Variations in blood pressure in adolescents and its correlation with different anthropometric measurements: a cross-sectional study

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Abstract

Background: Anthropometry is emerging as a useful tool in assessing the future risk of chronic diseases such as type 2 diabetes mellitus (and diabetic nephropathy, diabetic neuropathy, diabetic retinopathy), hypercholesterolemia, atherosclerosis, coronary artery diseases, nonalcoholic fatty liver disease (NAFLD). Body mass index (BMI) and waist–hip ratio (WHR) are used extensively in the forecast of cardio-vascular diseases. The main risk factor for such diseases is hypertension and the correlation of hypertension with BMI and/or WHR gives one the ability to forecast the diseases as risk assessment from a young age and proper techniques can be utilized to delay them. The aim of this study was to correlate BMI and WHR with hypertension in young adults and adolescents.

Material and methods: A cross sectional, record-based study of adolescents from age group 17–19 (n = 946) was done and analyzed.

Results: Data of a total of 465 males and 481 females (n = 946) were analyzed. In both males and females, mean blood pressure [both systolic (SBP) and diastolic blood pressure (DBP)] showed a positive correlation with increasing ranges of BMI and WHR. Values of Pearson correlation coefficient and p-value: Males: SBP -> BMI = 0.236 ($p < 0.0001$); DBP -> BMI = 0.187 ($p < 0.0001$); Males: SBP -> WHR = 0.194 ($p < 0.0001$); DBP -> WHR = 0.148 ($p < 0.0001$); Females: SBP -> BMI = 0.249 ($p <0.0001$); DBP -> BMI = 0.267 ($p < 0.0001$); Females: SBP -> WHR = 0.090 ($p < 0.0001$); DBP -> WHR= 0.116 ($p < 0.0001$). The correlation between BMI and WHR in males was 0.234 ($p < 0.0001$) and in females, it was 0.172 ($p < 0.0001$).

Conclusion: A steady increase in SBP and DBP is correlated with an increase in BMI and WHR. This leads to the efficacy of these methods in assessing future risks. It was found that hypertension was correlated with BMI and WHR; there was also a correlation between BMI and WHR.

Key words: anthropometry; BMI; waist-hip ratio; hypertension; risks

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Introduction

Medical field in recent years has underwent serial new modifications and is evolving everyday catering to humans and battling diseases. Increase in life expectancy is one of the most important and the biggest achievement in the medical field. With increasing life expectancy, some chronic systemic diseases have shown a higher prevalence rate than before.

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These chronic diseases namely coronary artery disease, atherosclerosis, myocardial infarction, hypertension, type 2 diabetes mellitus (and diabetic nephropathy, diabetic neuropathy, diabetic retinopathy), hypercholesterolemia, non-alcoholic fatty liver disease (NAFLD) are now prevalent in every country in every continent. Risk assessment of developing these has become the utmost priority in modern science. Assessing the chances of developing these diseases and working towards decreasing the modifiable factors is the key.

The prevalence of hypertension in young adults and adolescents is alarmingly increasing as per various news outlets. However, no specific study has confirmed this so far, although the prevalence of obesity and stress and other factors contributing to hypertension have significantly increased.

Anthropometry is currently emerging as one of the most useful tools to assess the risk of these diseases. Anthropometry refers to the use of height, weight, and hip and waist circumferences to derive specific value such as body mass index (BMI) or waist–hip ratio (WHR) to assess the health of any individual.

BMI and WHR are used extensively in forecasting cardio-vascular diseases. Waist circumference alone can also be used as an indicator of visceral fat. The main risk factor for the diseases mentioned above is hypertension [1]. The correlation of hypertension with BMI and/or WHR makes it possible to predict the risk of diseases from an early age and apply appropriate strategies to delay them.

More than half a century has passed since Gertler et al. reported in 1951 that young men at risk for coronary artery disease were about 5cm shorter than their healthy counterparts [2, 3].

In males aged 15–19 years, there seem to be definite tendency for systolic blood pressure to increase with height. In the older age-groups there may be a slight tendency for systolic pressure to decrease with increasing height. Systolic blood pressure is always higher in the shortest height groups than in the tallest groups. This may be accidental, but the tendency is so systematic that it may reveal a biological fact. Since such a relationship is not observed in the middle age-groups, this is especially related to old age [4].

Shorter individuals have higher BP levels than taller individuals. This may at least partly explain the inverse association between height and cardiovascular disease (CVD) [5]. Short people may be more susceptible to the effects of ageing on the arterial tree. Childhood growth may contribute to tracking of cardiovascular risk throughout life [6].

In adults of Western societies, the positive relationship between blood pressure and body weight has often been demonstrated, both cross-sectionally and longitudinally. This correlation is even stronger in children and young adults [7].

Tracking of blood pressure: If blood pressure levels of an individual were followed up for over a period of years from early childhood into adult life, then those individuals whose pressure were initially high in the distribution, would probably continue in the same track as adults. In other words, low blood pressure levels tend to remain low, and high levels tend to become higher as individuals grow older [8, 9]. This means that if blood pressure is on the slightly higher side.

The main aim of the study was to see if height, weight, waist circumference, and hip circumferences have any impact on a person's blood pressure. It can be stated with no doubt here that young population has a more vibrant cardiovascular system that can withstand the hypertensive stress and any other type of insults done on it. With increasing age, resilience and compliance along with elasticity of the cardiovascular system decreases. If, in young adolescents, it can be found that height and weight of individuals has a significant effect on blood pressure, it can be understood that with ageing, the impact of height and weight will only increase leading to higher changes in blood pressure and the relation between height and weight with blood pressure will only grow stronger. BMI and WHR are the main indices of height and weight measurement and are the impacting factors on blood pressure. We also wanted to see what is more reliable between BMI and WHR in assessing risk of chronic diseases and mainly hypertension.

Material and methods

Community Medicine Department affiliated with the Medical College every year collects data of new students admitted to the institute for research purposes of the department itself. The department here gathers wide range of data related to height, weight, waist and hip circumferences and blood pressure.

A cross-sectional study was designed to collect data. The records of last 4 years (records of the data collected by the department of the students who were admitted in the medical college in the last 4 years) obtained from Community Medicine Department were used in the study. At the time of data recording, the students signed informed consent form for the data they are providing. Yet, in the data acquisition for this research, identity of the subjects were not revealed.

All subjects belonged to the age group of 17–19 when the data was recorded at given point of time in last 4 years. This data from physical files was collected and digitalized so that proper statistical tests could be applied and results could be achieved.

As the data had been collected already and no interaction was done with the actual participants, the Ethical Board gave oral permission and no written permission was taken. The head of the Community Medicine Department gave her permission for the use of the said records for the purpose of this research.

Study design

Record-based cross-sectional study (records were collected originally by the Community Medicine Department).

Study population

Records of 946 students were included in the study, of them 481 were females and 465 were males.

Exclusion criteria were as follows:
- data was not recorded of any student having any predisposed or known medical conditions that are chronic in nature;
- who did not give consent at the time of data recording.

Measurements done on every subject

They all were made to sit in a classroom for 30 minutes for form filling to record all data that had to be gathered by the Community Medicine Department. The measurements were taken with the use of measure tapes which were put around the waist and hip for their circumference. A carefully calibrated weighing scale was used for the measurement of weight and for height, properly calibrated vertical instrument was used. The measurements included:
- height;
- weight;
- circumference at hips;
- circumference at waist
- blood pressure (both systolic and diastolic).

Derivations of measurements used in analysis

BMI [kg/m^2] was defined as the body mass divided by the square of the body height, and is expressed in units of kg/m^2, resulting from mass in kilograms and height in meters [10]. Formula:

mass [kg]/[height (in meters)^2]

Normal values:
- < 18.5 — underweight;
- 18.5–21.75 — normal (lower range);
- 21.75–25 — normal (upper range);
- 25–30 — overweight;
- > 30 — obese.

WHR was defined as the dimension less of the circumference of the waist to that of the hips [11].

Formula:

Circumference of waist/Circumference of hip

Normal values:
- < 0.75 underweight;
- 0.75–0.8 normal (lower range);
- 0.8–0.85 — normal (upper range);
- 0.85–0.9 — overweight;
- > 0.9 — obese.

Blood pressure [mm Hg], systolic (SBP) and diastolic (DBP), was taken three times and all three values were denoted in the records. The authors entered all three values and calculated the mean of it to put for further statistical analysis and results.

Statistical analysis was done with Microsoft Excel and SPSS 20. Statistical tests conducted:
- average;
- standard deviation;
- comparative analysis across ranges;
- standard error of the mean (SEM);
- confidence interval (95% CI);
- Pearson correlation (r value);
- statistically significant test (unpaired t test) (p-value);
- analysis of variance (ANOVA) (f statistics);
- charts and tables.

Results

Gender distribution in the study population is presented in Table 1.

Table 1. Sex distribution in the study population

	Females	Males	Total
Number of participants	481	465	946

Table 2. Blood pressure (BP) in females in different body mass index (BMI) ranges

	BMI					ANOVA F-statistics (p-value)
	< 18.50	18.50–21.75	21.75–25.00	25.00–30.00	> 30.00	
SBP						
Average	115.97	116.27	119.69	127.25	127.73	14.18 (< 0.0001)
SD	13.65	11.79	12.18	11.89	14.10	
N	126.00	157.00	102.00	67.00	26.00	
SEM	1.22	0.94	1.21	1.45	2.77	
95% CI	2.38	1.84	2.36	2.85	5.42	
DBP						
Average	74.98	75.05	78.17	84.49	85.23	12.59 (< 0.0001)
SD	11.24	9.70	11.00	8.29	13.32	
N	123.00	155.00	101.00	67.00	26.00	
SEM	1.01	0.78	1.09	1.01	2.61	
95% CI	1.99	1.53	2.15	1.99	5.12	
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	
R value = 0.249 (BMI *vs.* SBP) → R values = 0.267 (BMI *vs.* DBP)						

NR — normal; SBP — systolic blood pressure; DBP — diastolic blood pressure; SD — standard deviation; SEM — standard error of the mean; CI — confidence interval

Table 3. Blood pressure (BP) in males in different body mass index (BMI) ranges

	BMI					ANOVA F-statistics (p-value)
	< 18.50	18.50–21.75	21.75–25.00	25.00–30.00	> 30.00	
SBP						
Average	125.19	127.91	131.12	133.30	133.41	6.92 (< 0.0001)
Standard deviation	11.51	11.44	12.35	12.31	11.93	
N	79.00	105.00	132.00	97.00	39.00	
SEM	1.29	1.12	1.08	1.25	1.91	
CI95	2.54	2.19	2.11	2.45	3.74	
DBP						
Average	77.41	80.50	82.43	83.14	83.53	5.32 (< 0.0001)
SD	11.83	10.69	7.70	8.79	6.97	
N	75.00	105.00	129.00	94.00	36.00	
SEM	1.37	1.04	0.68	0.91	1.16	
95% CI	2.68	2.04	1.33	1.78	2.28	
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	
R value = 0.236 (BMI *vs*. SBP) → R values = 0.187 (BMI *vs*. DBP)						

NR — normal; SBP — systolic blood pressure; DBP — diastolic blood pressure; SD — standard deviation; SEM — standard error of the mean; CI — confidence interval

All data from the participants were gathered when they entered the Medical College as first-year students and hence all were from 17–19 age group.

Preliminary results and analysis

Table 2 and Table 3 provide sufficient evidence that in both males and females the average levels of both SBP and diastolic DBP are increasing with increasing ranges of BMI. Pearson's correlation test results [R value = 0.249 (BMI *vs.* SBP); R value = 0.267 (BMI vs. DBP)] (Fig. 1 and 2; Tab. 2) show that both SBP and DBP is positively correlated with BMI in female participants ($p < 0.0001$). In addition, the results of Pearson's correlation test [R value = 0.236 (BMI *vs.* SBP); R values = 0.187 (BMI *vs.* DBP)] (Fig. 3 and 4; Tab. 3) demonstrate considerable increases in SBP and DBP with increasing ranges of BMI in male participants ($p < 0.0001$).

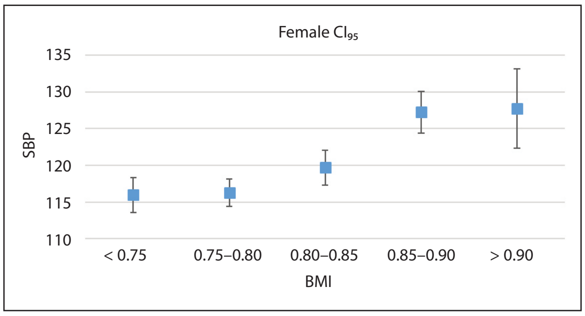

Figure 1. Confidence interval (CI) range and average in females. Systolic blood pressure (SBP) *vs*. body mass index (BMI)

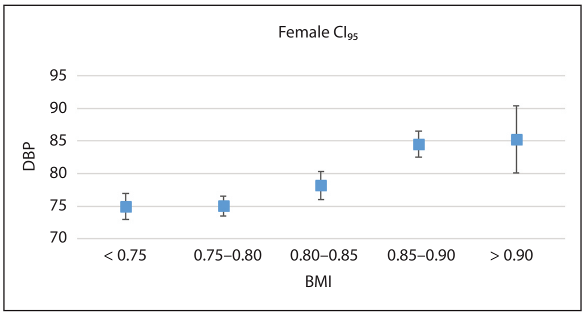

Figure 2. Confidence interval (CI) range and average in females. Diastolic blood pressure (DBP) *vs*. body mass index (BMI)

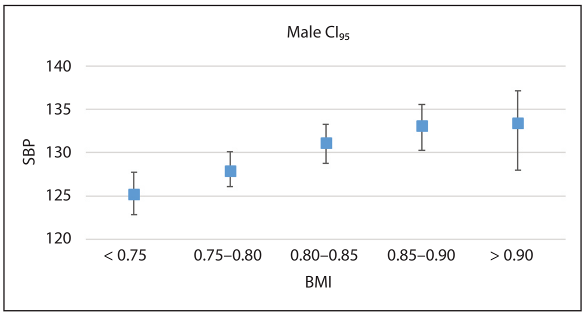

Figure 3. Confidence interval (CI) range and average in males. Systolic blood pressure (SBP) *vs*. body mass index (BMI)

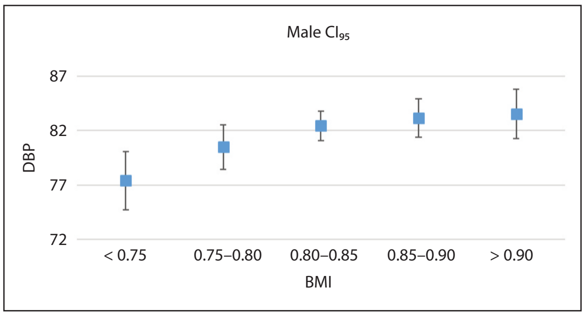

Figure 4. Confidence interval (CI) range and average in males. Diastolic blood pressure (DBP) *vs*. body mass index (BMI)

Table 4. Blood pressure (BP) in females in different waist-to-hip ratio (WHR) ranges

	WHR					ANOVA F-statistics (p-value)
	< 0.75	0.75–0.80	0.80–0.85	0.85–0.90	> 0.90	
SBP						
Average	117.44	119.32	120.17	122.29	124.12	2.69 (0.031)
SD	11.47	14.20	12.55	12.40	12.64	
N	95.00	135.00	133.00	66.00	42.00	
SEM	1.18	1.22	1.09	1.53	1.95	
95 % CI	2.31	2.40	2.13	2.99	3.82	
DBP						
Average	74.97	78.37	78.38	79.70	81.02	3.20 (0.013)
SD	10.55	12.16	9.09	10.16	10.66	
N	93.00	134.00	133.00	64.00	41.00	
SEM	1.09	1.05	0.79	1.27	1.66	
95% CI	2.14	2.06	1.54	2.49	3.26	
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	
R value = 0.090 (WHR *vs*. SBP) → R values = 0.187 (WHR *vs*. DBP)						

NR — normal; SBP — systolic blood pressure; DBP — diastolic blood pressure; SD — standard deviation; SEM — standard error of the mean; CI — confidence interval

Table 4 and Table 5 are sufficient to infer that in both males and females the average levels of both SBP and DBP are increasing with the increasing ranges of WHR. Pearson's correlation test results [R value = 0.090 (WHR *vs.* SBP); R values = 0.1157 (WHR *vs.* DBP)], (Fig. 5 and 6; Tab. 4) show that

Table 5. Blood pressure (BP) in males in different waist-to-hip ratio (WHR) ranges

	WHR					ANOVA F stat
	< 0.75	0.75–0.80	0.80–0.85	0.85–0.90	> 0.90	
SBP						
Average	122.50	125.66	128.60	131.53	132.85	5.67 (<0.0001)
SD	7.60	11.44	13.06	11.35	12.73	
N	16.00	47.00	87.00	136.00	145.00	
SEM	1.90	1.67	1.40	0.97	1.06	
95% CI	3.72	3.27	2.74	1.91	2.07	
DBP						
Average	77.87	79.45	80.28	81.13	83.16	2.40 (0.049)
SD	7.69	8.08	10.81	11.01	8.44	
N	15.00	47.00	83.00	134.00	141.00	
SEM	1.99	1.18	1.19	0.95	0.71	
95% CI	3.89	2.31	2.33	1.86	1.39	
p	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	
R value = 0.194 (WHRvsSBP) → R values = 0.148 (WHRvsDBP)						

NR — normal; SBP — systolic blood pressure; DBP — diastolic blood pressure; SD — standard deviation; SEM — standard error of the mean; CI — confidence interval

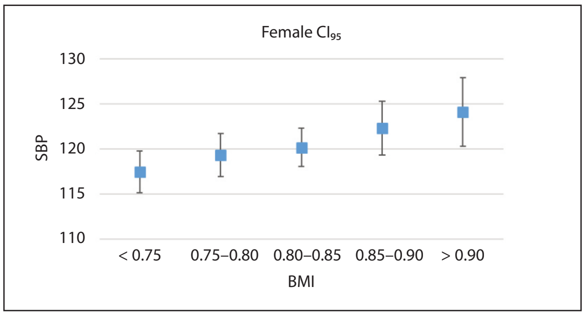

Figure 5. Confidence interval (CI) range and average in females. Systolic blood pressure (SBP) *vs*. waist-hip ratio (WHR)

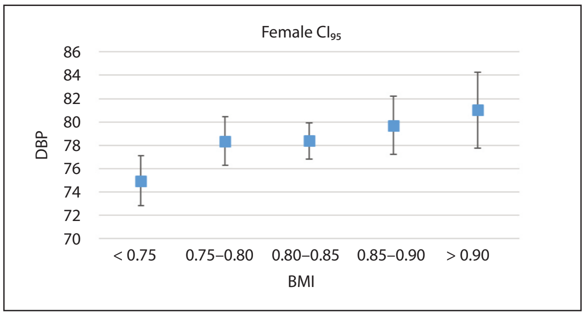

Figure 6. Confidence interval (CI) range and average in females. Diastolic blood pressure (DBP) *vs*.waist-hip ratio (WHR)

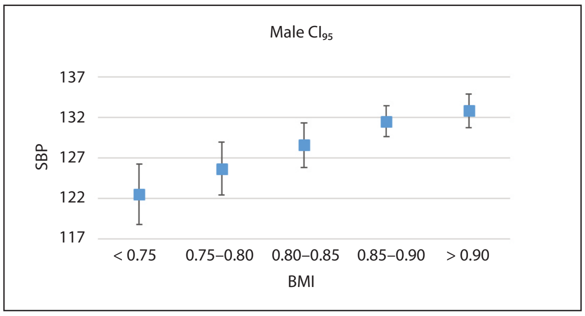

Figure 7. Confidence interval (CI) range and average in males. Systolic blood pressure (SBP) *vs*. waist-hip ratio (WHR)

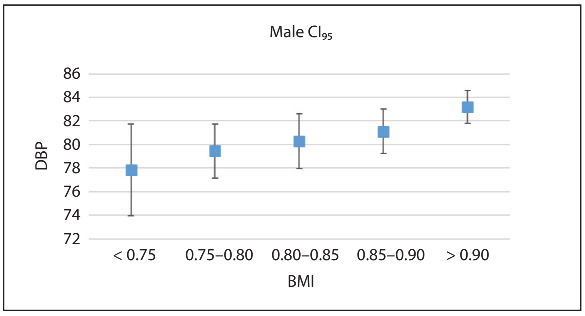

Figure 8. Confidence interval (CI) range and average in males. Diastolic blood pressure (DBP) *vs*. waist-hip ratio (WHR)

both SBP and DBP are positively correlated with WHR in female participants ($p < 0.0001$). In addition, the results of Pearson's correlation test [R value = 0.194 (WHR vs. SBP); R value = 0.148 (WHR *vs.* DBP)] (Fig. 7 and 8; Tab. 5) demonstrate considerable increases in SBP and DBP with increasing ranges of WHR in male participants ($p < 0.0001$).

Table 6. Relation between body mass index (BMI) and waist-to-hip ratio (WHR) in female patients

	BMI	WHR
BMI	1	
WHR	0.17	1

Table 7. Relation between body mass index (BMI) and waist-to-hip ratio (WHR) in male patients

	BMI	WHR
BMI	1	
WHR	0.23	1

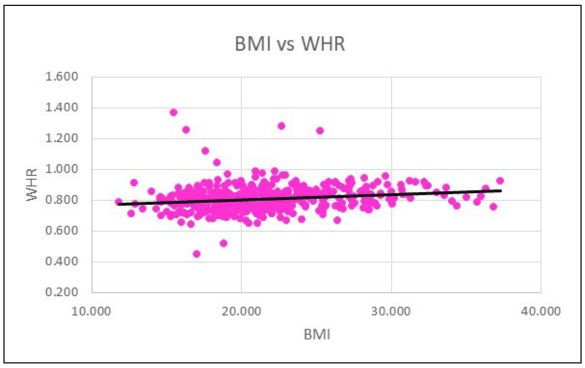

Figure 9. Relation between body mass index (BMI) and waist-to-hip ratio (WHR) in female patients

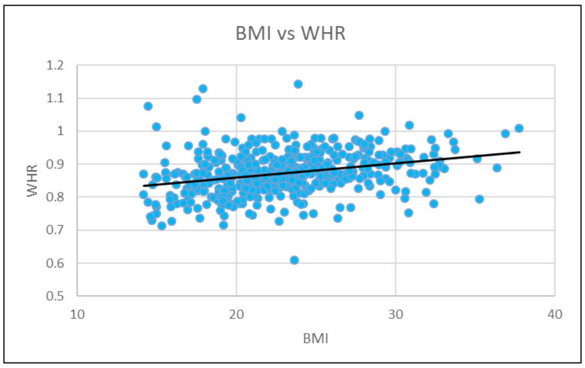

Figure 10. Relation between body mass index (BMI) and waist-to-hip ratio (WHR) in male patients

Table 6 and Figure 9 show the relation between BMI and WHR in female patients, assessed using Pearson's correlation coefficient (R value), and Table 7 and Figure 10 show the relation between BMI and WHO in male patients.

Table 6, Figure 9, Table 7 and Figure 10 show that in both males and females BMI is correlated with WHR and both show similarity in trends, as the Pearson's correlation coefficient although weak is still positive.

Discussion

While formulating comparison with research papers which try to show relationship between blood pressure and BMI, it was found that the results are aligned with a similar study on older study sample in Chinese population (mean age was 55.7 ± 9.8) [12], on Italian population (mean age was 55.4 ± 15) [13], and in Ghana (age groups 30–50) [14]. All of these studies indicate a direct increase in both SBP and DBP with increasing BMI ranges.

In a comparative study conducted by WHO [15] between different ethnicities of developing country, it was seen that BP was positively correlated with age and BMI, but almost no correlation was found between BMI and age itself or it was negative. A comparative study conducted in Africa [16] on lean population (BMI range 20–28) from Nigeria, Cameroon, Zimbabwe and Jamaica, a nonlinear (instead of linear [15]) was found between BMI and BP, which is the same trend as seen in our study. Similar trends of BMI and BP relations are seen in studies conducted in South Asia (stronger correlation at low cut off points of overweight) [17] and in Delhi, India (age group 18–50 showing pre-hypertensive conditions are correlated with BMI) [18] and in North-East India (where odd ratios showed overweight/obese subjects to be more likely to have hypertension than those with normal BMI) [19].

A study conducted on urban population of India suggested that BP correlates with BMI, weight and WHR but not with age and height [20] in contrast to papers [12–14, 18] where age was a factor affecting BP. A South African study on young women both waist circumference and hip circumference were correlated with pre-hypertension and hypertension [21]. Another study suggested that WC and WHR are positive correlation with BP and hence concludes that abdominal obesity may be considered as an important risk factor of CVD. The study suggested that WC and WHR has positively correlated with BP and hence concludes that abdominal obesity may be considered as an important risk factor of CVD [22].

A research conducted at NTB general hospital in Indonesia [23] found that BMI was not correlated with BP (was not statistically significant;

the results were mainly because study sample was smaller (61) and all patients were selected based on the criterion that they were already in the cardiology department due to hypertension), and another research found that in middle-aged men, a central distribution of body fat is associated with increased BP, independently of body mass index and insulin resistance [24].

A study published in *International Journal of Contemporary Pediatrics*, which is very close to our research design, showed that increased BMI and WC are good predictors of the increase in SBP and DBP. The authors suggested measurement of WC as a screening tool for childhood hypertension, because WC is easier to measure than blood pressure in terms of training and access to equipment [25]. Another similar study which was published in Nature News also came to a conclusion that BMI and WHR are strongly correlated with pre-hypertensive and hypertensive conditions and they found that BMI is superior than WHR in predicting elevated BP [26].

The above discussion suggests that weak correlation can be established between BMI and WHR, which means that both are interdependent. BMI and WHR are interdependent but the correlation coefficient is so weak that in clinical practice they can be taken as independent factors without any significant change in clinical outcome.

This also gives sufficient evidence to state that blood pressure increases with increasing BMI and WHR, even in healthy adolescents and young adults without any type of co-morbidity. Nowadays, it is generally seen that WHR is considered more important while assessing risk of chronic diseases as, arguably, BMI does not differentiate between fat weight, muscle weight and bone weight. However, looking at the trends of Pearson's correlation coefficient (R value), the correlation of BMI with blood pressure (both SBP and DBP) is stronger than that of WHR. Although R value for both BMI and WHR is not that strong, R value for BMI is higher in both males and females than for WHR.

The point is that the cardiovascular system is young and the most compliant and fresh without any morbidity. It can be thought of as the healthiest it will ever be. Most elastic and resilient it will ever be, and yet, the variation in both SBP and DBP was significant. With progressive damage and wear and tear of cardiovascular system and end-organ damage at multisystem level, in elderly the whole situation would be seen amplified. If small changes with different BMI and WHR ranges are so evident at young age, these changes will be multiplied largely with small changes in BMI and WHR at older ages when cardiovascular system's function will be diminished. This result and hypothesis can be taken into consideration as an interventional type of study to educate people in how maintenance of their health and body weight is important, as they can lead to disastrous outcomes with passing of time. If adolescent show this much changes of average ±10 mm Hg with the whole range of BMI and WHR, it would make a difference of hypotensive to hypertensive in elderly which can alter their whole lifestyle and survival rate. With diseases involving blood pressure, it is a matter of time that a patient would succumb to other chronic diseases namely coronary artery disease, type 2 diabetes mellitus, nephropathies, end-organ damage, vascular diseases, aneurysms, and other deadly conditions with lesser and lesser survival rate.

Conclusion

With increasing body weight or BMI or WHR, average blood pressure (both SBP and DBP) increases significantly even in young adults and adolescents. BMI and WHR show a weak but positive correlation with SBP and DBP and can be considered independent tools and separate entities when the need of using them in clinical practice arises. BMI has been found to be more reliable in assessing future risk of chronic disease than WHR.

Limitations

There are limitations of this study:

- small sample size: anthropometric researches usually require a very large sample size and even though we got statistically significant result, a larger sample size would mean a better estimation of actual average and hence a more accurate model;
- less randomization in sample: students whose data was actually used, although belonging to a wide range of population and representative of all strata, still the students belonged to the same country; additionally similar data of various countries could be taken here for a better applicability of the model

Further studies and interventions are suggested:

- a larger sample size can be taken for anthropometrical study like this;

- interventional study can be taken up with similar risk group and genetic disposition patient (future patients) and can be compared with a control group.

Longitudinal study on same study cohorts can yield better and more accurate findings for future predictions. (This study sample were medical students and, in their training, they will have mainly sedentary lifestyle resulting in weight gain. Another study can be organized here with main focus on the effects of primary prevention (life style changes) and its efficacy.)

Data availability

Availability of data and materials: the datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request

Conflict of interests

The authors declare that they have no competing interests.

Funding

None declared.

Authors' contributions

D.D. digitalized the data from the records and then analyzed it, made results and was major in writing the manuscript. A.S. was key in analysis of the data and writing of manuscript.

Ethical consideration

The research protocol was waived by relevant institutional review boards as it was a record-based study, and the authors have no conflict of interest to declare. The authors have not received any funding from anyone for this research project and have no financial dilemma.

References

1. Know Your Risk for Heart Disease [Internet]. Centers for Disease Control and Prevention. Centers for Disease Control and Prevention; 2019 . https://www.cdc.gov/heartdisease/risk_factors.htm#:~:text=High blood pressure is a,including your kidneys and brain (2021 Apr 23).
2. Bourgeois B, Watts K, Thomas DM, et al. Associations between height and blood pressure in the United States population. Medicine (Baltimore). 2017; 96(50): e9233, doi: 10.1097/MD.0000000000009233, indexed in Pubmed: 29390353.
3. Gertler MM, Garn SM, White PD. Young candidates for coronary heart disease. J Am Med Assoc . 1951; 147(7): 621–625, doi: 10.1001/jama.1948.02900060067036, indexed in Pubmed: 14873513.
4. Influence of Height, Weight and Age on Blood Pressure. Acta Medica Scandinavica. 2009; 157: 165–207, doi: 10.1111/j.0954-6820.1957.tb04117.x.
5. Korhonen P, Kautiainen H, Eriksson J. The shorter the person, the higher the blood pressure. J Hypertens. 2017; 35(6): 1170–1177, doi: 10.1097/hjh.0000000000001300, indexed in Pubmed: 28441691.
6. Langenberg C, Hardy R, Breeze E, et al. Influence of short stature on the change in pulse pressure, systolic and diastolic blood pressure from age 36 to 53 years: an analysis using multilevel models. Int J Epidemiol. 2005; 34(4): 905–913, doi: 10.1093/ije/dyi071, indexed in Pubmed: 15833796.
7. Staessen J, Fagard R, Amery A. The relationship between body weight and blood pressure. J Hum Hypertens. 1998; 2(4): 207–2017, indexed in Pubmed: 3070038.
8. Blood pressure studies in children : report of a WHO study group [meeting held in Geneva from 3 to 5 November 1983] World Health Organization. World Health Organization; 1985. https://apps.who.int/iris/handle/10665/38819 (2021 Apr 23).
9. Park K. Park's textbook of reventive and social medicine. 25th ed. Banarsidas Bhanot Publishers 2019.
10. Body Mass Index (BMI) [Internet]. Centers for Disease Control and Prevention. 2022 . https://www.cdc.gov/healthyweight/assessing/bmi/index.html (2022 Feb 3).
11. Waist-to-Hip Ratio: Chart, Ways to Calculate, and More [Internet]. Healthline. 2022. https://www.healthline.com/health/waist-to-hip-ratio (2022 Feb 3).
12. Linderman G, Lu J, Lu Y, et al. Association of Body Mass Index With Blood Pressure Among 1.7 Million Chinese Adults. J Am Med Assoc. 2018; 1(4): e181271, doi: 10.1001/jamanetworkopen.2018.1271, indexed in Pubmed: 30646115.
13. Landi F, Calvani R, Picca A, et al. Body Mass Index is Strongly Associated with Hypertension: Results from the Longevity Check-up 7+ Study. Nutrients. 2018; 10(12), doi: 10.3390/nu10121976, indexed in Pubmed: 30551656.
14. Vuvor F. Correlation of body mass index and blood pressure of adults of 30–50 years of age in Ghana. J health Res Rev Dev Countries. 2017; 4(3): 115–121, doi: 10.4103/jhrr.jhrr_93_16.
15. Who.int. 2021. https://www.who.int/ncds/surveillance/steps/EthiopiaSTEPSPaper.pdf (2021 Apr 23).
16. Kaufman J, Asuzu M, Mufunda J, et al. Relationship Between Blood Pressure and Body Mass Index in Lean Populations. Hypertension. 1997; 30(6): 1511–1516, doi: 10.1161/01.hyp.30.6.1511, indexed in Pubmed: 9403575.
17. Hossain FB, Adhikary G, Chowdhury AB, et al. Association between body mass index (BMI) and hypertension in south Asian population: evidence from nationally-representative surveys. Clin Hypertens. 2019; 25: 28, doi: 10.1186/s40885-019-0134-8, indexed in Pubmed: 31890277.
18. Dua S, Bhuker M, Sharma P, et al. Body mass index relates to blood pressure among adults. N Am J Med Sci. 2014; 6(2): 89–95, doi: 10.4103/1947-2714.127751, indexed in Pubmed: 24696830.
19. Mungreiphy NK, Kapoor S, Sinha R. Association between BMI, Blood Pressure, and Age: Study among Tangkhul Naga Tribal Males of Northeast India. J Anthropol. 2011; 2011: 1–6, doi: 10.1155/2011/748147.
20. Gupta R, Mehrishi S. Waist-hip ratio and blood pressure correlation in an urban Indian population . J Indian Med Assoc. 1997; 95(7): 412–415, indexed in Pubmed: 9425839.
21. Nkeh-Chungag BN, Mxhosa TH, Mgoduka PN. Association of waist and hip circumferences with the presence of hypertension and pre-hypertension in young South African adults. Afr Health Sci. 2015; 15(3): 908–916, doi: 10.4314/ahs.v15i3.27, indexed in Pubmed: 26957981.
22. Jena S. Correlation of abdominal obesity indices with blood pressure in young adults: A cross-sectional study. Adv Human Biol. 2018; 8(1): 46, doi: 10.4103/aihb.aihb_50_17.
23. Ehma HA, Pintaningrum Y, Syamsun A. Relationship Between Body Mass Index (BMI) and Blood Pressure in NTB General Hospital. J Hypertens . 2015; 33: e21, doi: 10.1097/01.hjh.0000469791.47704.e5.
24. Siani A, Cappuccio F, Barba G, et al. The relationship of waist circumference to blood pressure: the Olivetti heart study1. Am J Hypertens. 2002; 15(9): 780–786, doi: 10.1016/s0895-7061(02)02976-x, indexed in Pubmed: 12219872.

25. Dwivedi G, Sethi S, Singh R, et al. Association of blood pressure with body mass index and waist circumference in adolescents. Int J Contemp Pediatrics. 2016: 971–976, doi: 10.18203/2349-3291.ijcp20162375.
26. Kuciene R, Dulskiene V. Associations between body mass index, waist circumference, waist-to-height ratio, and high blood pressure among adolescents: a cross-sectional study. Sci Rep. 2019; 9(1): 9493, doi: 10.1038/s41598-019-45956-9, indexed in Pubmed: 31263167.