ISSN (electrónico): 1699-5198 - ISSN (papel): 0212-1611 - CODEN NUHOEQ S.V.R. 318

ARÁN

Nutrición Hospitalaria

Trabajo Original

Valoración nutricional

Waist circumference, waist-to-hip ratio, and waist-to-height ratio reference percentiles for abdominal obesity among Macedonian adolescents

Percentiles de referencia de circunferencia de la cintura, relación cintura-cadera y relación cintura-altura para la obesidad abdominal de los adolescentes macedonios

Danilo Bojanic[1], Milovan Ljubojevic[1], Dragan Krivokapic[1] and Seryozha Gontarev[2]

[1]Faculty for Sport and Physical Education. University of Montenegro. Nikšić, Montenegro. [2]Faculty of Physical Education, Sport, and Health. Ss. Cyril and Methodius University. Skopje, North Macedonia

Abstract

Background: the goal of this study was to define waist circumference (WC), wasis-to-hip ratio (WHR) and waist-to-height ratio (WHRt) smoothed reference percentiles for assessing abdominal obesity in Macedonian adolescents aged 11 to 18 years in order to investigate possible obesity cut-offs of WHR and WHtR, and to compare WC percentiles with those of other adolescents.

Methods: the research was conducted on a sample of 2,490 adolescents of the Republic of Macedonia aged 11 to 18 years: 1,288 males and 1,202 females. Weight, height, body mass index (BMI), WC, hip circumference (HC), WHR and WHtR were measured and percentiles were calculated using Cole's Lambda, Mu and Sigma (LMS) method. The relation between WHR, WHtR and general obesity, as defined by the International Obesity Task Force, was investigated with a receiver operating characteristic (ROC) analysis.

Results: the boys had statistically significant higher values in all anthropometric measures except in HC, where statistically significant gender differences were not found. BMI, WC, and HC showed an increasing trend with age. The WHtR variable is a better indicator for assessing general obesity in both boys and girls (AUC, 95 % CI: 0.905-0.928) than WHR, which showed lower AUC values (95 % CI: 0.697-0.734) in predicting IOTF obesity; the WHtR cut-off of 0.5 had a sensitivity of 74 % and a specificity of 92 % for both genders and all age groups.

Conclusions: the obtained reference percentile curves can be used temporarily for early detection of abdominal obesity among Macedonian adolescents aged 11 to 18 years; a WHtR of 0.5 may also be used as an obesity threshold in these age groups.

Keywords:

Abdominal obesity. Adolescents. Anthropometric measurements. LMS method. ROC analysis.

Resumen

Antecedentes: el objetivo de este estudio fue definir los percentiles de referencia suavizados perímetro abdominal (WC), relación cintura-cadera (WHR) y relacion cintura-talla (WHtR) para evaluar la obesidad abdominal en adolescentes macedonios de 11 a 18 años, con el fin de investigar posibles valores de corte de WHR y WHtR para la obesidad, y comparar los percentiles de WC con los de otros adolescentes.

Métodos: la investigación se realizó en una muestra de 2490 adolescentes de la República de Macedonia de 11 a 18 años de edad; 1288 varones y 1202 mujeres. Se midieron peso, altura, índice de masa corporal (IMC), WC, circunferencia de cadera (HC), WHR y WHtR, y se calcularon los percentiles utilizando el método LMS. La relación entre WHR, WHtR y la obesidad general, según lo definido por la International Obesity Task Force, se investigó con el análisis de las características operativas del receptor (ROC).

Resultados: los varones tuvieron valores estadísticamente más altos en todas las medidas antropométricas excepto en HC, donde no se encontraron diferencias estadísticamente significativas entre ambos sexos. IMC, WC y HC mostraron una tendencia creciente con la edad. La variable WHtR es un indicador para evaluar la obesidad general en niños y niñas (AUC, IC 95 %: 0,905-0,928) mejor que WHR, que mostró valores de AUC más bajos (IC 95 %: 0,697-0,734) para predecir la obesidad IOTF. El valor de corte de WHtR, de 0,5, tuvo una sensibilidad del 74 % y una especificidad del 92 % para ambos sexos y para todos los grupos de edad.

Conclusiones: las curvas de percentiles de referencia obtenidas pueden usarse temporalmente para la detección temprana de la obesidad abdominal entre los adolescentes macedonios de 11 a 18 años; una WHtR de 0,5 también puede utilizarse como un umbral de obesidad en estos grupos de edad.

Palabras clave:

Obesidad abdominal. Adolescentes. Mediciones antropométricas. Método LMS. Análisis ROC.

Received: 15/01/2020 • Accepted: 31/03/2020

Acknowledgments: we hereby express our most heartfelt gratitude to the adolescents who took part in this study, as well as to their parents and teachers.

Conflict of interests: The authors declare no conflict of interests.

Bojanic D, Ljubojevic M, Krivokapic D, Gontarev S. Waist circumference, waist-to-hip ratio, and waist-to-height ratio reference percentiles for abdominal obesity among Macedonian adolescents. Nutr Hosp 2020;37(4):786-793

DOI: http://dx.doi.org/10.20960/nh.03006

Correspondence:

Danilo Bojanic. Faculty for Sport and Physical Education. University of Montenegro. Nikšić, Montenegro
e-mail: danilo.bo@ucg.ac.me

INTRODUCTION

Obesity in children and adolescents is reaching an epidemic level worldwide (1). It is considered the most widespread disease in children in many countries, especially in developed countries (2). Macedonia is no exception to this trend, and the current prevalence figures are similar to those obtained in most countries of western and northern Europe (3). The body mass index (BMI = kg/m^2) is a widely used measure for overweight and obesity assessment in children, although BMI does not provide information on fat distribution. A central fat distribution is associated with an increased risk of cardiovascular and metabolic diseases in adults and children (4,5), and a large waist circumference (WC) in adults is associated with increased mortality regardless of BMI (6). Some authors (7) have found that the health risk in adults with overweight and obesity, as defined by BMI, was comparable with that of a normal-weight person given the same waist circumference. In children and adolescents, WC correlates with truncal adiposity as measured by dual-energy X-ray absorptiometry (8), as well as by MRI (9) and CT imaging (10).

Different approaches to define the cut-off values for WC are used in the literature, including the cut-off values based on the International Obesity Task Force (IOTF) definitions of overweight and obesity (11), extrapolations from adult cut-offs (12), and specific percentiles (13). The waist-to-height ratio (WHtR) has also been proposed as a useful clinical parameter for the assessment of overweight in children (14). It is assumed that a WHtR over 0.5 correlates with increased metabolic risk in children and adolescents (15). A certain number of studies so far suggest that this cut-off can also be used in pre-school children (16), although some authors disagree (17) and indicate the need for age-related reference charts. In addition, it is likely that ethnicity and environmental differences affect body proportions, which suggests the need to define national reference standards for control of variations among populations.

The goal of this research was to define WC, WHR and WHtR smoothed reference percentiles for the assessment of abdominal obesity among Macedonian adolescents aged 11 to 18 years, and to compare them with world curves generated for other adolescent populations, as well as to investigate possible WHR and WHtR cut-offs for detecting general obesity as defined by the IOTF.

METHODS

PARTICIPANTS

The sample included 2,490 adolescents from four (Polog, Skopje, Southeastern, and Southwestern) regions of North Macedonia, aged between 11 to 18 years. The sample was divided into two sub-samples by gender: 1,288 respondents were boys and 1,202 respondents were girls. The average age of the respondents was 14.4 (± 2.27).

Participants from selected schools and classes were informed about the objective of the study, and their parents signed the informed consent form for participation in the research. All adolescents were healthy at the time of this study. To avoid errors in the selection of the sample volunteer students were not included.

The sample included all students whose parents had provided their consent to participate in the research, who were psychologically and physically healthy, and who regularly attended physical fitness and health education lectures.

The respondents were treated following the Helsinki Declaration of 1961 (Edinburgh revision, 2013). The measurements were carried out in March, April and May 2017 under standard school conditions at regular physical and health education classes. Measurements were carried out by experts in the field of kinesiology and medicine, who were previously trained to measure specific anthropometric parameters.

ANTHROPOMETRIC MEASUREMENTS

For evaluation ten anthropometric variables were selected and measured according to the International Biological Program (IBP): body weight (BW), height (Ht), waist circumference (WC), and hip circumference (HC), with adolescents being barefoot and in minimal clothing. The following standard anthropometric instruments were used: for measuring body height an Martin anthropometer with 1-mm reading accuracy was used; a decimal weight scale; and an inextensible anthropometric tape, also with 1 mm reading accuracy, for measuring circumferences. Anthropometric measurements were made during school hours, not interrupting the lessons. Subjects were standing, facing ahead, and body height was measured as the maximum distance from the floor to the highest point on the head. Shoes were off, both feet together, and arms hanging at the sides. The heels, buttocks, and upper back were in contact with the wall. Body height measurement can vary throughout the day, usually being higher in the morning, so to ensure reliability we measured height at the same time of day. Waist and hip circumferences were measured twice using inextensible anthropometric tape with the adolescents standing erect and relaxed, with arms at the sides and feet positioned close together. Waist circumference was measured midway between the lowest border of the rib cage and the upper border of the iliac crest, at the end of normal expiration (18). HC was measured at the widest part of the hip, at the level of the greater trochanter. BMI was calculated as a weight-to-height ratio squared (kg/m^2), WHR was calculated as a waist-to-hip ratio, and WHtR as a waist circumference-to-height ratio.

STATISTICAL ANALYSIS

The arithmetic mean and standard deviation were calculated for the variables BW, Ht, BMI, WC, HC, WHR and WHtR. The normality of variable distribution was tested with the Kolmogorov-Smirnov test. The differences between mean values for anthropometric measurements for each age group and gender were tested using an independent t-test.

The relationship between BW, Ht, WC, HC, WHR, WHtR and overweight/obesity, as defined by the IOTF, was investigated with a ROC analysis. The discriminating power of BW, Ht, WC, HC, WHR, and WHtR was expressed as an area under the curve (AUC). Smoothed age- and gender-specific tables and graph percentiles were constructed for BMI, WC, WHR and WHtR using the LMS method. It estimates measurement centiles in terms of three age-sex-specific cubic spline curves: the L curve (Box-Cox power to remove skewness), M curve (median), and S curve (coefficient of variation). For the construction of the percentile curves, data were imported into the LMS Chart Maker software (v. 2.3; by Tim Cole and Huiqi Pan), and the L, M and S curves were estimated. Except for the LMS method calculations, we used the SPSS v. 22.0 software for Windows (SPSS, Chicago, Illinois, USA).

RESULTS

The research was conducted on a sample of 2,490 adolescents aged 11 to 18 years. The average age of the sample (± SD) was 14.4 (± 2.27) years. The male to female ratio was 1.08, with 51.8 % boys and 48.2 % girls. The descriptive statistical parameters for the BW, Ht, BMI, WC, HC, WHR and WHtR variables, in terms of gender and age, are presented in table I.

Table I shows the mean values of body weight (BW), height (Ht), body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) according to age and sex. Weight (BW) was significantly higher in males than in females at ages 11, 13, 14, 15, 16, 17 and 18 years. Also, height (Ht) was significantly higher in males than in females at ages 13 to 18 years. Body mass index (BMI) was significantly higher in males than in females at ages 11, 15, 16 and 18 years. Waist circumference (WC) was significantly higher in males than in females at ages 11, 12, 13 14, 16, 17 and 18 years. Hip circumference (HC) was significantly higher in males than in females at ages 15 and 18 years; from the age of 13 years the hip circumference was significantly higher in females than in males. The waist-to-hip ratio (WHR) was significantly higher in males than in females at ages 11 to 18 years. The waist-to-height ratio (WHtR) was significantly higher in males than in females at ages 11, 12, 13 14, 15 16 and 18 years. BMI, WC, and HC showed an increasing trend with age. WHR and WHtR showed discontinuous values in terms of age in both boys and girls. The following table displays the smoothed gender and age-specific percentile values

Table I. Mean values (±sd) for body weight (BW), height (Ht), body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) for Macedonian adolescents aged 11-18 years

Age (y)	Number	BW (kg)	Ht (cm)	BMI (kg/m²)	WC (cm)	HC (cm)	WHR	WHtR
Boys								
11	167	44.2 ± 11.1[a]	151.2 ± 7.0	19.2 ± 3.6[a]	69.2 ± 9.7[c]	82.4 ± 8.7	0.84 ± 0.05[c]	0.46 ± 0.06[c]
12	160	51.8 ± 14.4	158.3 ± 9.4	20.4 ± 4.2	72.0 ± 11.0[c]	87.5 ± 10.7	0.82 ± 0.06[c]	0.45 ± 0.06[c]
13	150	54.6 ± 13.5[a]	164.3 ± 9.8[c]	20.0 ± 3.6	71.3 ± 9.5[b]	88.1 ± 8.7	0.81 ± 0.06[c]	0.43 ± 0.05[a]
14	169	62.0 ± 14.4[c]	169.9 ± 7.6[c]	21.3 ± 4.1	75.4 ± 11.4[c]	92.4 ± 9.7	0.81 ± 0.07[c]	0.44 ± 0.06[a]
15	164	67.7 ± 13.6[c]	173.7 ± 6.8[c]	22.4 ± 4.3[b]	78.1 ± 11.3	94.0 ± 9.5[c]	0.83 ± 0.06[c]	0.45 ± 0.06[a]
16	161	69.1 ± 11.8[c]	175.3 ± 5.6[c]	22.5 ± 3.9[c]	77.6 ± 9.1[c]	92.8 ± 8.3	0.84 ± 0.06[c]	0.44 ± 0.06[b]
17	170	71.8 ± 13.5[c]	177.9 ± 6.5[c]	22.6 ± 3.9	79.5 ± 11.0[c]	94.9 ± 8.0	0.84 ± 0.07[c]	0.45 ± 0.06
18	147	75.1 ± 11.5[c]	179.1 ± 6.7[c]	23.4 ± 3.2[c]	80.0 ± 8.5[c]	97.6 ± 6.8[c]	0.81 ± 0.09[c]	0.45 ± 0.05[b]
Total	1288	61.9 ± 16.5	168.6 ± 12.0	19.2 ± 3.6	75.4 ± 10.9	91.1 ± 10.0	0.82 ± 0.06	0.45 ± 0.06
Girls								
11	158	42.6 ± 10.7	151.7 ± 6.8	18.3 ± 3.5	64.4 ± 8.5	83.5 ± 9.3	0.77 ± 0.05	0.42 ± 0.05
12	151	48.6 ± 8.8	157.4 ± 7.0	19.6 ± 3.3	67.3 ± 7.2	88.4 ± 7.6	0.76 ± 0.05	0.43 ± 0.05
13	156	51.7 ± 9.2	160.8 ± 6.3	19.9 ± 3.0	67.8 ± 8.0	90.7 ± 7.7[b]	0.75 ± 0.06	0.42 ± 0.05
14	156	56.1 ± 9.3	163.3 ± 6.2	21.0 ± 3.1	69.9 ± 7.7	94.3 ± 7.1	0.74 ± 0.05	0.43 ± 0.05
15	148	56.1 ± 9.1	163.0 ± 5.4	21.1 ± 3.3	70.7 ± 7.8	93.4 ± 7.5	0.75 ± 0.08	0.43 ± 0.05
16	150	56.2 ± 8.2	163.3 ± 6.0	21.1 ± 2.7	70.1 ± 7.6	93.3 ± 6.5	0.75 ± 0.06	0.43 ± 0.05
17	141	58.7 ± 9.3	163.5 ± 5.3	21.9 ± 3.2	72.0 ± 8.6	94.5 ± 7.2	0.76 ± 0.07	0.44 ± 0.05
18	142	57.4 ± 7.8	164.8 ± 5.7	21.2 ± 2.7	69.4 ± 6.0	94.4 ± 5.9	0.74 ± 0.04	0.42 ± 0.04
Total	1202	53.3 ± 10.4	160.9 ±7.4	20.5 ± 3.3	68.9 ± 8.0	91.5 ± 8.3	0.75 ± 0.06	0.43 ± 0.05

Significant gender differences: [a] p-value < 0.05; [b] p-value < 0.01; [c] p-value < 0.0001.

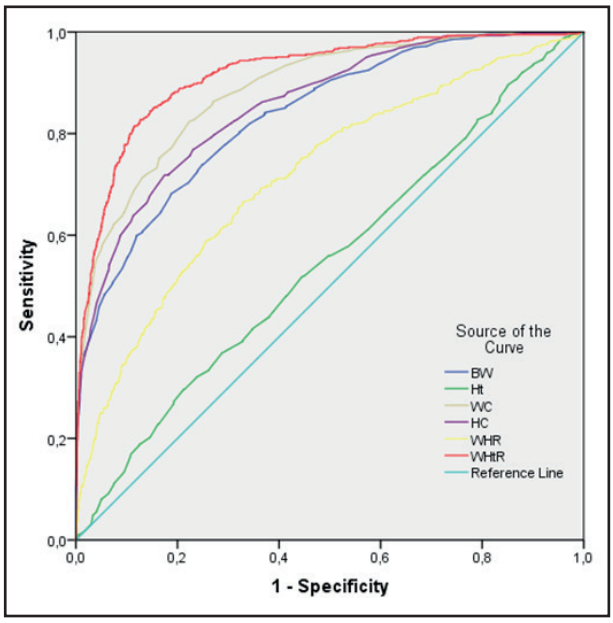

Figure 1.

Receiver operating characteristic (ROC) curve for the prediction of general obesity based on body weight (BW), height (Ht), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) in both genders.

at the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentiles, which were developed and smoothed by the LMS method.

The ROC analysis shows that the WHtR variable has greater discriminatory power for predicting IOTF obesity when compared to the WC and WHR variables (Fig. 1 and Table II).

For obesity, the WHtR cut-off > 0.46 had a sensitivity of 82.7 and a specificity of 87.3 for both genders (AUC, 0.898 ± 0.012 for girls, 0.929 ± 0.009 for boys) and all age groups together (AUC 0.917 ± 0.007). The cut-off for WHR > 0.77 in girls had a sensitivity of 54.1 and a specificity of 76,1 % (AUC, 0.681 ± 0.021) whereas the WHR > 0.82 cut-off in boys had a sensitivity of 71.0 and a specificity of 63.5 (AUC, 0.732 ± 0.016). The cut-off for WC > 72.0 in girls had a sensitivity of 75.4 and a specificity of 83.3 (AUC, 0.867 ± 0.014) whereas the WC > 77.5 cut-off in boys had a sensitivity of 82.5 and a specificity of 82.8 (AUC, 0.906 ± 0.009). The WHtR variable is a better predictor of general obesity than the BW, Ht, WC, HC, and WHR variables both in boys and girls.

COMPARISONS

To determine ethnic differences in abdominal obesity in adolescents, the reference curves obtained for the WC variable in this survey were compared to the curves obtained on the same variables from surveys that were carried out in other countries. Due to the different methodologies used in the publication of the national reference values for adolescents, attention is required when comparing the data on WC percentile values obtained from the various studies available. Therefore, the comparison was limited to the studies where the LMS method was used. To use contemporary data, only surveys conducted from year 2000 onwards were included. The results of the WC measurements of Macedonian adolescents were compared with those of countries in different geographic regions and with different ethnicities, such as Greece, Norway, Turkey, Poland, South India, Germany, and Kuwait (11,19-25). The percentile curves for these countries referred to data derived from transversal research. For adolescents aged 11 to 18 years, the average BMI is within the range from 20.4 to 24.2 for boys, and from 20.3 to 23.9 for girls (11,23,25). The respondents in this study had a mean BMI value of 21.45 for boys and 20.55 for girls (Table III).

The WC data are of particular interest at the 50th percentile (WC50) because they reflect the majority as the midpoint, and at the 90th percentile (WC90), as this reflects the pathological point of abdominal obesity. The comparison of WC50 (mean) and WC90 (abdominal obesity cut-off) for Macedonian adolescents with the percentiles of their counterparts, developed over the past 17 years in seven countries, is presented in table III.

Our findings suggest that higher values have been observed in Kuwaiti male adolescents, while Turkish, Indian, Polish, Norwegian, Australian and Chinese adolescents have lower values for the WC variable as compared to Macedonian adolescents in all age categories. Macedonian male adolescents had higher values for the WC variable when compared to Greek adolescents in all age categories, except at ages 12 and 13, where male Macedonian adolescents have lower values.

Table II. Area under the ROC curves (95 % CI) of anthropometric indices to predict general obesity

Variables	(Boys)	(Girls)	(All)
BW	0.835 (0.809 - 0.861)*	0.852 (0.822 - 0.881)*	0.837 (0.818 - 0.855)*
Ht	0.541 (0.507 - 0.575)	0.441 (0.398 - 0.483)	0.546 (0.519 - 0.573)
WC	0.906 (0.887 - 0.924)*	0.866 (0.839 - 0.893)*	0.887 (0.871 - 0.902)*
HC	0.878 (0.858 - 0.899)*	0.836 (0.806 - 0.866)*	0.856 (0.838 - 0.874)*
WHR	0.732 (0.701 - 0.764)*	0.681 (0.640 - 0.723)*	0.717 (0.692 - 0.742)*
WHtR	0.929 (0.912 -0.946)*	0.898 (0.875 - 0.921)*	0.917 (0.904- 0.931)*

*Data are AUC (95 % confidence interval). *p-value < 0.001. AUC: area under the receiver operating characteristic curve.*

Table III. Age - and gender-specific smoothed body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) percentiles for Macedonian adolescents aged 11-18 years

	Age (years)	Percentiles						
		3rd	10th	25th	50th	75th	90th	97th
Boys								
BMI	11	13.68	14.98	16.53	18.61	21.17	24.04	27.58
	12	14.49	15.75	17.26	19.32	21.93	24.97	28.92
	13	14.99	16.20	17.67	19.70	22.32	25.43	29.63
	14	15.86	17.04	18.48	20.48	23.11	26.31	30.79
	15	16.93	18.10	19.52	21.49	24.07	27.21	31.62
	16	17.27	18.44	19.85	21.79	24.29	27.31	31.44
	17	17.54	18.71	20.11	22.02	24.47	27.35	31.20
	18	18.41	19.60	21.01	22.87	25.15	27.70	30.88
WC	11	55.12	58.41	62.28	67.40	73.70	80.78	89.68
	12	56.70	59.93	63.74	68.81	75.10	82.26	91.40
	13	58.20	61.36	65.10	70.10	76.35	83.53	92.83
	14	60.79	63.92	67.64	72.64	78.90	86.15	95.66
	15	63.23	66.39	70.13	75.09	81.26	88.31	97.39
	16	64.29	67.47	71.21	76.13	82.16	88.92	97.42
	17	65.06	68.27	72.00	76.88	82.79	89.31	97.34
	18	66.68	69.94	73.68	78.48	84.15	90.23	97.46
WHR	11	0.74	0.77	0.80	0.83	0.87	0.91	0.95
	12	0.72	0.75	0.78	0.81	0.85	0.89	0.94
	13	0.72	0.74	0.77	0.81	0.85	0.89	0.94
	14	0.72	0.74	0.77	0.81	0.85	0.89	0.94
	15	0.73	0.75	0.79	0.82	0.87	0.91	0.96
	16	0.73	0.76	0.79	0.83	0.87	0.92	0.96
	17	0.72	0.76	0.79	0.83	0.87	0.92	0.96
	18	0.71	0.74	0.78	0.82	0.86	0.90	0.94
WHtR	11	0.74	0.77	0.80	0.83	0.87	0.91	0.95
	12	0.37	0.39	0.42	0.45	0.49	0.53	0.58
	13	0.37	0.39	0.41	0.44	0.48	0.53	0.59
	14	0.36	0.38	0.40	0.43	0.47	0.51	0.58
	15	0.37	0.38	0.40	0.43	0.47	0.51	0.58
	16	0.37	0.39	0.41	0.43	0.47	0.52	0.58
	17	0.37	0.39	0.41	0.43	0.47	0.52	0.58
	18	0.37	0.39	0.41	0.43	0.47	0.51	0.58
Girls								
BMI	11	13.53	14.68	16.06	17.92	20.23	22.87	26.21
	12	14.44	15.66	17.10	18.99	21.26	23.75	26.75
	13	15.23	16.49	17.94	19.81	22.03	24.40	27.18
	14	15.96	17.21	18.65	20.50	22.67	24.97	27.64
	15	16.39	17.60	19.00	20.80	22.90	25.13	27.72
	16	16.71	17.89	19.25	20.99	23.03	25.20	27.74
	17	17.06	18.19	19.50	21.18	23.18	25.32	27.86
	18	17.12	18.17	19.38	20.97	22.88	24.95	27.46

(Continuation in the next page)

Table III (Cont.). Age - and gender-specific smoothed body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) percentiles for Macedonian adolescents aged 11-18 years

	Age (years)	Percentiles						
		3rd	10th	25th	50th	75th	90th	97th
Girls								
WC	11	52.21	55.09	58.41	62.71	67.84	73.40	80.06
	12	55.41	58.44	61.87	66.19	71.16	76.32	82.21
	13	56.44	59.31	62.56	66.68	71.47	76.50	82.32
	14	58.97	61.61	64.65	68.57	73.22	78.25	84.27
	15	60.14	62.62	65.49	69.21	73.68	78.59	84.59
	16	60.25	62.70	65.54	69.23	73.66	78.53	84.50
	17	60.31	62.74	65.56	69.22	73.63	78.48	84.43
	18	60.48	62.76	65.40	68.85	73.00	77.60	83.29
WHR	11	0.69	0.71	0.74	0.77	0.80	0.84	0.88
	12	0.67	0.70	0.72	0.75	0.79	0.83	0.88
	13	0.66	0.69	0.71	0.74	0.78	0.82	0.87
	14	0.66	0.68	0.71	0.74	0.78	0.82	0.88
	15	0.66	0.69	0.71	0.74	0.78	0.83	0.89
	16	0.66	0.69	0.71	0.75	0.78	0.83	0.89
	17	0.66	0.68	0.71	0.74	0.78	0.83	0.89
	18	0.65	0.68	0.70	0.74	0.77	0.81	0.87
WHtR	11	0.34	0.36	0.39	0.42	0.45	0.49	0.54
	12	0.35	0.37	0.39	0.42	0.45	0.49	0.54
	13	0.35	0.37	0.39	0.42	0.45	0.49	0.55
	14	0.36	0.38	0.40	0.42	0.45	0.49	0.55
	15	0.36	0.38	0.40	0.42	0.46	0.50	0.56
	16	0.36	0.38	0.40	0.42	0.46	0.50	0.56
	17	0.37	0.38	0.40	0.42	0.45	0.49	0.55
	18	0.36	0.38	0.40	0.42	0.45	0.48	0.54

Higher values of the WC variable have been found in Macedonian female adolescents when compared to Norwegian, Australian, Turkish and Chinese adolescents; however, these values were lower than the ones of Kuwaiti and Indian adolescents. Greek and Polish female adolescents have lower values of the WC variable as compared to Macedonian adolescents in all age categories, except at ages 12 and 13, where Greek female adolescents have higher values, and Polish adolescents have higher values at 13 and 18 years of age.

Inter-country comparisons were also performed for adolescents' WC50 and WC90 at the mean age of 14 years as shown in table IV.

The results in the table show that at the 50th WC percentile value, Macedonian male adolescents show higher values when compared to Greek, Australian, Polish, Indian, Turkish, Norwegian, and Chinese adolescents, and lower values when compared to Kuwaiti adolescents. At the 90th WC percentile value, Macedonian male

Table IV. Comparison of WC_{50} (median) and WC_{90} (cut-off) for waist circumference (in cm) among 14-year-old boys and girls from different countries

	Boys		Girls	
	WC_{50}	WC_{90}	WC_{50}	WC_{90}
Greece	72.10	85.00	67.6	78.7
South India	69.40	83.40	70.2	82.5
Norway	63.90	77.80	61.4	73.3
Australia	69.40	79.90	66.8	77.0
Kuwait	74.90	98.50	74.9	98.5
Turkey	68.90	79.50	64.7	73.3
China	64.30	76.80	61.1	70.6
Poland	69.10	81.00	66.2	77.9
Macedonia	72.64	86.15	68.57	78.25

adolescents show higher values when compared to Australian, Polish, Indian, Turkish, Norwegian, and Chinese adolescents, and lower values when compared to Greek and Kuwaiti adolescents. At the 50th WC percentile value, Macedonian female adolescents show higher values when compared to Greek, Australian, Polish, Turkish, Norwegian, and Chinese adolescents, and lower values when compared to Indian and Kuwaiti adolescents. At the 90th WC percentile value, Macedonian female adolescents show higher values when compared to Australian, Polish, Turkish, Norwegian, and Chinese adolescents, and lower values when compared to Greek, Indian and Kuwaiti adolescents.

DISCUSSION

This study presents the initial gender- and age-percentile values for the WC, WHR and WHtR variables among Macedonian adolescents from 11 to 18 years of age. The data on the percentile values are calculated on a representative sample of 2,490 Macedonian adolescents. This is the first attempt to make smoothed percentile curves for the above-mentioned variables, and to suggest Macedonian cut-offs for defining abdominal obesity in this population group.

The obtained results of the research are consistent with those of previous studies performed on adolescents (11,19,21-28). Namely, WC shows an increasing trend with age in both girls and boys. This is expected, given the fact that puberty is a critical period for the development and distribution of body fat (29). In girls, WC is decreasing at the upper end of the age range. Boys have higher WC, WHR and WHtR values than girls in all age categories. This is probably due to the gender-specific influence on waist circumference, and it can be explained by the fact that central fat distribution dominates in boys more than in girls. In boys, fatty tissue is distributed mainly in the upper parts of the body (nape of neck, shoulders, epigastrium), while in girls it usually accumulates in the lower part of the body (13).

The obtained data on the WC percentile values could be of particular interest since the measurement of WC is the most widely accepted and simplest non-invasive clinical method for assessing central obesity in puberty. For adults, there is a cut-off for predicting the risk of metabolic syndrome. However, in adolescents it is necessary to calculate separate cut-off reference standards for WC in terms of age and gender, due to the natural increase in this anthropometric measure during puberty. Usually, the 90th percentile for WC (30-32) is proposed as a cut-off percentile wherein and beyond which the risk of metabolic syndrome in adolescence significantly increases. Since the cut-off values of WC differ depending on ethnicity, and due to the lack of such data for Macedonian adolescents, one of the goals of the research was to determine the 90th percentile for WC in an attempt to define specific reference standards for this age group of the population. Provided that a specific WC cut-off exists, measuring this anthropometric indicator will be a useful tool for screening cardiovascular and metabolic risk in adolescents, which will be used in primary health care in Macedonia.

In young children WC is reported to be a better estimate of body fat percentage when adjusting for gender and age, thus pointing to the importance of examining age range-specific subgroups (33). On the basis of the obtained results, one can conclude that 13.3 % of Macedonian adolescents have increased abdominal obesity (according to the 90th percentile). In terms of percentage, adolescents reach a peak at age 17 (then, on average, about 18.6 % of adolescents have increased abdominal obesity), and this trend decreases by the age of 18 (then, on average, about 9.3 % of adolescents have increased abdominal obesity). The age group of 17 years seems to be exposed to an increased risk of abdominal obesity. The percentage of abdominal obesity was higher among boys (14.1 %) than among girls (12.5 %).

International comparisons have shown that Macedonian adolescents have high levels of abdominal obesity in early and middle adolescence, and this does not seem to change by the age of 18 years. Unhealthy/poor eating habits, insufficient physical activity and a sedentary lifestyle are associated with obesity among Macedonian adolescents (34,35). The relative decline in abdominal obesity by the age of 18 in girls can be explained by the personal (identity research) and social motivation (peer pressure, sexual experimentation) that arises during the transition to middle adolescence, since body mass seems to affect dissatisfaction with the body shape and a reduction of self-esteem in girls (36). The differences seen in the percentile curves obtained in different countries confirm the evidence of ethnic differences in abdominal obesity and the need to provide population-specific WC reference curves for adolescents.

WHR and WHtR show variations with age in both genders. The cut-offs of WHR > 0.89 correspond to the 97th percentile in boys, while the cut-offs for WHR > 0.89 correspond to the 93rd-99th percentile in girls, regarding age. The cut-offs for WHR that are used in adults are inappropriate for the assessment of general obesity in adolescents due to a low sensitivity that has been proven with a ROC analysis. Studies so far have shown that a cut-off of WH at ≥ 0.5 is a useful indicator for estimating central obesity in representative samples of British, Norwegian, and German adolescents (15,22,25). This finding has been confirmed in our research as well. In the research it was found that this cut-off corresponds to the 85th-90th WThR percentile for all age groups in both boys and girls. Besides, the receiver operating curves (ROC) demonstrated that WHtR is a better indicator for estimating general obesity in both boys and girls (AUC, 95 % CI: 0.905-0.928) than WHR, which showed lower values (AUC, 95 % CI: 0.697-0.734) and WC (AUC, 95 % CI: 0.873-0.899) in the prediction of IOTF obesity.

The advantage of this study is that this is one of the first researches conducted on Macedonian adolescents. Anthropometric measures were collected by appropriately trained health workers who used the same anatomical points of measurement. The limitations of the study include lack of information regarding the impact of sexual maturation status on anthropometric indices, as well as the cross-sectional design of the study. Although the reference curves are obtained from contemporary data that are most probably representative of the current situation in Mace-

donia, the validity of the obtained percentile curves should be confirmed in future research using a longitudinal approach.

Based on the obtained results, a conclusion can be drawn that this is the first comprehensive study that determines the specific age- and gender-specific WC, WHR and WHtR percentile values among Macedonian adolescents aged 11 to 18 years. We propose that the obtained percentile values be temporarily used in clinical practice for the early detection of abdominal obesity among Macedonian adolescents. WHtR can be used as an additional or alternative tool for the diagnosis of general obesity in this age group.

REFERENCES

1. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. Int J Pediatr Obes 2006;1(1):11-25. DOI: 10.1080/17477160600586747
2. Reilly JJ, Kelly L, Montgomery C, Williamson A, Fisher A, McColl JH, Grant S. Physical activity to prevent obesity in young children: cluster randomised controlled trial. BMJ 2006;333(7577):1041.
3. Gontarev S, Kalac R. Association between obesity and socioeconomic factors in Macedonian children and adolescents. Advanced in Life Sciences and Health 2014;1(1):55-63.
4. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, et al. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000;24(11):1453-8. DOI: 10.1038/sj.ijo.0801401
5. Despres JP, Lemieux I, Bergeron J, Pibarot P, Mathieu P, Larose E, et al. Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. Arterioscler Thromb Vasc Biol 2008;28(6):1039-49. DOI: 10.1161/ATVBAHA.107.159228
6. Koster A, Leitzmann MF, Schatzkin A, Mouw T, Adams KF, van Eijk JT, et al. Waist circumference and mortality. Am J Epidemiol 2008;167(12):1465-75. DOI: 10.1093/aje/kwn079
7. Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr 2004;79(3):379-84. DOI: 10.1093/ajcn/79.3.379
8. Taylor RW, Jones IE, Williams SM, Goulding A. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. Am J Clin Nutr 2000;72(2):490-5. DOI: 10.1093/ajcn/72.2.490
9. Brambilla P, Bedogni G, Moreno LA, Goran MI, Gutin B, Fox KR, et al. Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcuta- neous adipose tissue in children. Int J Obes 2006; 30(1):23-30. DOI: 10.1038/sj.ijo.0803163
10. Rankinen T, Kim SY, Perusse L, Despres JP, Bouchard C. The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. Int J Obes Relat Metab Disord 1999;23(8):801-9. DOI: 10.1038/sj.ijo.0800929
11. Fredriks AM, van Buuren S, Fekkes M, Verloove-Vanhorick SP, Wit JM. Are age references for waist circumference, hip circumference and waist-hip ratio in Dutch children useful in clinical practice? Eur J Pediatr 2005;164(4):216-22. DOI: 10.1007/s00431-004-1586-7
12. Virani N. Reference curves and cut-off values for anthropometric indices of adiposity of affluent Asian Indian children aged 3-18 years. Ann Hum Biol 2011;38(2):165-74. DOI: 10.3109/03014460.2010.504194
13. Maffeis C, Pietrobelli A, Grezzani A, Provera S, Tato L. Waist circumference and cardiovascular risk factors in pre-pubertal children. Obes Res 2001;9(3):179-87. DOI: 10.1038/oby.2001.19
14. Maffeis C, Banzato C, Talamini G. Waist-to-height ratio, a useful index to identify high metabolic risk in overweight children. J Pediatr 2008;152(2):207-13. DOI: 10.1016/j.jpeds.2007.09.021
15. McCarthy HD, Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message-keep your waist circumference to less than half your height. Int J Obes 2006;30(6):988-92. DOI: 10.1038/sj.ijo.0803226
16. Campagnolo PD, Hoffman DJ, Vitolo MR. Waist-to-height ratio as a screening tool for children with risk factors for cardiovascular disease. Ann Hum Biol 2011;38(3):265-70. DOI: 10.3109/03014460.2010.526147
17. Roswall J, Bergman S, Almqvist-Tangen G, Alm B, Niklasson A, Nierop AF, et al. Population-based waist circumference and waist-to-height ratio reference values in preschool children. Acta Paediatr 2009; 98(10):1632-6. DOI: 10.1111/j.1651-2227.2009.01430.x
18. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. WHO Technical Report Series 854. Geneva: World Health Organization; 1995.
19. Nawarycz LO, Krzyzaniak A, Stawinska-Witoszynska B, Krzywinska-Wiewiorowska M, Szilagyi-Pagowska I, Kowalska M, et al. Percentile distributions of waist circumference for 7–19-year-old polish children and adolescents. Obes Rev 2010;11(4):281-8. DOI: 10.1111/j.1467-789X.2009.00694.x
20. Chiotis D, Krikos X, Tsiftis G, Hatzisymeon M, Maniati-Christidi M, Dacou-Voutetaki A. Body mass index and prevalence of obesity in subjects of Hellenic origin aged 0–18 years, living in the Athens area. Ann Clin Pediatr Univ Atheniensis 2000;51:139-54.
21. Kuriyan R, Tinku T, Lokesh DP, Sheth NR, Mahendra A, Joy R, et al. Waist circumference and waist for height percentiles in urban South Indian children aged 3–16 years. Indian Pediatr 2011;48(10):765-71. DOI: 10.1007/s13312-011-0126-6
22. Brannsether B, Roelants M, Bjerknes R, Júlíusson P. Waist circumference and waist-to-height ratio in Norwegian children 4-18 years of age: reference values and cut-off levels. Acta Paediatr 2011;100(12):1576-82. DOI:10.1111/j.1651-2227.2011.02370.x
23. Hatipoglu N, Ozturk A, Mazicioglu MM, Kurtoglu S, Seyhan S, Lokoglu F. Waist circumference percentiles for 7- to 17-year-old Turkish children and adolescents. Eur J Pediatr 2008;167(4):383-9. DOI: 10.1007/s00431-007-0502-3
24. Jackson RT, Al Hamad N, Prakash P, Al SM. Waist circumference percentiles for Kuwaiti children and adolescents. Public Health Nutr 2011;14(1):70-6. DOI: 10.1017/S1368980010002600
25. Haas GM, Liepold E, Schwandt P. Percentile curves for fat patterning in German adolescents. World J Pediatr 2011;7:16-23.
26. McCarthy HD, Jarrett KV, Crawley HF. The development of waist circumference percentiles in British children aged 5.0-16.9 y. Eur J Clin Nutr 2001;55(10):902-7. DOI: 10.1038/sj.ejcn.1601240
27. Fernandez JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. J Pediatr 2004;145(4):439-44. DOI: 10.1016/j.jpeds.2004.06.044
28. Eisenmann JC. Waist circumference percentiles for 7- to 15-year-old Australian children. Acta Paediatr 2005;94(9):1182-5. DOI: 10.1080/08035250510029352
29. Moreno LA, Fleta J, Mur L, Rodriquez G, Sarria A, Bueno M. Waist circumference values in Spanish children-gender related differences. Eur J Clin Nutr 1999;53:429-33.
30. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW, et al. Obesity and the metabolic syndrome in children and adolescents. N Engl J Med 2004;350(23):2362-74. DOI: 10.1097/01.ogx.0000140472.10719.95
31. Zimmet P, Alberti KG, Kaufman F, Tajima N, Silink M, Arslanian S, et al. The metabolic syndrome in children and adolescents - an IDF consensus report. Pediatr Diabetes 2007;8(5):299-306. DOI: 10.1111/j.1399-5448.2007.00271.x
32. Lee JM, Davis MM, Woolford SJ, Gurney JG. Waist circumference percentile thresholds for identifying adolescents with insulin resistance in clinical practice. Pediatr Diabetes 2009;10(5):336-42. DOI: 10.1111/j.1399-5448.2008.00474.x
33. Sijtsma A, Bocca G, L'abée C, Liem ET, Sauer PJ, Corpeleijn E. Waist-to-height ratio, waist circumference and BMI as indicators of percentage fat mass and cardiometabolic risk factors in children aged 3-7 years. Clin Nutr 2014;33(2):311-5. DOI: 10.1016/j.clnu.2013.05.010
34. Kosti RI, Panagiotakos DB, Mihas CC, Alevizos A, Zampelas A, Mariolis A, et al. Dietary habits, physical activity and prevalence of overweight/obesity among adolescents in Greece: the vyronas study. Med Sci Monit 2007;13(10):437-44.
35. Kapantais E, Chala E, Kaklamanou D, Lanaras L, Kaklamanou M, Tzotzas T. Breakfast skipping and its relation to BMI and health-compromising behaviours among Greek adolescents. Public Health Nutr 2011;14(1):101-8. DOI: 10.1017/S1368980010000765
36. Mäkinen M, Puukko-Viertomies LR, Lindberg N, Siimes MA, Aalberg V. Body dissatisfaction and body mass in girls and boys transitioning from early to mid-adolescence: additional role of self-esteem and eating habits. BMC Psychiatry 2012;12(1):35. DOI: 10.1186/1471-244X-12-35