ORIGINAL ARTICLE

Correlation between Body Mass Index and Percent Body Fat Estimated by Bio-Electrical Impedance Analysis in Children of Karachi

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Abstract

Background: The current definition of obesity implies a rise in total body fat, which may only be evaluated through an examination of body composition. Body Mass Index (BMI) cannot detect percent body fat (BF%) effectively, prompting the need for novel, simple, affordable, and resource-constrained methods of body fat assessment and measurement.

Objective: To determine the correlation of BMI and BF% estimated by BIA in children of Karachi

Methods: This cross-sectional study was performed in a school located in Karachi. The study was conducted from January to April 2023. The permission to conduct this study was taken from the National Institute of Child Health and School Administration. Healthy children of age 6-15 years of either gender were enrolled in this study.

Results: Total 132 children were studied with a mean age of 10.8 ± 2.5 years. The age range was 6-15 years. There was almost equal representation of both gender with 50.8% males and 49.2% females. Median weight, height, BMI, and BF% of study subjects were 30.5 (IQR=23.4-42.4) Kg, 139.5 (IQR=128-153) cm, 15.4 (IQR=13.8-17.6) Kg/m2 and 10.2 (IQR=6.1-16.7) % respectively. A significant strong positive correlation was seen for overall data (rs=0.645, p<0.001). Out of 132 observations, concordance between BMI and BF% was seen in 46.2% of observations yielding a weighted agreement of 0.2961 which was significant (p<0.001).

Conclusion: This study analyzed that there was a strong positive correlation between the two body measures. However, the classification in terms of BMI and BF% ranges showed a difference for the same individual with slight agreement. The finding for the Pakistani population should be validated in a larger study.

Keywords: *Body mass index, body fat, body composition, correlation, agreement, relationship.*

INTRODUCTION

Overweight and obesity (OW/OB) in children are complicated public health issues that affect the majority of industrialized countries globally [1]. They are impacted by genetics, biology, psychosocial factors, and health behaviours. Over 340 million people between the ages of 5 and 19 years and 41 million children below 5 years of age are thought to be overweight/obese [2, 3]. Rates of paediatric overweight and obesity have recently begun to climb substantially in certain developing nations, despite long being thought to be a problem affecting exclusively industrialized countries [4]. With over half of OW/OB in children under 5 occurring in Asia, prevalence is rising most rapidly in low and middle-income countries [1, 4].

Childhood OW/OB has substantial repercussions that may be short-term or long-term. Short-term repercussions including psychological comorbidities asthma, and low-grade systemic inflammation are more prevalent in OW/OB children. Additionally, cardiovascular and metabolic determinants are more prevalent in kids with OW/OB. Long-term risk factors for cardiovascular and musculoskeletal issues and diabetes, in adulthood that may lead to disability and premature death include being overweight or obese as a kid [5-8]. Overweight and obesity are linked to 3.8% of Disability Adjusted Life Years and 3.4 million deaths globally [9].

The cause of childhood OW/OB is excessive calorie intake followed by excessive gain in mass and body fat. Body mass index (BMI), which reflects weight that is acceptable for height in both adults and children, is the most often used indicator of obesity. BMI has been regarded as a conventional tool for anthropometry measurement due to its simplicity, affordability, and ease of use [10, 11]. The weight component of BMI has drawn criticism because it does not discriminate extra fat, muscle, or bone mass, nor does it depict fat distribution in the human body. Thus, while being a frequently used proxy for body fat and obesity in healthy young people, BMI% has been found to characterize body composition incorrectly in a variety of populations, even in healthy young people [12, 13].

The current definition of obesity implies a rise in total body fat percentage (BF%), which may only be evaluated through an examination of body composition. The need for novel methods for the detection and measurement of body fat that would be simple, affordable, and practical to employ in resource-constrained locations

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Table 1: Body mass index z-score and Body fat percentage classification.

Body Mass Index Z-Score Classification	Z-Score Threshold Values	Body Fat Percentage Classification	A Fat Percentage Threshold Value
Underweight	<15th percentile	Under fat	<2nd percentile
Healthy weight	15th-85th percentile	Healthy fay	3rd-84th percentile
Overweight	86th-95th percentile	Overfat	85th-94th percentile
Obese	>95th percentile	Obese	≥95th percentile

as well as in epidemiological research resulted from BMI's failure to reliably identify and measure body fat. Skin-fold caliper measurement, underwater weighing (densitometry), dual-energy X-ray absorptiometry, near-infrared reactance, magnetic resonance imaging, and bio-electrical impedance analysis (BIA) are a few alternative methods for determining excessive body fat deposits [14].

The BIA is a straightforward, inexpensive, non-invasive, and portable approach that has the potential to be used in field situations and is known to offer a quick and reasonably accurate evaluation of body composition [15]. A variety of reference methods, including air displacement plethysmography, whole-body water hydrodensitometry, and dual-energy X-ray absorptiometry have been used to test the validity of BIA using BF% as the output variable [16]. Even the link between BMI and BF% has been defined as either linear or curved by some [17, 18]. Furthermore, studies on this topic from Pakistan are uncommon. Because of this, it is crucial to assess the Pakistani population, that's why we designed this study intending to identify the relationship of BMI with BF% calculated through BIA in Karachi children.

METHODOLOGY

This cross-sectional study was commenced with ethical approval of the National Institute of Child Health, Karachi, Pakistan from January to April 2023. The study was performed in a school located near NICH. The nearby school was chosen due to the ease of researchers for data collection (weak point). Permission was also taken from hospital administration before the study commencement. Healthy children of age 6-15 years of either gender were included in the study. Children with any known disease, dehydration, nausea vomiting, mental illness, and those who are unwilling to participate were excluded from this study. The sample was estimated using PASS version 11. A correlation of 0.7 between BMI and BF% was taken from a previous study [19], power was 95% and confidence level was 95% yielded a sample of 13 children. Non-probability convenience sampling technique was used to enlist study subjects. All of the study subjects were enrolled between 11:00 a.m. to 11:30 a.m. during their lunch break and it was made sure that children did not have lunch before the study enrollment.

Parents of children were also contacted through phone calls for taking the history of children to labelling them as healthy. Recent history of doctor visits during the previous 7 days to one month because of viral fever or any other complaint was considered as criteria to label unhealthy children. Moreover, parents were asked about weight loss history or other psychological disorders to confirm that child was healthy and free from any disease. Body weight and height were measured with the standard protocol using an electronic weight machine and stadiometer respectively. Using a stadiometer, height was calculated to the nearest 0.1 cm. The weight was measured with a digital weighing scale to the closest 0.1 kg. Weight (in kilograms) divided by height (in meters squared) was used to compute BMI. The WHO 2007 reference for BMI for children aged 5 to 19 (z-score) was utilized, and it was age- and sex-specific. Subjects were classified as being underweight, normal, overweight, or obese depending on whether their z-score fell within the 15^{th}, 15^{th} to 85^{th}, 86^{th} to 95^{th}, or >95^{th} percentile [20]. Using commercially available equipment RMH2011 that was calibrated with an accuracy of 5-50%, total body fat percentage (BF%) was calculated. The total body impedance value and the subject's pre-entered personal information (age, gender, height, and weight) were used to calculate the subject's body fat percentage (BF%). The closest 0.1% of the BF% was estimated. McCarthy percentile values of BF% were used to categorize BF% into four categories: under-fat, normal, over-fat, and obese [21]. BMI z-score and BF% classification is presented in Table **1**.

STATA (version 14) was used to enter data and perform statistical analysis. Frequencies and percentages were reported for categorical variables. Normality assumption was first assessed for numerical variables using the Shapiro-Wilk test. Non-normal variables were expressed as median with inter-quartile range (IQR). Spearman rank correlation was applied to evaluate the relationship between BMI and BF%. The weighted Kappa agreement test was statistically used to assess the degree to which the BMI and BF% classification had concordance. Kappa of the strength of 0, 0-0.20, 0.21-0.40, 0.41-0.60, 0.61-0.80, and 0.81-1.0 was considered as poor, slight, fair, moderate, significant, and virtually excellent respectively [22]. At $p \leq 0.05$, statistical significance was considered to be present.

RESULTS

Socio-demographic and Anthropometric Profile of Study Subjects

A total of 132 children were studied with a mean age of 10.8 ± 2.5 years. The age range was 6-15 years. There was almost equal representation of both gender with 50.8% males and 49.2% females. Median weight, height,

Table 2: Summary of socio-demographics and anthropometric measures.

Variables	Frequency (%)
Age categories	
6-9 years	43 (32.6)
10 years and above	89 (67.4)
Gender	
Male	67 (50.8)
Female	65 (49.2)
Body mass index	
Underweight	38 (28.8)
Healthy weight	81 (61.4)
Overweight	10 (7.6)
Obese	3 (2.3)
Body fat	
Under fat	96 (72.7)
Healthy fat	26 (19.7)
Overfat	9 (6.8)
Obese	1 (0.8)

Table 3: Comparison of age and anthropometric profile among males and females.

Study variables	Male	Female	p-value
Age (in years)	12 (9-14)	11 (9-12)	0.005
Weight (Kg)	28.2 (21.5-43.9)	31.3 (26.2-40.1)	0.296
Height (cm)	131 (123-156)	142 (133-150)	*0.015
BMI (kg/m2)	15.6 (14.3-17.4)	15.4 (13.6-18.3)	0.419
Body fat (%)	7.4 (4.8-11.1)	14 (9.9-20.6)	**<0.001

All of the data is expressed as median with inter-quartile range, *Significant at p<0.05 level, **Significant at p<0.01 level.

BMI, and BF% of study subjects were 30.5 (IQR=23.4-42.4) Kg, 139.5 (IQR=128-153) cm, 15.4 (IQR=13.8-17.6) Kg/m2 and 10.2 (IQR=6.1-16.7) % respectively. Table **2** displays a summary of socio-demographics and anthropometric measures.

Table **3** shows a comparison of age, BMI, and body fat among male and female children. The two genders differed based on age (p=0.005), weight (p=0.015), and body fat (p<0.001).

Correlation of BMI and BF%

Table **4** represents the correlation of BMI with body fat. A significant strong positive correlation was seen for overall data (rs=0.645, p<0.001). **Fig. (1)** depicts a scatter plot of BMI and BF. The correlation was

Table 4: Correlation of body mass index and body fat index.

Variables	Correlation (r)	p-value
Overall	0.645	**<0.001
Age categories		
6-9 years	0.555	**<0.001
10 years and above	0.681	**<0.001
Gender		
Male	0.703	**<0.001
Female	0.804	**<0.001

Table 5: Agreement between body mass index and body fat range.

Body fat	Body Mass Index				Total
	Underweight n(%)	Normal n(%)	Overweight n(%)	Obese n(%)	
Low	36 (27.3)	58 (43.9)	2 (1.5)	0 (0)	96 (72.7)
Normal	2 (1.5)	20 (15.2)	4 (3)	0 (0)	26 (19.7)
High	0 (0)	3 (2.3)	4 (3)	2 (1.5)	9 (6.8)
Very high	0 (0)	0 (0)	0 (0)	1 (0.8)	1 (0.8)
Total	38 (28.8)	81 (61.4)	10 (7.6)	3 (2.3)	132 (100)

All of the data is expressed as n (%).

significantly moderate and positive for the age group 6-9 years (rs=0.555, p<0.001) whereas a strong significant correlation with positive direction was seen for the age group 10 years and above (rs=0.681, p<0.001). Among males, BF and BMI were found to be correlated significantly with a strong positive association (rs=0.703, p<0.001). Among females, the correlation between BF and BMI was significantly very strong and positive.

Agreement between BMI and BF%

Table **5** exhibits agreement between BMI and BF% ranges. Out of 132 observations, concordance was seen in 46.2% of observations yielding a slight agreement of (k=0.2961, p<0.001).

DISCUSSION

Our study's major goal was to comprehend the connection between Pakistani children's BMI and BF% (calculated using BIA). Numerous ethnic groups, notably in Western nations, have been researched in connection to the association between BMI and BF%. Asian children's bodies differ from those of other ethnic groups, including Black, Mongolians, and Caucasians. Since it has been observed that at the same level of obesity as determined by BMI, the population of South

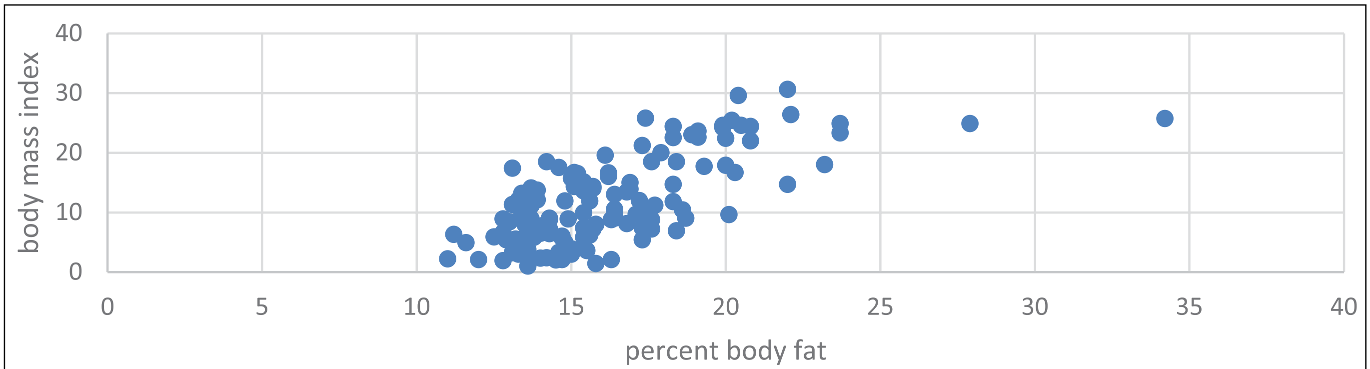

Fig. (1): Scatter plot of body mass index and body fat.

Asians may have a substantially higher BF% than that of other ethnic groups, it is necessary to comprehend the link of BMI with BF% in native Pakistani children. To the best of our knowledge, very few studies from Pakistan and other Asian countries have been published to address this research question.

In diverse populations, earlier research has shown a favorable association between BMI and BF% [23-25]. This study also supports the use of BIA to show a robust, positive connection between BMI and BF%. In a study done among 10-14 years children of India, a considerable correlation in a positive direction was observed between BMI and BF% ($r = 0.70$ and $P < 0.001$) [19]. A study from South Africa separately assessed the correlation for each age group from 7-13 years and it was demonstrated there was a moderate to strong positive correlation of BMI with BF% for all age groups ($r>0.5$) except for 8 years old children [24]. Another larger study investigating the correlation between BMI and BF% among 9-11 years children belonging to different countries including Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, the United Kingdom, and the United States, reported that correlation between BMI and BF% was ranging from 0.76 to 0.96 concerning children belonging to different countries [25]. Besides children and adolescent age groups, BMI and BF% relationship has also been studied among adults in different parts of countries which also reported results in line with our study [26-29].

Anthropometric measurements of child growth serve as a stand-in for changes in body composition [30]. A confluence of behavioural, genetic, and environmental factors causes changes in body composition with age [31, 32]. This study demonstrated that magnitude of BMI and BF% correlation was higher among children who were 10 years and above than children of age 6-9 years whereas direction was positive for both of the groups. Van Gent M *et al.* also found the influence of age on correlation as it was reported that BMI and BF% percent correlation was lower for 7 years ($r=0.69$) and 8 years children ($r=0.45$) whereas it was higher for children of age 9-12 years ranging from 0.71 to 0.77 [24]. Urrutia *et al.* also [33] reported that the relationship between BMI and BF% was higher for school children and adolescents than in pre-schoolers both male and female gender. Even the study conducted on adults also analyzed that age was a significant predictor of the relationship between BMI and BF% and it also showed that the correlation magnitude between two measures was increasing with increasing age [26]. Vanderwall *et al.* [27] also reported in their study that BMI z-score was a weak to moderate predictor of total fat mass and BF% among children of age <9 years.

Including age, another significant non-modifiable factor in the development of body fat in humans is gender [34]. In fact, during the first trimester of pregnancy, gender disparities in body size can be seen [35]. There has been growing evidence over the past 20 years that sex differences in body composition can be seen before puberty [36]. In this study, we also found a difference in correlation between males and females with a higher correlation for females. This finding was consistent with another similar study from China which reported that females had a better correlation between BMI and BF% compared to their male counterparts [37]. Urrutia *et al.* also demonstrated that the linear relationship of two adiposity measures was stronger in females ($R2=0.77$) than in boys ($R2=0.72$) [32]. Akindele *et al.* [26] reported a positive and strong correlation both for males and females but the magnitude was higher for females than males (0.89 *versus* 0.83).

In this study, although a positive relationship was seen there was disagreement in the classification of subjects based on BMI and BF% ranges. Using BMI, the majority were labelled as normal weight whereas the majority were identified to have low fat when BF% criteria were applied. The overall concordance was seen on only 46.2% of observations while the agreement level was slight. The lower concordance is alarming and raised a question on the accuracy of BMI as a measure of BF%. This finding is in line with the analysis of van Gent M *et al.* who found poor to moderate agreement for children of age 7-13 years old. Boys aged 7 to 11 presented with a weak measure of agreement ($k=-0.26$), while boys aged 9 to 11 presented with a weak measure of agreement ($k= 0.11$ to 0.18). The boys aged 12 and 13 displayed reasonable levels of agreement ($k = 0.22$ to 0.30). The eight-year-old boys had the highest level of agreement ($k=0.57$), which was nevertheless categorized as a moderate level of agreement [24]. A lower agreement rate between BMI and BF% was also found in a similar Saudi-based study with a kappa of 0.48 and 0.24 for boys and girls respectively [38].

This study was conducted on a limited sample size from a single school in Karachi. Moreover, anthropometry measures besides height and weight including waist and neck circumference, waist-to-hip ratio, and mid-upper arm circumference were not observed in this study. Further studies with larger sample sizes are necessary to be conducted using a nationally represented sample to confirm the results of the study.

CONCLUSION

This study analyzed that there was a strong positive correlation between the two body measures. However, the classification in terms of BMI and BF% ranges showed a difference for the same individual with slight agreement. The finding for the Pakistani population should be validated in a larger study.

ETHICAL APPROVAL

Ethical approval was obtained from the Institutional Ethical Review Board (IERB) of the National Institute of Child Health (NICH), Karachi (REF letter No. IERB-

35/2022). All procedures performed in studies involving human participants were following the ethical standards of the institutional and/ or national research committee and with the Helsinki Declaration.

CONSENT FOR PUBLICATION

Online informed consent was taken from survey respondents.

AVAILABILITY OF DATA

The data set may be acquired from the corresponding author upon a reasonable request.

FUNDING

Declared none.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORS' CONTRIBUTION

IS conceptualized the study. MNI designed the study protocol. SA and VRR were involved in data cleaning, analysis, result writing, and interpretation. IS and VRR prepared the initial draft of the manuscript. MNI provided constructive criticism and updated the original copy. The manuscript was reviewed and approved by all authors.

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