An Obesity Index Derived from Waist and Hip Circumferences Well-Matched with Other Indices in Children with Obesity

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Abstract**—**Indices derived from anthropometric measurements [waist-to-hip ratio (WHR)] or body fat mass compositions [trunk-to-leg fat ratio (TLFR)] are used for the evaluation of obesity. The best for clinical practices is still being investigated. The aim of this study is to derive an index, which best suits the purpose for the discrimination of children with normal body mass index (N-BMI) from obese (OB) children. 83 children participated in the study. Groups 1 and 2 comprised 42 children with N-BMI and 41 OB children, whose age- and sex-adjusted BMI percentile values vary between 15-85 and 95-99, respectively. The institutional ethics committee approved the study protocol. Informed consent forms were filled by the parents of the participants. Anthropometric measurements (weight, height (Ht), waist circumference (WC), hip circumference (HC), neck circumference (NC) values) were taken. BMI, WHR, (WC+HC)/2, WC/Ht, (WC/HC)/Ht, WC*NC were calculated. Bioelectrical impedance analysis was performed to obtain body's fat compartments in terms of total fat, trunk fat, leg fat, arm fat masses. TLFR, trunk-to-appendicular fat ratio (TAFR), (trunk fat+leg fat)/2 ((TF+LF)/2), fat mass index (FMI) and diagnostic obesity notation model assessment-II (D2I) index values were calculated. Statistical analysis was performed. Significantly higher values of (WC+HC)/2, (TF+LF)/2, D2I and FMI were observed in OB group than N-BMI group. Significant correlations were found between BMI and WC, (WC+HC)/2, (TF+LF)/2, TLFR, TAFR, D2I, FMI in both groups. Similar correlations were obtained for WC. (WC+HC)/2 was correlated with TLFR, TAFR, (TF+LF)/2, D2I and FMI in N-BMI group. In OB group, the correlations were the same except those with TLFR and TAFR. These correlations were not present with WHR. Correlations were observed between TLFR as well as TAFR and BMI, WC, (WC+HC)/2, (TF+LF)/2, D2I, FMI in N-BMI group. In OB group, correlations between TLFR or TAFR and BMI, WC as well as (WC+HC)/2 were missing. None was noted with WHR. In conclusion, the only correlation valid in both groups was that exists between (TF+LF)/2 and (WC+HC)/2, which was suggested as a link between fat-based and anthropometric indices. (WC+HC)/2, but not WHR, was much more suitable as an anthropometric obesity index.

Keywords**—**Children, hip circumference, obesity, waist circumference.

I. Introduction

OBESITY is an ever-increasing health problem and therefore, there is a need for some measurements, ratios or indices to evaluate this complicated endocrine status particularly in children. WC, BMI, WHR, WC-to-height ratio (WHtR) and many others were potential obesity indicators for determining the presence of cardiometabolic risk, which is one of the associates of obesity [1]-[5]. It was reported that higher BMI or WHR was associated with altered cardiometabolic traits in children [6].

A high prevalence of adiposity and cardiometabolic disease risk among the populations speeds up investigations in the field [7]. There are many weight-based measures and fat distribution-based measures for the screening of adulthood and childhood adiposity [2], [8]-[11]. Anthropometric measurements and mass or percent values obtained from the determination of body fat compartment analyses were in common use. Besides, ratios, formulas, equations are currently being developed.

The most frequently used anthropometric measurements are WC and HC. However, there are other indexes such as WHtR, recommended as an effective indicator for detecting adiposity in children and adolescents [12].

It is notable that the rate of increase in WC is greater than that in HC. WC-to-HC ratio found clinical usage for years in obesity studies [13]. Both WC and HC seem to make a significant breakthrough during the development of obesity. However, increases in WC come along more than increases in HC in proportion to increases in body adiposity degrees in obesity. Therefore, WHR ratio is still being commonly used for the evaluation of obesity.

Since both anthropometric measurements increase steadily as the severity of obesity increases, it was thought that (WC+HC)/2 may be introduced as a new obesity marker to be used in routine clinical practices. This study was organized based upon the hypothesis that this developed obesity ratio may be potentially more valuable in comparison with the benefits of WHR.

The aim of this study was to evaluate some anthropometric measurements, anthropometric ratios, weight-based measures, fat distribution-based measures, associated ratios and fat-based obesity indices both in children with normal BMI (N-BMI) and in OB children. Each parameter was compared between the groups and the parameter, which showed the greatest difference was pointed out. Also, the parameters potentially establish a link between anthropometry-based ratios and fat distribution-based ratios were investigated.

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II. Patients and Methods

A. Patients

The study was performed on children, who were with N-BMI (n = 42) and OB (n = 41). Children, whose ages were between 6-18 years were included in the study. OB children had their age- and sex-adjusted BMI percentile values between 95 and 99. The range for children with N-BMI was 15-to-85 [14]. Parents of the children filled the informed consent forms for joining in the study. Tekirdag Namik Kemal University, Non-interventional Clinical Studies Ethics Committee approved the protocol of the study.

B. Anthropometric Measurements and Related Ratios

Children's weight, Ht, WC, HC and NC values were measured and recorded. Within the scope of ratios, BMI, WHR, WHtR, (WC/HC)/Ht ratio (WHHtR), a product of WC and NC (WC*NC) and (WC+HC)/2 were calculated.

C. Parameters Related to Body Fat Composition and Ratios

Total body fat mass, total body fat percent, leg fat mass, leg fat percent, arm fat mass, arm fat percent were obtained from the measurements performed by TANITA Bioelectrical Impedance Analysis.

Appendicular fat mass and appendicular fat percent (sum of arm and leg fat) were calculated from related measurements of legs and arms. TLFR (trunk fat divided by leg fat), TAFR (trunk fat divided by appendicular fat), (trunk fat+leg fat)/2 (TF+LF)/2 were calculated.

D. Obesity Indices Based on Body Fat

Diagnostic obesity notation model assessment-II index (D2I) and FMI values were calculated by using the following formulas:

$$D2I = \text{total body fat (kg)} * 100 / \text{Ht (cm)}$$

$$FMI = \text{total body fat (kg)} / (\text{Ht (m)})^2$$

E. Statistical Analysis

Data were evaluated statistically with the statistical package program SPSS. The mean and standard deviation values of the parameters were calculated. t test was performed to find the statistically significant differences between two groups. Correlation analyses were performed and plots for linear regression were drawn.

III. Results

Age and gender ratios of the groups did not differ statistically ($p > 0.05$).

WC, and WC-related five ratios [WHR, WHtR, WHHtR, WC*NC, (WC+HC)/2] were compared. Three ratios using trunk fat and leg fat [TLFR, TAFR, (TF+LF)/2] were examined. The clinical utilities of two fat-based obesity indices (D2I, FMI) were also considered. Values for WC, WC-related ratios, ratios using trunk fat and leg fat, fat-based obesity indices and the statistical significance degrees calculated for the differences of the groups were given in Table I.

Statistically significant increases were detected for BMI, WC, HC and NC values in OB group. Compared with WHR, WHtR, and WHHtR, the differences between the groups were much more striking for (WC+HC)/2 ratio.

When TLFR and TAFR were compared, participation of arm fat into TLFR made the ratio more significant. However, (TF+LF)/2 ratio was the most prominent of all, considering the sum of body fat compartments related to both trunk fat and leg fat.

Both fat-based obesity indices, D2I and FMI, had the same significance to discriminate OB children from those with N-BMI.

Correlation analyses have shown strong associations between the anthropometric ratio; (WC+HC)/2 and fat ratio; (TF+LF)/2 in both N-BMI ($r = 0.847$; $p < 0.001$) and OB ($r = 0.856$; $p < 0.001$) groups. Significant correlations between (TF+LF)/2 and WHtR as well as WC*NC were also calculated. However, these correlations were weaker than those observed for (WC+HC)/2. An interesting relationship was also found between (WC+HC)/2 ratio and TLFR ($r = 0.480$; $p < 0.01$) as well as TAFR ($r = 0.457$; $p < 0.01$) (Figs. 1 and 2). These correlations were confined to children in N-BMI group. They were lost in the group of OB children.

TABLE I
Anthropometric, Measurements, Fat Distribution Ratios and Obesity Indices of the Groups (mean ± SD)

Parameter		N-BMI Group 1	OB Group 2
BMI*	kg/m^2	17.6 ± 3.0	23.7 ± 3.4
WC*	cm	64.8 ± 11.8	80.9 ± 8.4
HC*	cm	77.4 ± 14.7	93.2 ± 11.9
NC*	cm	29.3 ± 3.8	32.9 ± 3.7
WHR^{NS}		0.84 ± 0.07	0.87 ± 0.07
$WHtR^{NS}$		0.45 ± 0.05	0.53 ± 0.04
$WHHtR^{NS}$		0. 6 ± 0. 1	0. 6 ± 0. 1
WC*NC*		1939 ± 585	2685 ± 535
(WC+HC)/2*		71.1 ± 12.9	87.1 ± 9.5
$TLFR^{NS}$		0.96 ± 0.26	1.04 ± 0.20
$TAFR^{\#}$		0.73 ± 0.19	0.80 ± 0.15
(TF+LF)/2*	kg	3.29 ± 2.27	7.61 ± 3.04
FMI*	kg/m^2	3.39 ± 1.54	7.09 ± 2.12
D2I*	kg/m	5.01 ± 2.78	11.01 ± 3.78

NS = not significant; [$*^{1\text{-}2 < 0.001}$. $\#^{1\text{-}2 < 0.05}$]

Significant correlations between TLFR/TAFR and WC*NC were found. However, they were less strong than those observed for (WC+HC)/2.

IV. Discussion

So far, numerous studies were performed and the results were reported to be able to find the best anthropometric index, which is both simple and suitable for obesity studies [8], [9], [12].

WC and BMI were found to be strongly correlated with fat compartments in adults [15]. WC was reported as a better predictor of diabetes risk than BMI especially in women [16]. This anthropometric measurement, as the indicator of abdominal obesity, was suggested also the strongest predictor for aerobic fitness [17].

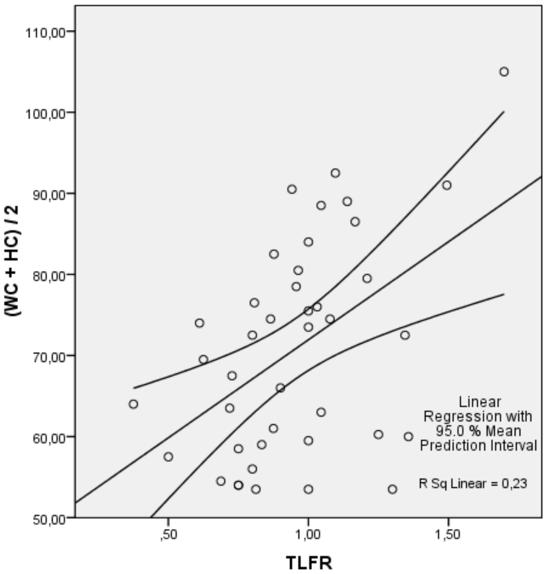

Fig. 1 Correlation between (WC+HC)/2 and TLFR in N-BMI group

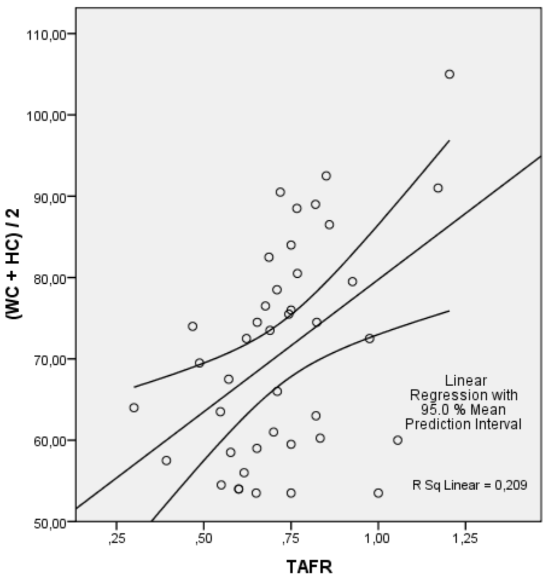

Fig. 2 Correlation between (WC+HC)/2 and TAFR in N-BMI index group

In our study, correlations between (TF+LF)/2 and (WC+HC)/2 were much stronger than those between (TF+LF)/2 and WC in both N-BMI and OB groups.

A product of WC and NC outperformed traditional anthropometric measurements to identify metabolic syndrome with diabetes in adults [18]. We have observed weaker correlations between (TF+LF)/2 and WC*NC than (TF+LF)/2 and (WC+HC)/2 in both groups.

WC-to-Ht ratio was recommended for home-based obesity screening in pediatric population [19]. It is associated with severe diabetic eye disease [20]. It is also suggested as the best index to discriminate metabolic abnormalities among adults [21]. This index was suggested to be used in association with other indices [22]. Like WC, it appears to be the index associated more closely with diabetes than WHR and BMI [23], [24].

Waist-to height ratio and WHHtR were reported as more valuable indices than BMI and WC for predicting cardiovascular diseases risk [13]. In the present study, for the discrimination of N-BMI and OB groups, they did not appear as suitable indices.

In adolescents, positive correlations were detected between NC and blood pressure values. However, BMI and WHR showed negative correlations with these parameters [25]. We have also observed negative correlations between WHR and the other traditional indices. There is another study reporting the preponderance of other anthropometric measurements and/or indices over WHR. BMI and WC showed a better performance for the identification of cardiometabolic risks than WHR [26]. In another study, a bias was reported for WHR [27]. WHR-associated myocardial infarction risk was found to be higher than the risks associated with WC and WHt ratio. It was reported that the increased risk for WHR-associated myocardial infarction was mathematically biased and anthropometrically inconsistent.

In this study, it was shown that TLFR as well as TAFR correlated both with anthropometric and fat-based indices in N-BMI group were not correlated with anthropometric indices such as BMI, WC, or (WC+HC)/2 ratio, but they exhibit correlations with fat-based indices such as D2I and FMI in OB group.

In conclusion, the association found between (WC+HC)/2 ratio and (TF+LF)/2 ratio was established as an interesting association because it was one between anthropometric and fat-based indices.

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