Original Article

Turk J Med Sci
2010; 40 (4): 515-523
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E-mail: medsci@tubitak.gov.tr
doi:10.3906/sag-0808-37

A novel cut-off for abdominal obesity derived from various anthropometric indices to predict body composition: arm fat area

Betül ÇİÇEK[1], Ahmet ÖZTÜRK[2], Mümtaz M. MAZICIOĞLU[3], Neriman İNANÇ[1], Selim KURTOĞLU[4]

Aim: Determination of fat and fat-free mass is of considerable interest in evaluation of nutritional status. The aim of the present study was to determine whether using arm fat area (AFA) is helpful in identifying abdominal obesity (waist circumference > 90th percentile) in Turkish children and adolescents with high risk. According to AFA ≥ 85th percentile indicating overweight, we determined age- and gender-specific cut-offs from anthropometric indices.

Materials and methods: This study was conducted with 5358 (2621 boys, 2737 girls) children and adolescents aged 6-17 years. Height, weight, arm span, waist circumference (WC), mid-upper arm circumference (MUAC), and triceps skinfold thickness (TSF) were measured. BMI, fat percentage, waist-to-height ratio (WHtR), waist-to-arm span ratio (WASR), and arm fat area (AFA) were calculated.

Results: According to AFA, overweight prevalence was 14.9% for the entire group. According to ROC analysis, the best predictors to explain overweight were BMI, WC, WHtR, and WASR for 6.0- to 10.9- and 11.0- to 13.9-year-old boys; BMI for 6.0- to 10.9-year-old girls; weight, BMI, and WC for 11.0- to 13.9-year-old girls. While weight, BMI, WC, and WHtR were the best predictors of being overweight for 14.0- to 17.9-year-old boys; they were BMI, WC, and weight for the girls in the same age range. According to WC > 90th percentile; for 6.0- to 10.9-years, 11.0- to 13.9-years, and 14.0- to 17.9-years the AUCs of AFA for boys were 0.84, 0.90, and 0.88; and for girls those values were 0.81, 0.87, and 0.88.

Conclusion: AFA can be a significant index with WC in determining abdominal obesity.

Key words: Adolescents, anthropometry, epidemiology, fat, overweight prevalence and indicators

Abdominal obezite için vücut bileşimini saptamada çeşitli antropometrik ölçümlerden elde edilen yeni bir kesim noktası: kol yağ alanı

Amaç: Beslenme durumunun değerlendirilmesinde yağ kitlesi ve yağsız kitlenin saptanması büyük önem taşımaktadır. Bu çalışmada amaç, yüksek risk taşıyan Türk çocukları ve adölesanlarında abdominal obeziteyi (bel çevresi > 90. persentil) tanımlamada kol yağ alanını kullanmanın yardımcı olup olmayacağını belirlemektir. Kol yağ alanı ≥85. persentil hafif şişmanlığı gösterdiği için, antropometrik ölçümlerden yaşa ve cinsiyete özel kesim noktaları hesaplanmıştır.

Yöntem ve gereç: Bu çalışma yaşları 6-17 olan 5358 (2621 erkek, 2737 kız) çocuk ve adölesan ile yürütülmüştür. Boy uzunluğu, vücut ağırlığı, kulaç uzunluğu, bel çevresi, üst orta kol çevresi ve triseps deri kıvrım kalınlığı ölçülmüştür. Beden kitle indeksi, yağ yüzdesi, bel/boy oranı, bel/kulaç uzunluğu oranı ve kol yağ alanı hesaplanmıştır.

Bulgular: Kol yağ alanına göre grubun tamamı için hafif şişmanlık prevalansı % 14,9 bulunmuştur. ROC analizine göre 6,0-10,9 ve 11,0-13,9 yaş grubu erkekler için hafif şişmanlığı açıklayan en iyi değişkenler beden kitle indeksi, bel çevresi, bel/boy oranı ve bel/kulaç uzunluğu oranı; 6,0-10,9 yaş grubu kızlar için beden kitle indeksi; ve 10,0-13,9 yaş grubu kızlar

Received: 30.04.2009 – Accepted: 15.10.2009

[1] Department of Nutrition and Dietetics, Faculty of Health Sciences, Erciyes University, Kayseri - TURKEY
[2] Department of Biostatistics, Faculty of Medicine, Erciyes University, Kayseri - TURKEY
[3] Department of Family Medicine, Faculty of Medicine, Erciyes University, Kayseri - TURKEY
[4] Department of Pediatric Endocrinology, Faculty of Medicine, Erciyes University, Kayseri - TURKEY
Correspondence: *Betül ÇİÇEK, Department of Nutrition and Dietetics, Faculty of Health Sciences, Erciyes University, Kayseri-TURKEY*
E-mail: betul.cicek@gmail.com

için vücut ağırlığı, beden kitle indeksi ve bel çevresidir. 14,0-17,9 yaş grubu erkekler için vücut ağırlığı, beden kitle indeksi, bel çevresi; ve kızlar için beden kitle indeksi, bel çevresi ve vücut ağırlığıdır. Bel çevresi > 90. persentile göre; 6,0-10,9, 11,0-13,9 ve 14,0-17,9 yaş grubu erkekler için eğri altında kalan alanlar sırasıyla 0,84, 0,90 ve 0,88 ve aynı yaş grubu kızlar için 0,81, 0,87 ve 0,88 bulunmuştur.

Sonuç: Abdominal obeziteyi belirlemede bel çevresi ile birlikte kol yağ alanı önemli bir göstergedir.

Anahtar sözcükler: Adölesanlar, antropometri, epidemiyoloji, yağ, hafif şişmanlık prevalansı ve göstergeleri

Introduction

Determination of fat and fat-free mass is of considerable interest in the evaluation of nutritional status. Both over-nutrition and under-nutrition contribute to increased mortality and morbidity. The burden of nutritional problems is shifting from energy imbalance to excess energy intake among children and adolescents (1).

Despite the growing concern about obesity-related problems among the young, no universally accepted classification system for adolescent obesity exists. Although body mass index (BMI in kg/m^2) is widely used for classification of adult overweight and obesity, its use in adolescents is controversial. An additional complication, for all age groups, is that relative risk associated with certain BMI values seems to be population dependent. The controversy around the classification systems makes it difficult to monitor global and national trends, make comparisons between studies, stratify for public health measures, and screen in clinical practice (2).

Although visceral fat can be accurately assessed by imaging techniques, such as computed tomography and magnetic resonance imaging, using these techniques to identify people with abdominal obesity in large-scale epidemiological studies or mass screenings may not be feasible (3). Waist circumference (WC) and waist-to-height ratio (WHtR) are simple, yet effective alternative ways of measuring abdominal obesity in adults and children, and may be better predictors of disease risk than BMI in adults and children. In particular, WC is a better indicator of visceral fat than BMI in children (4).

In the current literature, children or adolescents with a WC > 90^{th} percentile were considered to have abdominal obesity (4-7). WC could be a promising index of abdominal fat distribution when identifying overweight children. In children, obesity-related health risks normally increase within each of the BMI categories; but, within each category, the health risks are higher in children with the greatest WC compared to those with the lowest WC (7).

Arm anthropometry has been used as a proxy of body composition in both clinical and field research settings for decades. The cross-sectional arm muscle area (AMA) and arm fat area (AFA) were introduced for the assessment of nutritional status of children in community settings and proposed to be better than direct skinfold thickness and arm circumference measurements. This approach has been widely accepted and used to assess nutritional status in a variety of populations including pediatric populations. Despite the evolution of body composition measurement techniques, arm anthropometry is still popular because it is inexpensive and noninvasive, and can be measured without difficulty in almost any situation, including clinical settings where time and patients' tolerance is limited. However, the validity of this simple method for assessing body composition has not been established (8).

The value of arm muscle and fat area as proxies for fat-free and fat mass relies on the theoretical assumption that i) the arm is cylindrical in form, ii) the subcutaneous fat is evenly distributed around a circular core of muscle, and iii) triceps skinfold thickness (TSF) accurately separates fat and fat-free components of the arm and represents twice the thickness of subcutaneous fat in the arm (8).

The aim of this study was to determine the cut-offs for AFA to estimate overweight and obesity in a sample of Turkish children and adolescents, based on WC > 90^{th} percentile. Considering that WC > 90^{th} percentile is a better indicator than AFA > 85^{th} to define abdominal obesity, we aimed to determine cut-offs for AFA, based on WC > 90^{th} percentile.

Materials and methods

Study design, participants, and sample size

This cross-sectional study was conducted in the elementary and secondary schools of the 2 central and 10 outlying districts of Kayseri, Turkey. Kayseri is one of the 3 main cities in Central Anatolia with more than 1,000,000 inhabitants. Data were obtained from the Determination of Anthropometric Measurements of Turkish Children and Adolescents (DAMTCA-I) survey from February to April 2005. A stratified multistage probability sampling design was employed. The first stage was the random selection of state and private schools of the city center and peripheral districts by the stratified sampling method based on socio-economic levels.

A total of 47 (23 elementary, 24 secondary) schools were selected randomly among 699 schools in Kayseri; the second stage was the random sampling of participants from schools' registers. A total of 5358 students (2737 girls, 2621 boys) ranging from 6 to 17 years old were included. Among these, children who were absent from school were visited again to invite them to participate in the study; the response rate was 95%. Exclusion criteria were known growth disorders and using any kind of medication.

The study was approved by the Erciyes University School of Medicine Ethics Committee and Kayseri Province Educational Board and written consent was obtained from the parents prior to the study in accordance with the Declaration of Helsinki.

The chronological age was calculated as the decimal age by subtracting the observation date from the birth date. To calculate the age of the children and adolescents in days, the dates of birth were used (e.g. 7-year-old indicates 7.00-7.99 years). Initially data were classified by age, but, in order to have a more representative sample for each subgroup, children and adolescents were assigned to 3 age groups: 6.0- to 10.9-year-olds (n = 2245), 11.0- to 13.9-year-olds (n = 1363), and 14.0- to 17.9-year-olds (n = 1750).

Data collection

Anthropometric indices

Body weight, height, WC, arm span, TSF, and mid-upper arm circumference (MUAC) were measured twice by well-trained health technicians and the average was recorded for reference charts. All of the inter-observer correlation coefficients were ≥0.91. The test and re-test reliability of measurements were calculated, and coefficients of variability for the anthropometric indices were between 0.2% and 0.3%.

Body weight was measured to 0.1 kg using a standard beam balance using a Tefal Ultraslim (France) in minimal underclothes. Height (barefoot) was determined to the nearest 1 mm with portable stadiometers. The portable scales and stadiometers were calibrated weekly. WC was measured using a non-elastic tape with the subject in a standing position from midway between the lowest rib and the top of the iliac crest at the end of expiration (9).

Arm span was measured with a steel measuring tape from the tip of the middle finger on one hand to the tip of the middle finger on the other hand with the individual standing with his or her back to the wall as when measuring the standing height, and arms abducted to 90°, elbow and wrist extended, and the palm facing directly forward. Readings were taken to the nearest 0.1 cm. All measurements were performed by the same 2 observers (10,11).

TSF measurements were taken twice at the left side of the body to the nearest 0.1 mm, halfway between the acromion process and the olecranon process using a Holtain skinfold caliper (1).

MUAC measurements were taken in centimeters with a non-elastic tape to the nearest 0.1 mm on the left arm, halfway between the acromion process and the olecranon process. The child/adolescent stood relaxed with his/her side to the trained health professionals and the arm hanging freely at the side; the tape was then passed around the arm at the level of the midpoint of the upper arm and the measurements were recorded (1).

BMI was calculated according to the formula weight (kg)/height $(m)^2$. Waist measurement was divided by height to yield WHtR and to arm span measurement to obtain waist-to-arm span ratio (WASR).

The AMA, arm area (AA), AFA, and fat percent (%) were calculated according to the following formulae:

$$AMA\ (cm^2) = (MUAC - \pi TSF)^2/4\pi$$

AA (cm^2) = $\pi/4 \times (MUAC/\pi)^2$ ($\pi = 3.1416$)

AFA (cm^2) = AA – AMA, as the best indicator of body fat in school-aged children (12,13).

Fat % = AFA × 100/AA (14-16).

Statistical analysis

According to AFA ≥ 85th and BMI ≥ 85th percentile, the overweight classification was created by using age- and gender-specific percentiles. The 90th percentile values of WC for age and gender were used to identify children and adolescents with abdominal obesity (5). WHtR cut-off of 0.5 was used to define abdominal obesity for boys and girls (4).

MedCalc software (version 9.2.0.1, Mariakerke, Belgium) was used to test the significance of the differences for the areas under the receiver operating characteristic (ROC) curves (AUC). The performance and cut-offs of anthropometric indices of overweight were determined by ROC analysis (17).

The partial correlation coefficients (adjusted for age and gender) between BMI, WC, WHtR, and WASR were calculated. Concordance (Kappa [κ] statistic) and conformance (χ^2 test to McNemar) of WASR, WHtR, and abdominal obesity with AFA according to gender in age groups, were analyzed. Agreement between the anthropometric indices was assessed by Cohen's κ statistic, with values of 0.00 to 0.20 indicating poor, 0.21 to 0.40 fair, 0.41 to 0.60 moderate, 0.61 to 0.80 good, and 0.81 to 1.00 excellent concordance (18). Statistical significance was set at $P < 0.05$.

Results

Anthropometric indices of Turkish children and adolescents (aged 6- to 17-year-old) considered to be related with obesity are presented in Table 1. As expected, the body-size variables increased across age groups in Turkish boys and girls. There is no difference in WHtR and WASR between gender across the age groups. According to the comparison of age groups with gender, significant differences were detected for all anthropometric indices in the 14.0- to 17.9-year-old group. All anthropometric indices except height, weight, and arm span in the 6.0- to 10.9-year-old group, weight in the 11.0- to 13.9-year-old group, and WHtR and WASR in the 14.0- to 17.9-year-old were significant.

According to BMI 85th percentile, the prevalence of overweight and obesity was 15.0% for males, and 14.9% for females. According to AFA 85th percentile, for the entire group, the prevalence of overweight and obesity was 14.8% for males, and 14.9% for females. In order to produce ROC curves, age- and gender-specific 2 groups were created by using percentiles (overweight 85th percentiles).

The best predictors explaining AFA 85th percentile are given below. According to ROC analysis, for the 6.0- to 10.9-year-old group, the best predictors that explain overweight were BMI, WHtR, WASR, and WC for boys, and BMI for girls. For the 11.0- to 13.9-year-old group, the best predictors were BMI, WC, WASR, and WHtR for boys, and weight, BMI, and WC for girls. For the 14.0- to 17.9-year-old group, they were BMI, body weight-WC, and WHtR for boys, and BMI, body weight, and WC for girls (Table 2).

Table 3 shows the ROC analysis to determine cut-offs of anthropometric indices for WC > 90th percentile. Among 6.0- to 10.9-year-old boys and girls for AFA, the AUC was 0.84 and 0.81; among 11.0- to 13.9-year-old boys and girls, it was 0.90, and 0.87; and for 14.0- to 17.9-year-old boys and girls, it was 0.88 and 0.86, respectively.

There were moderate correlations between BMI, WC, WHtR, WASR, and AFA (0.65, 0.55, 0.55, and 0.53, respectively) ($P < 0.001$). There were fair correlations between BMI, WC, WHtR, WASR, and fat % (0.38, 0.26, 0.30, and 0.29, respectively) ($P < 0.001$) (Table 4).

The McNemar test for the comparison of the probability of body fat with BMI 85th percentile and AFA 85th percentile indicated a non-significant difference for the same age groups ($P > 0.05$). The McNemar test for the comparison of the probability of abdominal obesity (WC > 90th percentile, for WHtR, and WASR cut-offs of 0.5) and AFA 85th percentile, indicated a significant difference for 6.0- to 17.9-year-old groups ($P < 0.001$). The McNemar test for the comparison of the probability of body fat with BMI 85th percentile and AFA 85th percentile indicated a non-significant difference for the same age groups ($P > 0.05$).

Table 1. Characteristics of Turkish children and adolescents for anthropometric indices considered to be related to obesity.

Anthropometric indices	6.0- to 10.9-year-old group Boys x̄ (SD) n = 1144	6.0- to 10.9-year-old group Girls x̄ (SD) n = 1101	11.0- to 13.9-year-old group Boys x̄ (SD) n = 641	11.0- to 13.9-year-old group Girls x̄ (SD) n = 722	14.0- to 17.9-year-old group Boys x̄ (SD) n = 836	14.0- to 17.9-year-old group Girls x̄ (SD) n = 914	Total 6.0- to 17.9-year-olds Boys x̄ (SD) n = 2621	Total 6.0- to 17.9-year-olds Girls x̄ (SD) n = 2737	Total 6.0- to 17.9 year-olds Boys+Girls x̄ (SD) n = 5358
Height (cm)	132.2 (10.4)	132.3 (10.9)	158.2 (10.3)[a]	156.6 (6.6)	171.5 (6.6)[a]	159.9 (5.7)	151.1 (19.7)[a]	147.9 (15.4)	149.5(17.7)
Body weight (kg)	31.3 (8.1)	30.8 (8.0)	49.9 (11.1)	49.9 (8.9)	62.1 (10.0)[a]	55.0 (8.1)	45.7 (16.5)[a]	43.9 (13.8)	44.8(15.2)
BMI (kg/m^2)	17.6 (2.5)[a]	17.3 (2.5)	19.8 (2.9)[a]	20.3 (3.2)	21.1 (3.0)[a]	21.5 (3.0)	19.3 (3.2)[a]	19.5 (3.4)	19.4(3.3)
AFA (cm^2)	8.2 (3.9)[a]	9.5 (4.4)	9.9 (5.2)[a]	13.9 (6.6)	10.3 (6.4)[a]	15.6 (7.0)	9.3 (5.2)[a]	12.7 (6.6)	11.0(6.2)
Fat %	29.3 (8.5)[a]	33.0 (9.3)	26.1 (9.2)[a]	34.6 (10.9)	23.1 (9.7)[a]	36.6 (11.0)	26.5 (9.5)[a]	34.7 (10.5)	30.7(10.8)
WC (cm)	58.7 (7.5)[a]	56.9 (6.3)	68.1 (8.5)[a]	64.8 (6.9)	72.4 (8.1)[a]	66.9 (6.5)	65.4 (10.0)[a]	62.3 (7.9)	63.8(9.1)
TSF (mm)	9.5 (3.7)[a]	11.0 (4.3)	9.8 (4.5)[a]	13.8 (5.8)	9.4 (5.2)[a]	15.2 (6.1)	9.5 (4.4)[a]	13.1 (5.7)	11.4(5.4)
MUAC (cm)	18.5 (2.5)[a]	18.7 (2.4)	21.4 (2.9)[a]	22.0 (2.7)	23.1 (3.1)[a]	22.8 (2.5)	20.7 (3.5)[a]	20.9 (3.1)	20.8(3.3)
Arm span (cm)	132.3(11.6)	131.6 (12.0)	159.4 (11.5)[a]	157.5(7.5)	174.4 (7.5)[a]	161.2 (6.8)	152.3(21.3)[a]	148.3 (16.7)	150.3(19.2)
WHtR	0.44 (0.04)[a]	0.43 (0.04)	0.43 (0.05)[a]	0.41 (0.04)	0.42 (0.05)	0.42 (0.04)	0.43 (0.05)[a]	0.42 (0.04)	0.43(0.04)
WASR	0.44 (0.04)[a]	0.43 (0.04)	0.43 (0.05)[a]	0.41 (0.04)	0.42 (0.05)	0.42 (0.04)	0.43 (0.05)[a]	0.42 (0.04)	0.43(0.04)
AFA ≥85th percentile (%)	14.8	15	14.8	15	15	14.9	14.8	14.9	14.9

Values were expressed as mean (SD); [a] P < 0.05 for gender difference within age groups
Abbreviations: BMI: body mass index, AFA: arm fat area, WC: waist circumference, TSF: triceps skinfold thickness, MUAC: mid-upper arm circumference, WHtR: waist-to-height ratio, WASR: waist-to-arm span ratio

Table 2. The ROC curve analysis to determine cut-offs of anthropometric indices for AFA ≥ 85th percentile.

Anthropometric indices	Boys AUC (95% CI)	Boys Cut-offs	Boys P	Girls AUC (95% CI)	Girls Cut-offs	Girls P
	AFA ≥ 85th percentile					
6.0- to 10.9-year-old group		n = 1144			n = 1101	
Height (cm)	0.64 (0.57-0.63)[c]	<138.3	< 0.001	0.60 (0.57-0.63)[c]	<134.2	< 0.001
Body weight (kg)	0.72 (0.69-0.75)[b]	<32.7	< 0.001	0.73 (0.71-0.76)[b]	<35.2	< 0.001
BMI (kg/m^2)	0.78 (0.75-0.80)[a]	<19.6	< 0.001	0.81 (0.79-0.84)[a]	<18.0	< 0.001
WC (cm)	0.76 (0.74-0.79)[a]	<62.1	< 0.001	0.77 (0.74-0.79)[b]	<58.2	< 0.001
WHtR	0.78 (0.76-0.81)[a]	<0.45	< 0.001	0.76 (0.73-0.78)[b]	<0.43	< 0.001
Arm span (cm)	0.61 (0.58-0.64)[c]	<135.5	< 0.001	0.59 (0.56-0.62)[c]	<130.0	< 0.002
WASR	0.77 (0.75-0.80)[a]	<0.45	< 0.001	0.75 (0.72-0.78)[b]	<0.43	< 0.001
11.0- to 13.9-year-old group		n = 641			n = 722	
Height (cm)	0.56 (0.52-0.60)[c]	<155.5	< 0.069	0.53 (0.49-0.56)[c]	<161.5	0.397
Body weight (kg)	0.77 (0.73-0.80)[b]	<54.2	< 0.001	0.84 (0.81-0.86)[a]	<55.9	< 0.001
BMI (kg/m^2)	0.82 (0.79-0.85)[a]	<20.9	< 0.001	0.86 (0.83-0.89)[a]	<21.7	< 0.001
WC (cm)	0.82 (0.78-0.85)[a]	<73.6	< 0.001	0.82 (0.79-0.85)[a]	<67.5	< 0.001
WHtR	0.80 (0.76-0.83)[ab]	<0.46	< 0.001	0.82 (0.79-0.85)[b]	<0.43	< 0.001
Arm span (cm)	0.57 (0.53-0.61)[c]	<156.2	< 0.029	0.56 (0.52-0.60)[c]	<161.8	0.055
WASR	0.79 (0.75-0.82)[a]	<0.45	< 0.001	0.82 (0.79-0.84)[b]	<0.42	< 0.001
14.0- to 17.9-year-old group		n = 836			n = 914	
Height (cm)	0.53 (0.49-0.56)[c]	<167.5	< 0.361	0.51 (0.48-0.55)[d]	<156.2	0.648
Body weight (kg)	0.82 (0.79-0.85)[a]	<65.9	< 0.001	0.85 (0.83-0.88)[abc]	<61.4	< 0.001
BMI (kg/m^2)	0.84 (0.81-0.86)[a]	<22.3	< 0.001	0.88 (0.85-0.90)[a]	<22.6	< 0.001
WC (cm)	0.82 (0.79-0.85)[a]	<76.2	< 0.001	0.84 (0.82-0.87)[ab]	<68.8	< 0.001
WHtR	0.81 (0.78-0.84)[a]	<0.45	< 0.001	0.83 (0.81-0.86)[b]	<0.43	< 0.001
Arm span (cm)	0.56 (0.52-0.59)[c]	<178.5	< 0.055	0.54 (0.51-0.57)[d]	<165.0	0.131
WASR	0.80 (0.77-0.83)[b]	<0.44	< 0.001	0.81 (0.78-0.84)[c]	<0.42	< 0.001

AUC, area under curve; statistically significant (P < 0.05) difference between both anthropometric indices were labeled with different superscript letters.
Abbreviations: BMI: body mass index, WC: waist circumference, WHtR: waist-to-height ratio, WASR: waist-to-arm span ratio

Table 3. The ROC curve analysis to determine cut-offs of anthropometric indices for WC > 90th percentile.

	WC > 90th percentile					
	Boys			Girls		
Anthropometric indice	AUC (95% CI)	Cut-offs	P	AUC (95% CI)	Cut-offs	P
6.0- to 10.9-year-old group		n = 1144			n = 1101	
AFA	0.84 (0.82-0.86)	< 9.5	< 0.001	0.81 (0.79-0.83)	> 11.0	< 0.001
11.0- to 13.9-year-old group		n = 641			n = 722	
AFA	0.90 (0.88-0.92)	< 13.1	< 0.001	0.87 (0.84-0.89)	> 16.6	< 0.001
14.0- to 17.9-year-old group		n = 836			n = 914	
AFA	0.88 (0.85-0.90)	< 12.3	< 0.001	0.86 (0.84-0.88)	< 17.6	< 0.001

Abbreviations: AUC: area under curve, AFA: arm fat area

Table 4. Relationship (partial correlation coefficients[a] for age and gender) between the independent variables.

Independent variables	AFA (cm^2)	Fat %
BMI (kg/m^2)	0.65	0.38
WC (cm)	0.55	0.26
WHtR	0.55	0.30
WASR	0.53	0.29

[a]All correlation coefficients were significant at P <0.001 level.
Abbreviations: BMI: body mass index, WC: waist circumference, WHtR: waist-to-height ratio, WASR: waist-to-arm span ratio, AFA: arm fat area

The agreement between the 2 approaches defining abdominal obesity for the 6.0- to 10.9-year-old group according to AFA 85th percentile was weak with WC > 90th percentile (κ = 0.37), WHtR (κ = 0.32), and WASR (κ = 0.32), and moderate with BMI (κ = 0.44). For the 11.0- to 13.9-year-old group, the agreement of defining abdominal obesity for AFA 85th percentile was moderate with WC (κ = 0.42), WHtR (κ = 0.41), and BMI (κ = 0.47); and was fair with WASR (κ = 0.36). For the 14.0 to 17.9 year-old group, the agreement of defining abdominal obesity for AFA 85th percentile was fair with WASR (κ = 0.36) and WHtR (κ = 0.40), and was moderate with WC (κ = 0.43) and BMI (κ = 0.52).

The correlation coefficients and the κ statistics were similar across age groups.

Discussion

In recent years, while evaluating cardiovascular and metabolic disease risk, it is recommended to consider abdominal obesity, besides BMI. This study extended our knowledge of AFA, if it can be substituted with WC in determining abdominal obesity for each gender. The major strength of this investigation was the large representative sample and age range studied representing mid-to-late childhood through adolescence.

Anthropometric indices

The literature includes a limited number of studies calculating body fat % only from TSF measurements (14,15). Monir et al. (15) found the body fat % of Egyptian boys and girls (6-11 years) between 29.0 to 30.9 and 36.0 to 36.5 respectively. Musaiger et al. (19) calculated the fat % of Bahrainian boys and girls (6-11 years) as 12.2 and 14.1; 11.0- to 13.9-year-olds 14.0 and 16.3; 14.0- to 17.9-year-olds 14.5 and 19.6, respectively. In the current study, girls had significantly more body fat % than boys in each age group, besides having lower body fat % values than their Egyptian and higher than their Bahrainian counterparts (15,19).

The literature provides limited data on AFA of healthy children and adolescents also (13,15,20,21). In the present study, we calculated mean AFA values of Turkish boys and girls (n = 5358) as 8.2 and 9.5 cm^2 for 6.0- to 10.9-year-olds, 9.9 and 13.9 cm^2 for 11.0- to 13.9-year-olds, and 10.3 and 15.6 cm^2 for 14.0- to 17.9-year-olds, respectively. According to our results, Turkish boys and girls had lower AFA values than their Bahrainian, Egyptian, Chinese, and Icelandic counterparts (15,19,21,22).

Using cross-sectional data from a large cohort, this study demonstrated that WHtR and WASR during childhood is associated with age (and hence growth) and gender. The significant increase in mean WHtR and WASR across the age groups reflected the divergence in the velocities of growth in height, arm span, and WC with age. As height, arm span, and WC correlated, the increase in WC in childhood is due in part to linear growth. Exactly how growth in height affects growth in WC is unclear at this stage, but this should be considered when variations in age-related WC are examined. It is expected that WHtR would plateau around age 18 years when growth in height ceases, and the mean values for WHtR for the later age groups suggested this was the case, particularly in boys. WHtR would begin to increase when extra fat would begin to accumulate on the upper body. WHtR in girls at all age groups compared with boys reflects the differences in both body shape and body proportions.

Specifically, girls had lower arm span values than did boys in each age group while boys had lower AFA, fat %, and TSF values than did girls in each age group. In the 6.0- to 10.9-year-old group, height values were very similar, while in the 11.0- to 13.9-year-old group, weight values were the same across gender. In the 14.0- to 17.9-year-old group, WHtR and WASR were also the same across gender.

Among Turkish boys, the WC values were higher than those of girls in each age group. The largest relative increase in WC for boys occurred in the 14.0- to 17.9-year-old group. Similarly, Li et al. (4) found the largest relative increase for non-Hispanic black and Mexican-American boys in WC in 12- to 17-year-olds.

WC is highly correlated with visceral adipose tissue in children, adolescents, and adults (9,10,23,24). Measuring WC has the advantages of being safe, easy, non-invasive, and inexpensive. Nevertheless, the clinical use of WC in children and adolescents is limited due to the lack of an internationally accepted classification that gives age-specific WC cut-offs. Moreover, in most countries, there are no population-based reference values for WC. In this context, the first set of age-related WC percentile curves for British children by McCarthy et al. (25), and more recently similar curves for Turkish children and adolescents by Hatipoglu et al. (9), have been developed and published.

Recently, the WHtR has been suggested because it has the advantage of being independent of age and gender, and because it is easier to use than other anthropometric indices. At present, few data are available on the potential usefulness of WHtR plus BMI to identify overweight children and adolescents at higher risk.

Several authors have recently proposed a cut-off of 0.5 for WHtR; anything over this value is associated with an increased cardiovascular risk in adults (26,27). Some authors have suggested using the same WHtR cut-offs in children as those used for adults, although a validation is not available. A recent study by Li et al. (4) reported a potential overestimation of abdominal obesity in very young children (2- to 5-year-olds) when the WHtR cut-off of 0.5 was used. In older children, such as in our study, this risk seems to be low, although further studies are needed to compare measures of abdominal fat, such as magnetic resonance imaging or computer tomography, to validate WC as well as WHtR cut-offs. However, these techniques are not applicable to large scale epidemiologic studies. In an attempt to overcome these limitations, we analyzed the AUC of Turkish children and adolescents according to different age groups.

In the present study, we had no WHtR values exceeding 0.5, even 0.45. This situation indicated a lower trend towards obesity in terms of WHtR for Turkish children and adolescents than their US, British, Italian, and Chinese counterparts, whereas there was a similarity between their French counterparts (4,7,28-30). Moreover, our lower limit of the age groups began with 6.0 years and ended with the upper limit of 17.9 years. With the wide age group categories, the current study again emphasized the lower trend towards obesity among Turkish children and adolescents.

Furthermore, calculated values for WHtR and WASR were the same for Turkish children and adolescents. As this is the first study to mention WASR, and there are no available country values to compare with, the current data again reflect the lower trend towards obesity, in the context of WASR. The consistent patterns in mean WHtR and WASR suggest that WASR is as sensitive as WHtR in monitoring overweight and obesity. Thus, WASR may be a potentially useful surrogate measure for abdominal obesity across different age, gender, or racial/ethnic subpopulations.

As AFA was a good predictor to explain WC > 90^{th} percentile, we propose the use of AFA in the evaluation of abdominal obesity, cardiovascular disease risk, and metabolic syndrome, in addition to routine criteria.

Conclusion and recommendations

Further studies are needed to elucidate the interaction of AFA, other anthropometric indices, and BMI. In general, the best predictors to explain AUC for AFA ≥ 85^{th} percentile were BMI, WC, WHtR, and WASR. Besides these commonly preferred anthropometric indices for evaluation of cardiovascular diseases and metabolic sendrome, AFA may be introduced as a novel approach to predict abdominal obesity.

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