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Predictive ability of waist-to-hip-ratio and waist-to-height-ratio in relation to overweight/obesity in adolescents from Vojvodina (the Republic of Serbia) predictive ability of waist-to-hip-ratio and waist-to-height-ratio

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Summary. *Introduction/Aim* Overweight in childhood is a risk factor for later diseases in adulthood. It is necessary to identify thresholds for anthropometric indexes for assessing obesity. The aim of our study was to explore the accuracy of waist-to-height ratio (WHtR) and waist-to-hip ratio (WHR) and for the first time proposes the optimal thresholds of these indices for identifying overweight/obesity in Serbian adolescents aged 11-15 years. *Methods* The cross-sectional study was conducted with 2391 adolescents. Anthropometric measurements included body height, weight, waist circumference and hip circumferences. The relation between WHR and WHtR and general obesity as defined by the International Obesity Task Force IOTF was investigated with nonparametric receiver operating characteristic (ROC) analysis. *Results* Both of the indicators of central adiposity showed a higher mean in the group of children with exceeded weight. The correlation of WHtR and body mass index (BMI) was considerably greater than the correlation between WHR and BMI in both sexes. The WHtR was a better predictor of general obesity than the WHR in both boys and girls. The WHtR cut-offs of 0.464 for boys and 0.465 for girls, and 0.510 for boys and 0.504 for girls have been proposed to identify overweight and obesity, respectively, in Serbian adolescents. *Conclusion* WHtR is an accurate index with high applicability to screening adolescents with excess weight.

Key words: waist-to-height ratio, waist-to-hip ratio, body mass index, adolescents, Serbia

Introduction

In the period of adolescence excess body fat, especially in abdominal region, can be related to a number of metabolic disorders, such as dyslipidemia, hypertension and hyperinsulinemia, all of them reflecting metabolic syndrome (MetS) (1). Considering this, efficient diagnostic tools to identify children and adolescents with excess fatness are becoming very important. Waist-to-height ratio is receiving increasing attention as a measure of children and adolescents' abdominal obesity (2). It has been suggested that the same cut-off value of 0.5 could be used across all age groups in children and adolescents (3), although some studies indicate that the cut-point of WHtR of 0.5 is not ideal for all ages (4), suggesting the need for age-related references. Also, small variance may be present according to ethnic backgrounds (5). Beside WHtR, the WHR has been suggested for use instead of the BMI in predicting the health risk in adults and adolescents (6). The WHR is also one of the indicators of central obesity in adolescents (7,8).

Since abdominal obesity tends to increase more intensively than overall obesity in adolescents (9), it is important to determine specific values of indicators of abdominal obesity in various populations of children and adolescents. In Serbia, to the best of our knowledge, no population-based studies have evaluated the validity of WHtR and WHR as indicators of overweight/obesity in schoolchildren. The present study aimed to explore, for the first time, the feasibility and accuracy of WHtR and WHR and propose the optimal thresholds of these indices for identifying overweight and obesity in Serbian children aged 11-15 years.

Methods

The target population were schoolchildren attending primary schools in some regions of North and West Serbia. The cross-sectional study was performed in the period between 2012 and 2016 and included 2391 adolescents (1112 boys and 1279 girls) aged 11-15 years. The age was calculated as the difference between the date of birth and the date of data collection. The subjects were grouped into five age categories (10.50-15.49). Informed consent was obtained from participants and their parents before data collection and the inclusion of subjects was on voluntary basis. The research protocol was approved by the Scientific Committee of the Department for Biology and Ecology, University of Novi Sad and primary school principles. Anthropometric measurements were taken on standing participants wearing light clothing and without shoes using standard techniques. The same measurement protocol, as described by Weiner and Lourie (10) and Lohman et al. (11) was used in all measurements. Anthropometric measurements included body height, weight, waist circumference and hip circumferences. Height was measured with anthropometer (±1mm; SieberHegnerMaschinen AG Zürich Switzerland) with the head positioned in the Frankfurt plane, and portable electronic digital scale was used to measure weight with accuracy ± 0.1kg. Waist circumference (WC) was measured above the iliac crest and below the lowest rib margin at minimum respiration with an inelastic flexible tape in a standing position. Hip circumference (HC) was measured at the maximum protuberance of the buttocks. Body mass index was calculated from the ratio of weight/height^2 (kg/m^2). The subjects were classified into underweight, normal weight, overweight (OW) and obese (OB) categories according to age- and sex specific cut-off points proposed by the International Obesity Task Force (IOTF) (12). WHR was calculated as waist circumference (cm) divided by hip circumference (cm), and WHtR as waist circumference (cm) divided by height (cm). Abdominal obesity (AO) was defined according to WHR ≥ 0.9 (13) and WHtR ≥ 0.5 (3).

Statistical Analysis

Data were analyzed with SPSS software for Windows version 21 (SPSS Incorporation, Chicago, USA). Abdominal indices WHR and WHtR were expressed as mean ± standard deviation (SD). The correlation between the indicators of general (BMI) and abdominal obesity (WHtR and WHR) was determined by Spearman correlation coefficient. The overall significance level was set at $P < 0.05$. The relation between WHR and WHtR and general obesity as defined by the IOTF was investigated with nonparametric receiver operating characteristic (ROC) analysis. The discriminating power of the WHR and the WHtR was expressed as area under the curve (AUC) and 95% confidence intervals (CI). An AUC value of ≥ 0.90 was considered an excellent accuracy; 0.80-0.89 good; 0.70-0.79 satisfactory and <0,70 bad accuracy. The sensitivity and specificity of WHtR and WHR as indicators of overweight/obesity were determined with cut-off values. The Youden index was used to determine optimal cut-off values WHtR and WHR for identification of overweight/obesity (maximum value of (sensitivity + specificity -1)) (14).

Results

Overweight (OW) and obesity (OB) prevalence is nearly identical in boys (10.3% and 4.6%) and girls (10.1% and 4.7%, respectively). Higher percentages of abdominal obesity based on WHtR (14.9%) and WHR (13.5%) are also observed in boys than it is the case with girls (10.2%; 5.7%) (Table 1).

Means of WHR and WHtR in relation to nutritional status based on BMI, as well as the correlation of WHR and WHtR with BMI in both boys and girls are shown in Table 2. The means of WHR and WHtR in the nutritional status groups show a linear increase

Table 1. Prevalence of general and abdominal obesity (in boys and girls and total) [%(n)]

	BMI (kg/m2)			
	Overweight	Obesity	WHR≥0.90	WHtR≥0.50
Boys (N=1112)	10.3 (114)	4.6 (51)	13.5 (150)	14.9 (166)
Girls (N=1279)	10.1 (129)	4.7 (60)	5.7 (73)	10.2 (131)
Total (N=2391)	10.2 (243)	4.6 (111)	9.3 (223)	12.4 (297)

WHR: waist-to-hip ratio, WHtR: waist-to-height ratio, BMI: Body mass index

Table 2. Means of waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) in relation to nutritional status (BMI) and correlation of WHR and WHtR with BMI in boys and girls

		Boys		Girls		Total	
		WHR	WHtR	WHR	WHtR	WHR	WHtR
Underweight	n	128	128	181	181	309	309
	Mean	0.80	0.39	0.79	0.39	0.80	0.39
	SD	0.04	0.02	0.05	0.02	0.05	0.02
Normal weight	n	819	819	909	909	1728	1728
	Mean	0.83	0.44	0.80	0.43	0.81	0.43
	SD	0.07	0.04	0.07	0.03	0.07	0.04
Overweight	n	114	114	129	129	243	243
	Mean	0.86	0.52	0.83	0.50	0.84	0.51
	SD	0.06	0.04	0.07	0.04	0.07	0.04
Obesity	n	51	51	60	60	111	111
	Mean	0.88	0.58	0.84	0.56	0.85	0.57
	SD	0.05	0.05	0.09	0.06	0.08	0.06
BMI#	Rho	0.267	0.758	0.108	0.737	0.195	0.798
	P	0.000	0.000	0.000	0.000	0.000	0.000

Spearman correlation, Rho: Correlation Coefficient, P: Significance, BMI: Body mass index;

in both sexes. The WHR and WHtR are in significant positive correlation with BMI in both boys and girls. The correlation between WHtR and BMI is significantly greater than the correlation between WHR and BMI in all subjects.

Figures 1 and 2 show the ROC curves of WHR and WHtR for predicting OW and OB in both boys and girls. WHtR index shows greater predictability of exceeded weight overweight/obesity than WHR.

Table 3 presents the area under the ROC curve

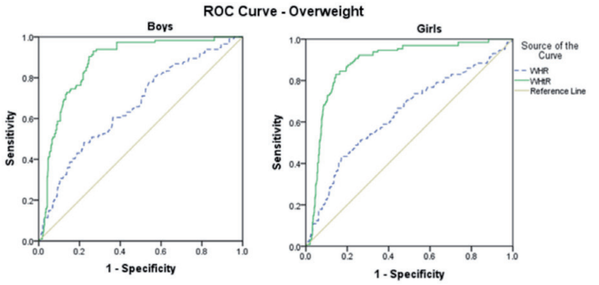

Figure 1. Receiver operating characteristic (ROC) curve for prediction of overweight from waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) in both sexes.

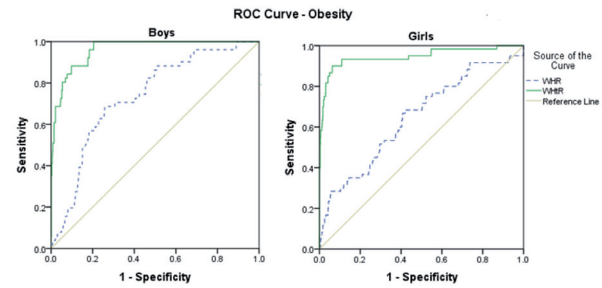

Figure 2. Receiver operating characteristic (ROC) curve for prediction of obesity from waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) in both sexes.

(AUC) of WHR and WHtR. The two indices show a satisfactory prediction capacity for identifying OW and OB in children of both sexes (95% CI > 0.5) in all ages referring to WHtR, and in most ages when it comes to WHR. ROC analysis shows that WHtR has higher discriminating power to detect IOTF obesity than WHR. In both boys and girls, WHtR proves to be a better predictor of general obesity than the WHR.

Optimal cut-off values of WHR and WHtR as indicators of overweight and obesity in boys and girls are shown in Table 4. Cut-off values of WHR for detecting OW equal 0.846 in case of boys and 0.803 in girls. Sensitivity is 60.5% and 66.7% and specificity 63.6% and 55.9% in boys and girls, respectively. In boys, WHR shows higher cut-off values for detecting obesity (0.866) than in girls (0.808). Sensitivity values are approximately identical in both sexes, while those referring to specificity are greater in boys. As for overweight, the obtained WHtR cut-off values of 0.464 in boys and 0.465 in girls give sensitivity of 90.4% and specificity of 75.6% in case of boys, and 82.9% and 85.5% in case of girls. For assessing overweight, highest cut-off values of WHR and WHtR are detected in boys aged 12 and girls aged 11. For assessing obesity in boys, the highest WHR and WHtR cut-off values are observed at the age of 12 and 13, respectively. In girls, the highest cut-offs of both indices are observed at the age of 11.

Discussion

This study presents the first gender specific optimal thresholds for WHR and WHtR for Serbian adolescents aged 11 to 15 years. The relationship between BMI and abdominal adiposity observed in the present study is consistent with previous study reports. Body mass index correlates with total and visceral body fat, which is considered an important risk factor for chronic-degenerative diseases (15). In our study, the correlation between WHtR and BMI is significantly higher than the correlation between WHR and BMI. This might seem as an expected result because both parameters take into account the body height. In the Tuscany (Italy) study (16) the correlation between WHtR and BMI was also high for the overall sample. Both indicators of central adiposity show a higher mean in the group of subjects with exceeded weight, and this re-

Table 3. Area under the ROC curve (AUC) for identification of optimal waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) for predicting overweight and obesity defined by BMI in relation to age and sex

Age (years)	Boys		Girls	
	WHR AUC (95% CI)	WHtR AUC (95% CI)	WHR AUC (95% CI)	WHtR AUC (95% CI)
Owerveight				
11	0.520 (0.401-0.671)	0.843 (0.738-0.908)	0.610 (0.506-0.790)	0.917 (0.856-0.979)
12	0.766 (0.689-0.843)	0.913 (0.880-0.947)	0.629 (0.484-0.717)	0.840 (0.774-0.906)
13	0.663 (0.566-0.761)	0.835 (0.747-0.918)	0.615 (0.517-0.733)	0.912 (0.878-0.946)
14	0.578 (0.409-0.682)	0.893 (0.848-0.938)	0.673 (0.559-0.787)	0.862 (0.787-0.941)
15	0.781 (0.617-0.846)	0.891 (0.832-0.950)	0.666 (0.538-0.795)	0.881 (0.846-0.953)
Total	0.662 (0.609-0.715)	0.875 (0.846-0.904)	0.639 (0.585-0.693)	0.882 (0.853-0.911)
Obesity				
11	0.821 (0.781-0.941)	0.955 (0.910-1.000)	0.594 (0.491-0.798)	0.988 (0.963-1.000)
12	0.775 (0.723-0.892)	0.996 (0.990-1.000)	0.603 (0.507-0.834)	0.892 (0.803-0.986)
13	0.776 (0.679-0.873)	0.983 (0.969-0.998)	0.651 (0.505-0.768)	0.909 (0.782-0.935)
14	0.698 (0.609-0.837)	0.929 (0.918-0.989)	0.648 (0.543-0.812)	0.981 (0.977-1.000)
15	0.607 (0.504-0.770)	0.941 (0.819-0.997)	0.739 (0.612-0.866)	0.961 (0.921-1.000)
Total	0.735 (0.672-0.799)	0.961 (0.943-0.979)	0.647 (0.571-0.723)	0.946 (0.907-0.985)

AUC: area under the curve, ROC: receiver operating characteristics, CI: confidence interval,

Table 4. Optimal cut-off values of waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) as indicators of overweight and obesity in boys and girls

		WHR				WHtR			
		Cut-off Value	**Se (%)**	**Sp (%)**	**Jouden Index**	**Cut-off Value**	**Se (%)**	**Sp (%)**	**Jouden Index**
Boys									
OW	11	0.809	59.8	75.3	0.35	0.461	95.4	71.9	0.67
	12	0.888	61.4	62.9	0.24	0.469	95.3	81.3	0.77
	13	0.847	60.2	65.5	0.26	0.464	89.4	72.8	0.62
	14	0.821	60.1	50.5	0.11	0.460	79.3	76.4	0.56
	15	0.865	61.2	63.8	0.25	0.466	92.5	75.5	0.68
	Total	0.846	60.5	63.6	0.24	0.464	90.4	75.6	0.66
OB	11	0.894	71.0	80.0	0.51	0.513	91.0	92.5	0.83
	12	0.898	69.3	79.3	0.49	0.519	96.6	94.1	0.91
	13	0.858	74.6	73.3	0.48	0.521	90.0	93.1	0.83
	14	0.849	64.9	69.9	0.35	0.486	81.3	88.8	0.70
	15	0.829	63.0	68.7	0.32	0.489	82.0	82.8	0.65
	Total	0.866	68.6	74.2	0.43	0.510	88.2	90.2	0.78
Girls									
OW	11	0.810	67.4	56.3	0.24	0.484	91.4	81.6	0.73
	12	0.805	70.4	53.9	0.24	0.457	78.6	77.8	0.56
	13	0.801	68.4	47.9	0.16	0.467	84.5	90.4	0.75
	14	0.800	64.9	60.0	0.25	0.449	77.5	86.7	0.64
	15	0.801	62.6	61.3	0.24	0.466	82.6	90.9	0.74
	Total	0.803	66.7	55.9	0.23	0.465	82.9	85.5	0.68
OB	11	0.821	62.1	59.1	0.21	0.520	100	94.0	0.94
	12	0.812	65.7	57.9	0.24	0.480	79.0	82.3	0.61
	13	0.803	71.9	53.1	0.25	0.504	91.3	86.6	0.78
	14	0.804	60.1	65.2	0.25	0.510	100	96.1	0.96
	15	0.801	81.8	55.0	0.37	0.506	98.0	91.1	0.89
	Total	0.808	68.3	58.0	0.26	0.504	93.7	90.0	0.84

Se: Sensitivity, Sp: Specificity; OW: Overweight; OB: Obesity

sult is in agreement with other studies on children and adolescents (17-19).

The results of the study point out that WHtR is a better predictor of general obesity than WHR in both boys and girls. According to AUC values WHtR appears to be good in predicting overweight and excellent for obesity prediction. In both sexes, the accuracy of WHtR ranged from 0.875 to 0.961 in identifying overweight and obese children. The accuracy of WHR, however, is lower (overweight: 0.875 vs. 0.662 in boys, 0.882 vs. 0.639 in girls; obesity: 0.961 vs. 0.735 in boys, 0.946 vs. 0.647 in girls). The results of research in other countries (20,21), also show that WHtR appeared as the best predictor to classify the nutritional status of children. In our investigation, the area under the curve for WHtR was greater in boys than in girls in defining obesity, the result being in line with other reported findings (20,22-25).

In case of WHR, the cut-offs to identify overweight were higher in boys than in girls, 0.846 vs 0.803. The same holds true for identification of obesity: WHR of 0.866 vs 0.808, and WHtR of 0.510 vs 0.504, respectively. The only exception refers to the cut-off values of WHtR for overweight, where the values were almost the same (0.464 and 0.465 for boys and girls, respectively). The present study shows that the optimal WHtR cut-off value of 0.46 for identifying overweight in adolescents aged 11-15 gives the sensitivity of 90.4% and specificity of 75.6% in case of boys, while in girls the values equal 82.9% and 85.5%, respectively.

In case of obesity, the best combination of sensitivity and specificity is detected in the optimal cut-off value of 0.510 in boys (88.2% and 90.2%, respectively) and 0.504 in girls (93.7 % and 90.0%, respectively). Similar values were obtained in children aged 6 to 14 in Spain (26) for overweight (0.47 and 0.48 both males and females) and obesity (0.51 males; 0.50 females). Slightly higher values have been observed in Korean children aged 6-18 years, where the WHtR cut-off value for discriminating OW has been reported to be 0.49 in case of boys and 0.48 in girls. As for obesity, similar values to ours are reported by Gil et al. (22), 0.51 in boys and 0.49 in girls. Hovewer in recent investigations in Korea (21) the cut-offs for obesity are lower than ours (boys 0.50; girls 0.47). Lower values were observed in Chinese (20), Brazil (27) and South India population (28).

Differences detected between age groups suggest age-specific WHR and WHtR values, i.e. WHR ranging from 0.809 to 0.888 among boys and 0.800 to 0.810 among girls for overweight and from 0.829 to 0.898 among boys and 0.801 to 0.821 among girls for obesity. As for WHtR, the values range from 0.460 to 0.469 among boys and 0.449 to 0.484 among girls for overweight and from 0.486 to 0.521 among boys and 0.480 to 0.520 among girls in case of obesity. The different cut-offs are maybe due to physical changes during adolescence. The same trend was noticed in the investigation of adolescents aged 10 to 15 years in Brazil (27) where differences in WHtR were observed in different age groups. However, among Spanish children and adolescents aged 6-16 years, no differences in WHtR cut-offs by pubertal stage were found (29).

The limitation of the present study lies in the fact that it was a cross-sectional and not a population-based survey with a representative sample. Therefore, the obtained results should be extrapolated with caution.

Conclusion

These data refer to one part of the adolescent population, however, the present results can be used as a starting point for future research in this field. The WHtR cut-off points of 0.464 in boys and 0.465 in girls, as well as those of 0.510 in boys and 0.504 in girls can be suggested to identify overweight and obesity, respectively, in Serbian adolescents.

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