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Laboratory Indices in Late Childhood Obesity: The Importance of DONMA Indices

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Abstract**—**Obesity in childhood establishes a ground for adulthood obesity. Especially morbid obesity is an important problem for the children because of the associated diseases such as diabetes mellitus, cancer and cardiovascular diseases. In this study, body mass index (BMI), body fat ratios, anthropometric measurements and ratios were evaluated together with different laboratory indices upon evaluation of obesity in morbidly obese (MO) children. Children with nutritional problems participated in the study. Written informed consent was obtained from the parents. Study protocol was approved by the Ethics Committee. Sixty-two MO girls aged 129.5±35.8 months and 75 MO boys aged 120.1±26.6 months were included into the scope of the study. WHO-BMI percentiles for age-and-sex were used to assess the children with those higher than 99th as morbid obesity. Anthropometric measurements of the children were recorded after their physical examination. Bio-electrical impedance analysis was performed to measure fat distribution. Anthropometric ratios, body fat ratios, Index-I and Index-II as well as insulin sensitivity indices (ISIs) were calculated. Girls as well as boys were binary grouped according to homeostasis model assessment-insulin resistance (HOMA-IR) index of <2.5 and >2.5, fasting glucose to insulin ratio (FGIR) of <6 and >6 and quantitative insulin sensitivity check index (QUICKI) of <0.33 and >0.33 as the frequently used cut-off points. They were evaluated based upon their BMIs, arms, legs, trunk, whole body fat percentages, body fat ratios such as fat mass index (FMI), trunk-to-appendicular fat ratio (TAFR), whole body fat ratio (WBFR), anthropometric measures and ratios [waist-to-hip, head-to-neck, thigh-to-arm, thigh-to-ankle, height/2-to-waist, height/2-to-hip circumference (C)]. SPSS/PASW 18 program was used for statistical analyses. p≤0.05 was accepted as statistically significance level. All of the fat percentages showed differences between below and above the specified cut-off points in girls when evaluated with HOMA-IR and QUICKI. Differences were observed only in arms fat percent for HOMA-IR and legs fat percent for QUICKI in boys (p≤ 0.05). FGIR was unable to detect any differences for the fat percentages of boys. Head-to-neck C was the only anthropometric ratio recommended to be used for all ISIs (p≤0.001 for both girls and boys in HOMA-IR, p≤0.001 for girls and p≤0.05 for boys in FGIR and QUICKI). Indices which are recommended for use in both genders were Index-I, Index-II, HOMA/BMI and log HOMA (p≤0.001). FMI was also a valuable index when evaluated with HOMA-IR and QUICKI (p≤0.001). The important point was the detection of the severe significance for HOMA/BMI and log HOMA while they were evaluated also with the other indices, FGIR and QUICKI (p≤0.001). These parameters along with Index-I were unique at this level of significance for all children. In conclusion, well-accepted ratios or indices may not be valid for the evaluation of both genders. This study has emphasized the limiting properties for boys. This is particularly important for the selection process of some ratios and/or indices during the clinical studies. Gender difference should be taken into consideration for the evaluation of the ratios or indices, which will be recommended to be used particularly within the scope of obesity studies.

Keywords**—**Anthropometry, childhood obesity, gender, insulin sensitivity index.

I. Introduction

OBESITY is a growing health problem in the world, threatening all of the communities. Beginning obesity in childhood establishes a ground for adulthood obesity, and this becomes a serious problem in children. The possibility of obesity to continue in adulthood is higher for both girls and boys with childhood obesity. Especially increasing rates of morbid obesity is responsible for serious health problems, such as diabetes and metabolic syndrome (MetS) during childhood and adolescence [1] [2].

Evaluation of anthropometric measurements as well as BMI values together with body fat ratios during the examination of the biological aspects of obesity is important for more comprehensive and reliable investigation of the individual.

So far, three laboratory insulin sensitivity indices (ISIs); homeostasis model assessment-insulin resistance (HOMA-IR) [3], fasting glucose to insulin ratio (FGIR) [4] and quantitative insulin sensitivity check index (QUICKI) [5] were widely included into the studies performed on obesity. Some have introduced also the discussions based upon BMI values [6]-[10]. However, any study investigating their associations with fat-based ratios and estimating anthropometric measurements as well as ratios above and below the cut-off points of these laboratory indices for MO children in both girls and boys has not been reported yet.

In our study, we emphasize that BMI, body fat ratios and anthropometric measurements as well as ratios for MO children have to be evaluated together with different laboratory indices during the evaluation of childhood obesity. Within this context, recently developed indices; diagnostic obesity nomination model assessment (DONMA) Index-I and DONMA Index-II were introduced. Their potential uses were compared to those of previously introduced ratios and indices such as waist-to-hip, head-to-neck, BMI, FMI, thigh-to-arm, thigh-to-ankle, WBFR and TAFR. The values were calculated and compared for the levels above and below the frequently used cut-off points of these laboratory indices (<2.5 and >2.5 for HOMA-IR, <6 and >6 for FGIR and <0.328 and >0.328

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for QUICKI). The parameters, which can be used to differentiate MO girls from MO boys were investigated.

II. Patients and Methods

A. Patients

Seventy-five MO boys and sixty-two MO girls (aged between 6 and 18 years) with nutritional problems admitted to Namik Kemal University, Faculty of Medicine, Department of Practice and Research Hospital, Clinic of Pediatrics, comprised the study group. The mean age of MO girls was 129.5±35.8 months. MO boys had a mean age of 120.1±26.6 months. Percentile values of BMIs consistent with the month of children that were identified by World Health Organization (WHO) were taken into account in the creation of the groups. When BMIs were evaluated by considering percentile values consistent with the months; boys in the >99 percentile were considered MO. Children with chronic diseases in their cardiovascular, respiratory, renal, hepatic, neurologic/ neuromuscular, hematologic, immunologic, endocrine and in particular gastrointestinal system, children with growth retardation and children using regular drug due to their chronic diseases were excluded from the study.

Written informed consent and agreement were obtained from the parents before any testing procedure was carried out. Approval of the protocol was obtained by the Local Scientific Committee. The study was conducted in accordance with the Declaration of Helsinki.

B. Measurements

Each child was anthropometrically measured following the physical examination after 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 patient were measured in addition to weight, height, waist C and hip C. Shoeless children with thin issued clothing were measured for their weight by an electronic weighing instrument that is sensitive to 0.1 kg intervals. Shoeless children were measured for their height 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, hips and ankles 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 malleolus 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, every boy was sent to the dietary outpatient clinic. Following the evaluation of the children, necessary nutrition and physical activity recommendations and treatments were given. Then, management controls were arranged at regular intervals. Nutritional status was also evaluated in detail in the dietary outpatient clinic, then, the parameters related to body fat were measured. The analyses of the body fat were performed by TANITA ® "MC 980 multi frequency segmental body composition analysis" (bio-electrical impedance analysis-BIA).

C. Ratio Calculations

Medical history, physical examination, anthropometric measurements, biochemical values and body fat ratios of the children in the extent of the study were evaluated together. BMI was calculated for each patient. Waist C/hip C (waist-to-hip), head C/neck C (head-to-neck), thigh C /arm C (thigh-to-arm) (right + left mid-thigh C:2/right + left mid-arm C:2), thigh C/ankle C (thigh-to-ankle) (right + left mid-thigh C:2/right + left ankle C:2), height:2/waist C (height/2-to-waist), height:2/hip C (height/2-to-hip), DONMA index I: [weight (kg) * 100/height (cm)] and DONMA index II: [total body fat mass (kg) * 100/height (cm)] were calculated for evaluation of the BMI and anthropometric ratios together. In order to evaluate body fat amount and BMI groups together, upper, lower and trunk fat ratio, WBFR [total body fat (kg) / body weight (kg)], FMI [total body fat (kg) / height (m) * height (m)], TAFR [trunk fat (kg) / upper + lower limbs fat (kg) ratio] were calculated.

D. Evaluation of Laboratory Indices

HOMA-IR [(fasting glucose (mg/dL)* fasting insulin (µIU/ml/ 22.5*0.0555)], HOMA/BMI, log HOMA-IR, FGIR [(fasting glucose(mg/dL)/fasting insulin(mU/L] and QUICKI [1/log.fasting insulin (µIU/ml)+log.fasting glucose (mg/dL)] [3]-[5] were used to evaluate MO children for their laboratory indices.

Seventy-five MO boys and 62 MO girls were grouped of based on HOMA-IR, FGIR and QUICKI indexes. This research has been planned on HOMA-IR index of <2.5 and >2.5, FGIR index of <6 and >6 and QUICKI index of <0.328 and >0.328 as frequently used cut-off points. Then they were evaluated for their BMI, body fat ratios and anthropometric measurements as well as ratios.

E. Statistical Evaluation

PASW 18 Statistics for Windows statistical package program was used to transfer the data onto a computer.

Student t test was used to determine whether there is a difference about the parameters between groups. Mann Whitney U test was used to evaluate the non-parametric measurements. Kruskall-Wallis variance analysis was used in case normality could not be maintained. Bivariate Correlation and significance tests were made to detect whether there is combined change between two parameters. Statistical significance level was accepted as $p \leq 0.05$.

III. Results

Table I shows that 75 MO boys and 62 MO girls aged 06-18 were evaluated for their BMI and body fat ratios according to their HOMA-IR < 2.5 and >2.5 (the frequently used cut-off point).

TABLE I
Evaluation of the Relationship between HOMA-IR and BMI as Well as Body Fat Ratios

parameter	HOMA cut-off value	$\bar{X} \mp sd$ (BOYS)	$\bar{X} \mp sd$ (GIRLS)	p value
BMI	>2.5	28.86 ∓ 3,35	32.10 ∓ 5.12	p ≤ 0.001(B)
	<2.5	26.20 ∓ 3.82	26.44 ∓ 3.85	p ≤ 0.001(G)
arms fat %	>2.5	4.77 ∓ 0.79	5.40 ∓ 1.09	p ≤ 0.05(B)
	<2.5	4.41 ∓ 1.19	4.67 ∓ 0.81	p ≤ 0.01(G)
legs fat %	>2.5	16.63 ∓ 3.10	16.46 ∓ 2.67	NS(B)
	<2.5	15.32 ∓ 3.00	14.87 ∓ 2.79	p ≤ 0.05(G)
trunk fat %	>2.5	15.37 ∓ 1.94	16.86 ∓ 3.07	NS(B)
	<2.5	14.52 ∓ 3.19	14.98 ∓ 3.03	p ≤ 0.05(G)
whole body fat%	>2.5	36.76 ∓ 5.15	38.71 ∓ 5.88	NS(B)
	<2.5	34.20 ∓ 6.65	34.53 ∓ 6.16	p ≤ 0.01(G)

TABLE II
Evaluation of the Relationship between FGIR and BMI as Well as Body Fat Ratios

parameter	FGIR cut-off value	$\bar{X} \mp sd$ (BOYS)	$\bar{X} \mp sd$ (GIRLS)	p value
BMI	>6	29.08 ∓ 3.25	31.73 ∓ 4.65	p ≤ 0.05(B)
	<6	26.61 ∓ 3.86	27.11 ∓ 4.76	p ≤ 0.001(G)
arms fat%	>6	4.77 ∓ 0.74	5.35 ∓ 1.06	NS(B)
	<6	4.47 ∓ 1.15	4.75 ∓ 0.91	p ≤ 0.05(G)
legs fat%	>6	16.97 ∓ 3.10	16.40 ∓ 2.80	NS(B)
	<6	15.44 ∓ 3.01	15.05 ∓ 2.70	NS(G)
trunk fat%	>6	15.34 ∓ 1.75	16.83 ∓ 3.18	NS(B)
	<6	14.69 ∓ 3.05	15.08 ∓ 3.00	p ≤ 0.05(G)
whole body fat%	>6	37.09 ∓ 4.96	38.58 ∓ 5.99	NS(B)
	<6	34.56 ∓ 6.48	34.89 ∓ 6.13	p ≤ 0.05(G)

Table II shows that MO boys and MO girls were evaluated for their BMI and body fat ratios according to their FGIR <6 and >6 (the frequently used cut off point).

Table III shows that MO children were evaluated for their BMI and body fat ratios according to QUICKI <0.328 and >0.328 (the frequently used cut off point).

MO children were classified as two groups based on the gender difference and each group is divided into two groups according to HOMA-IR levels of <2.5 and >2.5. Evaluation of the groups in terms of BMI showed that the groups with HOMA-IR level of >2.5 have significantly higher BMI values ($p \leq 0.001$). In girls, statistical difference was quite significant in terms of WBF and arms fat percentages ($p \leq 0.01$) and moderately significant in terms of trunk and lower extremity percentages ($p \leq 0.05$). In boys, statistical differences were not significant in terms of WBF, trunk fat and legs fat percentages.

TABLE III
Evaluation of the Relationship between QUICKI and BMI as Well as Body Fat Ratios

parameter	QUICKI cut-off value	$\bar{X} \mp sd$ (BOYS)	$\bar{X} \mp sd$ (GIRLS)	p value
BMI	>0.328	28.93 ∓ 3.53	31.70 ∓ 5.16	p ≤ 0.01(B)
	<0.328	26.39 ∓ 3.74	26.44 ∓ 3.85	p ≤ 0.001(G)
arms fat%	>0,328	4.78 ∓ 0.84	5.33 ∓ 1.10	NS(B)
	<0.328	4.43 ∓ 1.15	4.67 ∓ 0.81	p ≤ 0.01(G)
legs fat%	>0.328	17.05 ∓ 3.09	16.37 ∓ 2.62	p ≤ 0.05(B)
	<0.328	15.21 ∓ 2.91	14.87 ∓ 2.79	p ≤ 0.05(G)
trunk fat%	>0.328	15.26 ∓ 1.88	16.65 ∓ 3.11	NS(B)
	<0.328	14.65 ∓ 3.14	14.98 ∓ 3.03	p ≤ 0.05(G)
whole body fat%	>0.328	37.09 ∓ 5.27	38.36 ∓ 5.91	NS(B)
	<0.328	34.24 ∓ 6.46	34.53 ∓ 6.16	p ≤ 0.05(G)

MO boys and MO girls were divided into two groups according to FGIR levels of <6 and >6. In MO girls, except lower extremities fat percentage, all were significantly differed. In boys, none of the parameters exhibited significant difference. In the evaluation of MO girls after division into two groups based on QUICKI levels of <0.328 and >0.328, upper extremities ($p \leq 0.01$) as well as lower extremities, trunk and WBF percentages ($p \leq 0.05$) differed significantly between the groups. In boys, the only statistical significance was detected for lower extremities ($p \leq 0.05$) upon evaluation of this cut-off point.

Table IV shows that MO children were evaluated for their anthropometric measurements, ratios and indices according to their HOMA-IR values < 2.5 and >2.5.

Upon evaluation of anthropometric ratios with some weight- and fat-based laboratory indices, comparison of head-to-neck, HOMA/BMI, logHOMA, FMI, DONMA index I and DONMA index II between groups with HOMA-IR values of <2,5 and >2,5 revealed that statistical differences were quite significant for both genders ($p \leq 0.001$). In boys, waist-to-hip, thigh-to-arm, thigh-to-ankle, height:2-to-waist, height:2-to-hip, TAFR and WBFR were not statistically significant ($p \geq 0,05$). In girls, aside from height:2-to-hip, WBFR, all the above were the same. In girls, height:2-to-hip and WBFR were clearly significant ($p \leq 0.01$). Evaluation of DONMA index I based on body weight and DONMA index-II based on body fat were significantly different for groups of HOMA<2.5 and >2.5 for both genders ($p \leq 0.01$).

Table V shows that MO children were evaluated for their anthropometric measurements, ratios and indices according to their FGIR values < 6 and >6.

Classification of MO boys according to FGIR <6 and >6, and evaluation of anthropometric ratios in subgroups showed that waist-to-hip, thigh-to-arm, thigh-to-ankle, height:2-to-waist, height:2-to-hip, TAFR and WBFR values in boys, waist-to-hip, thigh-to-arm, thigh-to-ankle, height:2-to-waist and TAFR values in girls were not statistically significant as in the case of HOMA-IR.

TABLE IV
EVALUATION OF THE RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASUREMENTS/RATIOS/INDICES AND HOMA-IR IN MORBID OBESE CHILDREN

parameter	HOMA cut-off value	$\overline{X} \mp sd$ (BOYS)	$\overline{X} \mp sd$ (GIRLS)	p value
waist-to-hip	>2.5	0.98 ∓ 0.04	0.92 ∓ 0.06	NS(B)
	<2.5	0.98 ∓ 0.07	0.93 ∓ 0.06	NS(G)
head-to-neck	>2.5	1.59 ∓ 0.09	1.58 ∓ 0.10	p ≤ 0.001(B)
	<2.5	1.66 ∓ 0.13	1.69 ∓ 0.11	p ≤ 0.001(G)
thigh-to-arm	>2.5	1.85 ∓ 0.14	0.47 ∓ 0.04	NS(B)
	<2.5	0.83 ∓ 0.16	0.46 ∓ 0.04	NS(G)
thigh-to-ankle	>2.5	2.23 ∓ 0.16	0.59 ∓ 0.06	NS(B)
	<2.5	2.18 ∓ 0.22	0.56 ∓ 0.05	NS(G)
height:2-to-waist	>2.5	0.81 ∓ 0.06	0.81 ∓ 0.08	NS(B)
	<2.5	0.82 ∓ 0.07	0.84 ∓ 0.06	NS(G)
height:2-to-hip	>2.5	0.79 ∓ 0.05	0.74 ∓ 0.07	NS(B)
	<2.5	0.80 ∓ 0.06	0.78 ∓ 0.06	p ≤ 0.01(G)
HOMA/BMI	>2.5	0.15 ∓ 0.05	0.15 ∓ 0.05	p ≤ 0.001(B)
	<2.5	0.05 ∓ 0.03	0.05 ∓ 0.02	p ≤ 0.001(G)
logHOMA	>2.5	0.60 ∓ 0.13	0.65 ∓ 0.16	p ≤ 0.001(B)
	<2.5	0.02 ∓ 0.29	0.01 ∓ 0.29	p ≤ 0.001(G)
FMI	>2.5	10.75 ∓ 2.52	12.64 ∓ 3.77	p ≤ 0.05(B)
	<2.5	9.16 ∓ 3.03	9.30 ∓ 2,.90	p ≤ 0.001(G)
TAFR	>2.5	0.73 ∓ 0.10	0.78 ∓ 0.12	NS(B)
	<2.5	0.74 ∓ 0.13	0.77 ∓ 0.11	NS(G)
WBFR	>2.5	0.38 ∓ 0.05	0.39 ∓ 0.06	NS(B)
	<2.5	0.34 ∓ 0.07	0.35 ∓ 0.06	p ≤ 0.01(G)
DONMA index I	>2.5	43.97 ∓ 7.50	50.67 ∓ 10.01	p ≤ 0.001(B)
	<2.5	36.46 ∓ 7.65	36.86 ∓ 7.80	p ≤ 0.001(G)
DONMA index II	>2.5	16.38 ∓ 4.32	20.06 ∓ 6.64	p ≤ 0.01(B)
	<2.5	12.79 ∓ 5.03	13.07 ∓ 4.88	p ≤ 0.001(G)

Table VI shows that MO children were evaluated for their anthropometric measurements, ratios and indices according to their QUICKI values <0.328 and >0.328.

After classification of MO children according to QUICKI <0.328 and >0.328 values, evaluation of anthropometric ratios in subgroups revealed that waist-to-hip, thigh-to-arm, thigh-to-ankle, height:2-to-waist, height:2-to-hip ratios, TAFR and WBFR in boys, waist-to-hip, thigh-to-arm, thigh-to-ankle, height:2-to-waist ratios and TAFR in girls were not statistically significant as in the cases of HOMA-IR and FGIR.

Head-to-neck values were significantly reduced in FGIR<6, QUICKI <0.328 and HOMA-IR>2.5 groups in girls ($p \leq 0.001$). This parameter exhibited same significance for HOMA-IR in boys. The degree of significance was $p \leq 0.05$ for the remaining two ISIs in boys. Head-to-neck values were significantly differed between above and below the cut-off points of these three laboratory indices (Fig. 1).

Indices which are recommended for use in both genders were DONMA index-I, DONMA index-II, HOMA/BMI and log HOMA ($p \leq 0.001$). HOMA/BMI and log HOMA exhibited same degree of significance ($p \leq 0.001$) while they were evaluated by HOMA-IR, FGIR and QUICKI. Out of these parameters, DONMA index I and DONMA index II have been introduced recently. Aside from their beneficial uses for the childhood obesity studies (Figs. 2, 3), particularly the diagnostic use of DONMA index II in exhibiting gender difference was clearly shown in Fig. 3.

TABLE V
EVALUATION OF THE RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASUREMENTS/RATIOS/INDICES AND FGIR IN MORBID OBESE CHILDREN

parameter	FGIR cut-off value	$\overline{X} \mp sd$ (BOYS)	$\overline{X} \mp sd$ (GIRLS)	P value
waist-to-hip	>6	0.98 ∓ 0.06	0.93 ∓ 0.06	NS(B)
	<6	0.98 ∓ 0.04	0.92 ∓ 0.06	NS(G)
head-to-neck	>6	1.66 ∓ 0.12	1.68 ∓ 0.11	p ≤ 0.05(B)
	<6	1.57 ∓ 0.08	1.59 ∓ 0.09	p ≤ 0.001(G)
thigh-to-arm	>6	1.85 ∓ 0.15	0.46 ∓ 0.03	NS(B)
	<6	1.81 ∓ 0.15	0.47 ∓ 0.04	NS(G)
thigh-to-ankle	>6	2.20 ∓ 0.21	0.56 ∓ 0.06	NS(B)
	<6	2.20 ∓ 0.17	0.58 ∓ 0.05	NS(G)
height:2-to-waist	>6	0.82 ∓ 0.07	0.83 ∓ 0.07	NS(B)
	<6	0.81 ∓ 0.06	0.81 ∓ 0.07	NS(G)
height:2-to-hip	>6	0.80 ∓ 0.06	0.78 ∓ 0.06	NS(B)
	<6	0.80 ∓ 0.05	0.74 ∓ 0.06	p ≤ 0.05(G)
HOMA/BMI	>6	0.06 ∓ 0.03	0.05 ∓ 0.03	p ≤ 0.001(B)
	<6	0.17 ∓ 0.04	0.15 ∓ 0.06	p ≤ 0.001(G)
logHOMA	>6	0.10 ∓ 0.31	0.10 ∓ 0.30	p ≤ 0.001(B)
	<6	0.68 ∓ 0.09	0.62 ∓ 0.30	p ≤ 0.001(G)
FMI	>6	9.40 ∓ 3.02	9.68 ∓ 3.33	NS(B)
	<6	10.91 ∓ 2.37	12.44 ∓ 3.56	p ≤ 0.05(G)
TAFR	>6	0.74 ∓ 0.12	0.76 ∓ 0.10	NS(B)
	<6	0.72 ∓ 0.10	0.78 ∓ 0.13	NS(G)
WBFR	>6	0.35 ∓ 0.06	0.35 ∓ 0.06	NS(B)
	<6	0.37 ∓ 0.05	0.39 ∓ 0.06	p ≤ 0.05(G)
DONMA index I	>6	37.49 ∓ 7.87	38.26 ∓ 9.34	p ≤ 0.001(B)
	<6	44.88 ∓ 7.52	50.07 ∓ 9.82	p ≤ 0.001(G)
DONMA index II	>6	13.31 ∓ 5.08	13.76 ∓ 5.60	p ≤ 0.01(B)
	<6	16.82 ∓ 4.04	19.75 ∓ 6.55	p ≤ 0.001(G)

IV. DISCUSSION

Obesity is one of the most important health problems in the world, because it causes many life-threatening diseases [11]. Different dietary habits from birth on [12], phytonutrients [13], trace elements [14], toxic metals in the diet [15], [16], parental smoking habits [17], [18], pregnancy complications such as fetal overgrowth [19], reduced regulatory T cells [20] may participate in obesity and some strategies have been developed to solve this problem [21], [22].

Studies investigating anthropometric measurements and their relations with the values obtained for various indices were conducted on childhood obesity up till now. In a study performed on severely obese prepubertal Italian children, mean HOMA-IR and QUICKI values were detected as 3.2±1.5 and 0.327±0.019 for girls, 2.2±1.0 and 0.346±0.027 for boys, respectively [6].

In a study evaluating insulin sensitivity in adolescents with a mean age of 13, mean HOMA-IR index values were reported as 2.09±1.83 for BMI<85th group and as 3.41±2.37 for BMI>85th group [7].

TABLE VI
EVALUATION OF THE RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASUREMENTS/RATIOS/INDICES AND QUICKI IN MORBID OBESE CHILDREN

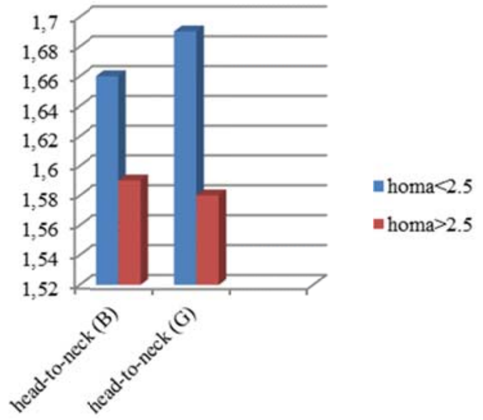
parameter	QUICKI cut-off value	$\overline{X} \mp sd$ (BOYS)	$\overline{X} \mp sd$ (GIRLS)	P value
waist-to-hip	>0.328	0.98 ∓ 0.07	0.93 ∓ 0.06	NS(B)
	<0.328	0.98 ∓ 0.04	0.92 ∓ 0.06	NS(G)
head-to-neck	>0,328	1.66 ∓ 0.12	1.69 ∓ 0.11	$p \leq 0.05$(B)
	<0.328	1.59 ∓ 0.10	1.59 ∓ 0.09	$p \leq 0.001$(G)
thigh-to-arm	>0.328	1.84 ∓ 0.16	0.46 ∓ 0.04	NS(B)
	<0.328	1.84 ∓ 0.15	0.47 ∓ 0.03	NS(G)
thigh-to-ankle	>0.328	2.19 ∓ 0.22	0.56 ∓ 0.05	NS(B)
	<0.328	2.22 ∓ 0.17	0.58 ∓ 0.06	NS(G)
height:2-to-waist	>0.328	0.82 ∓ 0.07	0.84 ∓ 0.06	NS(B)
	<0.328	0.81 ∓ 0.06	0.81 ∓ 0.07	NS(G)
height:2-to-hip	>0.328	0.80 ∓ 0.05	0.78 ∓ 0.06	NS(B)
	<0.328	0.79 ∓ 0.05	0.74 ∓ 0.07	$p \leq 0.05$(G)
HOMA/BMI	>0,328	0.05 ∓ 0.03	0.05 ∓ 0.02	$p \leq 0.001$(B)
	<0.328	0.16 ∓ 0.05	0.14 ∓ 0.05	$p \leq 0.001$(G)
logHOMA	>0.328	0.05 ∓ 0,30	0.01 ∓ 0.29	$p \leq 0.001$(B)
	<0.328	0.63 ∓ 0.12	0.63 ∓ 0.17	$p \leq 0.001$(G)
FMI	>0.328	9.22 ∓ 2,94	9.77 ∓ 2.90	$p \leq 0.05$ (B)
	<0.328	10.88 ∓ 2,62	12.38 ∓ 9.30	$p \leq 0.001$(G)
TAFR	>0.328	0.75 ∓ 0,13	0.77 ∓ 0.11	NS(B)
	<0.328	0.72 ∓ 0,09	0.77 ∓ 0.12	NS(G)
WBFR	>0.328	0.34 ∓ 0,06	0.35 ∓ 0.06	NS(B)
	<0.328	0.38 ∓ 0,05	0.38 ∓ 0.06	$p \leq 0.05$(G)
DONMA index I	>0.328	37.02 ∓ 7,71	36.86 ∓ 7.80	$p \leq 0.001$(B)
	<0.328	44.06 ∓ 7,82	49.63 ∓ 10.40	$p \leq 0.001$(G)
DONMA index II	>0.328	13.00 ∓ 4,94	13.07 ∓ 4.88	$p \leq 0.01$(B)
	<0.328	16.57 ∓ 4,46	19.51 ∓ 6.74	$p \leq 0.001$(G)

In another study suggesting neck C as a detection method for metabolic risk factors of obese children, HOMA-IR index values of pre-pubertal boys were detected as 1.11 (0.41-2.02) and 2.16 (0.32-9.15) in normal weight and overweight-obese group, respectively. The corresponding values for pre-pubertal girls were reported as 2.4 (1.72-4.20) and 3.4 (0.93-12.81) [23].

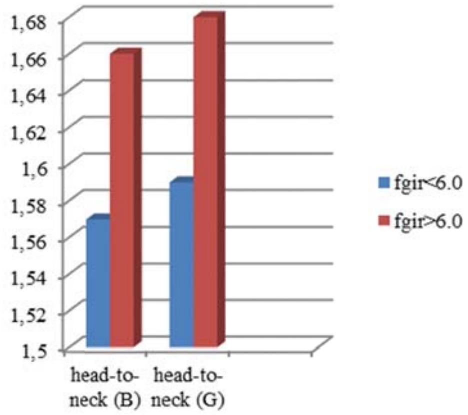
During the evaluation of cardiovascular risk factors among obese children, whose BMI values were above 95th percentile, high cardiovascular risk was defined as associated with dyslipidemia, hypertension or HOMA-IR values greater than 2.5. HOMA-IR values were reported as 2.45±1.48 in obese children with normal blood pressure and 3.99±1.07 among those with hypertension [8].

A study advocating that abdominal subcutaneous fat thickness is the best indicator for evaluation of hyperinsulinemia in childhood obesity reported that mean HOMA-IR index of BMI> 95th percentile obese children was 2.51±0.2. This value for the control group was found to be as 1.5±0.8 [24].

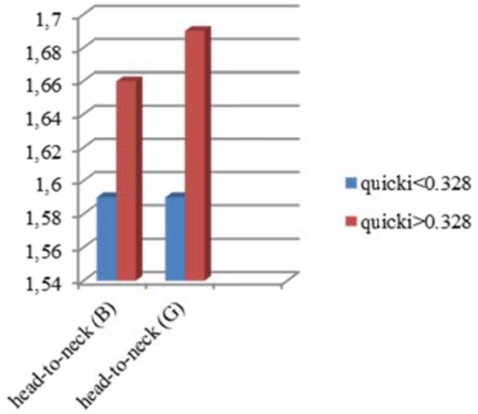
A study performed on prepubertal overweight-obese children reported that the most appropriate cut-off value for HOMA-IR is 2.5 [9]. In the risk evaluation of children and adolescents, with type 2 diabetes, whose BMI values were above 85th percentile, FGIR value below 6 was used as a criterion for inclusion into the study [10]. The value of 0.328 was accepted as cut-off point for QUICKI during the assessment of insulin sensitivity in obese children [25].



(a)



(b)



(c)

Fig. 1 Comparison of head-to-neck values above and below the cut-off points of three laboratory indices ((a) HOMA, (b) FGIR, (c) QUICKI)

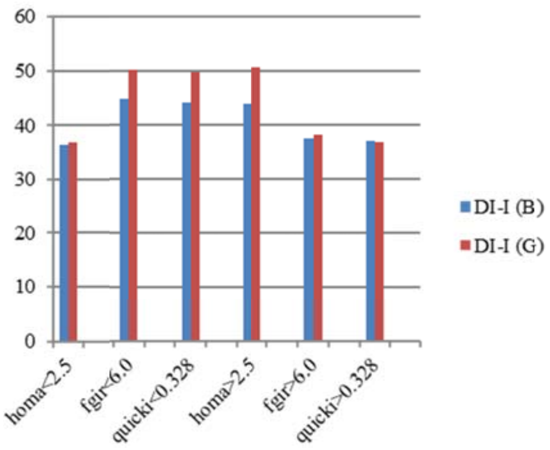


Fig. 2 DONMA index I values for MO boys and MO girls above and below the cut-off points of three laboratory indices

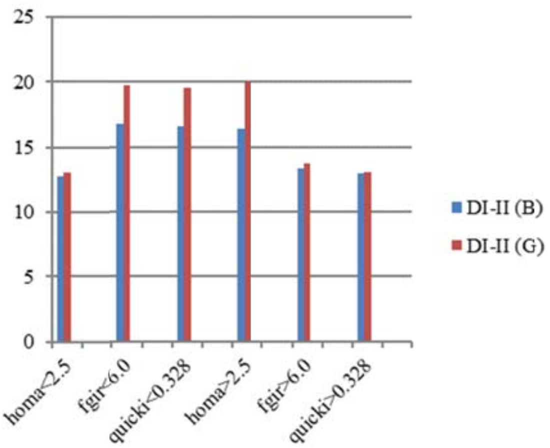


Fig. 3 DONMA index II values for MO boys and MO girls above and below the cut-off points of three laboratory indices

In the light of the studies summarized above, cut-off points were considered as 2.5 for HOMA-IR, as 6.0 for FGIR and as 0.328 for QUICKI in this study for the evaluation of MO children.

Upon evaluation of fat ratios, the results obtained with HOMA-IR revealed that this is a valuable index in evaluation of BMI and body fat ratios in girls. In boys, this cut off point of HOMA-IR index exhibits statistically important difference only for arms fat percentage ($p \leq 0.05$). These results revealed that 2.5 level of HOMA-IR value may be used only in assessment of arms fat percentage for MO boys.

In girls, FGIR was not valuable for fat ratio of lower extremities between groups, but it was significant for evaluation of fat percentages of upper extremities, trunk and whole body ($p \leq 0.05$). This level of FGIR was not valuable in the evaluation of fat ratios of MO boys.

Analysis of superiority between HOMA-IR and FGIR in evaluation of the groups revealed that HOMA-IR gives much more statistically significant results than FGIR. These results revealed that HOMA-IR is more valuable than FGIR for the evaluation of MO girls.

HOMA-IR and QUICKI have given similar results for MO girls. In MO boys, while HOMA-IR is prominent in arms fat percentage, QUICKI has shown significance for legs fat percentage. These results showed that HOMA-IR and QUICKI were of more possible diagnostic use than FGIR in both genders.

Waist-to-hip, thigh-to-arm, thigh-to-ankle, height:2-to-waist and TAFR did not exhibit statistically significant differences between two groups of HOMA-IR in both genders.

Based on HOMA-IR values, statistical insignificance of height:2-to-waist and statistical significance of height:2-to-hip ($p \leq 0.01$) revealed that adipose tissue is accumulated in hips and thigh among MO girls, so-called “gynecoid pear-shaped obesity” rather than abdominal and visceral obesity, and thus height:2-to-hip becomes more prominent ratio in girls. However in boys, height:2-to-waist and height:2-to-hip were both insignificant. This revealed that adipose tissue accumulation in MO boys takes place in hips, thigh leading to both abdominal as well as visceral obesity.

Evaluation of FMI ($p \leq 0.001$ in girls, $p \leq 0.05$ in boys) according to HOMA-IR values pointed out that increase in HOMA-IR index was directly proportional to the increase in body fat.

Evaluation of HOMA-IR and TAFR together exhibited no difference between subgroups, because during the development of obesity, accumulation of adipose tissue occurs at the waist, hip, upper and lower extremities in boys and at both waist and lower extremities in girls.

In the analysis between the groups based on FGIR <6 and >6, statistical differences for height:2-to-hip, FMI and WBFR were significant ($p \leq 0.05$) only in girls. Head-to-neck, HOMA-IR/BMI, logHOMA-IR, DONMA index I and DONMA index II were quite significant in both genders. These results revealed that FGIR gives similar results like HOMA-IR and its reliability is almost equivalent for that of HOMA-IR.

Classification and evaluation of the groups according to QUICKI<0.328 and >0.328 revealed that statistical differences were significant for height:2-to-hip and WBFR ($p \leq 0.05$) only in MO girls and were significant for head-to-neck, HOMA-IR/BMI, logHOMA-IR, FMI, DONMA index I and DONMA index II in both genders.

These results revealed that HOMA-IR, FGIR and QUICKI give similar results among MO children in both genders.

Evaluation of indices based on weight and body fat ratios revealed that DONMA index I and DONMA index II are much more sensitive formulas than BMI and FMI in both genders, respectively (Tables IV-VI).

V. Conclusion

During the management of childhood obesity by evaluation of laboratory criteria, BMI and body fat ratios are important approaches for upgrading the quality of life in children during their future lives.

As a result of the present study, head-to-neck, HOMA-IR/BMI, log HOMA-IR, DONMA index I and DONMA index II were statistically significant for groups constituted according to cut-off points of HOMA-IR <2.5 and >2.5, FGIR

<6 and >6, and QUICKI <0.328 and >0.328 in MO boys. In MO girls, the significance was valid for all the above parameters including also height:2-to-hip and WBFR, which are, therefore, also valuable ratios from gender difference point of view.

In conclusion, head-to-neck, DONMA index I and DONMA index II were all important and valuable indices when used with three different laboratory indices in the evaluation of MO boys as well as MO girls. Besides, DONMA index II had preponderance over DONMA Index I and head-to-neck in terms of exhibiting gender difference. In the evaluation of these parameters by HOMA-IR, FGIR and QUICKI, DONMA index I showed no difference between cut-off point levels of these laboratory indices. In both genders the degree of significance was $p \leq 0.001$. However, for DONMA index II, degrees of significance were $p \leq 0.01$ for MO boys and $p \leq 0.001$ for MO girls emphasizing the superiority of this recently introduced fat-based index.

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