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Gender Differences in Morbid Obese Children: Clinical Significance of Two Diagnostic Obesity Notation Model Assessment Indices

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***Abstract*—**Childhood obesity is an ever increasing global health problem, affecting both developed and developing countries. Accurate evaluation of obesity in children requires difficult and detailed investigation. In our study, obesity in children was evaluated using new body fat ratios and indices. Assessment of anthropometric measurements, as well as some ratios, is important because of the evaluation of gender differences particularly during the late periods of obesity. A total of 239 children; 168 morbid obese (MO) (81 girls and 87 boys) and 71 normal weight (NW) (40 girls and 31 boys) children, participated in the study. Informed consent forms signed by the parents were obtained. Ethics Committee approved the study protocol. Mean ages (years)±SD calculated for MO group were 10.8±2.9 years in girls and 10.1±2.4 years in boys. The corresponding values for NW group were 9.0±2.0 years in girls and 9.2±2.1 years in boys. Mean body mass index (BMI)±SD values for MO group were 29.1±5.4 kg/m^2 and 27.2±3.9 kg/m^2 in girls and boys, respectively. These values for NW group were calculated as 15.5±1.0 kg/m^2 in girls and 15.9±1.1 kg/m^2 in boys. Groups were constituted based upon BMI percentiles for age-and-sex values recommended by WHO. Children with percentiles >99 were grouped as MO and children with percentiles between 85 and 15 were considered NW. The anthropometric measurements were recorded and evaluated along with the new ratios such as trunk-to-appendicular fat ratio, as well as indices such as Index-I and Index-II. The body fat percent values were obtained by bio-electrical impedance analysis. Data were entered into a database for analysis using SPSS/PASW 18 Statistics for Windows statistical software. Increased waist-to-hip circumference (C) ratios, decreased head-to-neck C, height 'to' 'two'-'to'-waist C and height 'to' 'two'-'to'-hip C ratios were observed in parallel with the development of obesity ($p \leq 0.001$). Reference value for height 'to' 'two'-'to'-hip ratio was detected as approximately 1.0. Index-II, based upon total body fat mass, showed much more significant differences between the groups than Index-I based upon weight. There was not any difference between trunk-to-appendicular fat ratios of NW girls and NW boys ($p \geq 0.05$). However, significantly increased values for MO girls in comparison with MO boys were observed ($p \leq 0.05$). This parameter showed no difference between NW and MO states in boys ($p \geq 0.05$). However, statistically significant increase was noted in MO girls compared to their NW states ($p \leq 0.001$). Trunk-to-appendicular fat ratio was the only fat-based parameter, which showed gender difference between NW and MO groups. This study has revealed that body ratios and formula based upon body fat tissue are more valuable parameters than those based on weight and height values for the evaluation of morbid obesity in children.

***Keywords*—**Anthropometry, childhood obesity, gender, Morbid obesity.

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I. Introduction

Childhood obesity has both immediate and long-term health effects and its prevalence has increased at an alarming rate. Especially starting with the adolescent period, observation of higher fat percentages in children appears to be an important health problem in terms of the development of obesity. Obesity developing in children during childhood will most probably continue into adulthood [1], [2] and may be associated with cardiometabolic risk, atherosclerosis, women infertility, macrosomia, and metabolic syndrome (MetS) [3]-[7].

Assessment of anthropometric measurements, as well as some ratios and formulas, is important because of the evaluation of gender differences particularly during the late stages of obesity. Accurate measurement of obesity in children requires difficult and detailed evaluation and in general, weight-for-age, height-for weight and BMI are used. Waist C-to-hip C ratio used in adults has not been used in routine practice for the children yet. BMI is evaluated along with body fat ratio in the studies conducted in recent years [8]-[11]. In addition to these parameters, one study investigated only waist C [12] and another research investigated hip and neck Cs together with waist C [13], and other study examined whether BMI is a sufficient index [14]. In a study performed on adolescents, the relationship between body measurements and body fat mass was investigated [15]. In another study body, fat ratio was reported to be more valuable than BMI and waist C during childhood [12]. Increase in body fat ratio was detected to be closely related with waist C, obesity and MetS in children aged 6-13 years [16]. In a retrospective study performed on 76 obese children with mean age of 13, relationships of BMI with Cs of waist, hip and neck, and body fat mass were analyzed, and it was reported that BMI has the closest relationship with body fat ratios rather than body measures [14]. The controversial results pointed out the importance of new, different anthropometric measurements and ratios together with body fat ratios aside from waist-to-hip ratio for the evaluation of childhood obesity and led us to seek more informative indexes.

In this study, recently developed Diagnostic Obesity Notation Model Assessment (DONMA) indices; DONMA Index I derived from weight and height as well as DONMA Index II derived from total body fat mass and height were given. Obesity, an important health problem in children, has been evaluated with anthropometric measurements and recently developed formulas, as well as body fat ratios from a different point of view. This study was carried out to establish recent approaches for the prevention of obesity and the profile observed during late stages of the disease.

II. Patients and Methods

A. Patients

A total of 121 girls (81 MO and 40 NW) and 118 boys (87 MO and 31 NW) who were admitted with nutritional problems to Namik Kemal University, Faculty of Medicine, Department of Practice and Research Hospital, Clinics of Pediatrics were included into the scope of the study. Groups were constituted based upon BMI percentiles for age (MO) values recommended by World Health Organization (WHO). Those having BMI percentiles for age values higher than 99 and those between 85-15 were included in MO and NW groups, respectively. Children with chronic disorders of especially gastrointestinal tract, cardiovascular, respiratory, renal, hepatic, neurologic/neuromuscular, hematological, immunological and endocrine systems, children with growth retardation and children using drugs regularly due to a chronic disease were excluded from the study.

Study protocol was accepted by The Ethics Committee of Namik Kemal University, Faculty of Medicine. A signed written informed consent forms were obtained from the parents prior to the study. Procedures were carried out in accordance with the Declaration of Helsinki.

B. Measurements

Each child was anthropometrically measured following the physical examination and a detailed history taken from the parents. Head C, neck C, mid-Cs of left and right upper and lower limbs and ankle C of each child were measured in addition to weight, height, waist C and hip C. Shoeless children with thin issued clothing were measured for their weights by an electronic weighing instrument sensitive to 0.1 kg intervals. Shoeless children were measured for their heights by a portable stadiometer designed in 0.1 cm intervals, in a position that child looks at completely in the horizontal plane and in a position that her occiput, back, hip and heels are in contact with the vertical posterior plane. Waist C was identified as a horizontal line at the midpoint of the upper limit of the iliac crest and the lower rib followed by a normal expiration. Hip C was identified as a horizontal line passing through supra-pubically on the anterior aspect and the largest area of the gluteus on the posterior aspect. Head C was identified as a line passing through the glabella on the anterior aspect and the external occipital protuberance on the posterior aspect. Neck C was identified as the horizontal measurement passing through the most prominent part of the thyroid cartilage while the child is looking forward with neck in an upright position. Mid-arm C was identified as the horizontal line passing through midpoint between the greater tubercle of the humerus detected by palpation above and the lateral epicondyle below. Mid-thigh C was identified as the horizontal line passing through the midpoint between the greater trochanter detected by palpation the femur above and lateral condyle below. Ankle C was identified as the horizontal line passing through the narrow region just proximal to the medial and lateral malleoli detected by palpation of the tibia.

Measurements were performed by a flexible, non-elastic tape. All the measurements were carried out by pediatricians. Each measurement was taken twice and the mean was recorded.

After the measurements and the laboratory tests, each child was sent to the diet clinic. Following the evaluation of children, nutrition and physical activity recommendations, as well as treatment regimens were given. Measurements of body fat were performed following the detailed nutritional evaluation of the children. The analyses of the body fat were performed by TANITA ® “MC 980 multi frequency segmental body composition analysis” (bio-electrical impedance analysis-BIA). Then, follow-up monitoring was undertaken at regular intervals.

C. Ratio Calculations

Anamnesis, physical examinations, anthropometric measurements, biochemical values and body fat ratios of children participated in the study were evaluated. BMI [body weight (kg)/height (m) * height (m)] was calculated for each patient. Waist C/hip C, head C /neck C, thigh C/arm C (right+left mid-thigh C:2/right+left mid-arm C:2), thigh C/ankle C (right+left mid-thigh C:2/right+left ankle C:2), height ‘to’ ‘two’-‘to’-waist C, height ‘to’ ‘two’-‘to’-hip C, DONMA Index I: [weight (kg) * 100/height (cm)] and DONMA Index II: [total body fat mass (kg) * 100/height (cm)] were calculated. In order to evaluate body fat amount and BMI groups together, upper, lower extremities and trunk fat ratio, whole body fat percentage (WBF%), fat mass index (FMI) [total body fat (kg)/height (m) * height (m)], trunk to appendicular fat ratio (TAFR) [trunk fat (kg)/upper+lower extremities fat (kg) ratio] were calculated.

D. Statistical Evaluation

PASW 18 Statistics for Windows statistical package program was used to transfer the data onto a computer. Variance analysis (ANOVA) was used to determine the differences between the groups. Post Hoc Tests Multiple Comparisons Tukey HSD test was used to compare the binary groups. Also, Kruskall-Wallis variance analysis was used in case normality could not be maintained. Statistical significance level was accepted as $p \leq 0.05$.

III. Results

Based upon age and gender characteristics tabulated by WHO, 70% and 30% of 239 children were identified as MO and NW, respectively. Out of 121 girls, 67% were MO and 33% were NW. The corresponding values for 118 boys were 74% and 26%. Any statistically significant differences were not detected between mean age±SD values (years) of NW girls (9.0±2.0) and NW boys (9.2±2.1) as well as between MO girls (10.8±2.9) and MO boys (10.1±2.4) (p≥0.05).

TABLE I
DISTRIBUTION OF BMI, ANTHROPOMETRIC MEASUREMENTS AND BODY FAT RATIOS

Parameters	Sex	Group	mean±sd	p value
BMI	girls	MO	29,09±5,40	p≤0,001
		N	15,47±1,04	
	boys	MO	27,23±3,88 [a3]	p≤0,001
		N	15,92±1,06 [b4]	
Whole body fat%	girls	MO	36,96±6,98	p≤0,001
		N	18,44±2,67	
	boys	MO	34,88±6,05 [a3]	p≤0,001
		N	15,12±2,38 [b1]	
Waist C/Hip C	girls	MO	0,93±0,06	p≤0,001
		N	0,87±0,04	
	boys	MO	0,98±0,06 [a1]	p≤0,001
		N	0,90±0,05 [b2]	
Head C/Neck C	girls	MO	1,65±0,11	p≤0,001
		N	1,97±0,10	
	boys	MO	1,64±0,12 [a4]	p≤0,001
		N	1,89±0,10 [b2]	
Thigh C/Arm C	girls	MO	1,87±0,14	p≤0,05
		N	1,92±0,11	
	boys	MO	1,84±0,15 [a4]	p≤0,01
		N	1,92±0,10 [b4]	
Thigh C/Ankle C	girls	MO	2,28±0,22	p≤0,001
		N	1,96±0,19	
	boys	MO	2,20±0,20 [a3]	p≤0,001
		N	1,95±0,15 [b4]	
Height:2/Waist C	girls	MO	0,82±0,07	p≤0,001
		N	1,17±0,06	
	boys	MO	0,82±0,07 [a4]	p≤0,001
		N	1,16±0,06 [b4]	
Height:2/Hip C	girls	MO	0,76±0,06	p≤0,001
		N	1,01±0,05	
	boys	MO	0,80±0,05 [a1]	p≤0,001
		N	1,04±0,06 [b4]	
Fat mass index	girls	MO	11,00±3,71	p≤0,001
		N	2,88±0,53	
	boys	MO	9,70±2,87 [a3]	p≤0,001
		N	2,41±0,44 [b1]	
Trunk to appendicular fat ratio	girls	MO	0,78±0,11	p≤0,001
		N	0,63±0,12	
	boys	MO	0,74±0,11 [a3]	NS
		N	0,71±0,27 [b4]	
DONMA index I	girls	MO	42,83±11,16	p≤0,001
		N	19,73±2,91	
	boys	MO	39,61±8,62 [a3]	p≤0,001
		N	20,60±2,98 [b4]	
DONMA index II	girls	MO	16,46±6,62	p≤0,001
		N	3,71±0,97	
	boys	MO	14,18±5,00 [a3]	p≤0,001
		N	3,11±0,69 [b2]	

[a]MO girls-MO boys, [b]N girls-N boys, [1]p≤0,001, [2]p≤0,01, [3]p≤0,05, [4]p≥0,05

The values of BMI, WBF%, waist-to-hip, head-to-neck, thigh-to-arm, thigh-to-ankle, height 'to' 'two'-'to'-waist, height 'to' 'two'-'to'-hip ratios, as well the FMI, TAFR, DONMA Index I and DONMA Index II of girls and boys are shown in Table I.

Although normal BMI values did not differ in both sexes, MO girls were of significantly higher BMI values than MO boys (p≤0.05). NW girls had significantly greater WBF%s than NW boys (p≤0.001). This great difference was reduced as children progress towards morbid obesity (p≤0.05). NW boys exhibited significantly higher waist-to-hip ratios than NW girls (p≤0.01). This difference showed further increase in MO boys (p≤0.001). Significantly increased head-to-neck ratio was observed in NW girls compared to that of NW boys (p≤0.01). During MO stage this ratio was equalized (p≥0.05). Gender differences could not be observed in thigh-to-arm ratio both in NW and MO children. MO girls and MO boys showed statistically significant decreases (p≤0.05 *vs* p≤0.01) compared to NW children. However, this decrease was sharper in MO boys pointing out greater thigh C values in MO girls considering the same values for thigh-to-arm ratio in NW children. In spite of almost the same values observed for thigh-to-ankle ratio in NW state, a statistically significant increase was recorded in MO girls compared to MO boys (p≤0.05). As far as height 'to' 'two'-'to'-waist and height 'to' 'two'-'to'-hip ratios are considered, almost the same values were noted in NW boys and girls, as no difference in height 'to' 'two'-'to'-waist ratio was observed between MO boys and MO girls, significantly increased height 'to' 'two'-'to'-hip ratio was recorded in MO boys (p≤0.001). This was the indicator of greater progress in hip C in girls as they proceed from NW to MO stage.

The similar discussion made for WBF% was valid also for FMI. There was not a significant difference between TAFRs of NW boys and NW girls (p≥0.05). However, values obtained for MO girls were significantly higher than those for MO boys (p≤0.05). Significantly increased TAFR values for MO girls were observed in Fig. 1 (p≤0.001). There was not a significant difference between boys in NW and MO groups (p≥0.05).

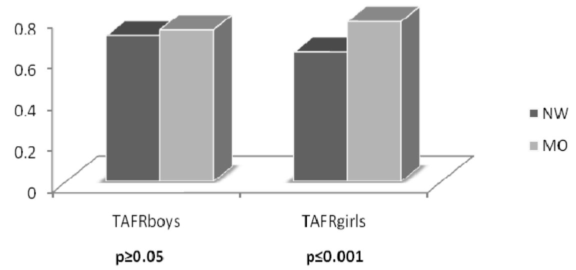
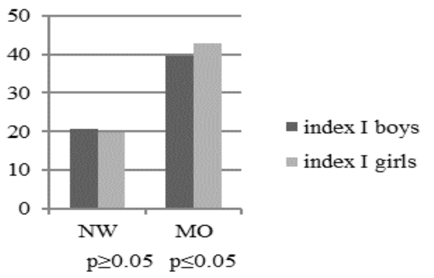
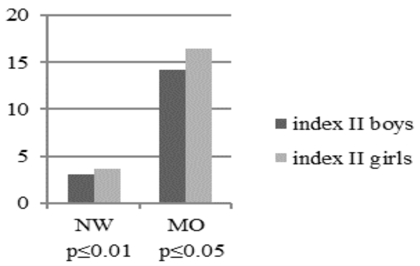


Fig. 1 Trunk-to-appendicular fat ratios of NW and MO children

DONMA Index I did not differ between NW girls and NW boys. However, values in MO girls were significantly higher than those in MO boys (p≤0.05). DONMA Index-II showed difference both in boys and girls even in their NW states, being higher in girls (p≤0.01). A somewhat reduced but still significant difference was kept during MO states of both genders (p≤0.05) (Fig. 2).



(a)



(b)

Fig. 2 Comparison of the statistical significances of (a) DONMA Index I and (b) DONMA Index II in NW and MO groups for both sexes

The values of BMI, DONMA Index I and DONMA Index II confined to MO and NW groups are shown in graphical forms in Fig. 3.

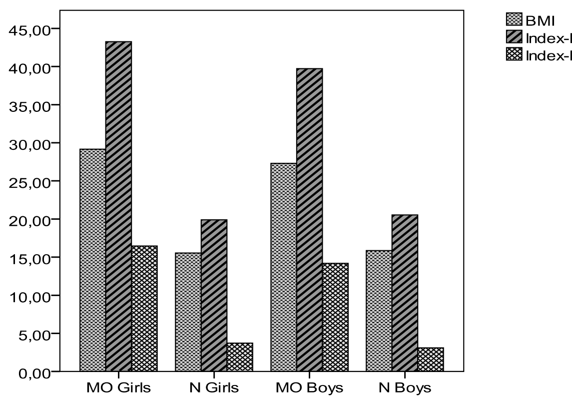


Fig. 3 BMI, DONMA Index I and DONMA Index II values in NW and MO children

The variations in waist-to-hip, head-to-neck, height 'to' 'two'-'to'-waist, height 'to' 'two'-'to'-hip values in MO and NW groups are demonstrated using graphical presentations in Fig. 4.

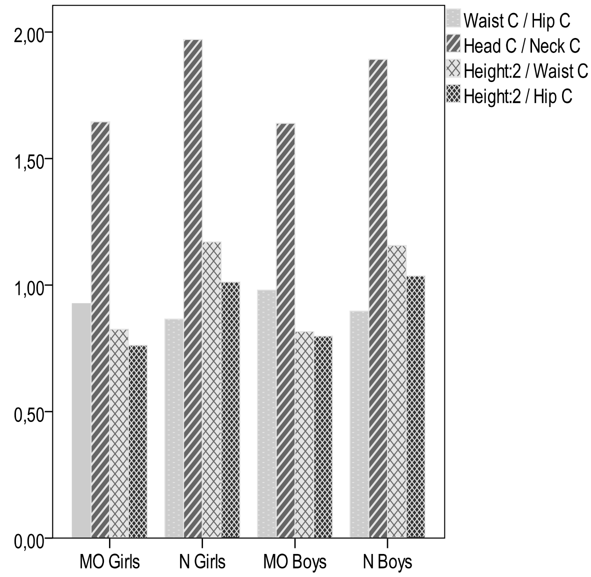


Fig. 4 Waist-to-hip, head-to-neck, height:2/waist, height:2/hip ratios in NW and MO children

IV. Discussion

Obesity, as the cause for many life-threatening diseases, is one of the leading, perhaps the most important, health problem in the world today [17]. The need for the detailed examination of the relationship between body fat ratios and obesity is highlighted in the investigations of the health problems related to this disease [18]-[20]. Types of nutrition from birth on [21], phytonutrients [22], trace elements [23], dietary toxic metals [24], [25], parental smoking habits [26] may affect obesity, and strategies have been developed to solve this problem [27], [28].

Anthropologists, also, state that different views should be included in the process of childhood obesity investigations [29]. Evaluation of anthropometric measurements with body fat ratios and indices will give much more valuable information during studies performed on obesity.

In this study, BMI was evaluated along with new and comprehensive anthropometric measurements in addition to detailed body fat ratios. Assessment of BMI values showed statistically significant differences between MO and N groups (p≤0.001) both in girls and boys. When percentages related to arms fat, legs fat, trunk fat and WBF were evaluated, statistically significant differences were detected between MO-NW groups (p≤0.001). Ratios of MO-to-NW groups were 1.71 (27.23:15.92) and 2.31 (34.88:15.12) in boys, 1.88 (29.09:15.47) and 2.00 (36.96:18.44) in girls, for BMI and WBF%, respectively. Fat ratios in MO groups were detected about two fold of those of NW groups. These findings pointed out that total fat percentage is more valuable than BMI evaluation.

BMI/WBF%s were determined as 0.79 (29.09:36.96) and 0.84 (15.47:18:44) in girls, 0.78 (27.23:34.88) and 1.05 (15.92:15.12) in boys for MO and NW groups, respectively.

This data gave the information that this ratio is kept within certain narrow limits.

Fat mass index values showed more significant differences than BMI values between the groups. Ratios between MO and NW groups in FMI [3.8 (11.00:2.88) in girls and 4.02 (9.70:2.41) in boys] showed more significant differences than BMI [1.88 (29.09:15.47) in girls and 1.71 (27.23:15.92) in boys]. These results showed that body fat ratios and FMI values are more valuable parameters than BMI values in our study.

Waist C and waist-to-height ratio were indicated as important anthropometric parameters for the evaluation of obesity in many studies up till now [12], [14], [30]. Children in our study were evaluated for their waist-to-hip ratios. Significant differences were found between MO-NW groups (p≤0.001). This observation suggested that waist-to-hip ratio is an important parameter to investigate and define MO children.

Upon evaluation of neck C values, boys were reported to have higher values than girls, but it was not suggested as a significant parameter for the evaluation of obesity in both sexes [31]. In another study, neck C was suggested as a new parameter for the evaluation of obese children [32]. In our study, when head-to-neck ratios were evaluated, decreasing rates of ratios in parallel with the increase in the obesity were detected. Statistically significant difference was observed between MO and NW groups (p≤0.001). The amount of accumulation of adipose tissue, particularly around the neck area of children, was much more in the transition from NW to MO. These findings suggested that accumulation of adipose tissue starts intensively in the neck region and increases during the transition from NW to MO. This parameter proved that fat accumulation occurs especially in the neck region, in particular, during the weight gain passing from NW to MO.

Waist C and height were evaluated without considering BMI in children aged 07-14 years, however, any relationship were not found between them [33]. In a study involving children aged 06-17 years, weight and BMI values were not considered, but a significant relation between arm length and height was reported [34]. In another study performed on children aged 06-17 years, weight, height, waist C, mid-arm C and arm fat area values were compared with demographic characteristics, but BMIs and other body fat ratios were not taken into consideration [35].

In our study, weight and height values as well as waist, arm, hip and thigh Cs and ratios, in addition to BMI and body fat ratios, were collectively taken into account in order to evaluate them along with other anthropometric measurements. Thigh-to-arm ratios obtained in our study did not show any difference between girls and boys in terms of their MO and NW groups (p≥0.05). This parameter showed a difference between NW-MO states of the genders. The difference between the groups in girls was p≤0.05. An advanced level of statistical difference was noted for boys (p≤0.01). These results proved that thigh-to-arm ratio is an interesting parameter to be investigated for the determination of obesity development, as well as the evaluation of the gender differences in children.

Evaluating the ratio of thigh-to-ankle, an increasing trend was observed between the groups in parallel with the development of obesity. Significant statistical differences were found between MO-NW groups (p≤0.001). This finding suggested that adipose tissue accumulates more around the thigh area than that of the ankle, resulting in its expansion in MO group.

Evaluating the ratios height ‘to’ ‘two’-‘to’-waist and height ‘to’ ‘two’-‘to’-hip ratios individually, decreases were observed in these ratios in parallel with the increases in BMI. Due to the expansion of waist and hip Cs, statistically significant differences between groups were detected (p≤0.001). Evaluating the ratios height ‘to’ ‘two’-‘to’-waist, height ‘to’ ‘two’-‘to’-hip and thigh-to-ankle ratios together showed that adipose tissue accumulation develops together with expansion of waist and hip Cs that are the indicators of fat accumulation in visceral region and hip rather than thigh region in transition from group NW to MO. When height ‘to’ ‘two’-‘to’-hip ratio was evaluated, the value was detected as about 1 for NW group in both genders, but the value for group MO was below 1 (0.76 in girls and 0.80 in boys). This finding revealed that reference normal value for height ‘to’ ‘two’-‘to’-hip ratio can be considered as “1” .

When we evaluate FMI values between groups, the difference is prominent between MO and NW groups in both genders (p≤0.001). Upon examination of FMI values, considerable amount of weight gain during transition from the group NW to MO was found as a result of the increase in fat tissue.

Even in studies reporting that fat distribution evaluated in terms of TAFR was related to blood pressure values in children and this ratio is valuable for evaluation of body fat, this information was said to be valid especially for boys and it was reported that such a relation was not found for girls [36]. This information is supportive for the inconsistent findings obtained about this ratio and it can be explained by the differences in visceral fat tissue between sexes. Upon evaluation of TAFR values in our study, there were significant differences between MO-NW (p≤0.001) in girls, however no statistically significant difference was detected between MO-NW (p≥0.05) in boys.

A study performed on children aged 05-15 years reported that measurement of BMI alone is not sufficient to determine body fat status. The same study reported that fat ratio increases as the ages of the children increase [37].

In our study, we evaluated body fat ratios by taking fat distribution in extremities and trunk into consideration, along with anthropometric measurements and ratios. Our study provides more detailed information compared to the other studies and is the first study in this field because it includes, detailed fat measurement analyses and detailed anthropometric measurements, as well as ratios including DONMA Index I and DONMA Index II among children.

Detailed evaluation of the child patient is important for follow-up and treatment options, because childhood obesity is closely associated with cardiovascular diseases and MetS developing in childhood and continues in the adulthood.

Within the scope of this study, DONMA Index I and DONMA Index II are introduced as new indices. Upon evaluation of DONMA Index I and DONMA Index II, there were quite significant differences between groups MO-NW ($p \leq 0.001$).

When the DONMA Index I values based upon weight and height were interpreted, MO/NW ratios were calculated as 2.17 (42.83:19.73) in girls and 1.92 (39.61:20.60) in boys, and when the DONMA Index II values based on body fat ratio were considered, MO/NW ratios were calculated as 4.44 (16.46:3.71) in girls and as 4.56 (14.18:3.11) in boys. As a result, DONMA index II values were found to be more than 2 fold of the values obtained for DONMA index I (4.44 *vs* 2.17; 2.05) in girls and (4.56 *vs* 1.92; 2.38) in boys. The statistical significances were the same ($p \leq 0.05$) between girls and boys in MO groups for both indices. However, in NW group, DONMA index II exhibited statistical significance ($p \leq 0.01$) whereas DONMA index I showed no significance between the genders during NW state ($p \geq 0.05$).

In this study, it was concluded that DONMA Index II may be more valuable than DONMA Index I because DONMA Index II showed more significant statistical differences between the groups. The fat mass index and DONMA Index II based upon fat tissue were found to be more valuable than BMI and DONMA Index I based on body weight, respectively. Trunk-to-appendicular fat ratio was found to be the only parameter, which exhibits meaningful differences between NW-MO states of girls and boys.

This research, under the light of these findings, revealed that ratios and formulas based upon body fat tissue may be more important parameters than those based upon weight and height for the assessment of obesity in children. Determination of whole body fat and the other indices derived from fat do not require a physician. These are simple and non-invasive measurements. The results can immediately be reported by the dietician and then evaluated by the pediatrician within a very short period. This point is important due to the limited time of pediatricians.

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