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ORIGINAL ARTICLE

Agreement Analysis among Measures of Thinness and Obesity Assessment in Iranian School Children and Adolescents

Seyyed-Mohammad-Taghi Ayatollahi[1AEFG], PhD, FSS, CStat; Zahra Bagheri[1ABCDG], PhD; Seyyed-Taghi Heydari*[2,1ABCEG], PhD

Authors' Affiliation:

1. Department of Biostatistics, Shiraz University of Medical Sciences, Shiraz, IR Iran
2. Jahrom University of Medical Sciences, Jahrom, IR Iran

Authors' Contribution

A Concept / Design
B Acquisition of Data
C Data Analysis / Interpretation
D Manuscript Preparation
E Critical Revision of the Manuscript
F Funds Collection
G Approval of the Article

*** Corresponding Author;**

Address: Jahrom University of Medical Sciences, Jahrom, Islamic Republic of Iran

E-mail: heidaryt@sums.ac.ir

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Abstract

Purpose: **This study investigated the agreement of four anthropometric-based measurements including weight-for-height (WH), body mass index-for-age (BMI), mid-upper arm circumference-for-age (MUAC) and triceps skinfold thickness-for-age (TST) to identify underweight and overweight children and adolescents.**

Methods: **Two data sets were used in this research. The first one was a multistage random sample of 2397 healthy school children in pre-pubertal stage in Shiraz. The second data set consisted of 487 healthy students in pubertal stage and 558 students in post-pubertal stage. The parametric LMS method was used to construct reference centiles curves for each measure. The Kappa statistic was applied to examine the pairwise agreement of the four indices for detecting thinness and obesity.**

Results: **Generally, the pairwise agreement of adiposity measures was higher for identifying obesity than thinness. There was an excellent agreement between WH and BMI for detecting both thin and obese children in almost all subgroups (P<0.001). MUAC had an excellent agreement with BMI in pre-pubertal individuals (P<0.001). However, TST had a weak agreement with the other three indices for detecting thinness and weak to good agreement for classification of obesity.**

Conclusion: **The performance of the four anthropometric-based measurements varied by sex and maturity level. MUAC as a simple and low-cost screening tool can also be used as an alternative to BMI for obesity assessment among pre-pubertal groups.**

Key Words: Anthropometry; Body Composition; Obesity; Adolescents; Children; Agreement Analysis

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INTRODUCTION

The worldwide growing pattern of childhood obesity has been identified as an important health problem over the past decades [1-5]. Obesity during childhood has been established to be strongly associated with that in adulthood and also with several chronic diseases such as diabetes, some types of cancer and cardiovascular diseases [1-6]. In addition, being underweight is an index of malnutrition and is also recognized as an underlying cause of some health disorders [7-8]. Therefore, proper assessment of the body composition is a critical concern in public health evaluation and clinical screening. The reference methods such as dual-energy X-ray (DXA) or underwater weighting, which can analyze body composition accurately, are limited to the clinical research due to their complexity and cost [9-11]. Instead, a variety of anthropometric-based measurements such as body mass index (BMI), weight-for-height (WH), triceps skinfold thickness (TST) and mid-upper arm circumference (MUAC) were introduced as simple, low cost and feasible methods [9-11]. Previous studies showed that different indices estimate different values for the prevalence of underweightness or overweightness which may lead to unnecessary and inappropriate clinical intervention [12]. Therefore, selecting the most appropriate and feasible method among a variety of existing obesity indices is an important key to a successful clinical decision. The performance of the aforementioned anthropometric measurements has been evaluated by pioneer researchers, demonstrating that each method has its own advantages and disadvantages and behaves differently in different age and sex groups [6, 9-11, 13]. However, a critical point which has not been comprehensively addressed is whether these body composition indices among various sex and maturation stage groups classify the same subjects as obese or thin which can be explored by agreement analysis. Although few studies have assessed the degree of pairwise agreement between a number of body composition indices in various age groups [10, 12, 14-16], to the best of our knowledge, no study has investigated the agreement of the all four obesity indices including BMI, WH, TST and MUAC simultaneously. Furthermore, most of the previously published studies have focused on just children or adolescents separately or have assessed children in a wide range of age altogether.

Therefore, the present study aimed at examining the pairwise agreement of these four indices for identifying thin and obese individuals based on two representative samples of school children and adolescents in Shiraz, Southern Iran. We also made an attempt to investigate the agreement analysis separately in different age groups according to maturation levels (pre-pubertal, pubertal and post-pubertal groups), which has not yet been considered in other studies.

METHODS AND SUBJECTS

Two data sets were employed for this study. To conduct agreement analysis among prepubertal school children we used a data set collected in the academic year of 2002-2003. This cross-sectional study includes measurements of weight, height, mid-upper arm circumference, triceps skinfold thickness and age of 2397 healthy school children (1129 girls and 1268 boys) in the age range of 6.5-11.5 years. The participants were randomly selected in a multistage method forming 2% of the school children from the four educational districts of Shiraz, one of the five main cities of Iran. The sample size was determined based on formula for each sex-age group (248 students), where is the variance of anthropometric measures estimated from previous study conducted in 1988 [17] and d is the precision. In each educational district, a 10% systematic random sample of schools was selected and within each school, using tables of random numbers, a 1in 5 sample of students were chosen. Three trained auxologists measured the anthropometric measurements of students in morning and evening shifts.

Height and weight were measured to the 0.1 cm and 0.1 kg respectively, using a SECA marked stadiometer. A non-stretchable strip was used to measure the MUAC to the nearest 0.1 cm, based on the method proposed by Cameron [18]. Triceps skinfold thickness was measured using a graded caliper and recorded inmm. In addition, the subjects' ages were calculated exactly as the difference between the date of the interview and that of birth, which were recorded in their birth certificate accurately. To ensure that all children in this sample were in the pre-pubertal stage just some questions were asked from students and also their parents about the signs of puberty and individuals which were in pubertal stage were excluded from the study.

The second data set consisted of a total of 487 students including 217 boys and 270 girls in pubertal stage (aged 11.5-14.5 years) and 558 students including 382 boys and 276 girls in postpuberal stage (aged 14.5-18.5 years) which were randomly sampled by a multi-stage random sampling procedure from guidance and high schools of the four educational districts of Shiraz in the Spring of 2011. Determination of sample size was conducted in a similar procedure as the former study described above. Two guidance schools and two high schools were selected randomly and in each grade of the schools a random sample of the students were selected. In this study, weight, height, MUAC, and age were measured using the same techniques and devices as the former one by two trained auxologists, except TST which was measured to the nearest 0.5 mm. In this study, no exact criteria were used to classify participants in pubertal and post-pubertal categories. However, based on the mean and median age of girls and boys in different pubertal stages reported in the studies performed previously in Iran [19-20], we categorized students in guidance school to pubertal stage and those in high school to post-pubertal stage. The subjects' body mass index was obtained as weight divided by squared height in metric system (kg/m^2). The LMS method [21] was applied to calculate sex-specific weight-for-height, BMI-for-age, MUAC-for-age, and also TST-for-age centiles in each of the three stages of maturity. The growth reference centile charts for prepubertal children were provided in the previous studies [22-25]. Although there is still no comprehensive consensus on how to define underweight and overweightness based on growth reference centiles, in this study the 5th and 95th centiles (according to a number of references [22, 26-27] were selected as cut-off points to identify underweight and obese children, respectively. Kappa statistic was used to assess the pairwise agreement of the WH, BMI, MUAC and TST for classifying underweight and obese children. A value of zero indicates no concordance and a value of unity indicates perfect concordance. Kappa coefficient greater than 0.75 represents excellent agreement, between 0.40 and 0.75 fair to good agreement, and smaller than 0.40 poor agreement [28]. In addition, Pearson correlation analysis was conducted to evaluate the linear association of anthropometric measures. Data analysis was performed using LMSchartmaker and SPSS 11.5 softwares.

RESULTS

Table 1 presents the descriptive statistics of height, weight, BMI, MUAC and TST of school children classified by age and sex. Based on independent sample t-test, no significant gender difference was observed in terms of their BMI in all age groups (P>0.05) with the exception of the last age group in

Table 1: Number, mean and standard deviation of weight, height, BMI, MUAC and TST by age and sex

	Age (years)	6.5-7.49	7.5-8.49	8.5-9.49	9.5-10.49	10.5-11.49	11.5-12.49	12.5-13.49	13.5-14.49	14.5-15.49	15.5-16.49	16.5-17.49	17.5-18.49
number	Boys	225	237	249	261	284	76	46	76	163	127	86	23
	Girls	184	212	212	245	267	77	63	120	87	111	76	11
Weight Mean (SD)	Boys	22.3(3.7)	25.1(5.3)	28.1(5.9)	31.1(6.7)	33.8(7.4)	42.9(13.1)*	46.6(14.2)	53.3(12.5)*	61.2(14.7)*	63.5(15.7)*	63.4(10.7)*	71.5(16.5)*
	Girls	22.0(3.9)	24.6(4. 7)	27.7(5.7)	30.8(6.5)	34.9(7.9)	48.1(12.5)	49.1(12.7)	49.55(8.1)	55.2(10.9)	54.9(11.2)	54.1(8.5)	51.0(6.3)
Height Mean (SD)	Boys	119. 7(5.2)	125.2(5.8)	130.7(6.3)	135.6(6.3)	139.9(6.5)*	146.0(6.8)*	152.3(9.4)	160.6(7.6)*	166.5(7.2)*	170.3(7.9)*	171(5.6)*	171.7(5.4)*
	Girls	119.2(5.9)	124.6(5.8)	130.4(6.5)	136.1(6.6)	141.5(7.4)	152.0(6.7)	154.6(6.7)	156.6(6.7)	158.3(4.6)	158.9(4.8)	159.1(5.7)	156.2(6.4)
BMI Mean (SD)	Boys	15.5(1.8)	15.9(2.4)	16.4(2.4)	16.8(2.6)	17.2(2.7)	19.9(4.6)	19.7(4.4)	20.5(3.8)	21.9(4.6)	21.8(4.6)	21.5(3.1)	24.2(5.1)*
	Girls	15.4(1.8)	15.8(2.1)	16.2(2.3)	16.5(2.6)	17.3(2.9)	20.7(4.6)	20.4(4.4)	20.2(2.8)	21.9(3.9)	21.7(4.1)	21.4(3.1)	20.9(2.2)
MUAC Mean (SD)	Boys	17.2(1.8)	17.8(2.4)	18.6(2.4)	19.4(2.6)	19.8(2.7)	20.8(4.1)*	21.4(4.3)*	21.9(3.4)*	23.7(4.5)*	23.8(6.4)	24.3(2.9)	25.93(2.9)*
	Girls	17.4(1.9)	18.1(2.3)	18.7(2.3)	19.5(2.6)	20.2(2.7)	23.9(4.0)	23.9(3.8)	24.3(3.6)	25.3(3.5)	25.0(3.5)	24.7(3.2)	23.7(2.4)
TST Mean (SD)	Boys	7.2(3.8)	7.8(4.9)	8.5(4.7)	8.9(4.9)	9.4(5.6)	14.9(7.7)*	14.2(6.4)*	14.0(6.5)*	19.5(9.2)	18.6(9.4)	14.5(6.5)*	18.8(9.2)
	Girls	7.1(3.7)	8.4(4.1)	8.9(4.4)	9.9(5.0)*	10.5(5.2)*	19.48(7.9)	18.1(7.8)	16.8(5.7)	17.8(5.9)	18.2(6.3)	17.8(6.2)	15.3(4.2)

Table 2: Prevalence (%) of thinness (under 5th centile), and fatness (above 95th centile) by sex and puberty stages.

	Underweight						Obesity					
	Pre-pubertal		Pubertal		Post-pubertal		Pre-pubertal		Pubertal		Post-pubertal	
	boys	girls	boys	girls	boys	girls	boys	girls	boys	girls	boys	girls
BMI	4.3	4.1	4.0	4.6	3.5	6.3	5.8	5.8	7.0	5.0	6.8	4.9
WH	4.9	4.4	4.0	5.0	5.0	5.6	5.4	5.2	5.5	5.8	5.8	5.2
MUAC	5.8	4.3	6.0	5.4	3.8	5.2	6.1	5.2	5.0	4.2	5.5	3.5
TST	5.5*	3.4	6.5	5.8	4.8	3.8	5.1*	4.5	4.5	4.2	3.5	6.3

* Significant difference between boys and girls at 5% level; BMI: Body mass index; WH: weight-for-height; MUAC: mid-upper arm circumference-for-age; TST: triceps skinfold thickness-for-age

which the boys had a significantly greater BMI as compared to the girls. In addition, in younger children (less than 11.5 years), there was no significant difference between the two genders regarding their weight and height, though in older ones the weight and height of the boys was significantly higher than those of the girls. In terms of MUAC, just in the middle-aged children as well as the last age group significant differences were observed between boys and girls in which boys' MUAC was greater than that of girls. However, the girls' TST was thicker than that of the boys (p-value<0.05) in the age groups of 9.5 to 14.49 and 16.5-17.49 years, reflecting a reverse pattern between boys and girls compared to the other indices.

The pubertal stage and sex-specific prevalence of thinness and obesity based on the four aforementioned growth reference centiles are presented in Table 2. Generally, obesity was more prevalent than thinness.

Nevertheless, in the post-pubertal girls, the prevalence of thinness was more pronounced on the basis of BMI, WH, and MUAC, but not based on TST. Moreover using chi-square test, the prevalence of thinness and obesity did not differ significantly between boys and girls based on all indices (p-value>0.05) except for TST in pre-pubertal individuals. Moreover, we reported the percentage of normal students based on the constructed reference centiles curve in Table 3.

Tables 4 and 5 display the pairwise agreement of the four body composition indices for detecting underweight and overweight children according to the three maturity levels. As shown in Table 4, the level of agreement between WH and BMI was excellent for assessing thinness in both sexes and each pubertal stage except for the pubertal girls and post-pubertal boys, revealing a good agreement. Moreover, the level of agreement between MUAC and BMI was moderate in all classifications with the exception of the pubertal girls which was poor. MUAC and WH had moderate agreement in the post-pubertal girls and boys and poor agreement in the others levels of maturity. However, TST showed extremely poor agreement with any of the other measurements (Kappa ranges from 0.09 to 0.37).

In general, the pairwise agreements of adiposity measures were higher for identifying obesity than thinness. As indicated in Table 5, for detecting obesity WH and BMI showed an excellent degree of agreement in each maturation level and gender with the exception of pre-pubertal and pubertal boys presenting reasonably good agreement. Furthermore, an excellent agreement between MUAC and BMI in the pre-pubertal stage and a moderate one in the other maturity

Table 3: Percentage of normal children and adolescents by sex and puberty stages based on the reference centiles

Parameter	Pre-pubertal		Pubertal		Post-pubertal	
	boys	girls	boys	girls	boys	girls
Body mass index	89.9	90.1	89.0	90.4	89.7	88.8
Weight-for-height	89.7	90.4	90.5	89.2	89.2	89.2
MUAC	88.1	90.5	89.0	90.4	90.7	91.3
TST	89.4	92.1	89.0	90.0	91.7	89.9

MUAC: Mid-upper arm circumference-for-age; TST: triceps skinfold thickness-for-age

Table 4: Degree of agreement between four body composition indices for detecting thinness by sex and puberty stage

Parametr	Body Mass Index						Weight-for-Height						Mid-Upper Arm Circumference-for-Age					
	Prepubertal		Pubertal		Postpubertal		Prepubertal		Pubertal		Postpubertal		Prepubertal		Pubertal		Postpubertal	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Body Mass Index	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weight-for-Height	0.78*	0.87*	0.75*	0.70†	0.57†	0.75*	-	-	-	-	-	-	-	-	-	-	-	-
MUAC	0.41†	0.40†	0.58†	0.27	0.61†	0.52†	0.38	0.40†	0.37‡	0.34‡	0.43	0.48†	-	-	-	-	-	-
TST	0.12‡	0.09‡	0.24‡	0.18‡	0.27‡	0.31‡	0.15‡	0.10‡	0.15‡	0.17‡	0.22‡	0.19‡	0.11‡	0.20‡	0.36‡	0.37‡	0.26‡	0.33‡

* excellent concordance, † moderate concordance, ‡ poor concordance ; MUAC: Mid-upper arm circumference-for age

Table 5: Degree of agreement between four body composition indices for detecting obesity by sex and puberty stage

Parametr	Body Mass Index						Weight-for-Height						Mid-Upper Arm Circumference-for-Age					
	Prepubertal		Pubertal		Postpubertal		Prepubertal		Pubertal		Postpubertal		Prepubertal		Pubertal		Postpubertal	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Body Mass Index	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Weight-for-Height	0.71†	0.85*	0.70†	0.84*	0.78*	0.82*		-	-	-	-	-	-	-	-	-	-	-
MUAC	0.83*	0.76*	0.58†	0.56†	0.50†	0.56†	0.58†	0.66†	0.68†	0.67†	0.41†	0.54†	-	-	-	-	-	-
TST	0.57†	0.46†	0.64‡	0.21‡	0.16‡	0.67†	0.44†	0.47†	0.55†	0.27‡	0.06‡	0.58†	0.60†	0.48†	0.61†	0.33‡	0.30‡	0.40†

* excellent concordance, † moderate concordance, ‡ poor concordance ; MUAC: Mid-upper arm circumference-for age

levels was observed. In addition, the level of agreement between MUAC and WH was reasonably good. Finally, TST had moderate agreement with the other three measurements in almost all cases, but in the pubertal girls and the post-pubertal boys had poor agreement.

Table 6 shows bivariate correlations between anthropometric measurements classified by sex and maturity level. Height is not as highly correlated with the other indices as weight. Its correlation coefficient declined with the increase of maturity stage and it reached its minimum value in the post-pubertal group. The correlation coefficient between weight and the other indices decreased with increase of maturity level and its correlation was weaker with TST as compared with the other measurements. The highest correlation between weight and BMI was observed in post-pubertal stage (0.93 for both genders). In addition, the correlation of BMI with MUAC was greater than with TST. The correlation of TST also reduced when the stage of puberty increased with the smallest values in the post-pubertal boys.

DISCUSSION

Based on our findings, different anthropometric-based measurements provide different prevalence rates of obesity and thinness which is in the same line with the earlier research [12]. However, generally the prevalence of obesity was higher than that of thinness in almost all sex and pubertal stage groups; this might be due to the socioeconomic improvement as well as modernization process which occurred in Iran in the past decades [25]. Nevertheless, based on the BMI, MUAC, and WH the prevalence of thinness is higher than that of obesity among post-pubertal girls. One possible reason is that in this stage girls are more likely to perceive themselves as overweight than boys, so they are likely to be engaged in weight control practice and lose their weight [29].

In most of previous studies, comparison of various body composition indices was carried out using correlation analysis [4,14,30-35] which cannot describe the nature and extent of misclassifications, and when the purpose is to discriminate obesity from non obesity it is inappropriate to make recommendations based on correlations alone [6,37]. To our knowledge, few studies have been conducted to examine the concordance of different measures to identify underweight and obese children and adolescents [10,12,14-15].

We performed both correlation and agreement analysis among the three maturation levels to achieve a more comprehensive insight about the performance of anthropometric indicators which rarely has been done in previous studies. Our results indicate an excellent agreement between WH and BMI for detecting both thin and obese children and adolescents. This coincides

Table 6: Bivariate correlation of anthropometric measures by sex and pubertal stage

		Weight		Height		Body mass index		MUAC		TST	
		boys	girls	boys	girls	boys	girls	boys	girls	boys	girls
Pre-pubertal	Weight	1	1	0.81*	0.82*	0.86*	0.84*	0.90*	0.87*	0.68*	0.62*
	Height	-	-	1	1	0.42*	0.39*	0.59*	0.58*	0.37*	0.35*
	BMI	-	-	-	-	1	1	0.90*	0.88*	0.74*	0.69*
	MUAC	-	-	-	-	-	-	1	1	0.77*	0.72*
pubertal	Weight	1	1	0.71*	0.52*	0.91*	0.91*	0.89*	0.81*	0.74*	0.64*
	Height	-	-	1	1	0.35*	0.13*	0.47*	0.24*	0.26*	0.18*
	BMI	-	-	-	-	1	1	0.92*	0.84*	0.83*	0.65*
	MUAC	-	-	-	-	-	-	1	1	0.82*	0.61*
Post-pubertal	Weight	1	1	0.53*	0.37*	0.93*	0.93*	0.68*	0.85*	0.60*	0.69*
	Height	-	-	1	1	0.19*	0.03	0.27*	0.13*	0.12*	0.07
	BMI	-	-	-	-	1	1	0.68*	0.87*	0.64*	0.72*
	MUAC	-	-	-	-	-	-	1	1	0.43*	0.77*

* Significant difference between boys and girls at 5% level; MUAC: Mid-upper arm circumference-for-age; TST: triceps skinfold thickness-for-age

with a number of the previous research, though they had focused on different age groups [12,36]. However, other studies have detected a weak agreement between BMI and WH, reporting that the two indices cannot be used interchangeably [38].

Although an excellent agreement between WH and MUAC was demonstrated by Anderson [14], our results revealed a weak to moderate agreement for distinguishing underweight and overweight in all sex and age groups. In addition, there was a moderate agreement between TST and BMI in all subgroups except in pubertal girls and post-pubertal boys; this is consistent with a previous study indicating moderate agreement between TST and BMI for detecting obesity in the age range of 12-18 years [15, 39].

As shown in our results, the BMI was highly correlated with weight and less correlated with height which is a good characteristic of weight/height indices and is in agreement with previous results [31]. In addition, the correlation between BMI and height decreased when levels of maturity increased. The same results were obtained in previous studies showing that BMI is independent of height in adults, but not in children [31]. In addition, the correlation of BMI with MUAC was stronger than that of TST which is not in accordance with the earlier studies indicating that BMI and TST are strongly correlated. Although previous research had demonstrated that BMI correlated less strongly with TST at younger age [31], the correlation of these two indicators was stronger in pre-pubertal individuals than that in pubertal and post-pubertal ones.

Our results revealed that different anthropometric-based indicators behaved differently in different genders and pubertal stage groups, which confirm the results of the previous studies [3, 9, 11, 31, 33]. The methods we assessed have their own advantages and drawbacks. For instance, BMI is accepted as a standard method to evaluate nutritional status of individuals in almost all age ranges [6, 10, 12, 30, 32-35], although it cannot present an accurate evaluation of body fat particularly in children and adolescents [38, 40]. WH is identified as an appropriate screening tool which has the main advantage of being usefulwhen the child's age is unknown or unreliable, as is often the case in developing countries [25]. A number of previous studies showed that BMI and WH can be used interchangeably and they have the same performance [9]. We concluded similarlyin our study, but another research focusing on 2-5 years old children demonstrated that they cannot produce the same results [6].

Against WH and BMI, most of the previous research recommended TST as a more accurate method to reflect body fatn in children and adolescents and better a alternative for BMI for monitoring obesity in children [3, 40]. However, it has been shown that BMI and TST can be used as interchangeable methods in epidemiologic applications [33] and in children aged 5-18 years they performed equally well for classifying obese individuals [11]. Also both indicators are dependent on sex during adolescence [3]. Despite logical appealing of TST to reflect body fat, it has some methodological problems [33], has low reliability for obese persons [33], and it does not provide additional information for individuals whose BMI is greater than the 95th percentile [12].

Although MUAC is introduced as another low cost screening method either for underweight or overweight classification in preschool children and assessing obesity at the end of childhood which can be performed quickly and only requires basic literacy level to be carried out, it should be applied with high accuracy and caution during maturity [23]. Since MUAC as well as TST have an association with sexual development and they change with the onset of puberty. A prior study recommended that MUAC for identifying underweightness should be applied only when weight and height are not available, as the prevalence of malnutrition based on this index was underestimated as compared with weight-for-height. However, another study made a conclusion that BMI, TST, and MUAC have reasonable success for detecting obesity among children and adolescents [6].

One limitation of our study is that since it is not clear which of the four measurement methods compared is a gold standard, we do not know which one represents true prevalence. Previous research revealed high correlation between BMI and Body Fat Mass (BFM) as an accurate index for assessing body fat among Iranian college students [41]. However, further research is needed on Iranian children and adolescents to determine the most reliable and valid index representing accurate assessment of thinness and

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obesity. Another limitation is that, no accurate criteria were applied for classification of participants in different stages of puberty; hence we recommended using more reliable and accurate methods than just considering the age of children for determination of puberty stage in future studies.

CONCLUSION

Based on our findings, the prevalence of obesity is more pronounced than that of thinness in school children and adolescents in Shiraz (Southern Iran). Therefore, preventive measures for controlling obesity are a must for public health promotion among school children in Iran. Another important finding is that WH and BMI can be used interchangeably in different pubertal stages and for detecting both underweight and overweightness. In addition, in pre-pubertal stage BMI and MUAC can be used instead of each other for classifying obesity. Overall, our results are consistent with the pioneer research suggest that caution should be taken for selecting an appropriate index to classify children and adolescents as obese or thin in different sex and age groups. In addition, a single index may not produce satisfactory results and use of multiple indicators may lead to more trustworthy conclusions.

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