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Anthropometric Indices in the Prediction of Hypertension in Female Adolescents

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Abstract

Background: Identifying the best marker for appropriate screening of risk factors of chronic diseases seems necessary in any society.

Objectives: This study aimed at performing a comparative evaluation of anthropometric indices to determine a better marker for prediction of high blood pressure in adolescents.

Methods: This cross-sectional study was done during 2013 on 1046 students, aged 11 to 19 year old in Kashan, who were chosen by cluster and class sampling method. Height, waist circumference (WC), waist-to-hip ratio (WHR), waist-to-high ratio (WHtR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) of the subjects were measured. Blood pressure of all subjects, who had their blood pressures measured during the first visit, was measured during the second and third visit again, and the three measured blood pressure averages was considered as subjects' blood pressure.

Results: This study showed a significant positive correlation between BP and body mass index (BMI), WC, WHR, and WHtR indices ($P < 0.001$). Receiver operating characteristic curve (ROC) analysis was performed. Area under the curve (AUC) was obtained for BMI (0.62 to 0.73), WC (0.67 to 0.76), WHR (0.57 to 0.67), and WHtR (0.63 to 0.77) in diastolic blood pressure and BMI (0.66 to 0.76), WC (0.68 to 0.78), WHR (0.57 to 0.67) and WHtR (0.67 to 0.77) in systolic blood pressure. The WHtR in adolescents had better distinguishing power than other anthropometric indices.

Conclusions: The WHtR, as a relatively simple, inexpensive, and convenient measurement method is the best anthropometric index for determination of blood pressure in these subjects.

Keywords: Hypertension, Adolescent, Body Mass Index, Waist Circumference, Waist-to-Hip Ratio, Waist-to-High Ratio

1. Background

Hypertension causes 1 in 8 deaths worldwide, being the third leading cause of death worldwide (1). In 2000, there were nearly one billion adults with hypertension around the world, and it is predicted that their number would reach 1.56 billion people in 2025 (2). Studies have shown that blood pressure problems may begin in adolescence and even in childhood and continue to adulthood (3-5). In other words, the root of blood pressure in adulthood often starts from childhood (4). Body mass index, as an index of obesity recommended by the world health organization, is a risk factor for high blood pressure (6, 7). Much attention has also been paid to the use of waist circumference (WC) for cardiovascular disease (CVD) risk assessment and management in adults (8, 9), as WC is strongly correlated with abdominal fat (10). Some studies have proposed waist as a better index than BMI and WHR to detect abdominal obesity and cardiovascular risk factors (11-13). However, this result was not confirmed in Asian countries, and still the best index for obesity predicting cardiovascular disease risk is yet to be determined (14, 15). Waist-to-high ratio (WHtR) is introduced as a better index than BMI and WC for screening blood pressure and diabetes in adults (16, 17). Although WHtR was widely used in adults, yet there is little information about WHtR in children and adolescents.

Given that to the best of our knowledge there were no studies on the investigation of the best anthropometric index to predict high blood pressure in adolescents, and that the predictive power of anthropometric indices for cardiovascular risk factors depends on the population of each region and varies from race to race, thus identifying a better marker for appropriate screening for risk factors of chronic diseases is necessary in any society.

2. Objectives

This study was performed to investigate the following objectives:

1- Determining the relationship between blood pressure and anthropometric indices in female teenage school students.

2- Comparative evaluation of anthropometric indices to determine a better marker for prediction of high blood pressure in adolescents.

3. Methods

This cross sectional study was done on female teenage students, aged 11 to 19 years old in Kashan (a city in the center of Iran), during year 2013, who were selected by cluster and class sampling. All the schools in Kashan city were divided to 5 regions (North, South, East, West and Center), and then from every region, the number of middle and high schools, depending on the number of schools in each region, was randomly selected and maximum of two classes from each level were selected randomly. Demographic information of all enrolled students was obtained before data collection; anthropometric indices of each participant, including weight, height, waist, and hip sizes, were measured and recorded using standard methods by a trained researcher.

3.1. Measurements

Height was measured to the nearest 0.5 cm when the subjects stood wearing socks and with their heads in the Frankfort horizontal plane. Weight was measured to the nearest 0.1 kg with a Seca scale (model 762, made in Germany). Every day before use of the Seca scale, accuracy of the system was controlled using standard weights. Height and weight were measured in duplicate, and the average of the 2 measurements was used to calculate the body mass index (BMI). Body mass index was calculated as weight (kg) divided by height (m) squared. Waist circumference was measured in triplicates, midway between the lowest rib and the superior border of the iliac crest, with a flexible tape. The average of the 3 waist circumference measurements was used in all analyses. The measurement was carried out at the end of a normal expiration while the subject stood upright with their feet together and arms hanging freely on their sides. Hip circumference was measured at the maximum point below the waist, without compressing the skin.

The WHtR was calculated from waist-to-height division and WHR was calculated from waist-to-hip division. Measurement of blood pressure was done according to the America heart association recommendations, in the sitting position from right arm after 5 minutes rest by using an appropriate cuff. A pressure cuff was used that covers at least two-thirds of the arm. Pressure cuff was closed 20 mm above the bend of the elbow and in all cases, the blood pressure of a person was measured by a Riester mercury manometer (made in Germany) with 5 mmHg precision. The manometer was inspected on a daily basis. In order to prevent errors between observers, measuring blood pressure and anthropometric indices was trained one person. For more accurate results, the following factors were considered:

- To reduce anxiety in all steps before the start.

- Subjects had no strenuous physical activity or exercise at least half an hour before blood pressure measurement.

- To reduce the error due to uncomfortable bladder dilatation, subjects were asked to evacuate the bladder before measuring blood pressure.

- Subjects did not eat chocolate, tea, coffee or heavy food during the one hour before measurement of blood pressure.

All subjects, who had a high blood pressure in the first visit, had their blood pressure measured on another visit (second time) and finally if in the second time they had high blood pressure, their blood pressure was measured on their third visit and the average of three measured blood pressures was considered as subjects' blood pressure. New guidelines were used for blood pressure classification of subjects, provided by the fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. According to the guidelines that are adjusted based on age, gender, and height, if the average of three measurements of systolic or diastolic blood pressure was equal or above 95% to 99%, it was considered as hypertension and if the average of three measurements of systolic or diastolic blood pressure was above 90% but less than 95%, it was considered as prehypertension, and blood pressure less than 90% was considered as normal blood pressure. The teens whose blood pressure was equal to or higher than 120/80 but less than 95% were considered to have prehypertension (18).

In order to determine underweightness and obesity, specific age-gender percentages of centers for disease control and prevention were used (19, 20). According to this classification, body mass index less than 5% was considered as underweight, 5% and above 85% was considered normal, 85% and above 95% was considered overweight (20). Waist of more than 75% was considered as abdominal obesity based on specific age and gender (21-23).

The WHtR was calculated by dividing waist to height and was classified in four groups: less than 0.4 (probably underweight), 0.4 to 0.5 (appropriate), 0.5 to 0.6 (probably needs to take action to reduce this ratio), more than 0.6 (there is a need to take action to reduce this ratio) (24). Also greater than 0.5 was considered as abdominal obesity (25, 26). All data was measured by one of the researchers.

Sample size was calculated on the basis of a previous study, which recorded prevalence of hypertension in a school-aged adolescent population as 10.3% (27). Considering 95% confidence interval, the required sample size was 920. However, a total of 1046 subjects were included in the study.

3.2. Data Analysis

Data were analyzed with SPSS software v.16.0 (SPSS Inc., Chicago, IL, USA). Kolmogorov-Smirnov test showed that the distribution of data was normal ($P < 0.05$). Results are expressed accordingly with means and standard deviations (SD). Quantitative variables were associated with analysis of variance (ANOVA). Receiver operator characteristic (ROC) for the different indexes and their combinations were used to identify the best cut off point with 95% confidence intervals. A $P < 0.05$ was considered significant.

3.3. Ethical Considerations

This study was approved by the ethics committee of Kashan University of Medical Sciences (grant no. 9092). The study participants were informed about the aim and the course of the study, being free to participate in the study, being free to withdraw from the study at any stage, and confidentiality of personal information. After obtaining consent from school administrators and receiving consent from parents and students, information was obtained from the participants.

4. Results

The study included a sample of 1046 female adolescents aged 11 to 19 years. The mean age was 15.33 years (SD = 1.51); the general characteristics of the participants are shown in Table 1. Analysis of variance (ANOVA) statistical test showed a significant positive correlation between BP and BMI, waist, WHR, and WHtR, all correlations were significant at $P < 0.001$ (Table 2). The area under the ROC curve (AURC) was obtained for BMI (0.67), WC (0.714), WHR (0.62), and WHtR (0.72) in diastolic blood pressure and BMI (0.71), WC (0.73), WHR (0.62) and WHtR (0.73) in systolic blood pressure. Tables 3 and 4 depict the best cut off values, sensitivity, specificity, likelihood ratio, positive (PPV) and negative (NPV) predictive values and the percentage of correctly classified patients with each index. Likelihood ratios were used for assessing the value of performing these tests. A PPV higher than 1 indicated that the test could be used to confirm the disease while a lower LR-indicates the test could be used to rule out the disease. The cut-off points were selected using Youden index, at which (sensitivity + specificity -1) is maximized (Youden index is the difference between the true positive rate and the false positive rate). Maximizing this index allows to find, from the ROC curve, an optimal cut-off point independently from the prevalence.

Table 1. General Characteristics of the Studied Subjects (n = 1046)

Variable	Mean ± SD Levels	Min	Max
Age, y	15.33 ± 1.51	11	19
Menarche age	11.72 ± 3.36	0	16
Height, cm	159.49 ± 6.21	135	183
Weight, kg	55.50 ± 11.88	30	106
BMI, kg/m^2	21.77 ± 4.27	12.96	41.15
Waist circumference, cm	73.57 ± 10.67	52	120
Waist-to-hip ratio, WHR	0.8 ± 0.07	0.53	1.21
Waist-to-high ratio, WHtR	0.46 ± 0.07	0.32	0.76
Systolic blood pressure, mmHg	71.23 ± 10.39	70	170
Diastolic blood pressure, mmHg	110.60 ± 15.68	50	106.67

5. Discussion

Early determination of pre-hypertension and high blood pressure cause early interference and likely prevent further complications and mortality of individuals (18). Our study showed that the best Anthropometric index for prediction of high blood pressure among female adolescents is WHtR. The prevalence of pre-hypertension in female adolescents in schools of Kashan was 6.8%, and overall prevalence of hypertension (high diastolic and systolic blood pressure) was 6.3%. In this study, 25.3% of studied subjects were overweight or obese, and the ANOVA statistical test showed a statistical relationship between diastolic and systolic blood pressure with BMI ($P < 0.001$), so that BMI increased with an increase in systolic and diastolic blood pressure, and the highest average blood pressure in adolescents with BMI was 95%. The relationship between blood pressure and BMI was expressed in several studies (28-32). Blood pressure in overweight and obese adolescents may be due to increased cardiac output, physical inactivity, high sodium intake, and alteration in receptors for various presser substances (27). Also, physiological changes, such as high activity of the sympathetic nervous system, the renin-angiotensin system (33, 34), and insulin resistance could be the cause of the relationship be-

Table 2. Relationship Between Systolic and Diastolic Blood Pressure by Anthropometric Indices[a]

Variable	Definitio	Diastolic blood Pressure, mmHg	Systolic Blood Pressure, mmHg	P Value[b]
BMI	< 5th	66.50 (10.21)	103.21 (15.93)	P < 0.001
	≥ 5th to 85th	70.06 (9.77)	108.15 (14.46)	
	≥ 85th to 95th	74.24 (10.28)	116.81 (14.72)	
	95th <	78.27 (11.25)	123.67 (16.36)	
WAIST	75th	70.26 (9.92)	109.31 (14.90)	P < 0.001
	75th <	78.51 (10.10)	120.21 (17.91)	
WHR	< 0.80	69.71 (9.67)	108.42 (15.05)	P < 0.001
	0.80 to 0.85	72.13 (10.35)	112.83 (15.02)	
	0.85 - 0.90	73.13 (11.96)	112.73 (15.49)	
	0.90 <	74.72 (10.25)	116.33 (17.76)	
WHtR	0.4 >	67.51 (8.85)	104.82 (13.43)	P <0.001
	0.4 - 0.5	70.49 (1.03)	110.08 (15.01)	
	0.5 - 0.6	76.02 (1.03)	116.96 (15.68)	
	0.60 <	79.20 (1.10)	119.94 (22.89)	

[a]Values are expressed as mean (SD).
[b]Anova.

Table 3. Areas Under the ROC Curve, Sensitivity, Specificity, Positive Predictive Value and Negative Predictive Value of BMI, WC, WHR and WHtR for the Prediction of Diastolic Hypertension

Variable	Diastolic Blood Pressure, mmHg						
	AURC (95%CI)	Cut off	Sen (95% CI)	Spe (95% CI)	PPV (95% CI)	NPV (95% CI)	Youden index
BMI, kg/m^2	0.67 (0.62 - 0.73)	24.3	0.50 (041 - 0.59)	0.80 (0.77 - 0.83)	0.23 (0.18 - 0.28)	0.93 (091 - 0.95)	0.30
Waist circumference, cm	0.71 (0.67 - 0.76)	79.5	0.58 (0.49 - 0.67)	0.75 (0.72 - 0.78)	0.23 (0.18 - 0.28)	0.94 (0.92 - 0.96)	0.34
waist-to-hip ratio (WHR)	0.62 (0.57 - 0.67)	0.79	0.71 (0.63 - 0.79)	0.59 (0.56 - 0.62)	0.15 (0.12 - 0.18)	0.93 (0.91 - 0.95)	0.22
waist-to-high ratio (WHtR)	0.72 (0.63 - .77)	0.48	0.71 (0.63 - 0.79)	0.67 (0.64 - 0.7)	0.21 (0.17 - 0.25)	0.95 (0.93 - 0.97)	0.39

Abbreviations: AURC, Areas Under the ROC Curve; NPV, Negative Predictive Value; PPV, Positive Predictive Value; Sen, Sensitivity; Spe, Specificity.

Table 4. Areas Under the ROC Curve, Sensitivity, Specificity, Positive Predictive Value and Negative Predictive Value of BMI, WC, WHR and WHtr for the Prediction of Systolic Hypertension

Variable	Systolic Blood Pressure						
	AURC (95%CI)	Cut off	Sen (95% CI)	Spe (95% CI)	PPV (95% CI)	NPV (95% CI)	Youden index
BMI, kg/m^2	0.71 (0.66 - 0.76)	23.4	0.59 (0.5 - 0.68)	0.74 (0.71 - 0.77)	0.24 (0.19 - 0.29)	0.93 (0.91 - 0.95)	0.33
Waist circumference, cm	0.73 (0.68 - 0.78)	78.5	0.62 (0.54 - 0.7)	0.73 (0.7 - 0.76)	0.24 (0.19 - 0.29)	0.93 (0.91 - 0.95)	0.35
waist-to-hip ratio (WHR)	0.62 (0.57 - 0.67)	0.79	0.70 (0.62 - 0.78)	0.51 (0.48 - 0.54)	0.16 (0.13 - 0.19)	0.93 (0.91 - 0.95)	0.22
waist-to-high ratio (WHtR)	0.73 (0.67 - 0.77)	0.48	0.71 (0.63,0.79)	0.66 (0.62,0.7)	0.225 (0.18 - 0.27)	0.94 (0.92 - 0.96)	0.37

Abbreviations: AURC, Areas Under the ROC Curve; NPV, Negative Predictive Value; PPV, Positive Predictive Value; Sen, Sensitivity; Spe, Specificity.

tween obesity and hypertension. Effectively, endothelial-dependent dilation, and arterial compliance in obese adolescents is reduced similar to adults, an issue proposed as an atherogenic process in any age when a person is exposed to extreme obesity (34). This shows the importance of clinical checking of BP and BMI from adolescence to adulthood.

The study results showed that an increase in waist-to-height ratio is associated with increasing systolic and diastolic blood pressure in female students of Kashan and there is a significant relationship between them ($P < 0.001$).

In the current study, 24.6% of studied adolescents were at risk for obesity and WHtR higher than 0.5. In Pakistani students this amount was 16.5% (35), which indicates a high prevalence of obesity in studied subjects. The ANOVA test showed a positive relationship between WHtR and mean systolic-diastolic blood pressure in adolescents ($P < 0.001$).

The findings were consistent with the results of some previous studies. The study results of Kahn et al. showed WHtR as a relatively simple ratio that requires no age or gender characteristics, and had the capability to replace specific percentage for age and gender, BMI to assess the risk of cardiovascular diseases associated with overweight and obesity (36). In a study done by Saeed et al., about anthropometric risk factors and predictors of hypertension, it was shown that WHtR is the most important anthropometric predictor of hypertension and blood pressure levels (37). Also, other studies showed a strong relationship between WHtR and cardiovascular diseases and metabolic risk in children, and measurement of waist-to-height ratio was recommended as a method to measure abdominal fat in children, independent of age, especially for early childhood care and epidemiological studies (38, 39).

WHtR indicates visceral or intra-abdominal adipose tissue mass that it is proved (for adults) to be associated with subcutaneous body fat mass (40). Visceral fat mass in children and adolescents is the lowest and in children is usually sporadic (41). Despite this, the presence of visceral fat in children and adolescents is interpreted as a sign of excessive fat storage. That is, even among youth with low or normal weight by BMI-percentile criteria, the emergence of more or larger adipocytes in the visceral compartment would indicate that these youth have already exceeded the capacity of their peripheral adipoc and other tissues to buffer and store normal amounts of lipid fuels (42). These fats are usually burned, yet may cause increase in triglycerides in the circulation (43). Ultimately their increase causes different diseases in the future. Additional fat may accumulate in fat storage tissues (such as muscle, liver and pancreatic beta cells) and lead to a metabolic disorder (44, 45). As a result, WHtR may be a more useful tool for global clinical screening with a weighted mean boundary value of 0.5, supporting the simple public health message: keep your waist circumference to less than half your height (16).

Study strengths and limitations: The strengths of this study were the large sample size, extensive age including adolescents aged 11 to 19 years old, comparison of the four anthropometric indices and use of mercury sphygmomanometer that is considered a gold standard for non-invasive BP measurements. Accurate and multiple blood pressure measurement are other strengths of this study, so that in subjects, who had high blood pressure, their blood pressure was measured for a second or third time and three measured blood pressure average was considered as subjects' blood pressure. Limitations of the study included a population sample limited to girls and not having annual visits. Further studies are needed to determine the relationship between blood pressure and anthropometric indices in males. Future studies might also compare anthropometric indices to determine a better marker for prediction of high blood pressure in male adolescents.

5.1. Conclusion

The current study showed that WHtR was relatively simple, inexpensive and convenient measurement method, which is the best anthropometric index for determination of risk factors that is CVD in subjects. With regards to hypertension and obesity being health problems in adolescent females, the design of training programs for adolescent females and their parents is essential. These should be educational programs on behavioral changes recommended by parents and students.

Additional work on other populations is required to determine the generalizability of these thresholds.

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Footnote

Conflict of Interests: The researchers were staff and faculty members of Kashan University of Medical Sciences and the project was funded by Deputy of Research, Kashan University of Medical Sciences, Kashan, Iran.

References

1. World Health Organization . *The World Health Report 2002: Reducing risks, promoting healthy life*. 2002. Available from: www.who.int/whr/2002/en/Overview_E.pdf.
2. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. *Lancet*. 2005;**365**(9455):217–23. doi: 10.1016/S0140-6736(05)17741-1. [PubMed: 15652604].

3. Kotchen JM, McKean HE, Neill M, Kotchen TA. Blood pressure trends associated with changes in height and weight from early adolescence to young adulthood. *J Clin Epidemiol*. 1989;**42**(8):735–41. doi: 10.1016/0895-4356(89)90069-3. [PubMed: 2760664].
4. Yong LC, Kuller LH, Rutan G, Bunker C. Longitudinal study of blood pressure: changes and determinants from adolescence to middle age. The Dormont High School follow-up study, 1957-1963 to 1989-1990. *Am J Epidemiol*. 1993;**138**(11):973–83. doi: 10.1093/oxfordjournals.aje.a116817. [PubMed: 8256782].
5. Nelson MJ, Ragland DR, Syme SL. Longitudinal prediction of adult blood pressure from juvenile blood pressure levels. *Am J Epidemiol*. 1992;**136**(6):633–45. doi: 10.1093/oxfordjournals.aje.a116543. [PubMed: 1442730].
6. World Health Organization . *Obesity: preventing and managing the global epidemic. Report of a WHO consultation on obesity 3-5 June 1997*. Geneva: World Health Organization; 1997.
7. Esmaillzadeh A, Mirmiran P, Azizi F. Waist-to-hip ratio is a better screening measure for cardiovascular risk factors than other anthropometric indicators in Tehranian adult men. *Int J Obes Relat Metab Disord*. 2004;**28**(10):1325–32. doi: 10.1038/sj.ijo.0802757. [PubMed: 15314626].
8. Despres JP. Health consequences of visceral obesity. *Ann Med*. 2001;**33**(8):534–41. doi: 10.3109/07853890108995963. [PubMed: 11730160].
9. Lemieux I, Poirier P, Bergeron J, Almeras N, Lamarche B, Cantin B, et al. Hypertriglyceridemic waist: a useful screening phenotype in preventive cardiology?. *Can J Cardiol*. 2007;**23 Suppl B**:23B–31B. doi: 10.1016/S0828-282X(07)71007-3. [PubMed: 17932584].
10. Klein S, Allison DB, Heymsfield SB, Kelley DE, Leibel RL, Nonas C, et al. Waist circumference and cardiometabolic risk: a consensus statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Am J Clin Nutr*. 2007;**85**(5):1197–202. [PubMed: 17490953].
11. Dobbelsteyn CJ, Joffres MR, MacLean DR, Flowerdew G. A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. The Canadian Heart Health Surveys. *Int J Obes Relat Metab Disord*. 2001;**25**(5):652–61. doi: 10.1038/sj.ijo.0801582. [PubMed: 11360147].
12. Cornier MA, Despres JP, Davis N, Grossniklaus DA, Klein S, Lamarche B, et al. Assessing adiposity: a scientific statement from the American Heart Association. *Circulation*. 2011;**124**(18):1996–2019. doi: 10.1161/CIR.0b013e318233bc6a. [PubMed: 21947291].
13. Decoda Study G, Nyamdorj R, Qiao Q, Lam TH, Tuomilehto J, Ho SY, et al. BMI compared with central obesity indicators in relation to diabetes and hypertension in Asians. *Obesity (Silver Spring)*. 2008;**16**(7):1622–35. doi: 10.1038/oby.2008.73. [PubMed: 18421260].
14. Azizi F, Esmaillzadeh A, Mirmiran P, Ainy E. Is there an independent association between waist-to-hip ratio and cardiovascular risk factors in overweight and obese women?. *Int J Cardiol*. 2005;**101**(1):39–46. doi: 10.1016/j.ijcard.2004.03.011. [PubMed: 15860381].
15. Woo J, Ho SC, Yu AL, Sham A. Is waist circumference a useful measure in predicting health outcomes in the elderly?. *Int J Obes Relat Metab Disord*. 2002;**26**(10):1349–55. doi: 10.1038/sj.ijo.0802080. [PubMed: 12355330].
16. Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obes Rev*. 2012;**13**(3):275–86. doi: 10.1111/j.1467-789X.2011.00952.x. [PubMed: 22106927].
17. Cai L, Liu A, Zhang Y, Wang P. Waist-to-height ratio and cardiovascular risk factors among Chinese adults in Beijing. *PLoS One*. 2013;**8**(7). e69298. doi: 10.1371/journal.pone.0069298. [PubMed: 23874938].
18. National High Blood Pressure Education Program Working Group on High Blood Pressure in C.Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics*. 2004;**114**(2 Suppl 4th Report):555–76. doi: 10.1542/peds.114.2.S2.555. [PubMed: 15286277].
19. Din-Dzietham R, Liu Y, Bielo MV, Shamsa F. High blood pressure trends in children and adolescents in national surveys, 1963 to 2002. *Circulation*. 2007;**116**(13):1488–96. doi: 10.1161/CIRCULATIONAHA.106.683243. [PubMed: 17846287].
20. CDC Growth Charts . *National Health and Nutrition Examination Survey*. 2016. Available from: http://www.cdc.gov/nchs/nhanes.htm.
21. Guimaraes IC, de Almeida AM, Santos AS, Barbosa DB, Guimaraes AC. Blood pressure: effect of body mass index and of waist circumference on adolescents. *Arq Bras Cardiol*. 2008;**90**(6):393–9. [PubMed: 18592092].
22. 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. [PubMed: 15480363].
23. de Ferranti SD, Gauvreau K, Ludwig DS, Neufeld EJ, Newburger JW, Rifai N. Prevalence of the metabolic syndrome in American adolescents: findings from the Third National Health and Nutrition Examination Survey. *Circulation*. 2004;**110**(16):2494–7. doi: 10.1161/01.CIR.0000145117.40114.C7. [PubMed: 15477412].
24. Ashwell Obe M, Blades M. Waist to height ratio and the Ashwell® shape chart could predict the health risks of obesity in adults and children in all ethnic groups. *Nutr Food Sci*. 2005;**35**(5):359–64. doi: 10.1108/00346650510625575.
25. Nambiar S, Hughes I, Davies PS. Developing waist-to-height ratio cut-offs to define overweight and obesity in children and adolescents. *Public Health Nutr*. 2010;**13**(10):1566–74. doi: 10.1017/S1368980009993053. [PubMed: 20100388].
26. Akobeng AK. Understanding diagnostic tests 3: Receiver operating characteristic curves. *Acta Paediatr*. 2007;**96**(5):644–7. doi: 10.1111/j.1651-2227.2006.00178.x. [PubMed: 17376185].
27. Basiratnia M, Derakhshan D, Ajdari S, Saki F. Prevalence of childhood obesity and hypertension in south of Iran. *Iran J Kidney Dis*. 2013;**7**(4):282–9. [PubMed: 23880805].
28. Mohan B, Kumar N, Aslam N, Rangbulla A, Kumbkarni S, Sood NK, et al. Prevalence of sustained hypertension and obesity in urban and rural school going children in Ludhiana. *Indian Heart J*. 2004;**56**(4):310–4. [PubMed: 15586739].
29. Ejike CE, Ugwu CE, Ezeanyika LU. Variations in the prevalence of point (pre)hypertension in a Nigerian school-going adolescent population living in a semi-urban and an urban area. *BMC Pediatr*. 2010;**10**:13. doi: 10.1186/1471-2431-10-13. [PubMed: 20214768].
30. Ejike CE, Ugwu CE, Ezeanyika LU, Olayemi AT. Blood pressure patterns in relation to geographic area of residence: a cross-sectional study of adolescents in Kogi state, Nigeria. *BMC Public Health*. 2008;**8**:411. doi: 10.1186/1471-2458-8-411. [PubMed: 19087334].
31. Agyemang C, Redekop WK, Owusu-Dabo E, Bruijnzeels MA. Blood pressure patterns in rural, semi-urban and urban children in the Ashanti region of Ghana, West Africa. *BMC Public Health*. 2005;**5**:114. doi: 10.1186/1471-2458-5-114. [PubMed: 16262905].
32. Rafraf M, Gargari BP, Safaiyan A. Prevalence of prehypertension and hypertension among adolescent high school girls in Tabriz, Iran. *Food Nutr Bull*. 2010;**31**(3):461–5. doi: 10.1177/156482651003100308. [PubMed: 20973466].
33. Couch SC, Krummel DA. *Krause's food and nutrition therapy*. 12th ed. Canada: Elsevier: Saunders Company; 2008. Medical nutrition therapy for hypertension; p. 865–98.
34. Torrance B, McGuire KA, Lewanczuk R, McGavock J. Overweight, physical activity and high blood pressure in children: a review of the literature. *Vasc Health Risk Manag*. 2007;**3**(1):139–49. [PubMed: 17583184].
35. Mushtaq MU, Gull S, Abdullah HM, Shahid U, Shad MA, Akram J. Waist circumference, waist-hip ratio and waist-height ratio percentiles and central obesity among Pakistani children aged five to twelve

years. *BMC Pediatr*. 2011;**11**:105. doi: 10.1186/1471-2431-11-105. [PubMed: 22104025].
36. Kahn HS, Imperatore G, Cheng YJ. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. *J Pediatr*. 2005;**146**(4):482–8. doi: 10.1016/j.jpeds.2004.12.028. [PubMed: 15812450].
37. Saeed AA, Al-Hamdan NA. Anthropometric risk factors and predictors of hypertension among Saudi adult population - a national survey. *J Epidemiol Glob Health*. 2013;**3**(4):197–204. doi: 10.1016/j.jegh.2013.08.004. [PubMed: 24206791].
38. Mokha JS, Srinivasan SR, Dasmahapatra P, Fernandez C, Chen W, Xu J, et al. Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. *BMC Pediatr*. 2010;**10**:73. doi: 10.1186/1471-2431-10-73. [PubMed: 20937123].
39. Flores-Huerta S, Klunder-Klunder M, Reyes de la Cruz L, Santos JI. Increase in body mass index and waist circumference is associated with high blood pressure in children and adolescents in Mexico city. *Arch Med Res*. 2009;**40**(3):208–15. doi: 10.1016/j.arcmed.2009.02.009. [PubMed: 19427973].
40. Ashwell M, Cole TJ, Dixon AK. Ratio of waist circumference to height is strong predictor of intra-abdominal fat. *BMJ*. 1996;**313**(7056):559–60. [PubMed: 8790002].
41. Goran MI, Nagy TR, Treuth MS, Trowbridge C, Dezenberg C, McGloin A, et al. Visceral fat in white and African American prepubertal children. *Am J Clin Nutr*. 1997;**65**(6):1703–8. [PubMed: 9174463].
42. Frayn KN. Adipose tissue as a buffer for daily lipid flux. *Diabetologia*. 2002;**45**(9):1201–10. doi: 10.1007/s00125-002-0873-y. [PubMed: 12242452].
43. Kahn HS, Valdez R. Metabolic risks identified by the combination of enlarged waist and elevated triacylglycerol concentration. *Am J Clin Nutr*. 2003;**78**(5):928–34. [PubMed: 14594778].
44. Unger RH. Minireview: weapons of lean body mass destruction: the role of ectopic lipids in the metabolic syndrome. *Endocrinology*. 2003;**144**(12):5159–65. doi: 10.1210/en.2003-0870. [PubMed: 12960011].
45. Unger RH. Lipid overload and overflow: metabolic trauma and the metabolic syndrome. *Trends Endocrinol Metab*. 2003;**14**(9):398–403. [PubMed: 14580758].