent possessed higher triceps ($p = 0.012$) and biceps skinfolds ($p = 0.03$) than their mixed counterparts. Significant ethnic differences in prevalence were observed with the CDC criteria, with 12% of preschoolers of mixed descent and 17.7% of East Indian descent being overweight and obese, compared with 25.3% of African descent preschoolers ($\chi^2 = 9.827$, df = 2, $p = 0.007$) (23).

Table 2 shows the diagnostic accuracy of anthropometric cut-offs in identifying excess adiposity by gender. Overall, sensitivities and AUC tended to be higher in females. Area under the curves for cut-offs based on CDC-BMI, WHO-BMI, IOTF-BMI, WHtR, and MUAC *z*-scores were able to identify a greater proportion of females than males with excess body fat. Sensitivities for the various recommended anthropometric cut-offs ranged from 20% to 75% and 57% to 97% among males and females, respectively. Cut-offs based on TSF *z*-scores had the lowest sensitivities among both males and females. Sensitivities for cut-offs based on MUAC *z*-scores were also low among males. Similarly, specificities for the various cut-offs ranged from 86.6% to 99.6% among both sexes. Among males, specificities for cut-offs based on TSF *z*-scores were significantly higher than cut-offs based on other anthropometric variables. Among females, cut-offs based on TSF *z*-scores had significantly higher specificities that other anthropometric based cut-offs with the exception of those based on MUAC *z*-scores.

The PPV for various cut-offs ranged from 42.9% to 85.7% and 26.3% to 89.9% among males and females, respectively. Among females, the PPV for cut-offs based on TSF *z*-scores were significantly higher than those for WHtR, IOTF-BMI and CDC-BMI. The NPV for cut-offs ranged from 90.6% to 96.1% and 97.6% to 99.8% among males and females, respectively. For each of the anthropometric based cut-offs, NPVs were significantly higher in females than in males. Among females, LR+ for cut-offs based on TSF *z*-scores were significantly higher than those for cut-offs based on WHtR, IOTF-BMI and CDC-BMI. While this trend was observed among males, the considerable overlapping of the 95% confidence interval for the LR+ for the other anthropometric based cut-offs rendered the differences non-significant. Table 3 shows the diagnostic ability of the various anthropometric-based cut-offs in detecting excess adiposity by gender

Table 2: Diagnostic accuracy of anthropometric cut-offs in identifying excess adiposity by gender

	Boys					
	AUC (CI)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR+
CDC-BMI	80.0 70.4, 89.6	72.2 56.0, 84.2	87.2 82.6, 90.7	44.1 32.2, 56.7	95.7 92.3, 97.7	5.6 3.9, 8.2
WHO-BMI	76.2 65.0, 87.4	58.3 42.2, 72.9	95.3 92.0, 97.3	63.6 46.6, 77.8	94.3 90.7, 96.5	12.5 6.8, 23.3
IOTF-BMI	79.9 69.5, 90.2	66.7 50.3, 79.8	93.0 89.2, 95.5	57.1 42.2, 70.9	95.2 91.9, 97.3	9.6 5.8, 15.8
WHtR 0.50	78.9 69.3, 88.6	75.0 58.9, 86.2	86.0 81.3, 89.7	42.9 31.4, 55.1	96.1 92.8, 97.9	5.4 3.8, 7.7
MUAC *z*-score	69.5 57.7, 81.4	43.3 27.4, 60.8	95.7 92.2, 97.6	56.5 36.8, 74.4	92.9 88.9, 95.5	10.1 4.8, 20.9
TSF *z*-score	59.8 47.7, 71.8	20.0 9.5, 37.3	99.6 97.6, 99.9	85.7 48.7, 97.4	90.6 86.4, 93.6	46.4 5.8, 372.4
	Girls					
	AUC (CI)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR+
CDC-BMI	93.2 89.9, 96.5	96.9 75.9, 99.7	86.6 82.1, 90.1	29.2 18.7, 42.6	99.8 98.1, 100.0	7.2 5.3, 9.9
WHO-BMI	97.6 95.9, 99.3	96.9 75.9, 99.7	94.5 91.1, 96.6	50.0 33.4, 66.6	99.8 98.2, 100.0	17.5 10.7, 28.6
IOTF-BMI	94.6 91.8, 97.4	96.9 75.9, 99.7	89.1 84.9, 92.2	33.7 21.8, 48.1	99.8 98.1, 100.0	8.9 6.3, 12.6
WHtR 0.50	91.6 87.8, 95.4	96.9 75.9, 99.7	84.5 79.8, 88.2	26.3 16.7, 38.7	99.8 98.0, 100.0	6.2 4.7, 8.3
MUAC *z*-score	95.4 87.5,100.0	92.9 68.5, 98.7	98.0 95.4, 99.1	72.2 49.1, 87.5	99.6 97.7, 99.9	46.4 19.3, 111.9
TSF *z*-score	78.4 62.0, 94.8	57.1 32.6, 78.6	99.6 97.8, 99.9	88.9 56.5, 98.0	97.6 95.0, 98.9	142.9 19.2, 1064

AUC = area under the curve; BMI = body mass index; CDC = Centers for Disease Control; IOTF = International Obesity Task Force; LR+ = positive likelihood ratio; MUAC = mid-upper arm circumference; PBF = percentage body fat; PPV = positive predictive value; tsf = triceps skinfold; WC = waist circumference; WHO = World Health Organization; WHtR = waist-to-height ratio.

and ethnicity. The results suggest that they performed similarly in each ethnic group.

DISCUSSION

The finding of boys being twice as likely as girls to have excess adiposity, and children of African ancestry possessing overall higher anthropometric measurements are explained elsewhere (23). Preschool boys tended to exhibit overall unhealthier lifestyles. They consumed less fruit and vegetables, drank more fizzy beverages, watched more television, and ate family meals less frequently (A Ramcharitar-Bourne, unpublished results). Trinidadian preschool children, especially the boys, may therefore be highly susceptible to the early adoption of obesogenic lifestyles, and interventions should focus on targeting this group.

The ROC analysis in this study refers to the ability of the various classification systems to discriminate excess adiposity from normal fat levels (26) as determined by BIA via PBF. We evaluated the predictive ability of several anthropometric-based predictors of excess adiposity. Our results suggest that diagnostic performance of the anthropometric based cut-offs in predicting excess adiposity was influenced by gender and cut-off value (27–29). Overall, the cut-offs were able to identify higher proportions of preschool females with excess adiposity. This pattern was independent of race/ethnic group (30, 31). In fact, five of the six recommended cut-offs yielded significantly higher AUC in females than males. This suggests that the recommended cut-offs were better at identifying females with excess adiposity (28, 31). It further suggests the need to develop cut-offs based on population-specific data among male preschoolers (32, 33). When data were analysed using a population-specific approach, a cut-off BMI of 18.9 in girls resulted in an AUC of 99.7 (99.3, 100). This was

Table 3: Diagnostics for the various classification systems in detecting excess adiposity by gender and ethnicity

	CDC	WHO	IOTF	Ashwell	MUAC: *z*	TSF: *z*
E Boys						
AUC	80.2 68.5, 91.9	72.1 58.5, 85.6	77.7 65.1, 90.3	77.9 66.2, 89.6	64.3 49.4, 79.2	54.5 39.8, 69.1
Sensitivity	69.6 47.0, 85.9	47.8 27.4, 68.9	60.9 38.8, 79.5	69.6 47.0, 85.9	35.0 16.3, 59.1	10.0 1.8, 33.1
Specificity	90.8 83.4, 95.3	96.3 90.3, 98.8	94.5 87.9, 97.7	86.2 78.0, 91.8	93.7 86.2, 97.4	98.9 93.4, 99.9
E Girls						
AUC	94.3 90.1, 98.6	96.5 93.3, 99.7	94.3 90.1, 98.6	92.6 87.5, 97.7	98.6 96.5, 100	74.5 48.6, 100
Sensitivity	100 56.1, 100	100 56.1, 100	100 56.1, 100	100 56.1, 100	100 56.1, 100	50.0 13.9, 86.1
Specificity	88.7 81.1, 93.6	93.0 86.3, 96.7	88.7 81.1, 100	85.2 77.1, 90.6	97.1 91.2, 99.3	99.0 94.0, 99.9
A Boys						
AUC	78.8 63.4, 94.1	85.0 70.0, 100	83.8 68.7, 98.8	88.8 77.1, 100	75.8 52.7, 98.8	71.4 46.6, 96.3
Sensitivity	80.0 44.2, 96.5	80.0 44.2, 96.5	80.0 44.2, 96.5	90.0 54.1, 99.5	57.1 20.2, 88.2	42.9 11.8, 79.7
Specificity	77.5 66.5, 85.8	90.0 80.7, 95.3	87.5 77.8, 93.5	87.5 77.8, 93.5	94.4 85.4, 98.2	100 93.6, 100
A Girls						
AUC	90.6 83.2, 97.9	97.8 94.9, 100	93.3 87.5, 99.1	91.7 94.9, 98.4	99.4 97.9, 100	100 100, 100
Sensitivity	100 39.6, 100	100 39.6, 100	100 39.6, 100	100 39.6, 100	100 39.6, 100	100 39.6, 100
Specificity	81.1 71.2, 88.3	95.6 88.4, 98.6	86.7 77.5, 92.6	83.3 73.7, 90.1	98.8 92.4, 99.9	100 94.4, 100
M Boys						
AUC	79.5 47.1, 100	83.3 50.4, 100	81.8 49.1, 100	77.2 45.1, 100	83.3 50.4, 100	66.7 28.4, 100
Sensitivity	66.7 12.5, 98.2	66.7 12.5, 98.2	66.7 12.5, 98.2	66.7 12.5, 98.2	66.7 12.5, 98.2	33.3 1.8, 87.5
Specificity	92.3 82.2, 97.1	100 93.0, 100	96.9 88.4, 99.5	87.7 76.6, 94.2	100 92.7, 100	100 92.7, 100
M Girls						
AUC	95.8 91.1, 100	97.9 94.8, 100	96.5 92.3, 100	93.0 86.5, 99.4	86.7 61.1, 100	62.5 29.5, 95.5
Sensitivity	100 39.6, 100	100 39.6, 100	100 39.6, 100	100 39.6, 100	75.0 21.9, 98.7	25.0 1.3, 78.1
Specificity	91.5 81.9, 96.5	95.8 87.3, 98.9	93.0 83.7, 97.4	85.9 75.2, 92.7	98.4 90.2, 99.9	100 92.7, 100

A = African ancestry, CDC = Centers for Disease Control; E = East Indian ancestry, IOTF = International Obesity Task Force; M = mixed ancestry, MUAC = mid-upper arm circumference; TSF = triceps skinfold; WHO = World Health Organization.

significantly higher than the AUC for the international recommended cut-offs. Similarly, the AUC for WHtR based on a population cut-off of 0.53 was significantly higher than that based on the cut-off of 0.50 (99.4: 98.6, 100.0 *vs* 91.6: 87.8, 95.4). Among males, there were significant differences in the AUCs between the international recommended TSF-*z* and WC cut-offs based on our population data. This further supports the need for developing population-specific cut-offs (32, 33).

Among females, cut-offs based on TSF *z*-scores had significantly lower AUCs than those based on WHO-BMI. Nevertheless, the large likelihood ratio associated with TSF *z* suggests that in practice it may be significantly superior to those based on CDC-BMI, IOTF-BMI and WHtR at identifying females with excess body fat. The TSF was the only measure that attempted to measure adiposity by measuring fat folds (34). These findings also suggest that TSF may be the better measure for tracking adiposity over time in this group. We should also note that the confidence intervals for the positive likelihood ratio of WHO-BMI overlapped with those of TSF *z*. Notwithstanding, all recommended anthropometric-based cut-offs performed better than chance at identifying participants at increased risk for obesity in this population. Screening systems based on population and gender specific cut-offs for BMI, WHtR and TSF *z*-scores should be used to rule out children with normal body fat.

The major strength of the study is that schools were randomly selected and all measurements were taken by one trained person. This would have ensured a high degree of consistency. Since the last published study on adiposity in Trinidad was done at least 10 years ago, this study provides timely and relevant information on the current nutritional status of our preschool children. It also allows for international comparisons with other studies. The study's cross-sectional nature does not however allow for gauging changes in adiposity in individual children over time. A longitudinal-type design may further improve our understanding of adiposity in this population, especially in males and in children of African descent. Future research should focus on exploring associations between cut-offs and obesity-related health outcomes in Trinidadian preschool children.

CONCLUSION

The indices that produced lower sensitivity ratings could have their existing cut-offs lowered, so as to correctly identify more children with excess adiposity. This is highly recommended in health screening programs if one is to accurately identify the child with excess adiposity and intervene at earlier stages. Hence, high sensitivity may be a more important consideration than specificity in choosing an appropriate screening tool for childhood obesity (35). Screening systems based on population and gender-specific cut-offs should therefore be used to rule out children with normal body fat.

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