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Comparison between BMI and Inverted BMI in Evaluating Metabolic Risk and Body Composition in Iranian Children

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Abstract

***Objectives*:** To compare BMI and inverted BMI in evaluating body measurement, resting blood pressure, Dual energy X-ray absorptiometry (DEXA) parameters of fat mass and metabolic risk factors in Iranian children

***Materials and Methods*:** This is a cross-sectional study on 477 children aged 9-18 years in the South of Iran. Weight, height, resting blood pressure, waist and hip circumference and pubertal stage of all participants was measured with standard methods. DEXA was used to determine body composition index. Blood samples were checked for serum lipid profiles and fasting blood sugar (FBS). Metabolic risk score (MRS) was calculated by the summation of the Z-scores for TC, TG/HDL, LDL, systolic blood pressure, and waist circumference minus HDL Z-score.

***Results*:** BMI did not have a normal distribution in our participants but iBMI had a normal distribution. IBMI had more significant correlation with waist to hip ratio and systolic blood pressure (r^2=0.053 and r^2=0.182) than BMI (r^2=0.041 and r^2=0.101). MRS had a positive correlation with BMI (P<0.05, r=0.466) and a negative correlation with iBMI (P<0.05, r=-0.458) in all children and both genders**.** Android/Gynecoid ratio had a positive correlation with BMI (P<0.05, r=0.497) and a negative correlation with iBMI (P<0.05, r=-.649). Fat mass index had a significant correlation with both BMI (P<0.05, r^2=0.589) and iBMI (P<0.05, r^2=0.541).

***Conclusion*:** This study revealed that iBMI could be a suitable alternative for BMI in estimating waist to hip ratio, resting systolic blood pressure, FBS, lipid profiles, fat mass index, Android/ Gynecoid fat ratio, and metabolic risk score. Because of normal distribution of iBMI, it is more reliable than BMI for use in statistical analysis.

***Key Words*:** Anthropometry, Body mass index, Children, Inverted BMI.

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1- INTRODUCTION

Obesity is a major global health problem in children (1) and is no longer limited to industrially developed countries (2). In recent years, Iran like other developing countries has been experiencing an increase in childhood obesity due to urbanization, nutrition transition and change in lifestyle. Obese children are predisposed to many cardiovascular complications and metabolic risks which could be prevented by decrease in the weight (2). Some studies in adults showed that android obesity profile (accumulation of fat around abdomen) significantly increases the risk of heart disease and metabolic risk whereas gynecoid obesity profile (accumulation of fat around hips) protects against cardiovascular disease (3- 5).

Body mass index (BMI, kg/m^2) has been used widely as a measure of weight status (6) due to its simplicity, cost and labor effectiveness compared with other techniques (7). The validity of BMI in assumption of adiposity has been questioned by some investigations that showed strong evidence of curvature in this association (8, 9). This is more prominent in children as growth and puberty influences the BMI-body fat ratio (10). On the other hand, some previous studies showed that BMI has not a normal distribution in children. Thus, when applied in statistical analysis, it interferes with assumption of normality and so results of correlations cannot be trusted (11). Some researchers have suggested another measure named inverted BMI (iBMI, cm^2/kg) as a better proxy for body fatness in epidemiological studies (12, 13). These studies showed that iBMI has a normal distribution and is a suitable predictor of physical activity (14), resting blood pressure (11) and body fat in children (12). One study on adults has also shown that iBMI is an alternative to BMI to evaluate the effect of body weight on metabolic risk score and cardiorespiratory fitness (13). Lack of sufficient data on the comparison of iBMI with BMI in evaluating metabolic risks in children, lack of data about the relationship of iBMI with Dual X-ray energy absorptiometry determined body fatness in Asian children, and insufficient data about association of iBMI with body measurements prompted us to do this study.

2- MATERIAL AND METHODS

This is a cross-sectional study on children aged 9-18 years who were permanent residents of Kawar, located 50km east of Shiraz, the capital city of Fars province in the south of Iran. An age-stratified systematic randomized sampling of 7.5% was used to gather our sample group that enrolled 500 participants (250 girl and 250 boys), that were attending elementary, guidance, or secondary school. All participants and their parents signed the informed consent form.

Finally 477 children (241 boys and 236 girls) participated in the study (95.4%). Children were excluded if they had chronic illnesses like hypo- or hyperthyroidism, diabetes mellitus, renal failure, adrenal insufficiency, recurrent fracture, or if they had used anticonvulsants or steroids, or if they had precocious or delayed puberty.

2-1. Anthropometric measurements, pubertal stage and BMI

Weight, height, waist and hip circumference and pubertal stage of all participants were measured by one physician. Weight was measured with a standard scale (Seca, Germany) to the nearest 0.1kg and height with a wall-mounted meter to the nearest 0.5 cm, while the child was dressed in light clothing, without shoes. It is noteworthy that the initial examinations of the students, by a general practitioner, with the assistance of a female nurse has been done.

Body mass index (BMI) was calculated by dividing weight (kg) by height^2 per square meter. Inverted BMI (iBMI) was calculated by dividing height^2 (cm) per square centimeter by weight (kg). He measured waist circumference half way between the rib cage and pelvis and hip circumference at maximal circumference of the hips. Puberty was assessed by five stage classification of tanner (15).

2-2. Resting Blood pressure

One trained physician assessed the resting blood pressure while the child sat after 10-15 minute rest period. Measurements were taken with the standard method (16), using an ALPK2 sphygmomanometer (Zhejiang, China) with the appropriate cuff. The average of three reading blood pressures with 5-minute interval was estimated as child's resting blood pressure.

2-3. Body fat mass

Dual X-ray energy absorptiometry (DEXA) (Hologic system, Discovery QDR,USA) was used to determine Android fat (kg) Gynecoid fat (kg), fat mass index (FMI, kg/m^2), lean mass index (LMI, kg/m^2), Android fat mass index (g/cm^2), and Gynecoid fat mass index (g/cm^2). The android area of fat mass was defined inferiorly at the pelvis cut line, superiorly above the pelvis cut line by 20% of the distance between the pelvis and neck cut, and laterally at the arm cut lines. Gynoid area of fat mass was defined superiorly below the pelvis cut line by 1.5 times the height of the android area of fat mass, inferiorly below the superior line by two times the height of the android area of fat mass, and laterally at the outer leg cut lines. The cut lines for the regions were manually assessed by one expert technician.

2-4. Biochemical analysis

5cc venous blood samples of each child was taken after 12h fasting, to check the serum total cholesterol (TC), high density lipoprotein (HDL), triglycerides (TG) and fasting blood sugar (FBS). Auto-analyzer Bio-system A-25 was used to evaluate the lipid profile (TC, HDL and TG) and Fetal-bovine serum (FBS). Low density lipoprotein (LDL) was calculated using the Friedewald equation (17): LDL=TC-HDL-0.2×TG.

2-5. Metabolic risk score

Due to lack of a universal definition for dysmetabolic syndrome in children and adolescents (18), we used Anderson's metabolic risk score (19). It was derived from the serum TC, TG/HDL, LDL, systolic blood pressure, and waist circumference. The summation of the z-score for each of these variables (from the sample mean after normalization) was calculated. Then, HDL z-score was multiplied by-1 (as a protective metabolic factor) and added to the previous summation to obtain metabolic risk score (MRS). A lower metabolic risk score in a child indicated a lower cardiovascular risk.

2-6. Ethic

The study was approved by Shiraz university of Medical Sciences ethics Committee with the project number of 89-5127. Written informed consent form was signed by all the participants and their parents.

2-7. Statistical analysis

The relationship between BMI, iBMI and each parameter of body composition, serum biochemical, body fat mass and metabolic risk score was determined using Pearson's product moment for the whole sample and then split by gender, and for MRS split also by gender and weight status. Normality of data was assessed by One Sample Kolmogorov-Smirnov Test. Normal Q-Q plots were also shown as a means to visually represent the normality of data. Multiple regression analysis of

covariance was used to determine the extent to which BMI and iBMI were predictive of each parameter of body measurement, biochemical analysis, and body fat mass, controlled for age and tanner stage. P values less than 0.05 were considered statistically significant. The data were analyzed using the statistical package for social sciences (SPSS, version 18, Chicago, IL, USA).

3- Results

Ultimately 477 (241 boys and 236 girls) children aged 13.7 ± 2.9 years participate the study to the end (95.4%). Pubertal status of the participants is summarized in (Table.1). Puberty was assessed by five stage classification of tanner (15). Also, general characteristics including body measurements, lipid profile, fasting blood sugar, and body composition of the children (total and in each male and female sexes) are all summarized in (Table.2).

Table 1: Percentage and numbers of children in each tanner stage classified by gender

Tanner stage	Boys		Girls		Total	
	number	%	number	%	number	%
I	59	24.5	34	14.3	93	19.5
II	40	16.4	27	11.5	67	14
III	28	11.8	48	20.3	77	16
IV	62	25.9	26	11.1	88	18.5
V	52	21.4	101	42.9	152	32
Total	241	100	236	100	477	100

Table 2: General characteristics and the result of DEXA parameters of body composition of the children classified by gender

Parameters	Boys		Girls		Total	
	Mean	SD	Mean	SD	Mean	SD
BMI	17.8	3.2	17.5	3.1	17.7	3.2
Inverted BMI	577	100	585	93	581	97
Waist circumference	69.5	10.2	47.8	10.7	68.6	10.4
Hip circumference*	82.9	10.3	80.4	10.7	81.7	10.6
Waist to hip ratio	0.83	0.05	0.84	0.08	0.84	0.07
Systolic Bp	108	10.6	109	9.7	108	10
Diastolic Bp	68.3	9.86	71.6	8.66	70.4	9.2
FBS*	74.5	9.9	79.1	13.1	76.9	11.9
TG	69.5	48	74.6	55	72.2	52
Cholestrol *	160.9	29.7	151.6	32.1	156	31.3
HDL	46.5	16	47	16.4	46.8	16.2
TG/HDL ratio	1.77	1.97	1.8	1.6	1.78	1.78
Total body%fat*	28.5	5.8	17.4	6.7	22	8.4
Android/gynecoid fat ratio	0.812	0.172	0.778	0.129	0.797	0.156
Fat mass index*	5.36	1.97	3.39	3.2	4.2	2.9
Lean mass index*	12.9	1.58	15.47	13.7	14.4	10.6
Android fat mass index*	784	428	508	432	626	451
Gynecoid fat mass index*	2479	913	1457	844	1896	1009

* Significant P-value of comparison of parameters in both male and female sexes (P< 0.05).

3-1. Comparison of data distribution between BMI and iBMI

Distribution of BMI and iBMI in the whole sample is illustrated in (Figures 1a and 1b). According to the results of Kolmogorov–Smirnov Test, BMI did not have a normal distribution in our participants but iBMI had a normal distribution. The Q-Q plots in Figures 1a and 1b clearly demonstrated more deviation of observed values from the

expected values for the BMI in the whole sample, whereas this deviation was less for iBMI. When we split the participants by gender, a similar pattern was observed (Figures 2, 3).

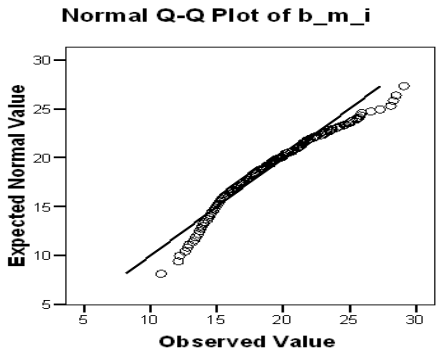

Fig1a-Normal Q-Q Plot of BMI in all participants

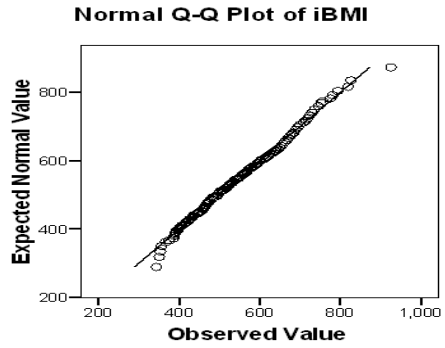

Fig1b-Normal Q-Q Plot of iBMI in all participants

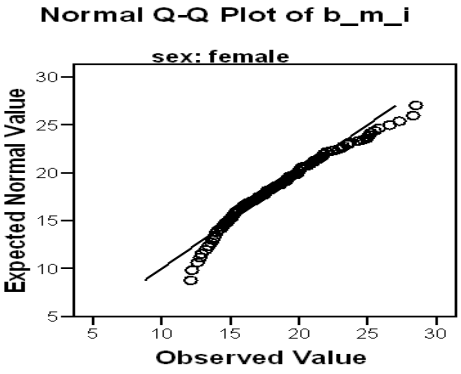

Fig.2a.Normal Q-Q Plot of BMI in female patients

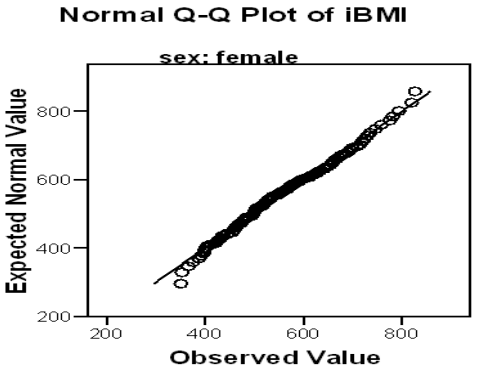

Fig.2b.Normal Q-Q Plot of iBMI in female participants

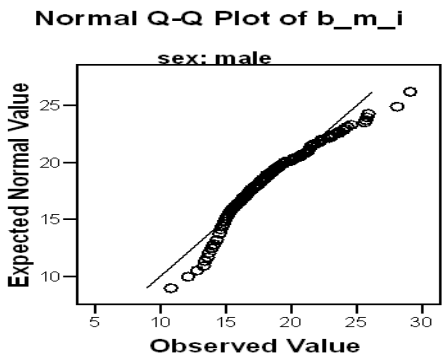

Fig.3a.Normal Q-Q Plot of BMI in male patients

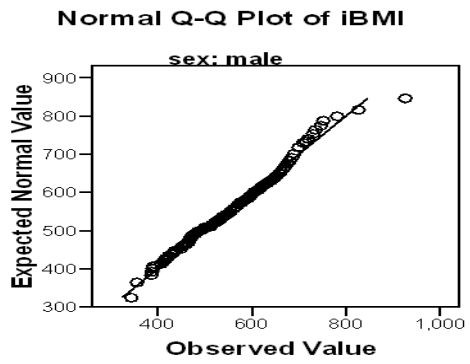

Fig.3b.Normal Q-Q Plot of iBMI in male patients

3-2. Association of waist and hip circumference and BMI vs. iBMI

Results of Pearson moment correlation showed that BMI had a significant positive correlation with waist circumference (P<0.001, r=0.771). This correlation was present in both genders (Table.3). Also, BMI represents a significant positive correlation with hip circumference in the whole sample (P<0.001, r= 0.781) and in both genders (Table.3). There is a positive correlation between BMI and waist to hip ratio in all the participants (P<0.001, r=0.18) and in both genders (Table.3). Pearson moment correlation showed a significant negative correlation between iBMI and waist circumference (P<0.001, r=-0.759), hip circumference (P<0.001, r= 0.773) and waist to hip ratio (P<0.001, r=-0.458) in the whole sample. This inverse correlation persists after splitting the sample by gender (Table.3). After multiple regression analysis of the correlation of BMI and iBMI with waist and hip circumference for tanner stage and age of participants (Table.4), it was demonstrated that both BMI and iBMI had a significant correlation with waist and hip circumference (Table.5); however, iBMI showed a more significant correlation with waist to hip ratio (P< 0.001, r^2= 0.053) than BMI (P<0.001, r^2=0.041).

Table 3: Results of Pearson product moment correlations between BMI (kg/m^2) and iBMI (cm^2/kg) and each of the parameters split by gender

Parameter	BMI			iBMI		
	Boys	Girls	Total	Boys	Girls	Total
Waist circumference	r = 0.75 P < 0.001	r = 0.792 P < 0.001	r = 0.771 P < 0.001	r= -0.739 P < 0.001	r = -0.782 P< 0.001	r = -0.759 P < 0.001
Hip circumference	r = 0.743 P < 0.001	r = 0.82 P < 0.001	r = 0.781 P < 0.001	r = -0.736 P < 0.001	r = -0.812 P < 0.001	r = -0.773 P < 0.001
Waist/hip ratio	r = 0.178 P = 0.003	r = 0.202 P = 0.001	r = 0.18 P < 0.001	r = -0.174 P = 0.004	r = -0.2 P = 0.001	r = -0.177 P < 0.001
Systolic BP	r = 0.422 P < 0.001	r = 0.338 P = 0.022	r = 0.386 P < 0.001	r = -0.435 P < 0.001	r = -0.361 P = 0.015	r = -0.401 P < 0.001
Diastolic BP	r = 0.179 P = 0.08	r = 0.1 P = 0.28	r = 0.136 P = 0.09	r = -0.153 P = 0.118	r = -0.111 P = 0.259	r = -0.12 P = 0.119
FBS	r = -0.001 P = 0.49	r = -0.257 P < 0.001	r = -0.117 P = 0.008	r = -0.02 P = 0.37	r = 0.255 P < 0.001	r = 0.102 P = 0.018
HDL	r = -0.168 P = 0.006	r = -0.06 P = 0.2	r = -0.114 P = 0.009	r = 0.202 P = 0.001	r = 0.09 P = 0.09	r = 0.146 P = 0.001
LDL	r = 0.044 P = 0.256	r = 0.027 P = 0.35	r = 0.045 P = 0.176	r = -0.16 P = 0.408	r = -0.046 P = 0.26	r = -0.039 P = 0.213
TG	r = 0.383 P < 0.001	r = 0.237 P < 0.001	r = 0.31 P < 0.001	r = -0.359 P < 0.001	r = -0.212 P < 0.001	r = -0.285 P < 0.001
Cholestrol	r = 0.083 P = 0.108	r = 0.07 P = 0.16	r = 0.084 P = 0.042	r = -0.034 P = 0.306	r = -0.063 P = 0.187	r = 0.054 P = 0.136
TG/HDL ratio	r = 0.378 P < 0.001	r = 0.127 P = 0.036	r = 0.239 P < 0.001	r = -0.365 P < 0.001	r = -0.124 P = 0.04	r = -0.23 P < 0.001
Fat mass index	r = 0.317 P < 0.001	r = 0.811 P < 0.001	r = 0.442 P < 0.001	r = -0.295 P < 0.001	r = -0.758 P < 0.001	r = -0.415 P < 0.001
Lean mass index	r = 0.106 P = 0.09	r = 0.809 P < 0.001	r = 0.127 P = 0.017	r = -0.118 P = 0.068	r = -0.777 P < 0.001	r = -0.133 P = 0.013
Android/Gyn. ratio	r = 0.448 P < 0.001	r = 0.622 P < 0.001	r = 0.497 P < 0.001	r = -0.457 P < 0.001	r = -0.573 P < 0.001	r = -0.486 P < 0.001
Android fat mass index	r = 0.684 P < 0.001	r = 0.788 P < 0.001	r = 0.703 P < 0.001	r = -0.629 P < 0.001	r = -0.727 P < 0.001	r = -0.649 P < 0.001
Gynecoid fat mass index	r = 0.751 P < 0.001	r = 0.807 P < 0.001	r = 0.686 P < 0.001	r = -0.706 P < 0.001	r = -0.77 P < 0.001	r = -0.654 P < 0.001
MRS	r = 0.544 P < 0.001	r = 0.389 P < 0.001	r = 0.466 P < 0.001	r = -0.524 P < 0.001	r = -0.399 P < 0.001	r = -0.458 P < 0.001

3-3. Correlation of resting blood pressure and BMI vs. iBMI

Pearson product moment showed that there was a significant positive correlation between BMI and systolic blood pressure in the whole sample (P<0.001, r= 0.386) and in both genders (Table 3), but BMI did not have any significant correlation with diastolic blood pressure (P=0.09) (Table.3). After multiple regression analysis for age and tanner stage, it was shown that iBMI had a more significant correlation with systolic blood pressure (P=0.006, r^2=0.182) than BMI (P=0.007, r^2=101) (Table.4).

3-4. Association of fasting blood sugar and serum lipid profile and BMI vs. iBMI

There was a negative correlation between BMI and fasting blood sugar in the whole sample and female patients (Table.3). Also, iBMI had a positive correlation with fasting blood sugar in all the children and females, but iBMI or BMI did not have a correlation with FBS in boys (Table.3). After multiple regression analysis for tanner stage and age, it was demonstrated that both iBMI and BMI was correlated with FBS (P=0.049, r^2=0.121 and P=0.028, r^2=0.11) respectively.

Serum HDL had a negative correlation with BMI and positive correlation with iBMI in the whole sample and boys (Table.3), but after multiple regression analysis only iBMI showed a significant correlation with HDL (P=0.049, r^2=0.037) (Table.4).

Total cholesterol was correlated with BMI in the whole sample (Table.4). After regression analysis for tanner stage and age, both BMI and iBMI had a correlation with total cholesterol. However, correlation of iBMI with total cholesterol was more significant (r^2=0.07) than BMI (r^2=0.06) (Table.5). LDL was not correlated with BMI or iBMI (Table.3).

According to the result of Pearson product moment, there was a significant positive correlation between serum triglyceride and BMI (P<0.001, r=0.31) and a negative correlation between TG and iBMI (P<0.001, r=-0.285). After multiple regression analysis for age and tanner stage, these correlations persisted (P<0.001) (Table.4). However, TG/HDL ratio was more correlated with iBMI (P<0.001, r^2= 0.07) than BMI (P<0.001, r^2=0.06).

Table 4: Results (P-value and adjusted r^2) of multiple regression analysis on the correlation of BMI or iBMI with body measurement, DEXA parameters of fat mass and metabolic risk factors adjusted for tanner stage and age of children

Parameters	BMI	iBMI
Waist circumference	P<0.001, r^2=0.716	P<0.001 , r^2=0.699
Hip circumference	P<0.001, r^2=0.783	P<0.001 , r^2=0.770
Waist to hip ratio	P<0.001 , r^2=0.041	P<0.001 , r^2=0.053
Systolic Blood pressure	P=0.007 , r^2=0.101	P=0.006 , r^2=0.182
Diastolic Blood pressure	P=0.078 , r^2=0.016	P=0.098 , r^2=0.094
FBS*	P=0.028 , r^2=0.11	P=0.049 , r^2=0.121
TG	P<0.001 , r^2=0.103	P<0.001 , r^2=0.098
Cholestrol	P<0.001 , r^2=0.063	P<0.001 , r^2=0.067
HDL*	P=0.198 , r^2=0.016	P=0.049 , r^2=037
TG/HDL ratio	P<0.001 , r^2=0.061	P<0.001 , r^2=0.07
Android/Gynoid ratio	P<0.001 , r^2=0.308	P<0.001 , r^2=0.300
Android fat mass	P<0.001 , r^2=0.658	P<0.001 , r^2=0.590
Gynecoid fat mass	P<0.001 , r^2=0.602	P<0.001 , r^2=0.651
Fat mass index	P<0.001 , r^2=0.589	P<0.001 , r^2=0.541
Lean mass index	P=0.101 , r^2=0.005	P=0.083 , r^2=0.03

3-5. Correlation of metabolic risk score (MRS) and BMI or iBMI

MRS had a positive correlation with BMI in the whole sample and both genders (Table.5) and a negative correlation with iBMI in all children and both genders (Table.5). After splitting the sample by gender, this correlation persisted in both genders; however, the correlation of BMI or iBMI with MRS was more significant in boys (P<0.001, r=0.544 and P<0.001, r=-0.524, respectively) than in girls (P<0.001, r=0.389 and P<0.001, r=0.399, respectively).

Table 5: Pearson correlations (r) between BMI (kg/m^2) and iBMI (cm^2/kg) and metabolic risk score (MRS) in children split by gender

Parameters	BMI		iBMI	
	r	P-value	r	P-value
Boys	0.544	<0.001	-0.524	<0.001
Girls	0.389	<0.001	-0.399	<0.001
Total	0.466	<0.001	-0.458	<0.001

3-6. Association of DEXA parameters of body fat and BMI vs. iBMI

Fat mass index had a significant positive correlation with BMI (P<0.001, r=0.442) and a negative correlation with iBMI (P<0.001, r=-0.415). After multiple regression analysis, it was shown that BMI had a more significant correlation with fat mass index (P<0.001, r^2=0.589) than iBMI (P<0.001, r^2=0.541). Result of Pearson correlation showed a positive correlation between lean mass index and BMI in the whole sample and girls and a negative correlation with iBMI in all children and female ones (Table.3); however, after multiple regression analysis these correlations were not significant (Table.4).

Both Android and Gynecoid, fat mass was associated with BMI and iBMI (Table.3); however, after multiple regression analysis it was shown that BMI was more correlated with android fat mass and iBMI was more correlated with Gynecoid fat mass (Tables 3, 4).

Android/Gynecoid ratio had a positive correlation with BMI (P<0.001, r=0.497) and a negative correlation with iBMI (P<0.001, r=-0.649). These correlations persisted after multiple regression analysis for tanner stage and age.

4- DISCUSSION

This study compared the utility of iBMI versus BMI in predicting DEXA determined body fat mass, and resting blood pressure, fasting blood sugar and serum lipid profiles for the first time in Asian children; also, we evaluated the correlation of iBMI and BMI with waist to hip ratio, and DEXA determined Android/Gynecoid Fat Ratio, for the first time in Iranian children.

4-1. Data distribution of BMI and iBMI

This study showed that BMI did not have a normal distribution but iBMI had a normal distribution in children. Q-Q plots in (Figures.1-3) clearly showed a greater deviation of observed values from the expected ones in the case of BMI. After splitting the data by gender, a similar pattern was observed. Similar to our results, Duncan et al. and Nevil et al. showed that iBMI with a normal distribution was more reliable for statistical analysis than BMI which had not a normal distribution (12, 13). These data showed that iBMI was a more reliable tool than BMI for statistical analysis (13).

4-2. Association of waist and hip circumference with iBMI versus BMI

This study revealed that waist and hip circumference and waist/hip ratio had a positive relationship with BMI and an inverse correlation with iBMI; however, iBMI had a more significant correlation with waist to hip ratio, as a measure of disease risk (20). A recent WHO report suggested that waist circumference could be used as an alternative tool to BMI for evaluating the weight status and disease risk (21). This is a more important issue in

children due to changes in body size during growth and maturation (20).

4-3. Association of resting blood pressure with BMI vs. iBMI

The present study demonstrated that systolic blood pressure had a positive correlation with BMI and an inverse relationship with iBMI, but diastolic blood pressure was not correlated with BMI or iBMI. This relationship was more significant for iBMI than BMI (P=0.006, r^2=0.182 vs. P=0.007, r^2=0.101). In 2011, Duncan et al. showed that both systolic and diastolic blood pressure were correlated with BMI in Portuguese adolescents (20).

Also, other studies revealed that BMI was the most important factor among all demographic and clinical factors associated with hypertension (22, 23). In line with our study, Mirza et al. also showed mean systolic blood pressure was significantly higher in overweight children (24). However, we did not find any investigation about relationship between iBMI and blood pressure in Asian children.

4-4. Association of fasting blood sugar and serum lipid profiles with BMI vs. iBMI

This study showed that BMI had a positive correlation with FBS, cholesterol, TG and TG/HDL ratio. IBMI had an inverse correlation with FBS, TG, TC and TG/HDL ratio and positive correlation with HDL. According to adjusted r^2 of multiple regression analysis which are summarized in (Table.5), correlation of iBMI with FBS and serum lipid profile was more significant than that of BMI with these factors. The only study which investigated the correlation of BMI and iBMI with metabolic risks by Duncan et al. revealed that both iBMI and BMI could predict metabolic risk score that includes serum FBS, TG, HDL, TG/HDL, LDL and systolic blood pressure. However, they did not evaluate these factors separately (13). Tanha et al. revealed that obesity was associated with increase in resting profiles of blood glucose and lipids (25). On the other hand, obesity, hypertension, dyslipidemia and impaired glucose tolerance were components of metabolic syndrome that were associated with cardiovascular morbidity (2) and was considered in many pediatric studies (26-30), but correlation of iBMI or BMI with these metabolic profiles has not been studied yet.

4-5. Association of BMI or iBMI with metabolic risk score (MRS)

The present investigation found that MRS had a positive relationship with BMI and an inverse association with iBMI. This correlation was not dependent on the gender. Metabolic risk score was proposed for the first time by Anderson et al. (19) due to lack of a universal definition of metabolic syndrome in children (18). Some previous reports have identified that obesity was correlated with hypertension, high serum lipids and impaired glucose tolerance (13, 25, 26, 28-30). However, comparison between iBMI and BMI and metabolic risk score was done only in Duncan et al.'s study (13). They revealed that iBMI offers an alternative to BMI to assess the metabolic risk score. They showed both BMI and iBMI could be an estimate of metabolic risk score (13) which was an indicator of overall cardiovascular risk factor profile (19, 18).

4-6. Association of BMI or iBMI with DEXA determined body fat parameters

The present study showed that both BMI and iBMI had a significant correlation with fat mass index. But lean mass index was not correlated with BMI or iBMI. Jeddi et al. revealed thatregional variation in genetic, dietary, and physical activity determine differences in body composition values in various nations. Results of this study suggest that using fat mass index

values for classification of obesity (31). Duncan et al. revealed that both BMI and iBMI could be an estimate of body fat mass index (12, 13). They suggested that iBMI is a similar proxy for body fat mass index compared to BMI in children (12). Another study by Nevil et al. showed that both BMI and iBMI had an association with body percent of fat. However, they suggest that due to normal distribution of iBMI, and less curvature in relationship between body percent of fat and iBMI, iBMI appears to be a better proxy of body fat than BMI. It offers fewer negative consequences in statistical analysis, so iBMI could be more suitable over BMI, especially in statistical models (6). Also, this study has added to previous ones, by evaluating the correlation of Gynecoid and Android fat mass with BMI or iBMI which has not been studied in children yet. LRP5 gene polymorphism may be an important determinant of body fat composition because it has a key role in making a balance between myogenesis and adipogenesis (32).

We found that BMI was more correlated with Android fat mass and iBMI was more associated with gynecoid fat mass. Also, this study revealed that Android/Gynecoid ratio had a positive relationship with BMI and an inverse correlation with iBMI. Previous studies suggested that DEXA determined android to gynecoid fat ratio may be a useful and simple tool to evaluate distribution of body fat which was correlated with an increase in insulin resistance in obese children (33). Another study on adults revealed that android fat mass and the ratio of android to gynecoid fat mass had a significant correlation with hypertension, impaired glucose and elevated triglyceride (3).

5- CONCLUSION

This study revealed that iBMI could be a suitable alternative for BMI in estimating waist to hip ratio, resting systolic blood pressure, FBS, lipid profiles, fat mass index, Android to Gynecoid fat ratio and metabolic risk score. Because of normal distribution of iBMI, it is more reliable than BMI for using in statistical analysis.

6- CONFLICT OF INTEREST: None.

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