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ORIGINAL ARTICLE

BAIp as an Indicator of Measuring Adiposity among Preschool Children of Jalpaiguri, West Bengal, India

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ABSTRACT

Childhood obesity is a global concern, with approximately 39 million children under five being overweight or obese worldwide in 2020. The Body Mass Index (BMI) includes lean mass and fat components of the body, which may differ in children with similar BMI. Recently proposed Body Adiposity Index (BAI) is an alternative to BMI and this index shows equivalence in paediatric populations (i.e. BAIp). The present cross-sectional study was done on 1240 preschool children (boys 625; girls 615) aged 2-5 years from 48 Integrated Child Development Scheme centres in Maynaguri Block, Jalpaiguri, West Bengal, India to evaluate childhood obesity and association between adiposity index and anthropometric variables to depict the adiposity. For this study various anthropometric measurements were recorded following standard methods. This study shows a significant sex difference was found in children's height and weight with higher mean values for boys than girls. The correlation between BAIp and Waist Height Ratio (WHtR) was higher than for BMI, Body Mass Adiposity Index (BMAI) and Tri ponderal Mass Index (TMI) respectively. The correlation between BMI and BMAI was higher than BAIp, TMI and WHtR respectively. Research shows that good adiposity measures should have a strong relationship with BMI, which is an indicator of overall adiposity. The present study confirmed the existing hypothesis that BAIp, as a new index for children's body fatness measures, works with acceptable accuracy, suggested researchers. It must be mentioned that the advantage of BAIp over other anthropometric measures of adiposity should be validated by other direct adiposity measures.

KEYWORDS

• Body Adiposity Index paediatrics • Preschool • Adiposity • Children

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INTRODUCTION

Childhood obesity is a global concern, with approximately 39 million children under five being overweight or obese worldwide in 2020 (Okunogbe *et al*., 2022). The health consequences of obesity increase the chance of long-lasting morbidities and an increased risk of premature mortality (WHO, 2009). Child obesity is associated with an increased risk of adult obesity and is considered one important health risk factor for many diseases (Brownell *et al*., 2009; Puder *et al*., 2011). While body mass index (BMI) is the recommended method for population or community-based screening, it has lower accuracy for the prediction of body fat among adults and children (Ellis *et al*., 1999). Kumar (2009) has proposed a new index of adiposity, namely the body mass abdominal index (BMAI), which was shown to differ in children having a similar BMI value, depending on their waist circumference measurements. The BMI consists of lean mass and fat mass components of the body, which differ due to body composition variation in children having similar BMI. Bergman argued the body adiposity index (BAI) was recently proposed as an alternative to BMI, and it can be calculated without the weight data, in field research which is much more convenient (Bergman *et al*. 2011). However, it is still unknown whether BAI performs better than BMI in children. Studies aimed to compare the accuracy of BMI and BAI for predicting PBF in a sample of children of the same ethnicity (Freedman *et al*., 2012; Zhao *et al*., 2013). BMI is not always considered to be a reliable indicator of adiposity because body mass includes both fat mass and lean body mass (Cole *et al*., 2007). BMI is unable to estimate the differentiation of fat mass from fat free mass during childhood growth (Wells, 2010; Thibault & Pichard, 2012.). Central obesity measures such as waist hip ratio (WHR) and waist height ratio (WHtR) are also associated with cardio metabolic comorbidities in young children (Browning *et al*., 2010; Baioumi, 2019). The relation of waist to height ratio and child adiposity shows not influenced by age and sex for children (Taylor *et al*., 2022). Body adiposity Index (BAI) utilised in adults but in contrast, BAIp shows its equivalence in paediatric populations represents a new index for estimating the body fatness of children, with acceptable accuracy when compared with a bioimpedance measures, done by El Aarbaoui *et al*., 2013. Building on the concept of BAI, the paediatric body adiposity index (BAIp) has recently been developed specifically as a screening tool for childhood obesity (Alves *et al*., 2017; Mahmoud *et al*., 2021). Tri ponderal mass index (TMI) is observed to be a practical convenient approach consistent throughout childhood and adolescence (Peterson *et al*., 2017; Ashley-Martin *et al*., 2019). It remains unclear whether TMI is superior to BMI in prediction of body fat in preschool children (Wang *et al*., 2020). Besides, BMI does not offer insight into body fat distribution, a crucial aspect of health assessment (Bray, 2023).

The use of BMI is limited by differences in body fatness for a given age, sex, and ethnic background (Freedman *et al*., 2008; Camhi *et al*., 2011; Datta Banik *et al*., 2016). Estimation of body fat percentage in children was developed by El Aarbaoui *et al*., in 2013 which was derived from the adiposity index which was developed by Bergman *et al*., 2011 essentially used to screen adults. El Aarbaoui *et al*., 2013 developed that BAIp equation is meant to be valid for large scale surveys.

The present study aims to evaluate the utilisation of the adiposity index for paediatrics as a tool to measure childhood obesity and its association with anthropometric variables to depict the adiposity among children of Maynaguri, Jalpaiguri, West Bengal, India. This investigation aims to verify the validity of adiposity measures in relation with BAIp among studied preschool children.

MATERIAL AND METHODS

The present cross-sectional study was done on 1240 preschool children (boys 625; girls 615) aged 2-5 years from 48 ICDS centres in Maynaguri Block, Jalpaiguri, West Bengal, India. All measurements were taken by a first author (AB). Anthropometric measurements were recorded following standard international protocol (Weiner & Lourie, 1981; Lohman *et al*., 1988). The heights of the subjects were recorded with the help of an anthropometer to the nearest 0.10 cm. The weight of the children wearing minimal clothing and with bare feet was recorded using a portable digital weighing machine to the nearest 0.1 kg. Waist and hip circumferences were measured using a plastic fibre tape (non-stretchable) directly on the skin at the level of the iliac crest (for waist) and at the maximum extension of the buttocks (for hip) (Wang *et al*., 2009).

Other derived indices included

WHR = waist circumference (cm) / hip circumference (cm). (WHO, 1995).

WHtR = waist circumference (cm) / height (cm) (WHO, 1995).

BMI (kg/m^2) = Weight (kg) / Height (m^2) (WHO, 1995).

Conicity Index (CI) = waist circumference / (0.109 x square root of weight/ height)] (Taylor *et al*., 2000).

TMI (kg/m^3) = Weight(kg)/ Height $(m)^3$ (Peterson *et al*., 2017).

BMAI = weight / height x waist circumference / height

= weight / $(height)^2$ x waist circumference

= BMI x waist circumference where weight is in kg and waist circumference and height is in metres (Kumar, 2009).

BAIp (%) = Hip Circumference/$(Height)^{0.8}$– 38 (El Aarbaoui *et al*., 2013).

Statistical analysis

Student t-tests were performed to test for significant sex differences of various adiposity measures. Linear regression and Pearson correlation coefficient (r) were performed to test for association of BAIp and BMI with other adiposity measures. All types of statistical analysis were performed on SPSS (v 18).

RESULTS

Table 1: Descriptive statistics of age and anthropometric characteristics among studied preschool children

Variables		N	Mean	SD	t
Age (years)	Boys	625	3.48	1.10	.539^{NS}
	Girls	615	3.44	1.04	
Height (cm)	Boys	625	97.54	9.58	3.766***
	Girls	615	95.52	9.28	
Weight (cm)	Boys	625	14.23	3.36	4.010***
	Girls	615	13.50	3.08	
Waist Circumference (cm)	Boys	625	47.73	4.25	1.449^{NS}
	Girls	615	47.38	4.22	
Hip Circumference (cm)	Boys	625	50.12	4.64	-.344^{NS}
	Girls	615	50.21	4.78	
Waist Hip Ratio	Boys	625	0.94	0.02	5.403***
	Girls	615	0.95	0.03	
Waist Height Ratio	Boys	625	0.49	0.03	-3.284**
	Girls	615	0.50	0.04	
Body Mass Index (kg/m^2)	Boys	625	14.83	1.73	1.506^{NS}
	Girls	615	14.68	1.69	
Conicity Index	Boys	625	1.15	0.05	-3.332**
	Girls	615	1.16	0.05	
Tri Ponderal Mass Index (kg/m^3)	Boys	625	15.37	2.46	-1.209^{NS}
	Girls	615	15.53	2.48	
Body Mass Adiposity Index	Boys	625	7.11	1.40	1.529^{NS}
	Girls	615	6.99	1.35	
Body Adiposity Index (p)	Boys	625	13.23	3.24	-4.964***
	Girls	615	14.18	3.53	

**p<0.01; ***p<0.001; NS - not significant

Table 1 shows mean (± standard deviation) values of age in boys (3.48 ± 1.10 years) and girls (3.44± 1.04 years) were not significantly different (p> 0.05). A t test shows significant sex difference (p< 0.05) was found in children's height and weight with higher mean values for boys than girls. On the other hand, significant sex difference ($p< 0.05$) was found with respect to WHR, WHtR, CI, and body adiposity index (BAIp) were also observed where girls had higher mean values than boys.

Table 2: Regression analysis of body adiposity index (BAIp) in response to the anthropometric characteristics among studied children

	Predictors	B	SeB	Beta	t	R	Adj R2	F change
Model 1	Constant	-12.376	.719					
	Sex	1.118	.119	.164	9.375***			
	Age	-2.182	.064	-.684	-34.235***			
	WC	.672	.016	.833	41.658***	.790	.623	684.252***
Model 2	Constant	-12.885	.575					
	Sex	.815	.101	.119	8.047***			
	Age	-2.388	.055	-.749	-43.470***			
	HC	.671	.012	.924	53.658***	.854	.728	1106.233***
Model 3	Constant	46.112	3.250					
	Sex	.658	.181	.096	3.642***			
	Age	-1.010	.084	-.317	-11.986***			
	WHR	-31.508	3.306	-.255	-9.532***	.398	.156	77.524***
Model 4	Constant	-34.557	.851					
	Sex	.360	.093	.053	3.857***			
	Age	.777	.051	.244	15.162***			
	WHtR	91.037	1.503	.978	60.571***	.879	.772	1397.586***
Model 5	Constant	-8.651	.578					
	Sex	1.161	.112	.170	10.384***			
	Age	-.540	.053	-.169	-10.255***			
	BMI	1.523	.033	.766	46.325***	.818	.669	835.753***
Model 6	Constant	-6.747	2.134					
	Sex	.737	.178	.108	4.143***			
	Age	-1.100	.085	-.345	-12.929***			
	CI	19.975	1.892	.283	10.560***	.414	.169	85.145***
Model 7	Constant	-8.273	.770					
	Sex	.784	.134	.115	5.854***			
	Age	.801	.080	.251	9.987***			
	TMI	1.166	.035	.843	33.461***	.725	.525	457.089***
Model 8	Constant	2.132	.324					
	Sex	1.156	.098	.169	11.797***			
	Age	-1.286	.046	-.403	-27.819***			
	BMAI	2.025	.036	.817	56.314***	.864	.747	1213.991***

***p<0.001

The linear regression models for BAIp in relation to the adiposity measures (separately for WC, HC, WHR, WHtR, BMI, CI, TMI, BMAI) along with sex and age in boys and girls showed consistently significant ($p< 0.05$) interrelationships between the dependent variable (BAIp) and predictors (Table 2). The regression models were significant, and residuals were normally distributed in the present result. The regression coefficient of WHtR (91.031) was quite high and adjusted R-square (0.77) value showed highest variation in BAIp explained by the predictors (Model 1). Another index for central obesity, CI also showed significant interrelationship with BAIp where regression coefficient 19.975 and adjusted R-square (0.16) (Model 2). However, the regression coefficient was found for BMAI (2.025), BMI (1.523) and TMI (1.166) respectively.

1. Pearson's correlation between Body Adiposity Index (BAIp) and anthropometric characteristics

	BAIp		
Variables	**Boys**	**Girls**	**Sex Combined**
WC	.469**	.536**	.492**
HC	.521**	.572**	.544**
WHR	-.226**	-.188**	-.221**
WHtR	.859**	.845**	.852**
BMI	.789**	.806**	.782**
CI	.145**	.254**	.211**
TMI	.694**	.690**	.689**
BMAI	.745**	.780**	.747**

**p<0.01

Table 3 shows the correlation between BAIp and WHtR (boys: r = .859, girls: r = .845, sex combined: r = .852) was higher than for BMI, BMAI, TMI respectively and other anthropometric parameters (p< 0.05) in boys and girls. In case of sex combined sample BAIp is highly correlated with WHtR then BMI, BMAI and CI respectively, negative correlation found only with WHR.

2. Pearson's correlation between Body Mass Index (BMI) and anthropometric characteristics

	BMI		
Variables	**Boys**	**Girls**	**Sex Combined**
WC	.512**	.551**	.532**
HC	.521**	.514**	.517**
WHR	-.082*	.026	-.018
WHtR	.677**	.736**	.699**
BAIp	.789**	.806**	.782**
CI	-.245**	-.096*	-.176**
TMI	.754**	.775**	.761**
BMAI	.893**	.904**	.899**

*p<0.05; **p<0.01

Table 4 shows the correlation between BMI and BMAI (boys: r = .893, girls: r = .904, sex combined: r = .899) was higher than BAIp, TMI and WHtR respectively and other anthropometric parameters (p< 0.05) in boys and girls. In case of sex combined sample BMI is highly correlated with BMAI then BAIp, BMAI TMI and WHtR respectively, negative correlation found with WHR and CI.

DISCUSSION

The diagnostic criteria on children obesity have become an important topic for research in the last decade. The "BAI" is a direct estimate of percent body fat as a result of overweight and obesity in adults. Calculating BAI does not require a measurement of body weight (Bergman *et al*., 2011). BAIp may both over and under estimate the percent body fat as adiposity measure when the weight status, gender and age category of children are considered (El Aarbaoui *et al*., 2013). Body adiposity index (BAI) is not able to predict percent body fat in children and indeed overestimates percent body fat (Filgueiras *et al*., 2019; Ye *et al*., 2020). Whereas the equivalence of BAIp in paediatric populations represents a new index for estimating the body fatness of children, each adiposity indicator has its own limitation on accuracy. Body composition and obesity levels vary among different ethnic groups (El Sayed *et al*. 2011). Therefore, one should consider ethnic-specific characteristics, and the advantage of adiposity indicators such as BAIp and BMAI (Biswas and Bose, 2010; Zhao *et al*., 2015).

Study revealed the difference in the effectiveness of BMI, BAIp and TMI for obesity screening in preschool children between sexes differs due to physiological disparities in body fat and body composition distribution (Freedman and Sherry, 2009). Research argued that BAIp is a better marker of overweight and body fat in obese children than BAI (Daboshi *et al*., 2017). Studies suggest that BAIp equations were developed to evaluate body composition and can be utilised as an alternative to BMI in the diagnosis of overweight and obese children (Bergman *et al*., 2011; de Souza *et al*., 2015; Filgueiras *et al*., 2019). Research reported on Brazilian children where BAIp shows lower agreement with DXA for the estimation of body fat (Filgueiras *et al*., 2019). Wang *et al*., 2024 reported BAIp proves to be more reliable indicators of obesity in boys compared to BMI and TMI but BAIp and BMI shows similar screening performance in girls.

Assessing adiposity is challenging and important during preschool age. Research shows that good adiposity measures should have a strong relationship with BMI, which is an indicator of overall adiposity (Biswas and Bose, 2010), Adiposity measures in particular sites may reflect the regional adiposity but fail to be accurate with overall body mass index (Biswas and Bose, 2010). The correlation of BMI with BMAI was similar to the present finding reported by previous research (Biswas and Bose, 2010; Das and Bose, 2011). BAIp measures among children should be assessed due to inexpensive, simple, non-invasive methods, use of portable instruments and be applicable in large-scale surveys (Datta Banik *et al*., 2016). The previous studies developed one such indicator (BAIp) to estimate adiposity in children using anthropometric measurements (El Aarbaoui *et al*., 2013; Datta Banik *et al*., 2016). However, it is well established that there exist significant ethnic differences in the relationship between regional adiposity and overall adiposity (Biswas and Bose, 2010).

Our study has further indicated that BMI may not be considered as a reliable measure of adiposity due to its limitation among preschool children. In the studied sample, boys showed a higher mean value of BMI than girls, but no sex difference was found, whereas girls showed higher mean of BAIp and CI with significant sex difference ($p < 0.05$) similar to previous study (Datta Banik *et al*., 2016). The regression models showed that WHtR predicted BAIp with highest coefficient while other anthropometric parameters also had significant association ($p < 0.05$) supporting the previous finding (Datta Banik *et al*., 2016). The present study confirmed the existing hypothesis that BAIp, as a new index for children's body fatness measures, works with acceptable accuracy suggested researchers (El Aarbaoui *et al*., 2013; Datta Banik *et al*., 2016).

Present findings suggest the mean adiposity measures are compatible with Bengalee Muslim children of Nadia, West Bengal (Biswas and Bose, 2010), Hindu caste tribal children of Purulia, West Bengal (Datta Banik *et al*., 2016) may be the reason for similar regional backgrounds.

The advantage of using BAIp over other anthropometric measures of adiposity should be validated with other measures of adiposity like BMI, BMAI CI, TMI. The identification of a variety of non traditional obesity measures is essential for better prediction than the traditional adiposity measures. Although few studies reported that BMI is better predictor tool than BAI for estimating adiposity in the paediatric field (Zhao *et al*., 2013; El Aarbaouli *et al*., 2013; Dong *et al*., 2015; Yu *et al*., 2015). Thus, we suggest that similar studies, utilising BAIp and BMAI be undertaken with other conventional adiposity measures among children.

Present study has its limitations due to cross sectional nature and small sample size; present study limited our ability to assess the accuracy of BAIp tracking changes over time. Factors like regional variation and socioeconomic status could influence the generalisability of the present finding. Further studies are required to improve its predictive ability of adiposity among preschool children of different populations.

CONCLUSION

Our research clearly indicates the new index of adiposity has distinct advantages and is strongly associated with adiposity measures. BAIp could potentially serve as a promising alternative of screening adiposity indicators among preschool children of different community settings. However, it is recommended that the public health sector consider incorporating BAIp as routine screening. Thus, our study suggests that similar studies be undertaken among preschool children of various ethnic/racial groups by using the new index BAIp. It must be mentioned that the advantage of BAIp over other anthropometric measures of adiposity should be validated by other direct adiposity measures like magnetic resonance imaging (MRI) and Dual X-Ray Absorptiometry (DEXA) among preschool children.

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