Using Receiver Operating Characteristic Curve Analysis in Detecting Excess Adiposity in 9-13-year Old South African Children

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ABSTRACT

Objective: Little is known concerning the applicability of receiver operating characteristic (ROC) curve analysis in detecting excess adiposity in preadolescent South African children. Therefore the purpose of this study was to evaluate the sensitivity and specificity of body mass index (BMI) and skinfold thickness:BMI (subcutaneous to overall fat) in detecting excess adiposity in preadolescent urban South African school children.

Methods: This was a cross-sectional survey of 1136 randomly selected children (548 boys and 588 girls) aged 9-13 years old in urban (Pretoria Central) South Africa. Body mass, stature, skinfolds (subscapular, triceps, supraspinale and biceps) and waist circumference were measured. Receiver operating characteristic curve analysis was used to assess the sensitivity and specificity of BMI, and $\log_{10}$ SF4:BMI to detect excess adiposity. Excess adiposity was defined as levels of $\log_{10}$ SF4 greater than the internally derived 85th percentile ($\log_{10}$ SF4 > 85th percentile).

Keywords: Adiposity, body mass index, children, obesity, receiver operating characteristic (ROC) curve analysis, sensitivity, specificity

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Results: Compared to $\log_{10}$ SF4:BMI, BMI had a high specificity (0.88; 95% CI 0.84, 0.90). The $\log_{10}$ SF4:BMI identified excess adiposity with a sensitivity and specificity of 0.62 (95% CI 0.60, 0.67) and 0.68 (95% CI 0.64, 0.70), respectively. Besides, a decrease in overall misclassification with the use of $\log_{10}$ SF4:BMI instead of BMI at the 95th percentile (9.7% *versus* 27.1%) was observed.

Conclusion: Similar to other studies, although with varying degrees, the present study confirms that $\log_{10}$ SF4:BMI at conventional cut-off points has a relatively high sensitivity and specificity in detecting excess adiposity, and therefore could be used to identify the excess adiposity in South African children. As such, defining obesity based on population-specific percentiles rather than using cut-off points derived from other geographical settings with contrasting levels of socio-economic development becomes imperative.

INTRODUCTION

In recent years, the prevalence of childhood obesity has risen dramatically in most parts of the world (1). Both developed and developing countries are experiencing upward trends in childhood overweight and obesity with varying dimensions (2). Current estimates (3) have shown that in 2010, 43 million children (35 million in developing countries) are overweight and obese and 92 million are at risk of overweight. The global prevalence of childhood overweight and obesity is shown to have increased from 4.2% in 1990 to 6.7% in 2010 (3).

The estimated prevalence of childhood overweight and obesity in Africa in 2010 is 8.5% and is expected to reach 12.7% in 2020 (3). In the sub-Saharan Africa (4–6), overweight and obesity rates of 17.1–22.8% have been reported among South African children. The surging trends in overweight and obesity worldwide indicate the public health consequences of the rapid westernization, urbanization, and mechanization of modern society.

The consequences of childhood obesity and adolescent overweight and obesity are enormous and include the subsequent development of chronic non-communicable diseases, psychological dysfunction and excess adiposity in adulthood (7–10). The short-and long-term risks to both physical and psychological health in childhood obesity translate into a reduced quality of life (11, 12). Given the adverse consequences of obesity, it is necessary to prevent and control childhood overweight and obesity in order to produce a healthy population in the future.

It is postulated that prevention of childhood obesity might not be feasible unless tracking is done appropriately (13). Usually, the body mass index (BMI) has been used to track obesity in children because of a significant association between BMI and fat mass (13). One possible way is to utilize sensitivity (true-positive rate) and specificity (false-positive rate) of BMI and skinfold thickness to detect excess mass in children (13). The use of receiver operating characteristic (ROC) curve analysis is to evaluate the accuracy of a diagnostic test by summarizing the potential of the test to discriminate between the absence and presence of a health condition (14, 15). Several studies (13, 16, 17) have reported that BMI generally has low sensitivity compared to skinfolds in tracking excess adiposity when applied to children, adolescents and young adults. It is not known whether this is applicable to South African children as hardly any study has been undertaken utilizing sensitivity and specificity in detecting excess adiposity in South African children. Such data could be useful to define overweight and obesity in South African children. It was hypothesized that the specificity and sensitivity of BMI and log10 SF4:BMI would not yield significantly conflicting results in detecting excess adiposity among South African children.

SUBJECTS AND METHODS

This study was a cross-sectional survey among primary school children aged 9-13 years, attending public schools in Pretoria Central, Gauteng province in South Africa. A total of 1286 children were selected to participate in the study. However, due to absenteeism and incomplete data of 150 participants, 1136 participants (548 boys and 588 girls) eventually completed the tests and their data were used in the statistical analysis.

The sampling frame was defined using the enrolment number for each school. This study employed a stratified, two stage cluster sampling strategy. This procedure ensures adequate representativeness of the study population in the sample. The procedure involved arrangement of the study population into schools and class-level clusters. The first stage involved selecting randomly, schools with a probability proportional to the size and enrolment of each school. The second stage involved selecting classes within the participating schools systematically and with equal probability of participation. This afforded all learners, in the selected classes, the eligibility to participate in the study.

The nature and scope of the study were explained to the children and their parents who gave informed consent. Approval for the study was given by the Gauteng Department of Education (DoE), Johannesburg, South Africa. The Ethics Committee of the Tshwane University of Technology, Pretoria, South Africa approved the research protocol before data collection.

Participant's body mass was measured without shoes and with light clothing to the nearest 0.1 kg, using a digital scale (Tanita-HD 309, Creative Health Products, MI, USA). Their stature was measured to the nearest 0.1 cm using mounted stadiometer. Skinfolds to the nearest 0.1 mm (subscapular, triceps, supraspinale and biceps) were measured according to the standard procedure of the International Society for the Advancement of Kinanthropometry [ISAK] (18). Body mass index and the sum of four (subscapular + triceps + supraspinale + biceps) skinfolds (SF4 in mm) were calculated. The SF4:BMI was derived.

The statistical procedures (13, 16) were followed for data analyses. The procedure involved log transformation ($\log_{10}$) of four skinfolds to obtain a normal distribution and the transformed values were used for further analyses. Consequently, four measured skinfolds (triceps, subscapular, biceps and supraspinale) were summed to obtain a composite of subcutaneous fat [4SF] (19). The percentiles (85^{th} and 95^{th}) were presented. Receiver operating characteristic curve analysis was used to assess the sensitivity and specificity of BMI, and $\log_{10}$ SF4:BMI to detect excess adiposity (13). Excess adiposity was defined as levels of $\log_{10}$ SF4 greater than the internally derived 85^{th} percentile [$\log_{10}$ SF4 > 85^{th} percentile] (13). All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 17.0. The statistical significance was set at $p \leq 0.05$.

RESULTS

Shown in Table 1 are the means and percentiles (85th and 95th) of BMI, $\log_{10}$ SF4 and SF4:BMI variables included in the ROC curve analysis. Table 2 provides a summary of the results on ROC curve analysis used to determine the sensitivity and specificity of BMI and $\log_{10}$ transformed skinfold thickness in detecting excess mass among the sample children. Compared to $\log_{10}$ SF4:BMI, BMI had a high specificity (0.88; 95% CI 0.84, 0.90). Together $\log_{10}$ SF4:BMI identified excess adiposity with a sensitivity and specificity of 0.62 (95% CI 0.60, 0.67) and 0.68 (95% CI 0.64, 0.70), respectively. Also, there was a decrease in overall misclassification with the use of $\log_{10}$ SF4:BMI instead of BMI at the 95th percentile (9.7% *versus* 27.1%).

DISCUSSION

The present study seeks to confirm whether $\log_{10}$ SF4:BMI at conventional cut-off points has a relatively high sensitivity and specificity in detecting excess adiposity in South African children as previously reported among Indian (13), Italian (16) and Jamaican (20) children. Body mass index data are commonly applied to detect excess adiposity in children (13). Nevertheless, several studies on children and adolescents have reported low sensitivity and high specificity associated with conventional BMI cut-off points used to classify overweight (13, 16, 20). The present study found the 95th percentile of BMI demonstrates a low sensitivity (0.37; 95% CI 0.35, 0.42) and relatively high specificity (0.62; 95% CI 0.60, 0.67) compared to the sensitivity of BMI in other studies (13, 16, 21) which were higher.

The present study observed that there was relatively high sensitivity (0.62; 95% CI 0.60, 0.67) and specificity (0.68; 95% CI 0.64, 0.70) at the 95th percentile of $\log_{10}$ SF4:BMI in detecting excess adiposity. Achieving high sensitivity and specificity simultaneously seems impossible and because of this, one has to give more premium to the relative importance of sensitivity and specificity (16). The use of the 85th percentile of $\log_{10}$ SF4:BMI (13, 16, 21) among South African children was associated with 11% less true negative and 2% more true positive compared to the 85th percentile of BMI. However, the 90th percentile of $\log_{10}$ SF4:BMI was associated with 7% more true positive than the corresponding BMI percentile. This observation seems similar to those reported in studies on Indian (13) and Jamaican (20) children. Among the Jamaican children, as assessed by triceps skinfold and sum of skinfolds, which was higher, the misclassification of the children was between 14% and 30%, respectively.

For the Indian children, the use of 90th percentile was associated with 10% true positive than corresponding BMI percentile.

The limitations of the study are worth noting. The use of BMI might not necessarily be appropriate in detecting excess adiposity in South African children. Direct assessments of fat mass using computed tomography (CT) and dual energy X-ray absorptiometry (DEXA) or other direct measures could have been more reliable, instead of SF4 which is used as proxy indicator. However, financial limitation hampers the feasibility of such undertaking. Additionally, only schoolchildren were studied. Therefore, the results of the present study do not necessarily apply to all South African children. Although the findings may not be representative of all South African children, the random sampling technique used in this survey optimized the representativeness of the samples.

In summary, the study confirms earlier studies indicating that $\log_{10}$ SF4:BMI at conventional cut-off points has a relatively high sensitivity and specificity in detecting excess adiposity and therefore could be used to identify excess adiposity in South African children. It will also be important in future studies to define obesity based on population-specific percentiles rather than using cut-off points derived from other geographical settings with contrasting levels of socio-economic development.

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Table 1: Mean and percentiles (85^{th} and 95^{th}) of BMI, $\log_{10}$ SF4 and SF4:BMI of participants (n = 1136)

Variable	Mean ± SD	Percentiles	
		85^{th}	**95^{th}**
Stature (cm)	145 ± 11	150.3	155.3
Body mass (kg)	42.1 ± 12.0	48.4	55.6
BMI (kg m^{-2})	19.7 ± 3.7	22.8	25.2
$\log_{10}$ SF4	44.0 ± 23.2	64.8	86.2
$\log_{10}$ SF4:BMI	2.23 ± 0.62	2.68	3.00

BMI: body mass index; SF4: skinfold thickness of subscapular, triceps, supraspinale and biceps

Table 2: Sensitivity and specificity of the 95^{th} percentile of BMI and $\log_{10}$ SF4:BMI in South African children

Variable	**SN (95% CI)**	**SP (95% CI)**
BMI	0.37 (0.35, 0.42)	0.88 (0.84, 0.90)
$\log_{10}$ SF4:BMI	0.62 (0.60, 0.67)	0.68 (0.64, 0.70)

Excess adiposity was defined as levels of $\log_{10}$ SF4 greater than the internally derived 85^{th} percentile ($\log_{10}$ SF4 > 85^{th} percentile).

BMI: body mass index; SN: sensitivity; SP: specificity