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Body Adiposity is Associated With a Risk of High Blood Pressure in Macedonian Children

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Abstract: *The goal of this study was to determine the relationship between waist circumference (WC), body mass index (BMI), body fat percentage (BFP), waist-to-height ratio (WHtR), adiposity index (API) and high blood pressure (HBP) and to determine which anthropometric parameters can best predict HBP in Macedonian children from 6 to 10 years of age. The research was conducted on a sample of 1228 boys and girls from 6 to 10 years of age. Blood pressure was measured three times in an interval of 60 seconds, and the mean value of the three measurements was used as a result for processing. Logistic regression analysis was used to assess the associations and to calculate odds ratios. Adjusted odds ratios in the highest quartiles of WC, BMI, BFP and WHtR were statistically significant in boys (girls): hypertension – 5.19 (6.38), 3.16 (3.76), 4.39 (4.48), and 3.95 (4.84). In Macedonian children from 6 to 10 years of age, the anthropometric indices - WC and API (particularly WC) - showed stronger associations with HBP and were better at predicting HBP, compared to the other applied anthropometric indices.*

Keywords: *Blood pressure, Schoolchildren, Adiposity, Weight status.*

Introduction

Hypertension (known as high or elevated blood pressure) is one of the most common and most important problems in public health globally (WHO, 2013). High blood pressure is associated with adverse cardiovascular outcomes (Lim et al., 2012). It is considered the leading risk factor for mortality in the world, causing 7.5 million deaths annually, which is 12.8% of all deaths (WHO, 2009). The prevalence of elevated BP increased from 594 million to 1.13 billion in the period from 1975 to 2015 in people older than 18 years (Maldonado et al., 2011). The epidemiological studies have reported a high prevalence of elevated blood pressure in different age groups from childhood to adolescence in different countries (Rosner et al., 2013; 10. De Moraes et al., 2015; Maldonado et al., 2017).

The general medical examinations and meta-analyses show that the condition of BP persists from childhood to adulthood (Toschke et al., 2010). Hypertension during childhood and puberty is a powerful predictor of hypertension in adults (Liang et al., 2011). Many different, interrelated: genetic, metabolic, environmental, behavioral, psychosocial, and socioeconomic risk factors, as well as family and personal medical history, may affect hypertension in children (1Ewald & Haldeman, 2016). Early atherosclerotic lesions, left ventricular hypertrophy, increased intima-media thickness of the carotid artery, vascular changes in the retina, and cognitive impairments have been found in children with HBP (Falkner, 2010). Early identification of HBP in children can prevent the development and progression of cardiovascular diseases and their accompanying complications (Litwin, 2018).

Childhood and adolescence obesity is associated with a higher risk of cardiovascular, metabolic, and endocrine disorders (hypertension, dyslipidemia, endothelial dysfunction, chronic inflammation, metabolic syndrome, type 2 diabetes mellitus and puberty disorders) (Ebbeling,2002) renal, gastrointestinal, pulmonary, musculoskeletal, dermatological, neurological and psychosocial disorders (Güngör, 2014). Abdominal obesity in children is also related to several adverse cardiometabolic risk factors such as: hypertension metabolic syndrome, lipid abnormalities, glucose intolerance, and insulin resistance, which contribute to an increased risk for atherosclerosis development (Forkert et al., 2016). Childhood and adolescence obesity continues into adulthood (Simmonds, et al., 2016) and is associated with cardiovascular morbidity and mortality in adults (Sommer & Twig 2018).

The goal of this study was to determine the relationship between waist circumference (WC), body mass index (BMI), body fat percentage (BFP), waist-to-height ratio (WHtR), adiposity index (API) and high blood pressure (HBP) and to determine which anthropometric parameters can best predict HBP in Macedonian children from 6 to 10 years of age.

Materials and Methods

Sample of respondents

The research was conducted on a sample of 1228 children of Macedonian nationality, from 19 primary schools in the central and eastern part of the Republic of North Macedonia, 8 of which are in rural areas, and 11 in urban areas. The sample is divided into two subsamples according to gender, whereby 679 respondents are boys and 549 respondents are girls. The average age of the respondents of both genders was 8.03 ± 1.24 years.

The study included all students whose parents consented to their children's participation in the research, who were psychophysically healthy, and who regularly attended Physical and Health Education classes. The respondents were treated in accordance with the Helsinki Declaration.

The measurements were performed in the months: March, April and May 2019, in standard school conditions during the regular classes in Physical and Health Education. The measurement was performed by experts in the field of kinesiology and medicine, previously trained to perform functional tests and to take anthropometric measures.

Anthropometric measures and body composition

The measurement of anthropometric measures was carried out according to the recommendations of the IBP-International Biological Program. The height of the subjects (without shoes) was measured to the nearest 0.1 cm with a portable stadiometer. BMI was calculated as weight divided by height squared. WC was measured with a inflexible measuring tape at a level midway between the lower rib margin and the iliac crest to the nearest 0.5 cm. WHtR was calculated as the WC divided by body height

The components of the body composition are determined by bioelectrical impedance method (measuring the electrical conductivity - Bioelectrical Impedance Analysis - BIA). The measurement is realized by Body Composition Monitor, model "OMRON - BF511", and with whose help the body weight, body fat percentage, and muscle mass percentage is measured. Before starting the measurement in Body Composition Monitor were entered the parameters of gender, age and body height of the respondent. In order to ensure better accuracy of the results obtained from the assessment of body composition, before each measurement were fulfilled prerequisites recommended by ACSM.

Although the three different adiposity indicators (BMI, WC, and BFP) are all associated with some degree of measurement error, each measure provides specific information regarding body fat mass (Ledoux et al., 2011). Thus, in this study, a principal component analysis was performed with exploratory factor analysis (EFA) to obtain a construct (i.e., a factor or a latent variable) for overall adiposity based on these three anthropometric indicators, similarly to the analysis proposed by Ledoux et al. (2011). Principal component analysis using the three anthropometric indicators revealed a construct representing 87% of the shared variance, with a Cronbach's alpha of 0.91 and factor loadings of 0.94 for BMI, 0.91 for WC, and 0.95 for BFP; additionally, high communalities were observed (0.89, 0.83, and 0.90, respectively). This construct was termed the adiposity index and represents overall adiposity.

Blood pressure

The blood pressure measurement (systolic and diastolic) is realized by experts from the medicine, doctor-specialists pediatrician fields. Blood pressure measurements were performed using the oscillometric method through a calibrated Omron (Kyoto, Japan) electronic and digital device model HEM 742, with cuffs of appropriate size to fit the arms of adolescents. This device has been validated for use with adolescents (Christofaro et al. 2009). Participants were informed about the procedures and were instructed to remain at quiet rest for at least five minutes in a quiet environment and without noise, with emptied bladder, not having performed exercise 90 min before the tests or smoked or ingested food, coffee, alcoholic drinks or mate at least 30 min before data collection. The atmosphere was quiet and with no noise. Blood pressure was measured three times at intervals of 60 seconds, and the result was the median value of the three measurements. NBP was defined as BP < 90^{th} percentile; prehypertension was defined as

BP between the ≥90th percentile and the <95th percentile; and hypertension was defined as BP ≥ 95th percentile. The mean arterial pressure (MAP) was calculated using the traditional formula. The pulse pressure (PP) was calculated as SBP minus DBP. We adopted the methodological recommendations of the Update on the Task Force Report on High Blood Pressure in Children and Adolescent.

Statistical analysis

Categorical variables were tested by the chi-squared (χ^2) test, and were expressed as numbers and percentages. The Kolmogorov-Smirnov test was used to test the normality of the distribution of the continuous variables. Non-normally distributed continuous variables were compared using nonparametric tests (the Mann-Whitney U test, and the Kruskal-Wallis test). WC, BMI, BFP and WHtR values were converted to age and gender-specific z-scores. Pearson's correlation coefficients were calculated between anthropometric indices z-score and SBP, DBP, MAP, and PP. Quartiles of anthropometric indices were calculated according to the study subjects' age and gender. Logistic regression analyses were conducted separately for boys and girls to evaluate the associations between the quartiles of anthropometric parameters (WC, BMI, BFP and WHtR) and HBP. Crude and adjusted odds ratios with 95% confidence intervals (CI) were calculated.All the analyses were performed using the Statistical Package for Social Sciences software (SPSS, v. 22.0 for WINDOWS; SPSS Inc., Chicago, IL, USA), and values of $p < 0.05$ were considered statistically significant.

Results

The research was conducted on a sample of 1228 respondents, of which 679 (55.3%) were boys and 549 (44.7%) were girls from 6 to 10 years of age. The mean age of the respondents was 8.03 ± 1.24 years (Table 1).

Table 1. *Characteristics of the study participants by gender*

Variables	Boys		Girls		P*
	Mean	SD	Mean	SD	
Age (years)	8.58	1.17	8.53	1.34	0.492
Weight (kg)	132.87	9.23	132.18	10.08	0.211
Height (cm)	32.98	10.82	32.87	9.82	0.845
BMI (kg/m2)	18.00	5.84	17.51	5.77	0.145
BFP	24.39	7.78	23.68	8.08	0.136
WC (cm)	62.17	9.68	60.26	8.65	0.000
WHtR	0.47	0.06	0.46	0.05	0.000
API	-0.01	1.00	0.02	1.00	0.595
SBP (mm Hg)	104.77	18.81	101.87	19.33	0.008
DBP (mm Hg)	66.68	16.46	66.75	18.16	0.946
MAP (mm Hg)	79.38	15.52	78.46	17.35	0.325
PP (mm Hg)	38.09	16.11	35.12	14.01	0.001

**Boys versus girls. BP – blood pressure. BMI – body mass index. BFP – body fat percentage. WC – waist circumference. WHtR – waist-to-height ratio. API – adiposity index. SBP – systolic blood pressure. DBP – diastolic blood pressure. MAP – mean arterial pressure. PP – pulse pressure.*

Table 1 shows the characteristics of the sample. From the overview of the table that shows the values of: the arithmetic means, the standard deviations and the level of statistical significance, it is observable that no statistically significant differences were found between the male and female respondents in the variables: age, weight, height, BMI, BFP, API (adiposity index), DBP (diastolic blood pressure) and MAP (mean arterial pressure). The mean values of WC and WHtR are higher in boys than in girls. Boys also have higher mean values of SBP (systolic blood pressure) and PP (pulse pressure) than girls. The prevalence of prehypertension was 9.7% in boys and 6.7% in girls, while the prevalence of hypertension was 21.9% in boys and 20.6% in girls.

The comparison of the respondents with HBP (hypertension) showed statistically significant differences in the anthropometric indices in both genders separately (Table 2). The number of cases and the frequency of HBP increased with the increase of the quartiles in most anthropometric parameters in both genders (first quartile, compared to fourth quartile).

Table 2. *Characteristics of the study participants according to BP level*

Variables	Normotensive		Hypertensive		p
Boys					
Quartiles of WC:					
1st	138	30.0%	35	13.5%	0.000
2nd	122	26.5%	57	21.9%	
3rd	112	24.3%	53	20.4%	
4th	88	19.1%	115	44.2%	
Quartiles of BMI:					
1st	131	28.4%	47	18.1%	0.000
2nd	128	27.8%	38	14.7%	
3rd	111	24.1%	71	27.4%	
4th	91	19.7%	103	39.8%	
Quartiles of BFP:					
1st	136	31.4%	38	15.8%	0.000
2nd	107	24.7%	41	17.0%	
3rd	106	24.5%	59	24.5%	
4th	84	19.4%	103	42.7%	
Quartiles of WHtR:					
1st	125	27.2%	38	14.6%	0.000
2nd	134	29.1%	34	13.1%	
3rd	107	23.3%	75	28.8%	
4th	94	20.4%	113	43.5%	
Weight (kg)	132.14	9.30	134.15	9.68	0.006
Height (cm)	31.59	10.60	36.81	10.81	0.000
WC (cm)	61.05	8.89	65.38	10.25	0.000
BMI (kg/m^2)	17.58	5.74	18.95	6.28	0.003
BFP	23.54	7.70	27.39	7.67	0.000
WHtR	0.46	0.05	0.49	0.06	0.000
API	-0.12	0.97	0.48	1.03	0.000
SBP (mm Hg)	96.07	11.29	128.36	19.48	0.000
DBP (mm Hg)	60.37	8.77	86.36	23.19	0.000
MAP (mm Hg)	72.27	8.28	100.36	18.71	0.000
PP (mm Hg)	35.70	10.67	42.01	24.63	0.000
Girls					
Quartiles of WC:					
1st	115	28.9%	35	13.5%	0.000
2nd	123	30.9%	57	21.9%	
3rd	100	25.1%	53	20.4%	
4th	60	15.1%	115	44.2%	
Quartiles of BMI:					
1st	111	28.0%	47	18.1%	0.000
2nd	117	29.5%	38	14.7%	

3rd	104	26.2%	71	27.4%	
4th	65	16.4%	103	39.8%	
Quartiles of BFP:					
1st	109	29.2%	38	15.8%	0.000
2nd	99	26.5%	41	17.0%	
3rd	99	26.5%	59	24.5%	
4th	66	17.7%	103	42.7%	
Quartiles of WHtR:					
1st	113	28.4%	38	14.6%	0.000
2nd	112	28.1%	34	13.1%	
3rd	103	25.9%	75	28.8%	
4th	70	17.6%	113	43.5%	
Weight (kg)	131.53	9.58	134.15	9.68	0.001
Height (cm)	31.56	8.96	36.81	10.81	0.000
WC (cm)	58.96	7.91	65.38	10.25	0.000
BMI (kg/m^2)	17.08	5.40	18.95	6.28	0.000
BFP	22.40	7.69	27.39	7.67	0.000
WHtR	0.45	0.05	0.49	0.06	0.000
API	-0.16	0.91	0.48	1.03	0.000
SBP (mm Hg)	94.07	11.83	128.36	19.48	0.000
DBP (mm Hg)	58.99	8.46	86.36	23.19	0.000
MAP (mm Hg)	70.68	8.33	100.36	18.71	0.000
PP (mm Hg)	35.08	10.62	42.01	24.63	0.000

The chi-square (χ2) test was used for categorical variables. BMI – body mass index. BFP – body fat percentage. WC – waist circumference. WHtR – waist-to-height ratio. API – adiposity index. SBP – systolic blood pressure. DBP – diastolic blood pressure. MAP – mean arterial pressure. PP – pulse pressure.

The respondents (boys and girls separately) with hypertension showed significantly higher mean values of all analyzed variables, compared to the normotensive participants (Table 2). The mean values of all variables (SBP, DBP, MAP, and PP) increased with the increase of the quartiles of BMI, BFP, WC, and WHtR. The highest mean values of SBP, DBP, MAP and PP were found in the respondents in the highest quartiles (fourth quartile) of anthropometric indices, especially WC (these data are not presented).

The Pearson correlation coefficients between the anthropometric indexes z-scores and BP are presented in Table 3. WC z-score, BMI z-score, BFP z-score, WHtR z-score and API z-score positively and significantly correlated with BP in boys and in girls, but the strongest correlations found for BP with WC z-score, WHtR z-score and API z-score. In particular, the highest correlations were found between WC z-score and SBP and between WC z-score and MAP in boys and girls. SBP correlated significantly with DBP (for boys: $r = 0.590$, $p < 0.001$; for girls: $r = 0.723$, $p < 0.001$). Strong correlations were found between MAP and SBP (for boys: $r = 0.821$, $p < 0.001$; for girls: $r = 0.870$, $p < 0.001$) and DBP (for boys: $r = 0.945$, $p < 0.001$; for girls: $r = 0.966$, $p < 0.001$).

Correlation coefficients between BMI z-score and WC z-score ($r = 0.597$ for boys and $r = 0.617$ for girls), between BMI z-score and BFP z-score ($r = 0.854$ for boys and $r = 0.992$ for girls), between WC z-score and BFP z-score ($r = 0.784$ for boys and $r = 0.783$ for girls), between WHtR z-score and BFP z-score ($r = 0.784$ for boys and $r = 0.850$ for girls),between BMI z-score and WHtR z-score ($r = 0.603$ for boys and $r = 0.579$ for girls), and between WC z-score and WHtR z-score ($r = 0.915$ for boys and $r = 0.922$ for girls) were positive and statistically significant (all $p < 0.001$).

Table 3. *Pearson's correlation coefficients between anthropometric parameters z-scores and blood pressure*

		WC z-score	BMI z-score	BFP z-score	WHtR z-score	API z-score
SBP (mm Hg)	Boys	.368**	.241**	.288**	.328**	.325**
	Girls	.333**	.218**	.280**	.291**	.301**
DBP (mm Hg)	Boys	.359**	.179**	.304**	.327**	.343**
	Girls	.331**	.175**	.310**	.283**	.336**
MAP (mm Hg)	Boys	.395**	.218**	.325**	.357**	.367**
	Girls	.360**	.206**	.325**	.310**	.351**
PP (mm Hg)	Boys	.041	.092	.009	.028	.011
	Girls	.036	.073	-.004	.040	.857

***Correlation is significant at the level of 0.01 (2-tailed).*

In both genders, aORs increases with the increase of the quartiles of WC and BFP, while for BMI and WHtR, aORs increases after the third quartile (Table 4). Adjusted odds ratios in the highest quartiles of WC, BMI, BFP and WHtR were statistically significant in boys (girls): hypertension – 5.19 (6.38), 3.16 (3.76), 4.39 (4.48), and 3.95 (4.84). The increase of aORs in the quartiles of WC was higher than the corresponding increase of the quartiles of BMI, BFP and WHtR (except in the third quartile for WHtR in boys and girls and BFP in boys). The odds ratios were the lowest in BMI quartiles. In boys, no significant associations were found for HBP in the second quartiles of BMI, BFP and WHtR. In girls, no significant associations were found for HBP in the second quartiles of WC, BMI, BFP and WHtR.

Table 4. *Crude and adjusted odds ratios and 95% confidence intervals for HBP in quartiles of anthropometric parameters (BMI, WC, BFP and WHtR) by gender (univariate and multivariate analyses)*

	Hypertension (Boys)		Hypertension (Girl)	
Variables	**OR (95% CI)**	**aOR (95% CI)**	**OR (95% CI)**	**aOR(95% CI)**
Quartiles of WC:				
1st	1.00	1.00	1.00	1.00
2nd	1.84 (1.13-2.10)	1.85 (1.14 -3.07)	1.52 (0.93 - 2.49)	1.52 (0.93 - 2.49)
3rd	1.87 (1.14-3.06)	1.87 (1.14 - 3.01)	1.74 (1.05 - 2.88)	1.76 (1.06 - 2.92)
4th	5.15 (3.24 -8.18)	5.19 (3.27 - 8.26)	6.30 (3.8 - 10.28)	6.38 (3.90 - 10.43)
Quartiles of BMI:				
1st	1.00	1.00	1.00	1.00
2nd	0.83 (0.51 - 1.35)	0.83 (0.51 - 1.36)	0.77 (0.47 - 1.26)	0.77 (0.47 - 1.27)
3rd	1.78 (1.14 - 2.79)	1.79 (1.14 - 2.79)	1.61 (1.02 - 2.54)	1.63 (1.03 - 2.57)
4th	3.15 (2.04 - 4.88)	3.16 (2.04 - 4.89)	3.74 (2.36 - 5.94)	3.76 (2.37 - 5.96)
Quartiles of BFP:				
1st	1.00	1.00	1.00	1.00
2nd	1.37 (2.77 - 6.96)	1.37 (0.82 - 2.28)	1.19 (0.71 - 2.00)	1.19 (0.71 - 2.00)
3rd	1.99 (1.23 - 3.22)	1.99 (1.23 - 3.22)	1.71 (1.05 - 2.79)	1.71 (1.05 - 2.80)
4th	4.39 (0.82 - 2.28)	4.39 (2.76 - 6.96)	4.48 (2.77 - 7.25)	4.48 (2.77 - 7.24)
Quartiles of WHtR:				
1st	1.00	1.00	1.00	1.00
2nd	0.83 (0.49 - 1.41)	.83 (.49 - 1.41)	0.90 (0.53 - 1.54)	0.90 (0.53 - 1.53)
3rd	2.31 (1.44 - 3.68)	2.32 (1.45 - 3.70)	2.17 (1.35 - 3.47)	2.19 (1.36 - 3.51)
4th	3.95 (2.51 - 6.23)	3.96 (2.51 - 6.24)	4.80 (2.99 - 7.71)	4.84 (3.02 - 7.78)

Crude and adjusted odds ratios and 95% confidence intervals for HBP in quartiles of anthropometric parameters (BMI. WC. BFP and WHtR) by gender (univariate and multivariate analyses). OR – crude odds ratio; aOR1 – adjusted odds ratios for age; CI – confidence interval. Bold typeface indicates significance.

Discussion

In our study we found a large prevalence of prehypertension (8.4%) and hypertension (21.3%) in Macedonian children from 6 to 10 years of age, which is partly in line with the findings of other studies conducted in different populations of children and adolescents in other countries, for example, in 9–13 year-old Greek schoolchildren (prehypertension – 14.2% and hypertension – 23%) (Karatzi et. al., 2017), in Chinese schoolchildren aged 5 to 18 years (prehypertension – 15.2% and hypertension – 20.5%) (Guo et al., 2012), in Portuguese children and adolescents aged 4 to 18 years (prehypertension – 21.6% and hypertension – 12.8%) (Maldonado et al., 2011), in Spanish children aged 4 to 6 years (prehypertension – 12.3% and hypertension – 18.2%) (8), in 11–14 year-old Italian schoolchildren (prehypertension – 10.3% and hypertension – 10.1%) (Cairella et al., 2007), or in South African adolescents aged 13–17 years (prehypertension – 12.3% and hypertension – 21.3%) (Nkeh-Chungag et al., 2015). However, the differences in the times of BP visits, BP measurement methods (the auscultatory method or the oscillometric technique), sample size, age of respondents, ethnic differences, socioeconomic status, and different geographical regions that exist between surveys make it difficult to compare results. However, epidemiological data suggests that HBP is an important and common health problem in children and adolescents. Therefore, it is essential to develop and implement effective public health strategies to prevent and control prehypertension and hypertension.

Early identification, control and treatment of risk factors and a healthy lifestyle (especially in children and adolescents) may reduce the risk of cardiovascular diseases and other chronic noncommunicable diseases and may reduce the burden on public health in the future. It is also important to focus the attention on subjects with diagnosed prehypertension or hypertension – with a high risk or very high risk for cardiometabolic comorbidities. However, taking into account the recommendations and guidelines used for the evaluation and treatment of HBP in children and adolescents, it can often be underdiagnosed. For instance, in a large cohort study of pediatric population, a high frequency of undiagnosed prehypertension and hypertension was found (Hansen et al., 2007). There is evidence that both prehypertension and hypertension in children and adolescents are significant determinants of cardiovascular target organ damage (Urbina, et, al., 2011), and these adverse changes are strongly related to an increased risk of cardiovascular problems in adulthood. The meta-analysis from the analyzed studies showed that prehypertension and hypertension are related to a higher risk of: stroke, myocardial infarction and overall cardiovascular outcomes (Guo et al., 2013).

In this research the WC z-score, BMI z-score, BFP z-score, WHtR z-score and API z-score significantly correlated with SBP, DBP and MAP. However, the correlations of BMI z-score with BP were weaker than the correlations of WC z-score, BFP z-score, WHtR z-score and API z-score. The aORs for HBP in WC quartiles were higher than in BMI quartiles. The aORs were significant in the fourth and third quartile in all anthropometric indicators in both genders. Significant associations were found in the second quartiles of WC among boys.

In the research by Silva et al. which included Brazilian adolescents from 14 to 19 years of age, it was found that elevated blood pressure has been statistically significantly associated with central and general obesity only in boys, but not in girls, by comparing the fourth and first quartile of the WC (≤69 cm vs. ≥80.1 cm) and BMI (≤18.6 kg/m^2 vs. ≥23.5 kg/m^2) (aOR = 6.97 and aOR = 6.44, respectively), while the aOR for the second and third quartile was not statistically significant after the adjustment of age in the multivariate analysis. In NHANES (National Health and Nutrition Examination Survey) (1988–2008), BMI (the third vs. the first quartile, OR = 1.43; and the fourth vs. the first quartile, OR = 2.00) and WC (the fourth vs. the first quartile, OR = 2.14) were statistically significantly associated with elevated blood pressure in children and adolescents from 8 to 17 years of age, after age and gender adjustment (Rosner et al., 2013). The results of the transversal study conducted with Taiwan children aged 6 and 7 years showed that in the combined group of boys and girls, high WC was statistically significantly associated with high blood pressure (aORs were 1.78, 2.45, and 6.03 in the second, third, and fourth quartiles of WC) (Choy et al., 2011). In a research that included 7-year-old Taiwan children it was found that aORs for the elevated BP, elevated SBP, and elevated DBP were statistically significant in the second, third and fourth quartile for WHtR (Chen et al., 2012).

The results of our research suggest that the WC z-score and the API z-score show a higher association with HBP and both indices were better predictors of HBP for both boys and girls. Both WC and API can be used to assess cardiovascular risk in children in North Macedonia. There are still no specific national reference values and limit values for WC for children and adolescents in our country. The epidemiological studies have shown that children with low BMI, but high WC may have a higher risk of HBP (Zhang et al., 2016). In addition, adolescents and children with very high WC values are classified into any BMI group. They have an increased risk of elevated BP and elevated values of: cholesterol, glucose, triglycerides, and high-density lipoproteins (Lee et al., 2016). This study confirmed the previous research where it was found that the application of several obesity indices is more effective than either measurement alone in identifying the risk of HBP (Zhang et al., 2016).

BMI, WC and WHtR are easy, fast, non-invasive, easy to measure, and can help prevent the risk of cardiovascular diseases (Millar et al., 2013). BMI cannot make the difference between a fat-free and a fat component. WC and WHtR cannot distinguish visceral from subcutaneous adipose tissue (Berker et al., 2010). The measurement of WC, unlike WHtR, does not show a difference in height because the subjects with a similar WC but different height do not have the same risk for cardiometabolic risk factors (Schneider et al., 2011). Thus, there is no international agreement or a standard for accepted waist circumference cutoff values (which vary depending on age, gender, ethnicity, and race) for defining abdominal obesity among children and adolescents. Different WC measurement methods can result in different obtained WC values (Yang & Wang, 2017). During childhood and adolescence, the intensity of growth varies as a result of different factors (gender, age, onset of puberty and other factors), WC and height may increase differently, and not simultaneously in each individual, and the WHtR ratio is different and variable during these periods of growth and development (Tybor et al., 2008). The researches so far have shown that the value of WHtR, which is equal to or greater than 0.5, indicates increased health risks in children and adults (Ashwell et al., 2005). Meanwhile, according to the past researches, the WHtR cutoff value of ≥0.5 can be used to define abdominal obesity and to predict greater cardio-metabolic risk in 6-year-old children and older, regardless of gender, age or ethnicity (Yoo, 2016). However, studies conducted in children and adolescents have shown that a WHTR limit value of less than 0.5 may predict a risk of developing high blood pressure (Kromeyer-Hauschild et al., 2013). Our study suggests that the respondents with a WHtR value below 0.5 are exposed to an increased risk for HBP, and the third and fourth quartiles of WHtR were a risk factor for hypertension in both boys and girls.

In the research by Brambilla et al., according to the analysis of the data obtained with magnetic resonance imaging, it was found that WC can be considered a good predictor of visceral adipose tissue as well as BMI of subcutaneous adipose tissue in respondents from 7 to 16 years of age (Brambilla et al., 2006). Barreira et al. analyzed the association between the anthropometric parameters and fat mass and abdominal adiposity (based on the results of the magnetic resonance imaging and dual energy X-ray absorptiometry) in respondents from 5 to 18 years of age and found that WC and WHtR were associated with the visceral adipose tissue (regardless of gender and race). However, they more strongly related with subcutaneous adipose tissue and fat mass (dependent on gender and race) (Barreira et al., 2014). The Framingham Heart Study found that the subcutaneous and visceral adipose tissue were associated with adverse metabolic risk factors, whereby the influence of the visceral adipose tissue was greater. A meta-analysis showed that BMI and WHtR are more correlated with body fat (assessed by dual-energy X-ray absorptiometry) in children. (Martin-Calvo et al., 2016)

The mechanisms of the association between obesity and hypertension can be explained by adipose tissue dysfunction characterized by decreased levels of adiponectin, hyperleptinemia, increased infiltration of macrophages, increased level of free fatty acid and elevated resistin levels, leading to activation of the sympathetic nervous system and the renin-angiotensin-aldosterone system, augmented systemic inflammation and oxidative stress, and chronic vascular inflammation, leading to hypertension (Dorresteijn et al.,2012).

The research has some limitations too. In our study, the blood pressure values were measured three times over a 1-minute period with a clinically confirmed oscillometric device. However, according to the Fourth Report (2005), with HBP (exceeding the 90th percentile), the obtained data with the oscillometric device should be repeated with auscultation, and in addition to this, in order to confirm the diagnosis of hypertension, the measurement should be repeated in at least three different days. The research did not consider biochemical parameters, socioeconomic factors, family history and dietary factors. Furthermore, in our research we included a relatively small age group of the student population - only children aged 6 to 10 years. Further research is required in order to investigate the prevalence of elevated blood pressure and to determine the factors that affect it, in both children and adolescents of all ages. The design of this study was transversal, making it impossible to determine the causal relationship.

In North Macedonia, public health strategies should be more focused on the understanding and prevention of risk factors for cardiovascular diseases. The results of our study would be useful for preparing prevention programs to improve children's health. Healthy lifestyle changes and correction of unfavorable lifestyle habits (by increasing physical activity, maintaining a healthy weight and healthy eating habits, reducing sodium intake, increasing potassium intake in the diet, reducing smoking and alcohol consumption) are essential for preventing HBP.

Conclusion

The results of this study showed that the two anthropometric indices - WC and API (particularly WC) - were more expressly associated with hypertension, both separately and in combination. In addition, they were superior to BMI in predicting elevated BP in Macedonian children from 6 to 10 years of age.

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