

Comparison of Body Mass Index (BMI) and fat percentage criteria classification of 7-13 year old rural boys in the Eastern Cape, South Africa

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Abstract

Background:

The aim of this paper is to investigate whether BMI and fat percentage classification criteria, would classify a sample in similar criteria's.

Methods:

A cross-sectional study with a stratified random sampling included 602 rural boys (7–13 years old). Fat percentage criteria classification and BMI was measured. Maturity, age and peak height velocity (PHV) were indirectly determined. Statistical techniques included descriptive, Pearson product correlation, the Kappa agreement test and the McNemar's test. The level of statistical significance was set at $p \leq 0.05$.

Results:

All age groups presented statistically significant high correlations between BMI and fat percentage, and low to medium correlations between fat percentage and maturity age (MA). Measurement of agreement between BMI and fat percentage classifications showed poor to fair agreements for all age groups, with the exception of the eight-year old group which presented a moderate agreement.

Conclusion:

Classifications according to BMI and fat percentage, results in different classifications for the same population. Classifications for categorizing purpose should make use of adiposity rather than BMI, as it includes fat free mass within the assessment protocol.

Background

Developing countries, such as South Africa, have to address malnutrition, which includes the double burden of both under nutrition and overweight/obesity among its population [1, 2]. Under nutrition (stunting and wasting) is linked more to lower socio-economic or rural areas [3]. Monyeki et al. [4] indicated that researchers reported high incidences of underweight, stunting and wasting among South African children, even more among boys from rural areas. Studies conducted among rural boys in South Africa have also reported increases in the prevalence of overweight and obesity [5–7]. Malnutrition was assessed in these studies by making use of the Body Mass Index (BMI). This method, and the interpretation of results related to BMI in children, has been questioned by some researchers [8, 9].

The biggest criticism against using BMI to assess overweight and obesity is that it also reflects fat-free mass [10] and, therefore, cannot be considered an accurate indicator of body fat mass [11] and

subsequently can contribute to misdiagnosis of malnutrition among children [12–14]. Roubenoff et al. [9] suggests that BMI inadequately predicts the percentage of body fat, while Craig et al. [8] suggests that BMI based assessments of body fatness tend to be conservative compared to other body composition methods.

More recent studies suggest that to combat overweight and obesity in children and adolescents, emphasis should rather be placed on assessing fat mass, and that the use of BMI as an indicator of the nutritional status should be used with caution [10, 13, 15] It should also be emphasized that various other factors such as environment, race, gender and sexual maturation, also influences BMI, which are not always reflected in the classification cut-off points [10].

In addition, early sexual maturation is associated with a greater prevalence of overweight and obesity when using BMI as the method of assessment [16–18]. Sampei et al. [19] states that differences in body composition can exist between different ethnic groups within the same population and that this could be due to sexual maturation and the wide variability in the onset of the growth spurt. Ribeiro et al. [16] also found early sexual maturation to be a risk factor associated with obesity among males, while Benedet et al [17] reported a lower prevalence of obesity among late maturing males. As such, it could be suggested that the onset of the growth spurt (maturity), and the wide variance among different ethical groups, might influence nutritional classification when using BMI.

Sampei et al. [19] also found that among 10–11 year old Japanese and Caucasian girls, the BMI correlated well with other classification methods of obesity. However, it was also reported in the same study that among 16–17 year old girls, the BMI presented low to no agreements with any other methods of determining obesity [19]. This suggests that maturity might be a factor that influences the method of classification used when classifying obesity, at least in girls. The question, however, is whether this would be the case for boys living in rural areas of South Africa? In South Africa, it has been reported that rural boys enter puberty later [20], and as international studies seem to suggest, those who mature at a later stage, tend to show a lower rate of obesity [16, 17], which is in contradiction with some of the nutritional studies published in South Africa [5–7]. Therefore, the aim of the study is to compare BMI and fat percentage criteria classifications of underweight, normal weight, overweight and obesity among rural boys, aged 7–13 years, residing in the Eastern Cape, South Africa.

Methods

Study design

This was a cross-sectional study and formed part of a bigger study titled “Evaluation of the national school nutrition programme and the Tiger Brands Foundation in-school breakfast programme in the Lady Frere and Qumbu district of the Eastern Cape, South Africa” [21]. This study was a joined project between Tiger Brands Foundation, the Centre for Social Development in Africa at the University of Johannesburg and the University of Fort Hare, South Africa.

Samples

A sample of 158 boys (aged 7–13 years) from secondary, combined and primary schools in the Lady Frere district and a further 243 in the Qumbu district of the Eastern Cape were included in the study. Lists of all the schools per district (Lady Frere and Qumbu) were obtained from the Eastern Cape Department of Basic Education, South Africa. Stratified random sampling was used to select the participating schools per district. A criterion for the inclusion of the schools was that they had to be Quantile 1–3 classification protocols for schools. Quantile 1–3 schools are schools that represent very poor to poor economic sectors from the same geographical environment. Stratified random sampling was used for the study to ensure that there was an adequate representation of schools at the 95% confidence level with a 5% margin for error. A total of 41 schools were identified. Within each school, stratified sampling by grade and gender was used to determine which students would participate in the study. Once the data set was cleaned, the final sample included 602 boys (aged 7–13 years). This provided a 2.57% margin for error at the 95% confidence level.

Instruments and measurements

All anthropometric measurements were taken according to the ISAK protocol (International Society for the Advancement of Kinanthropometry) [22]. Participants were measured with minimal clothing and no shoes. Body mass was measured to the 0.1 kg by making use of a SECA electronic scale. Body stature was measured as the perpendicular distance between the transverse planes of the *Vertex* and the inferior aspect of the feet, to 0.1 cm. Sitting height was measured as the perpendicular distance between the transverse planes of the *Vertex* and the inferior aspects of the buttocks when seated, to 0.1 cm. Arms span was measured as the perpendicular distance between the *dactylia* on the left and right arms with the arms outstretched horizontally, to 0.1 cm.

The triceps and calf skinfolds measures were taken using an Innovare skinfold calliper and were recorded to the nearest 0.5 mm. The triceps skinfold was taken parallel to the long axis of the arm at the triceps skinfold site (posterior surface of the arm, in the mid-line, at the level of the *Mid-acromiale-radiale* landmark), while the medial calf skinfold measurement was taken vertically at the medial calf skinfold site (the point on the most medial aspect of the calf at the level of the maximum girth). All measurements were taken twice, and in the event that the first two measurements differed with more than 0.5 cm/kg for the body mass and stature, and 0.5 mm for skinfolds, a third measurement was taken. The first two measurements were averaged and used. In the event of a third measurement, the median value was used. The sum of skinfolds consisted of triceps and calf skinfolds and fat percentage was calculated by making use of (Slaughter et al. 1988) fat percentage charts for boys. The BMI was calculated by dividing body mass with stature (kg/m^2).

Chronological age was calculated by subtracting the date of birth from the date of measurement, and classified in one-year intervals, for example, seven-year-old boys would be classified from 6.5–7.49 years. Table 1 indicates the total number of participants per age group as well as the ranges for each age group. Maturity age was defined by the timing of the adolescent growth spurt. Peak height velocity (PHV) and

age at PHV were determined for each participant. This estimation was done by making use of the equation of Mirwald et al. [23] by which maturity age is calculated by subtracting the age at PHV from the chronological age at the time of measurement. Those participants who matured early were classified with a maturity age less than - 0.50, while children who fell between - 0.49 to 0.48 were classified as those who matured averagely, while boys with a maturity age of more than 0.49 were classified as those who matured late. All the boys in this study were classified as those who matured late.

Data analyses and statistical methods

Descriptive statistics were calculated by using SPSS 23 for all variables and the mean, standard deviation and range (-95% and 95% Confidence levels) are reported in Table 1. Frequency statistics were used to establish the percentage classification in the BMI and fat percentage group criteria's. BMI values were classified according to International cut off points for thinness (grade1, 2, 3), overweight and obesity according to gender and age (2–18 years) [8, 24, 25]. The BMI classification for thinness, overweight and obesity for seven-year old boys (≤ 14.04 ; 17.92; 20.63), eight-year old boys (≤ 14.15 ; 18.44; 21.60), nine-year old boys (≤ 14.35 ; 19.10; 22.77), 10-year old boys (≤ 14.64 ; 19.84; 24.00), 11-year old boys (≤ 14.97 ; 20.55; 25.10), 12-year old boys (≤ 15.35 ; 21.22; 26.02) and 13-year old boys (≤ 15.84 ; 21.91; 26.84) were used. All other BMI values obtained not in the cut off values mentioned were classified as normal. Fat percentage criteria classification was done for low adiposity (≤ 10 mm), normal adiposity (11–25 mm) and high adiposity (≥ 26 mm) [26].

The Pearson product correlation matrix was used to establish relationships between BMI, Fat percentage and Maturity age. Correlation values were classified as low ($r = 0.1$), medium ($r = 0.3$) and high ($r = 0.5$) [27]. Lastly, the agreement of methods between the BMI and Fat percentage classification was statistically evaluated by making use of the Kappa agreement test [28]. The McNemar's test [29] was used to assess the significance of the differences between the two correlated proportions (according to the BMI and fat percentage classifications). The level of statistical significance was set at $p \leq 0.05$.

Results

Table 1 represents the descriptive statistics for 7–13 year old boys. As expected, stature and body mass increased with increasing age. The lowest BMI value was found for the eight-year old boys (15.98 ± 1.30) and this group only presented the third lowest fat percentage (9.61 ± 2.19) while the seven-year olds (9.34 ± 2.62) and nine-year olds (9.44 ± 4.17) had lower fat percentages. The 13-year old boys presented with the highest BMI values (17.73 ± 2.03), the second highest fat percentage (11.84 ± 4.96) and the lowest maturity age (1.92 ± 0.51), which indicates that they were the closest to reaching their PHV (sexual maturation). Another expected result was the maturity age in which it showed to be the highest for the seven-year olds (5.35 ± 0.23) as they were the furthest away from PHV. It is clear from Table 1 that all boys in this study were late developers in terms of reaching sexual maturation.

Table 2 presents the percentage occurrence into each criterion for BMI and fat percentage classifications. The highest percentage, when using BMI as classification criteria, is present in the normal weight

category among all the ages. However, when using fat percentage as classification criteria, the highest occurrence is in the low adiposity groups for seven to 10-year olds, as well as for the normal adiposity category for 11–13 year olds. It is noted that no occurrence was found in the high adiposity category for 7–8 year old boys, while 5.6%-4.9% was reported in the overweight/obesity category for the same age group. The occurrence of high adiposity classification and overweight/obesity classification are almost similar for nine to 13 year of boys. The percentage occurrence, in the low adiposity category, range from 52–59.2% for 7–13 year old boys, while the percentage occurrence in the thinness category is much lower, ranging from 3–12.3%. The most prominent difference between these two criteria for classification seems to apply to normal weight and thinness categories (in BMI) and the low-and normal adiposity (fat percentage) categories.

Table 3 represents the relationship between BMI, fat percentages and maturity age. Correlating BMI and fat percentage, the researchers controlled for maturity age (MA) as to exclude the variable from the correlation. Most of the age groups, with exception of the eight-year olds, presented high positive and significant correlation ($r \geq 0.50$) ($p \leq 0.05$) between BMI and fat percentage. The correlation between BMI and MA presented significant low ($r=-0.23$) to medium ($r=-0.46$) negative correlations for the 7–9 and 13-year old boys, while high significant negative correlations were found for 10–12 year old boys ($r=-0.51$; $r=-0.52$; $r=-0.64$). The correlation between fat percentage and MA presented similar tendencies that were observed between BMI and MA. However, the only age group that presented high significant negative correlations were the nine-year old ($r=-0.48$) and 12-year old ($r=-0.49$) boys. This seems to suggest that there is less of a relationship between MA and fat percentages, compared with MA and BMI.

The Kappa [28] and McNemar [29] analysis was done to determine the agreement between the classification criteria for BMI and fat percentage is presented in Table 4. The seven-year old boys presented with poor measure of agreement ($\kappa = -0.26$), while the nine to 11-year old boys presented with a slight measure of agreements ($\kappa = 0.11$ to $\kappa = 0.18$). The 12 and 13-year old boys presented fair measure of agreements ($\kappa = 0.22$ to $\kappa = 0.30$). The highest measure of agreements were found for the eight-year old boys ($\kappa = 0.57$). The McNemar test [29] to determine the differences between the paired proportion (in other words the proportions of how the children were classified according to BMI and fat percentage categories) indicated significant differences between these two classification methods.

Discussion

The main aim of this study was to compare BMI and fat percentage criteria for classification of underweight, normal weight, overweight and obesity among of 7-13-year old rural boys in the Eastern Cape Province, South Africa. The first shortcoming that needs to be mentioned is that maturity age was calculated indirectly and, therefore, limited studies are available that used this method. Our findings of the 7–13 year old boys maturing late is still in line with findings by Cole et al. [25] who also found that rural African boys tend to enter puberty later compared to other ethnic groups. A possible explanation for this could be that these boys come from very poor surroundings, which would result in some nutritional deficiencies. It is well documented that nutritional status is also known to affect puberty (maturation) [16, 30] and that this could explain why all the boys were classified as maturing late. The second shortcoming

is, that no “gold standard” method for assessing body composition was used, and it therefore cannot be concluded which of the methods used is more appropriate for this specific population. Nevertheless, the results present some correlations between BMI, fat percentage and MA as well as comparing the BMI and fat percentage classification criteria's.

The overweight and obesity occurrence among the 7–13 year old boys were much in accordance with other studies done in South Africa. It was reported that among 6–13 year old boys, 14.0% were overweight and 3.2% obese [7]. However, this study included all race groups from various socio-economical environments. It was also reported in another study that 6.4% were overweight and 3.3% had obesity among 6–7 year old children from Quantile 1–3 schools in the North-West province [31]. Although one study [17] reported a lower prevalence of overweight and obesity among late maturing males, it seems in this case that maturing boys are still classified as having high occurrences of overweight/ obesity. None of the boys in this present study presented with severe thinness, however, small percentages of thinness were still observed in grade 1–3, as determined by Cole et al [25].

The present study found a significant high correlation between BMI and fat percentage for all age groups, which is aligned with previous studies [10, 12, 13, 32–34]. It was however noted that higher correlations were found between BMI and MA in more age groups, compared to correlations between fat percentage and MA. This might imply that MA has a stronger relationship to BMI compared to fat percentage, which could possibly influence the classification criteria. Some studies have also found associations between obesity and sexual maturation, although not using the indirect method, when BMI was used as a classification criterion [16–18]. Not many studies could be found that used this indirect method of determining maturity and comparing it to body composition. One such study of Juliano-Burns et al. [35] conducted among adolescents, found that late maturing boys had more bone mineral density, more lean mass and were taller at the age of PHV compared to those who matured early. Seeing that all the boys in this study were maturing late, it might explain the high negative correlations between BMI and maturity age. The high lean mass could possibly influence the criteria classification according to BMI, as previous studies have highlighted this as a possible limitation of BMI [10, 13, 14]. Unfortunately, no studies could be found that reported any association between sexual maturation and fat percentage (using the skinfold method).

Conclusion

The differences in classification criteria of BMI and fat percentage for the 7–13 year old boys are evident. The strength of agreement between BMI and fat percentage criteria classification is poor to moderate, indicating that these two methods of criteria classification do not classify the same population in similar nutritional classifications. Although it cannot be said which of these classification criteria's are more appropriate for this population, it does warrant further investigation and some suggestions should be considered. Firstly, even though the use of BMI is acknowledged as cost effective and requiring low skill levels to administer, the limitation that it's a measure of heaviness rather than fatness cannot be ignored. Therefore, alternative methods should be developed that focus more on adiposity while considering the

influence of maturity. Some studies have investigated the height-to-waist ratio as a possible nutritional classification index [36–38] but there are still a few studies including rural populations. Secondly, future research should investigate the longitudinal influence of maturity (directly measured) on various body composition components among rural populations.

Abbreviations

BMI - Body Mass Index

PHV - Peak Height Velocity

MA - Maturity Age

ISAK - International Society for the Advancement of Kinanthropometry

Declarations

Ethics approval and consent to participate

This study was a joined project between Tiger Brands Foundation, the Centre for Social Development in Africa at the University of Johannesburg and the University of Fort Hare, South Africa. Ethical approval was obtained from the University of Fort Hare in collaboration with the Johannesburg (Reference number: GEN011). Both participants and parents/guardians provided consent to participate.

Consent for publication

N/A

Availability of data and materials

All data generated or analysed during this study available upon request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MVG collected data, formulated the paper and assisted in the write up. AP and HN reviewed the paper and assisted with the paper formulation and write up. All authors have read and approved the manuscript

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Tables

Table 1 The Anthropometrical measurements of 7-13 year old rural boys (mean ± SD, range)

Anthropometrical measures	7 year old n=71	8 year old n=82	9 year old n=93	10 year old n=100	11 year old n=101	12 year old n=82	13 year old n=73
Chrono logical age (years)	7.04 ± 0.29 6.51-7.49	8.06 ± 0.26 7.54-8.49	9.02 ± 0.30 8.52-9.47	9.97 ± 0.28 9.50-10.49	11.08 ± 0.27 10.53-11.49	11.92± 0.30 11.50-12.49	13.00 ± 0.29 12.51-13.49
Body mass (kg)	22.89 ± 2.52 22.29-23.48	24.71 ± 2.68 24.13- 25.30	27.02 ± 4.79 26.04-28.01	29.43 ± 5.20 28.32-30.46	32.88 ± 4.92 31.90-33.85	35.28 ± 6.41 33.87-36.69	39.70 ± 6.95 38.08-41.33
Body stature (cm)	119.32 ± 4.30 118.30- 120.33	124.29 ± 4.69 123.26- 125.32	128.97 ± 5.99 127.73- 130.20	132.91 ± 5.74 131.78- 134.05	138.31 ± 5.81 137.16- 139.46	141.99 ± 7.22 140.40- 143.58	149.29 ± 7.67 147.50- 151.08
BMI (kg/ml)	16.05 ± 1.28 15.75 - 16.35	15.98 ± 1.30 15.69-16.26	16.19 ± 2.10 15.76-16.62	16.58 ± 2.01 16.18-16.98	17.13 ± 1.84 16.76-17.50	17.39 ± 2.19 16.91-17.87	17.73 ± 2.03 17.20-18.27
Triceps skinfold (mm)	6.79 ± 2.28 6.24 - 7.32	6.82 ± 1.72 6.44-7.20	6.62 ± 3.02 6.00-7.25	7.24 ± 2.83 6.67-7.79	7.91 ± 3.56 7.21-8.62	8.35 ± 4.00 7.47-9.23	8.18 ± 4.07 7.24-9.13
Calf skinfold (mm)	6.90 ± 2.48 6.31 - 7.48	7.30 ± 2.24 6.82-7.80	7.21 ± 4.11 6.37-8.06	8.11 ± 3.98 7.32-8.90	8.99 ± 4.62 8.07-9.90	9.84 ± 5.45 8.64-11.04	9.58 ± 4.63 8.50-10.66
Sum of skinfolds (mm)	13.68 ± 4.29 12.76 - 14.70	14.12 ± 3.47 13.36-14.89	13.84 ± 6.84 12.43-15.25	15.35 ± 6.35 14.08-16.61	16.90 ± 7.69 15.38-18.42	18.20 ± 8.80 16.26-20.13	17.76 ± 8.13 15.87-19.66
Fat (%)	9.34 ± 2.62 8.72 - 9.97	9.61 ± 2.19 9.15-10.08	9.44 ± 4.17 8.58-10.30	10.36 ± 3.88 9.59-11.13	11.31 ± 4.70 10.38-12.24	12.10 ± 5.37 10.92-13.23	11.84 ± 4.96 10.68-13.00
Age at PHV (years)	12.40 ± 0.25 12.33 - 12.45	12.91 ± 0.22 12.87-12.96	13.35 ± 0.32 13.28-13.42	13.78 ± 0.33 13.71-13.84	14.25 ± 0.34 14.19-14.32	14.62 ± 0.42 14.53-14.71	14.92 ± 0.47 14.81-15.03
Maturity age (years)	5.35 ± 0.23 5.29 - 5.40	4.85 ± 0.25 4.80-4.91	4.32 ± 0.30 4.27-4.39	3.80 ± 0.36 3.72-3.87	3.16 ± 0.377 3.09-3.24	2.70 ± 0.44 2.60-2.79	1.92 ± 0.511 1.80-2.04

Table 2 Percentage occurrence of BMI and Fat percentage classification criteria of 7-13 year old rural boys

Age groups	Body mass index (BMI)			Fat percentage		
	Thi %	NW %	OW/OB %	LA %	NA %	HA %
7 year old	5.6%	88.7%	5.6%	59.2%	40.8%	0%
8 year old	6.1%	89.0%	4.9%	58.5%	41.5%	0%
9 year old	9.7%	87.1%	3.2%	65.6%	31.2%	3.2%
10 year old	6.0%	91.0%	3.0%	52%	45.0%	3.0%
11 year old	3.0%	94.0%	3.0%	43.6%	50.5%	5.9%
12 year old	9.8%	81.7%	8.5%	42.7%	47.6%	9.8%
13 year old	12.3%	83.6%	4.1%	42.5%	50.7%	6.8%

Thi = Thinness; NW= normal weight; OW/OB = overweight/ obese; LA = Low adiposity; NA= normal adiposity; HA= high adiposity

Table 3 Correlation between Body Mass Index (BMI), Fat percentage (Fat %) and Maturity Age (MA) for 7-13 year old boys (controlled for Maturity Age (MA))

Age groups	BMI vs Fat % <i>(Controlling for MA)</i>		BMI vs MA		Fat % vs MA	
	<i>r-value</i>	<i>p-value</i>	<i>r-value</i>	<i>p-value</i>	<i>r-value</i>	<i>p-value</i>
7 year old	0.69†	0.00*	-0.23	0.00*	-0.20	0.10
8 year old	0.45†	0.00*	-0.36	0.00*	-0.32	0.04*
9 year old	0.75†	0.00*	-0.44	0.00*	-0.48†	0.00*
10 year old	0.77†	0.00*	-0.51†	0.00*	-0.39	0.00*
11 year old	0.70†	0.00*	-0.52†	0.00*	-0.33	0.01*
12 year old	0.71†	0.00*	-0.64†	0.00*	-0.49†	0.00*
13 year old	0.54†	0.00*	-0.46†	0.00*	-0.25	0.03*

Low correlation $r = 0.1$; medium $r = 0.3$; high correlation $r = 0.5$ †; statistical significance $p \leq 0.05$.

Table 4 Kappa and McNemar measure of agreement between BMI and Fat percentage categorise for 7-13 year old rural boys

Age groups	Measure of agreement Kappa		McNemar test for significance
	Kappa (κ)	SoA	
7 year old	-0.26	Poor	0.00*
8 year old	0.57	Moderate	0.00*
9 year old	0.14	Slight	0.00*
10 year old	0.18	Slight	0.00*
11 year old	0.11	Slight	0.00*
12 year old	0.22	Fair	0.00*
13 year old	0.30	Fair	0.00*

SoA= Strength of agreement; Kappa Strength of agreement: Poor = <0.00; Slight =0.00-0.20; Fair =0.21-0.40; Moderate=0.41-0.60; Substantial = 0.61-0.80; Almost perfect = 0.81-1.00

Significance= $p \leq 0.05$

Supplementary Files

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