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Body Mass Index, Waist Circumference and Waist-to-Hip-Ratio in the Prediction of Obesity in Turkish Teenagers

Vatan Kavak[1], Mara Pilmane[2] and Dzintra Kazoka[2]

[1] Dicle University, Medical Faculty, Department of Anatomy, Diyarbakir, Turkey

[2] Riga Stradiņš University, Institute of Anatomy and Anthropology, Department of Morphology, Riga, Latvia

ABSTRACT

The aim of this study was to identify the usefulness of body mass index (BMI), waist circumference (WC) and waist--to-hip ratio (WHR) in screening for obesity in teenagers by using the receiver operating characteristic (ROC). To select the sample set in this cross-sectional study, a stratified random sampling approach was utilized. Weight, height, WC, hip circumference and body fat percentage (BFP) were measured in 1118 children of both genders (597 boys and 521 girls), aged from 10 to 15 years old. Percentiles of BMI and Centers for Disease Control and Prevention-United States (CDC-US)-growth chart for boys and girls aged from 10 to 15 years old were presented. ROC analyses were then used to evaluate the performances of three anthropometric indices; BMI, WC and WHR had strong positive correlations with BFP (r=0.49–0.77) in both girls and boys within indicated age group. The area under the curves (AUCs) were high in both girls and boys for BMI, 0.795 and 0.893, respectively, and WC, 0.767 and 0.853, respectively, and were a little lower, 0.747 and 0.783, respectively, for WHR. In conclusion, this study demonstrates that the prevalence of being overweight and obese among teenagers of both sexes in our data set does not differ from CDC-US-growth chart. In addition, BMI and WC are two important predictors for teenagers to become overweight and obese, while WHR is less useful for this purpose.

Key words: *teenagers, obesity, boys, girls, anthropometric indices*

Introduction

The prevalence of being overweight and obese in children and adolescents has increased dramatically. Childhood obesity is associated with negative health and psychosocial outcomes[1–7]. Excess body fat is the primary defining characteristic of obesity, and a precise measurement of the body fat percentage (PBF) is considered to be the reference method to define obesity. Anthropometric indices, such as body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR) are the most commonly used tools for assessing obesity because of their simplicity and low cost, as well as their strong correlation with PBF[8–13]. WC and WHR, which are various anthropometric indices, are reference methods used to determine the fat developed in abdominal region of the body, whereas PBF as well as BMI methods are anthropometric indices generally used to determine all the fat of the body. Growth charts are widely used as clinical and research tools to assess nutritional status, general health and well-being of children and adolescents. BMI is a valuable expression of the body fat percentile during childhood and adolescence. According to the Centers for Disease Control and Prevention-United States (CDC-US) growth charts, which are relatively specific, the 85th percentile is the cutoff point for being overweight, whereas the 95th percentile is the cutoff point for obesity[14,15]. Receiver-operating characteristic (ROC) analysis is a very useful tool for visualizing and evaluating classifiers and utilized to evaluate the accuracy of a diagnostic test by summarizing the potential of the test to discriminate between the absence and presence of a health condition. BMI, WC and WHR identify subjects as being above or below a certain cutoff that denotes obesity risk[16,17]. In the present study we use three anthropometric indices (BMI, WC and WHR) to predict obesity in teenagers, us-

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ing PBF measured by skinfold to define obesity. The diagnostic accuracy refers to the ability of these anthropometric variables to discriminate obesity from non-obesity with adverse health outcome cutoffs in girls and boys. The overweight and obesity among teenagers that were found by BMI for both sexes were compared with CDC-US-growth chart. Actually our primary aim was to describe methodological method, but the second aim was epidemiological one.

Materials and Methods

Cross-sectional anthropometric data were collected in the course of this study. The current study enrolled 1118 healthy students, 597 boys and 521 girls ranging in age from 10 to 15 years, and was conducted between May 2005 and May 2006. Teenagers aged between 10–15 years were selected because the prevalence of being overweight has more than doubled since the 1970s[18,19]. A stratified random sampling approach was used to select the sample set. The sample size was calculated by choosing 10% from each age stratum for both genders. Thus, a total of 1118 subjects were sampled according to the stratified random sampling method. These subjects were 10–15 years old for both genders and were students in Diyarbakir, a city situated in the Southeastern Anatolia region of Turkey. The survey was carried out face-to-face. The study protocol was approved by the Directorate of National Education in Diyarbakir; date and number: May 3, 2005 (B.08.4.MEM.4.21.00.08.311/11466). Written permission from parents for measuring their children was obtained.

Anthropometric measurements

All measurements were performed in the school's infirmary or in a designated room that allowed privacy during the procedures. Children were asked to wear loose clothing. Shoes and jewelry were removed before measurement. We informed school children and their parents about the study. The parents completed a detailed questionnaire form including personal data for the study and parents acceptance of the study by written permission.

Height was measured to the nearest 0.1 cm by using a stadiometer (Holtain Ltd., Crymych, UK) when the subjects stood wearing socks and with their heads in the Frankfort horizontal plane. Weight was measured to the nearest 0.1 kg with an electronic portable scale (Seca-delta, Model 707). BMI was calculated as weight (kg) divided by height (m) squared. A metal tape was used to measure the circumference of the buttocks. Waist circumference was measured at a level midway between the lowest rib and the crista iliaca superior. The measurement was carried out at the end of a normal expiration while the subject stood upright with feet together and arms hanging freely at the sides. Hip circumference was measured at the maximum point below the waist, without compressing the skin. WHR was calculated by dividing the waist measurement by the hip measurement. Subcutaneous fat thickness (SFT) was measured by two trained examiners (generally, this was the observer) using a Lange calliper (Beta Technology Inc., Santa Cruz, CA) and three measurements were taken from sites on the right side of the body[20], to average them as the skinfold measurement. For the triceps (back of the upper arm) site, the mid-point of the posterior aspect of the upper arm, between the tip of the olecranon and the acromial process, was determined by measuring the arm flexed at 90°. With the arm hanging freely at the side, the calliper was applied vertically at the marked level. For the biceps (on the upper arm) site, the SFT was measured at the same level as for the triceps, with the arm hanging freely and the palm facing forward. For the subscapular site, the SFT was measured below the inferior angle of the scapula at 45° relative to the vertical axis, along the natural cleavage lines of the skin. The suprailiac SFT was measured above the iliac crest, just posterior to the midaxillary line and parallel to the cleavage lines of the skin, with the arm being lightly held forward. The body fat percentage was also estimated from the thickness of subcutaneous fat at biceps, triceps, subscapular and suprailiac sites[21].

Body fat estimated from the body mass index from Deurenberg et al[22]. The relationship between densitometrically determined body fat percentage (BF%) and BMI, taking age and sex into account Internal and external cross-validation of the prediction formulas showed that they gave valid estimates of body fat in males and females at all ages. In obese subjects, however, the prediction formulas slightly overestimated the BF%. The prediction error is comparable to the prediction error obtained with other methods of estimating BF%, such as skinfold thickness measurements or bioelectrical impedance. For children aged 15 years and younger, the relationship differed from that in adults, due to the height-related increase in BMI in children. In children the BF% was predicted by the formula:

$$BF\% = (1.51\times BMI) - (0.70\times Age) - (3.6\times gender) + 1.4$$

In adults the prediction formula was:

$$BF\% = (1.20\times BMI) + (0.23\times Age) - (10.8\times gender) - 5.4$$

where gender was 1 for males and 0 was for females. Percentage body fat ($\%BF_{SF}$), calculated from the equations devised by Slaughter et al.[23], was based on triceps and subscapular skinfold values, taking into account gender, ethnicity and stage of maturation. Fat body mass by skinfold (FBM_{SF}) was calculated as follows: $FBM_{SF}=\%BF_{SF}\times$weight (kg). Lean body mass by skinfold (LBM_{SF}) was calculated as follows: $LBM_{SF}=$weight (kg) – FBM_{SF}.

Statistical analysis

A non-experimental cohort design was used to estimate the prevalence of obesity in teenagers. We used BMI, WC and WHR to determine the percentiles of overweight and obesity of girls and boys in six age groups, accordingly. The criteria were based on CDC-US growth charts, which set the 85th percentile as the cutoff point for being overweight, whereas the 95th percentile as the cutoff point for obesity[24].

Before analysis, all group values were tested for normal distribution by using the Shapiro-Wilks test and, if the variable did not fit with normal distribution, logarithmic transformations of the data were performed. Pearson correlation coefficients were used to assess the associations between anthropometric indices and PBF. We used Kolmogorov-Smirnov two sample test to determine whether BMI and WHR for girls and boys (85th and 95th) had the same distribution or not.

Derivation of the ROC curves was based on a method by Obuchowski[25] for continuous-scale gold standards. ROC analyses were performed in order to evaluate the general performance of the BMI, WC and WHR[17]. The percentage of body fat was considered as the reference standard for the ROC curve analysis of BMI for girls and boys. The accuracy of the diagnostic test derived from the ROC analysis is reflected by the area under the curve (AUC). The estimates of AUCs and their 95% confidence intervals (95% CI) were calculated. In the present study, the estimates of AUCs, their 95% CIs and the statistical comparisons between the diagnostic usefulness of BMI, WC and WHR were performed by employing a non-parametric approach, which was implemented in Statistical Packages for Social Sciences (SPSS).

Two-sided p values were considered statistically significant at $p<0.05$ and $p<0.001$. Statistical analyses were carried out by using the statistical packages of SPSS 12.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Table 1 presents the 85th and 95th percentiles of BMI for the present study and for the CDC-US-growth chart, which is the international classification standard, for boys and girls aged from 10 to 15 years. The distributions of the two growth charts (for the present study and the CDC-US growth chart) for girls (85th and 95th) and boys (85th and 95th) according to their age groups were analyzed and the differences were not found to be significant. This finding implies absence of a difference between the values of BMI in the present study and the values of the CDC-US-growth chart.

In the present study, considering that fattening starts at the age of 13 for girls; between 85th and 95th reliability interval, BMI values are 22.1–25.0, respectively also these values are found as 22.6–26.2 in CDC-US growth chart.

In the scope of this study, considering that fattening starts at the age of 12 for boys; between 85th and 95th reliability interval, BMI values are 20.6–23.3, respectively also these values are found as 21.0–24.2 in CDC-US growth chart.

The correlations were statistically significant between PBF and anthropometric indices (BMI, WC and WHR) in both girls and boys and in both age groups; they are presented in Table 2. All of the correlations were significant in boys, and the coefficients of the correlations ranged from 0.51 to 0.77 for boys aged from 10 to 15 years. The correlation coefficients for the girls were slightly lower, but they were still statistically significant, ranging from 0.49 to 0.72. The distribution of the percent of PBF and the mean value of BMI according to the age groups for girls and boys are presented by Figures 1 and 2, respectively. The observed correlations between the percent of PBF and the mean value of BMI according to the age groups were positive for both sexes and are presented in Figures 1 and 2. As shown in Figure 1, in the measurements of girls according to the age groups (10–15 years) we found that PBF and BMI started increasing at age 13

TABLE 1
PERCENTILES OF BMI AND CDC-US-GROWTH CHART FOR BOYS AND GIRLS AGED 10–15

	Age (yr)	N	Percentiles of BMI Present Study				Percentiles of CDC-US-Growth Chart			
			85th	N (%)*	95th	N (%)*	85th	N (%)*	95th	N (%)*
Girls	10	78	19.7	7 (9.0)	22.6	4 (5.1)	20.0	7 (9.0)	23.0	4 (5.1)
	11	97	20.1	9 (9.3)	23.7	3 (3.1)	20.8	10 (10.3)	24.1	4 (4.1)
	12	142	21.0	13 (9.2)	24.6	2 (1.4)	21.7	8 (5.6)	25.2	2 (1.4)
	13	89	22.1	9 (10.1)	25.0	4 (4.5)	22.6	7 (7.9)	26.2	1 (1.1)
	14	84	23.3	9 (10.7)	25.5	4 (4.8)	23.4	7 (8.3)	27.2	1 (1.2)
	15	36	23.7	3 (8.3)	26.3	1 (2.8)	24.0	2 (5.6)	28.1	0
Boys	10	45	19.0	6 (13.3)	21.2	5 (11.1)	19.4	6 (13.3)	22.2	3 (6.7)
	11	131	19.8	8 (6.1)	22.9	3 (2.3)	20.2	8 (6.1)	23.2	4 (3.1)
	12	146	20.6	17 (11.6)	23.3	8 (5.5)	21.0	18 (12.3)	24.2	8 (5.5)
	13	141	21.0	12 (8.5)	24.4	5 (3.6)	21.8	12 (8.5)	25.2	4 (2.8)
	14	87	22.4	9 (10.3)	24.6	6 (6.9)	22.6	7 (8.1)	26.0	4 (4.6)
	15	56	22.8	4 (7.1)	27.9	1 (1.8)	23.6	1 (1.8)	26.8	1 (1.8)

* BMI and CDC (85th and 95th) distribution by Kolmogorov-Smirnov test; BMI – body mass index, CDC-US – Centers for Disease Control and Prevention

TABLE 2
THE CORRELATION BETWEEN PBF AND ANTHROPOMETRIC INDICES OF BMI, WC AND WHR

Anthropometric index	Boys 10–15-yr (N=597)		Girls 10–15-yr (N=521)	
	r	p	r	p
BMI–PBF	0.77	0.001	0.72	0.001
WC–PBF	0.75	0.001	0.70	0.001
WHR–PBF	0.51	0.001	0.49	0.001

BMI – body mass index, PBF – percentage body fat, WC – waist circumference, WHR – waist-to-hip ratio

years (age like a risk factor). As shown in Figure 2, in the measurements of boys according to the age groups (10–15 years) we found that PBF and BMI started increasing at age 12 years (age like a risk factor).

The AUC from an ROC analysis and the 95% CIs for BMI, WC and WHR index are shown in Table 3. The AUC for BMI, WC and WHR differ significantly ($p<0.001$) in girls aged 10–15 years, with values of 0.794 (95% CI: 0.751–0.838), 0.767 (95% CI: 0.719–0.815) and 0.747 (95% CI: 0.702–0.793), respectively. In boys of the same age, the AUC for BMI, WC and WHR also differ significantly ($p<0.001$) with values of 0.893 (95% CI: 0.833–0.953), 0.853 (95% CI: 0.795–0.911) and 0.783 (95% CI: 0.716–0.851), respectively. The difference between AUCs for BMI, WC and WHR were not statistically significant in either sex, indicating that these three indices performed equally well in predicting obesity. The area under the receiver operating characteristic curve is frequently used as a measure for the effectiveness of diagnostic markers. It has been observed that the AUC values for BMI, WC and WHR in girls were 0.794, 0.767 and 0.747, respectively, and for boys they were 0.893, 0.853 and 0.783, respectively. The AUC values for BMI, WC and WHR for the boys were slightly higher than the values for the girls.

The ROC curves for PBF and anthropometric indices in girls and boys aged 10–15 years are shown in Figures 3 and 4. Analysis F curves reveals possibility to predict obesity in both sexes using BMI, WC and WHR parameters. The more the ROC curve drifts toward the left up-

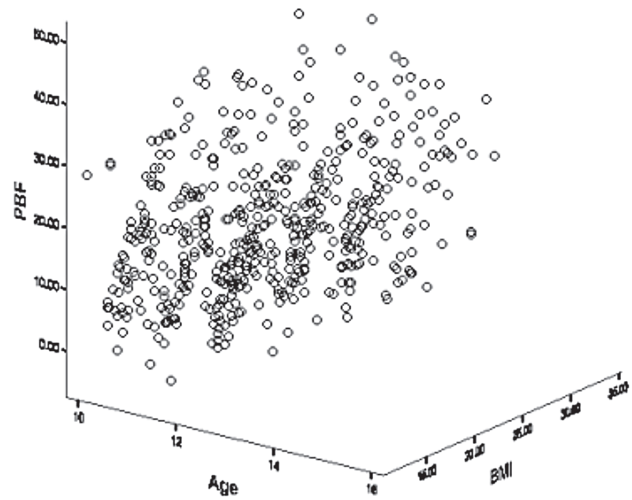

Fig. 1. The distribution of the percent of PBF and the mean value of BMI according to the age groups (10–15 years) in girls (N=521). PBF – percentage body fat, BMI – body mass index.

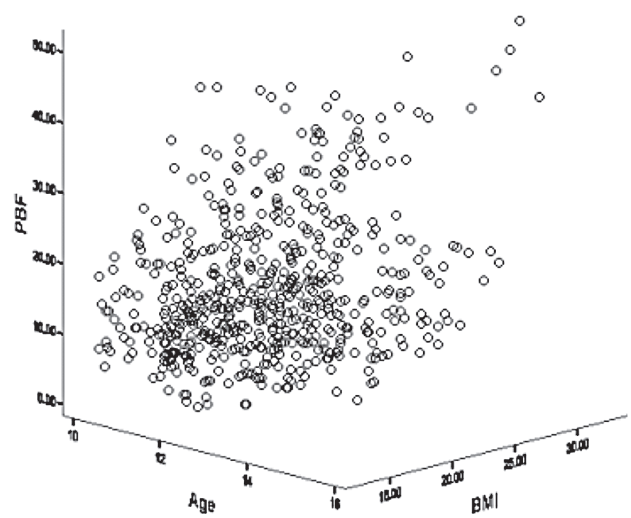

Fig. 2. The distribution of the percent of PBF and the mean value of BMI according to the age groups (10–15 years) in boys (N=597). PBF – percentage body fat, BMI – body mass index.

TABLE 3
AREAS AND THEIR 95% CIS UNDER THE RECEIVER-OPERATING CHARACTERISTIC CURVES FOR GIRLS AND BOYS

	Variables	Area	Standard Error	p	95% Confidence Interval	
					Lower Bound	Upper Bound
Girls (N=521)	BMI	0.794	0.022	0.001	0.751	0.838
	WC	0.767	0.025	0.001	0.719	0.815
	WHR	0.747	0.023	0.001	0.702	0.793
Boys (N=597)	BMI	0.893	0.031	0.001	0.833	0.953
	WC	0.853	0.030	0.001	0.795	0.911
	WHR	0.783	0.034	0.001	0.716	0.851

BMI – body mass index, WC – waist circumference, WHR – waist-to-hip ratio

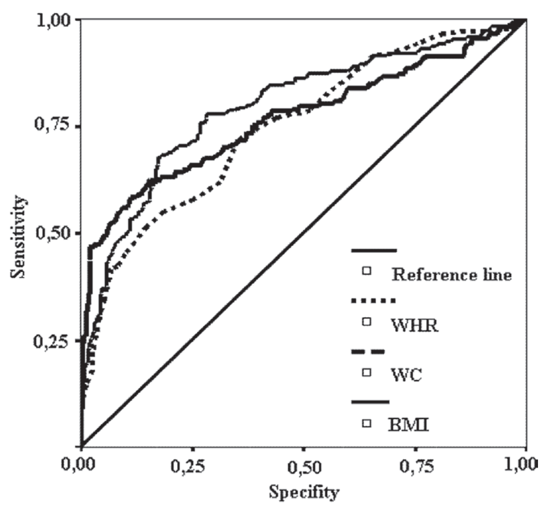

Fig. 3. ROC curves for BMI, WC and WHR in 10–15 year-old girls (N=521). ROC – receiver operating characteristic, BMI – body mass index, WC – waist circumference, WHR – waist-to-hip ratio.

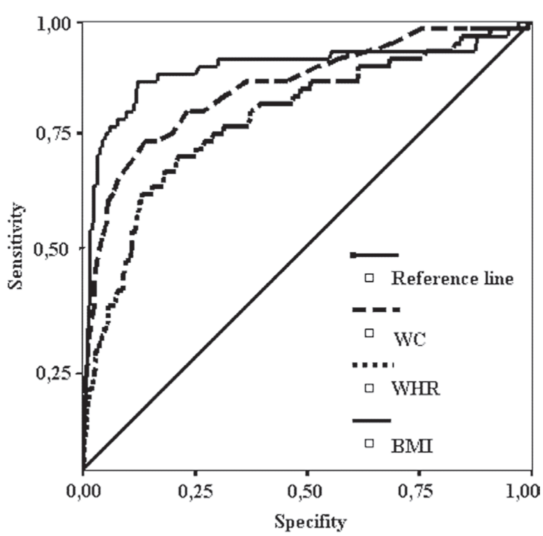

Fig. 4. ROC curves for BMI, WC and WHR in 10–15 year-old boys (N=597). ROC – receiver operating characteristic, BMI – body mass index, WC – waist circumference, WHR – waist-to-hip ratio.

per corner, which represents a perfect dichotomous test with 100% sensitivity and 100% specificity, the better is the quality of the test. In our hands, the ROC curves for BMI, WC and WHR for girls and boys, F indicated age were located toward the left upper corner. Also, the ROC curves of BMI, WC and WHR for boys were slightly higher than the values for girls, as determined by the values of AUC in both sexes.

Discussion

Background obesity is known to be a problem all over the world: World Health Organization (WHO) reported that one billion people are overweight and that 300 million are obese[26]. Epidemiological data report that the prevalence rates are increasing not only in industrialized countries, but also in developing countries[27].

In this study, we used BMI to determine the prevalence of being overweight and obese in teenagers of both sexes living in the Southeast region of Turkey and compared the obtained data to the CDC-US growth chart. The prevalence of being overweight and obese in children in Turkey has increased over the last decades. The reasons behind this increase are explained by differences in lifestyle (physical activity, diet, etc.) and socioeconomic status[28]. Factors contributing to excess energy intake by the pediatric population include the expansion of eating and food establishments, eating tied to leisure activities (many of which are sedentary), children making more food and eating decisions, larger portion sizes and inactivity. Inactivity plays a major role in development of obesity, it either results from extensive television and computer use, limited opportunities for physical activity or safety concerns that prevent children from enjoying free play outdoors. Nutrient needs during adolescence are higher than at any other time in the lifecycle, and failure to consume a healthy balanced diet during this time can have adverse affects on young people's well-being, energy and health. In addition to the impact on growth and development, a poor diet during this life stage can cause a number of immediate health problems, such as being overweight and obese in the short-term[29].

The prevalence of being overweight and obese in teenagers has been investigated in many different countries. Various studies have reported very different values. To get more clear information about this particular subject, some recent studies were surveyed. A few studies reported about the prevalence of being overweight and obese in Turkish teenagers living in different regions of country and have mostly been published in Turkish medical journals rather than in international ones[30]. The published studies of Turkish teenagers' dealt with different regions of Turkey. The last study was published by Oner et al.[31] determined the prevalence of being overweight and obese in children (between 12 to 17 years old) in the Western region of Turkey, in rural and urban areas of Edirne center. The authors detected that the rates of being overweight and obese among girls were in 10.6 and 2.1%, respectively, while these indices were 11.3 and 1.6% for boys. The results of our study determined the prevalence of overweight and obese 10–15 year old teenagers of both genders in the Southeastern part of Turkey.

The prevalence of being overweight and obese among teenage boys according to BMI in the representative sample was between 6.1–13.3% and 1.8–11.1%, respectively. In the meanwhile, according to the CDC-US-Growth Chart this parameter varied between 1.8–13.3% and 1.8–6.7%.

The overweight and obesity ratios of children in European countries were found to be different in some studies. It has been found that the results of obesity and overweight prevalence in Swiss children[32], aged 6–12 years and French children[33], aged 7–9 years, where were similar according to International Obesity Taskforce (IOTF) and Centers for Disease Control and Prevention (CDC) criteria, and the values of these indices in the above-mentioned child population were 18.1 and 20.9%, and 3.8 and 6.4%, respectively. On the other hand, these ratios were found to be higher in English children. The overweight and obesity values in boys aged 5–10 years in English children were 22.6 and 6.0% and in girls they were 23.7 and 6.6%, respectively[34], which indicates an increase of these ratios more in UK children than in Swiss and French children. According to the results of Will et al.[35] the prevalence of being overweight (9.1%) and obese (1.9%) in German children aged 6–7 years were found to be lower than those of the other countries; however, the age differences in the above mentioned studies should be noted in these comparisons.

The most recent data published by Ogden et al.[36] determined that 17.1% of children and adolescents were overweight and 32.2% of adults were obese in the United States during 2003–2004. Tests for a trend were statistically significant for male and female children and adolescents, indicating an increase in the prevalence of being overweight in female children and adolescents from 13.8% in 1999–2000 to 16.0% in 2003–2004 and an increase in the prevalence of being overweight in male children and adolescents from 14.0% to 18.2%. Villa-Cabellero et al.[37] reported the prevalence of being overweight and obese in the Hispanic children living in the United States aged 6–13 years as 23.2 and 3.7% in boys and 21.7 and 3.8% in girls, respectively. Interestingly, the prevalence of overweight and obesity for two genders aged from 10 to 15 years old in our study was found to be lower than the ratios of European and American teenagers. The reason behind such a finding could be explained by different socioeconomic conditions and nutritional opportunities in these areas.

In addition, we looked at the possibility to form teenager risk groups for obesity based on BMI, WC and WHR calculations and by other anthropometric and functional measurements as well as to identify the usefulness of these anthropometric indices by using ROC. An ROC curve is a graph that connects sensitivity-specificity pairs obtained for different cutoff values. The more that the ROC curve move toward the left upper corner, which represents a perfect dichotomous test with 100% sensitivity and 100% specificity, the better the quality of the test is reflected. The area under the receiver operating characteristic curve is frequently used as a measure of the effectiveness of diagnostic markers[38]. There is not a consensus concerning the anthropometric criteria most appropriate for classifying overweight and obese children and adolescents. Therefore, CDC growth charts, reference curves of BMI for age, BMI, WC, WHR, and PBF have been used for that purpose[39,40].

The ideal classification system for obesity, interpreted as excessive fatness, would be based on direct measurement of body composition, such as PBF[41]. Therefore, we compared the value measures of BMI, WC and WHR with PBF, as determined by measuring skinfold thickness. BMI, WC and WHR displayed strong positive correlations with PBF measured by skinfold thickness in boys. The observed correlations were also significant in girls; however, they were slightly lower. In the evaluation of the diagnostic tests, the nature and extent of misclassifications were described through the use of ROC curves[42]. We used the AUC from an ROC analysis as an indicator of the overall performance in anthropometric indices of obesity. Our results indicated that AUCs exceeded 0.72–0.95 for all anthropometric indices of obesity. The AUCs for BMI and WC were higher than the AUCs for WHR in both girls and boys. Therefore, BMI and WC measurements are more important indicators of obesity in teenagers relative to WHR.

Yang et al.[9] and Neovious et al.[42] also used ROC curves to evaluate obesity from BMI, WC and WHR data. They also found that BMI and WC indices were suitable for diagnostic tests; however, WHR was less useful. This trend observed in our study is in line with that observed during previous investigations by the above mentioned authors.

Conclusion

This study has shown that the prevalence of being overweight and obese among teenagers of both sexes in our data set was not found to be different when compared with CDC-US-Growth Chart. In addition, BMI and WC are two important predictors of teenagers becoming overweight and obese, while WHR is less useful for this purpose.

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V. Kavak

Dicle University, Medical Faculty, Department of Anatomy, 21280 Diyarbakir, Turkey
e-mail: kavakv@dicle.edu.tr

INDEKS TJELESNE MASE, OPSEGA STRUKA I OMJERA OPSEGA STRUKA I KUKA U PREDVIĐANJU PRETILOSTI KOD TURSKIH TINJEDŽERA

S A Ž E T A K

Cilj ovog istraživanja bio je utvrditi korisnost indeksa tjelesne mase (BMI), opseg struka (WC) i omjer opsega struka i kuka (WHR) u prikazu pretilosti kod tinjedžera pomoću ROC karakteristika. Pri odabiru uzorka u ovoj cross-sectional studiji, korišteno je stratificirano nasumično uzorkovanje. Težina, visina, WC, opseg kuka i postotak masnog tkiva izmjereni su kod 1118 djece oba spola (597 dječaka i 521 djevojčica), starosti između 10 i 15 godina. Predstavljeni su postoci indeksa tjelesne mase i shema rasta dječaka i djevojčica između 10 i 15 godina starosti prema Centru za kontrolu bolesti i prevenciju u Sjedinjenim Američkim Državama (CDC-US). Zatim su korištene ROC analize pri procjeni izvedbe tri antropometrijska indeksa; BMI, WC i WHR imali su jake pozitivne korelacije sa BP (r=0,49-0.77) kod dječaka i djevojčica unutar naznačene dobne skupine. Površina ispod krivulje (AUC) bila je visoka kod dječaka i djevojčica za BMI – 0,795 i 0.893 – odnosno, 0,767 i 0,853 za WC i nešto niža kod WHR, 0,747 i 0,783. U zaključku, ova studija prikazuje kako se prevalencija prekomjerne tjelesne težine i pretilosti kod tinjeđera oba spola u našoj bazi podataka ne razlikuje od CDC-US sheme rasta. Nadalje, BMI i WC prikazani su kao dva važna predskazatelja pretilosti i debljine kod tinjeđera, dok se WHR pokazao manje korisnim.