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Research Article

Correlation of Body Mass Index and Puberty with Blood Pressure in Healthy Adolescents

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ABSTRACT

Background: Limited research in the Indian population hinders our understanding of how blood pressure is influenced by factors such as body mass index and puberty.

Objective: To study the relation of body mass index and pubertal stage with blood pressure in healthy adolescents.

Methods: The study design was an observational descriptive study. Participants included 518 adolescents aged 10 to 18 years at Kalawati Saran Children's Hospital, with representation from each pubertal stage. The primary outcome aimed to examine the correlation between body mass index and blood pressure, particularly within different pubertal stages. The secondary outcome focused on the correlation between height and blood pressure, as well as the development of a blood pressure nomogram based on body mass index.

Results: Height showed a significant ($p < 0.05$) positive correlation with systolic ($r = 0.604$ in males, $r = 0.509$ in females) and diastolic blood pressure ($r = 0.566$ in males, 0.488 in females). The body mass index positively correlated with systolic ($r = 0.356$ for males, $r = 0.366$ for females) and diastolic blood pressure ($r = 0.336$ for males, $r = 0.435$ for females). Percentiles for systolic and diastolic blood pressure were calculated across different body mass index and height groups for both males and females. Correlation coefficients between puberty and systolic blood pressure were 0.5 ($p < 0.01$) and 0.4 ($p < 0.01$) in males and females, and for diastolic blood pressure were 0.4 ($p < 0.01$) for both genders.

Conclusion: A positive correlation exists between systolic and diastolic blood pressure with height, body mass index and all pubertal stages in both males and females in all age groups.

Keywords: Adolescent, Blood Pressure, Body Mass Index, Observational Descriptive Study, Puberty, Tanner Staging

Introduction

The measurement of blood pressure constitutes a crucial component of routine pediatric physical examinations. According to the National Institute of Health, it is recommended that blood pressure measurements be incorporated into regular examinations, with the frequency set at a minimum of once per year.[1] Adjusting blood pressure values for weight, height, age, and gender is crucial to prevent misclassification in children at extreme growth levels. Height is a more suitable indicator of blood pressure change, which is why blood pressure norms for children consider age, gender, and height simultaneously.[2] Various studies done in different parts of the world showed a positive correlation of systolic and diastolic blood pressure with height, weight, and body mass index of adolescents.[3,4] Blood pressure increases at an accelerated rate during puberty, and acceleration is more in males than in females.[5] However, this practice has not been implicated in many parts of the world including India. We hypothesized that body mass index and pubertal growth influence values of blood pressure in adolescents.[6–8] Numerous studies have explored the correlation between body mass index and blood pressure in healthy adults. However, a notable research gap exists in the context of healthy adolescents within the Indian population, specifically in the absence of blood pressure nomograms based on body mass index for this demographic. By investigating the influence of body mass index and pubertal stages on blood pressure, our study aims to provide valuable insights that will enhance the accurate identification of abnormal blood pressure values in adolescents and improve the interpretation of blood pressure measurements within this age group. Consequently, our research focuses on examining the interplay between body mass index, puberty, and blood pressure in healthy adolescents.

Materials and Methods

We conducted an observational descriptive study among adolescents (10–18 years) attending the outpatient department for minor illnesses or as accompanying persons at the Center of Adolescent Health, Department of Pediatrics, Kalawati Saran Children's Hospital and Lady Hardinge Medical College, New Delhi, between November 2017 and March 2019. The study protocol was approved by the institutional ethics committees. A sample of 518 adolescents was taken in various groups (Figure 1). However, we excluded adolescents with known hypertension and kidney disease, those on steroids and cyclosporine or any drug influencing blood pressure, and those with limb deformities. Eligible participants were recruited consecutively after obtaining written informed consent from their parents or caregivers. Verbal assent was obtained from children aged more than 10 years.

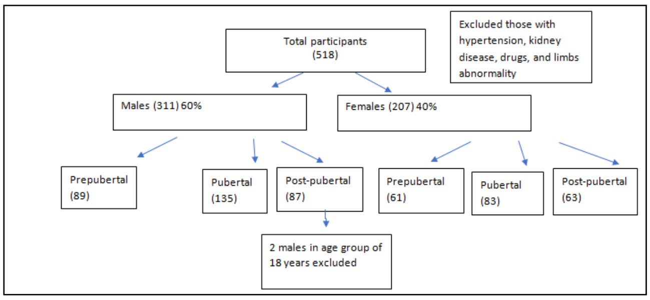

Figure 1.Eligibility Criteria Showing the Inclusion and Exclusion Criteria

Participants were asked to remove their heavy outer garments and shoes, and then their weight was recorded to the nearest 100 g using electronic scales. For measuring height, each participant was asked to stand with their back to the height rule. The back of the head, back, buttocks, calves, and heels should be touching the upright, feet together, looking straight in Frankfurt's plane (i.e., a plane passing through the top of the external auditory meatus and the inferior margin of the bony orbit). The headpiece of the stadiometer was lowered so that the hair was pressed flat. Height was recorded to the resolution of the height rule (i.e., nearest 1 mm). Body mass index was calculated in kg/m² and classified according to the WHO growth standards.

Blood pressure was measured using an aneroid manometer (Heine Gamma G5) on the right upper arm with an appropriately sized cuff to cover at least 40% of the arm circumference, at a point midway between the olecranon and the acromion. Each subject was allowed to sit calmly for 5 minutes with their back supported, feet on the floor, and right arm supported. After applying the cuff snugly over the cubital fossa of the right arm at heart level, the bladder was inflated 30 mmHg above the point when the radial pulse was no longer palpable. Systolic blood pressure was recorded at the onset of the "tapping" Korotkoff sound (K1), and diastolic blood pressure was recorded at the disappearance of the Korotkoff sound (K5). At least two readings 1–2 minutes apart were taken, and the average of the two readings was recorded.

We noted the pubertal stages using Tanner's staging after providing appropriate privacy and obtaining verbal consent. Adolescents who declined a genital examination were asked to complete a picture-based questionnaire.

The primary outcome was to study the association between body mass index and pubertal stage in healthy adolescents. The secondary outcomes were to study the association of height and blood pressure in healthy adolescents and to create blood pressure nomograms according to body mass index.

Statistical Analysis

Age was considered as age on the last birthday. As only two subjects were in the age group of 18 years, they were not included in the data analysis. Thus, study subjects from 10 to 17 years were included in the data analysis and in making the nomograms. Data analysis was done using STATA software. Descriptive analysis was conducted, and the correlation of various determinants of blood pressure with measured blood pressure was calculated. Correlations were determined using the Pearson correlation coefficient. Percentiles of blood pressure (nomograms) were calculated according to height and body mass index values. The chi-square test and t-test were used for the comparison of proportions and means, respectively. A p value of less than 0.05 was considered significant. Data confidentiality was ensured as the identity of the subjects was not revealed. Prior permission from the Ethics Committee for Human Research was obtained before the study began.

Results

Out of the 518 participants, 311 (60%) were males and 207 (40%) were females, with mean ages of 13.17 ± 2.15 years for males and 13.3 ± 2.5 years for females. The median age for the entire cohort was 13 years. Participants were categorized into three groups based on pubertal maturity: pre-pubertal (29%, n = 150), pubertal (42%, n = 218), and post-pubertal (29%, n = 150). In terms of anthropometric measurements, males exhibited a higher mean height (155.9 ± 12.9 cm) compared to females (149.9 ± 9.2 cm). The mean weight for males was 45.08 ± 12.7 kg, while for females, it was 41.5 ± 9.8 kg. Body mass index (BMI) was slightly higher in males (18.26 ± 3.4 kg/m^2) than in females (18.29 ± 3.1 kg/m^2).

Our study revealed a statistically significant positive correlation ($p < 0.05$) between height and BMI with systolic and diastolic blood pressure in both males and females. Pearson correlations between height and blood pressure were strong in males (systolic: r = 0.604, diastolic: r = 0.566) and moderate in females (systolic: r = 0.509, diastolic: r = 0.488). BMI also had moderate positive correlations (males - systolic: r = 0.356, diastolic: r = 0.366; females - systolic: r = 0.336, diastolic: r = 0.435), indicating that higher BMI was associated with increased systolic and diastolic blood pressure.

Correlation coefficients of BMI with systolic blood pressure were statistically significant with a $p < 0.05$ in all age groups except 14-15 and 15–16 years. Similarly, correlation coefficients of diastolic blood pressure in various age groups were also statistically significant with a p value of less than 0.05 in all age groups except 13–14, 14–15, and 15–16 years suggesting as the BMI increase systolic and diastolic blood pressure also increases but only to a small extent and this increase may not be visible as the age increases as depicted in Table 1.

Percentile charts for systolic and diastolic blood pressure were constructed within distinct height and BMI categories for both males and females. As body mass index rises, systolic and diastolic blood pressure also increase within the same percentile group for both genders as shown in Tables 2 and 3.

Table 1.Pearson's Correlation of Body Mass Index with Systolic and Diastolic Blood Pressure in Different Age Groups

Age (in years)	10–11	11–12	12–13	13–14	14–15	15–16	16–17
BMI and SBP	0.304	0.448	0.425	0.291	0.130	0.016	0.478
t test p value	0.000	0.000	0.000	0.016	0.390	0.907	0.000
BMI and DBP	0.365	0.513	0.491	0.185	0.137	0.05	0.465
t test p value	0.000	0.000	0.000	0.132	0.362	0.717	0.000

Table 2.Percentile Nomogram Charts for Systolic and Diastolic Blood Pressure in Different BMI Groups in Males

BMI (kg/m^2)	Diastolic Blood Pressure				Systolic Blood Pressure			
	5th	50th	95th	97th	5th	50th	95th	97th
11–15	58.2	62	74.6	80.76	92	102	125.6	127.48
16–20	60	69	81	81.86	98	110.5	128	131.93
21–25	60.6	70	82	84.44	100	112	128.75	133.64
26–30	64	70.5	85	85	104	121	131	131.90

Table 2.Percentile Nomogram Charts for Systolic and Diastolic Blood Pressure in Different BMI Groups in Females

BMI (kg/m^2)	Diastolic Blood Pressure				Systolic Blood Pressure			
	5th	50th	95th	97th	5th	50th	95th	97th
11–15	59	62	72.2	74.59	91.45	102	119.55	120.53
16–20	59.75	63	75.8	78.56	94	103	120	123.84
21–25	60.6	70	80	80.25	100	112	120.4	129
26–30	70	73	83	83.75	111	120	133	133

Moreover, we observed a significant positive correlation between sexual maturity rating and systolic blood pressure, with Pearson correlation coefficients of 0.566 in males and 0.481 in females, as well as with diastolic blood pressure, exhibiting Pearson correlation coefficients of 0.485 in males and 0.495 in females, all of which were statistically significant at $p < 0.05$. Our study demonstrated that height, BMI, and sexual maturity ratings were positively associated with systolic and diastolic blood pressure. The strength of these associations varied from mild to moderate, and percentile charts for blood pressure in different BMI groups were established.

Discussion

In our study, we identified a statistically significant positive correlation between systolic blood pressure (SBP) and diastolic blood pressure (DBP) with height and body mass index (BMI) in both males and females. This correlation remained consistent across all age groups, indicating the influence of these anthropometric factors on blood pressure. Notably, the strength of this association varied among different age groups, potentially due to sample size variations.

Our findings align with previous research. Studies by Sayemmuddin et al.[9] (r = 0.9 SBP with height and r = 0.8 DBP with height) showed a positive correlation between height BMI and blood pressure. Anand et al.[1] also found that SBP and DBP both showed a positive correlation with BMI, age, height and weight (Pearson's correlation coefficients: 0.29, 0.12, 0.40, 0.33, respectively) ($p < 0.05$). Bahl et al.[6] found that a statistically significant positive correlation of systolic blood pressure was seen with weight ($r = 0.4$; $p < 0.001$), height ($r = 0.2$; $p < 0.001$), and BMI ($r = 0.3$; $p < 0.001$). Diastolic blood pressure was positively correlated with weight ($r = 0.4$; $p < 0.001$), height ($r = 0.3$; $p < 0.001$), BMI ($r = 0.3$; $p < 0.001$). Goel et al.,[7] Al-Bachir and Bakir,[10] and Saha et al.[8] also demonstrated positive correlations between height, BMI, and blood pressure parameters. Additionally, Taksande et al.[11] and Ramalingam and Chacko[12] reported similar positive associations. A comparison of the correlation coefficient between systolic and diastolic blood pressure with height and body mass index in our study versus various studies is shown in Table 4.

Furthermore, our study explored the correlation between sexual maturation stages (SMR) and blood pressure, with significant correlations observed in both males and females. Chen and Wang[13] research supported the influence of the Tanner stage on blood pressure, particularly in girls.

Our study reaffirmed the trend of increasing SBP and DBP with advancing Tanner stages from 1 to 5 in both genders, consistent with Shankar et al.[14] findings. Tu et al.[15] highlighted the relevance of pubertal growth spurts in the rate of change in systolic blood pressure. Marlatt et al.[16] also emphasized the impact of Tanner stages on blood pressure, particularly DBP.

One of the strengths of our study is that it sheds light on the impact of body mass index on blood pressure, which can aid in the more accurate identification of abnormal blood pressure values in adolescents. Furthermore, our research contributes to the development of blood pressure nomograms based on body mass index, which is currently lacking for the Indian population, although we acknowledge limitations, including a relatively small sample size and potential discrepancies in self-reported Tanner stages affecting our results.

Table 4.Comparison of the Correlation Coefficient between Systolic and Diastolic Blood Pressure with Height and Body Mass Index in Our Study versus Various Other Studies

Sources	SBP				DBP			
	Height		BMI		Height		BMI	
	F	M	F	M	F	M	F	M
Anand et al.[1]	0.40		0.29		0.29		0.23	
Sayeemuddin et al.[9]	0.93	0.91	0.82	0.83	0.88	0.92	0.85	0.89
Goel et al.[7]	Not stated		r = 0.701		Not stated		r = 0.664	
Taksande et al.[11]	0.39		0.16		0.31		0.14	
Ramalingam et al.	0.333		0.388		0.298		0.381	
Bahl et al.[6]	r = 0.2; p < 0.001		r = 0.3; p < 0.001		r = 0.3; p < 0.001		r = 0.3; p < 0.001	
Our study	0.5	0.6	0.5	0.6	0.4	0.5	0.4	0.3

Recommendation

Studies with an adequate number of adolescents in various pubertal stages should be conducted to better elucidate the effects of puberty on blood pressure as data is lacking in the Indian population.

Conclusion

Our study found a significant positive correlation between systolic and diastolic blood pressure and height, as well as body mass index, in both males and females. Additionally, we observed a positive correlation between puberty and blood pressure across all age groups in both genders. As Tanner stages progressed from stage 1 to stage 5, mean systolic and diastolic blood pressure increased in both males and females. It's important to note that adolescents of the same age but in different pubertal stages may have varying blood pressure values, although a definitive relationship is yet to be established.

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Conflict of Interest: None

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