ORIGINAL ARTICLE

Body Mass Index, Blood Pressure, and Hypertension Risk: A Regression Analysis Among Adolescents in a North Indian City

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Abstract
Teens who are overweight have a higher likelihood of becoming obese adults as they get older, which increases their risk of developing a variety of ailments. Growing the amount of physical activity among adolescents between the ages of 11 and 17 requires immediate attention, based on global trends for teens who participate in insufficient physical activity. The objective of the study was to test the relationship between BMI and blood pressure, as well as to provide recommendations for preventing adolescent hypertension. This cross sectional study was conducted among 800 students between the ages of 12 and 14 years. It was found that the population's average BMI was 18.89± 3.9 kg/m2. BMI and blood pressure were shown to be significantly correlated. For the systolic and diastolic blood pressure of teenagers in the study, a significant logistic regression was obtained (R2 = 0.130, p 0.00), and (R2= 0.047, p 0.00), respectively. This is essential for early prevention due to the increase in non-communicable diseases, which can be achieved through IEC activities and raised awareness by children

Keywords
Adolescents, Blood pressure, BMI, Hypertension, School Going

Introduction
There has been a notable transition from communicable to non-communicable diseases in developing countries, whereas the developed countries have already gone through it. While emerging nations are following this trend, developed countries have already made this transformation. The contemporary lifestyle is associated with a higher risk of heart disease and hypertension. The estimated prevalence of systemic HT is 1%–2% in wealthy nations and 5%–10% in poor nations like India. One of the major changes that have occurred in this transition is the lack of physical activity leading to higher prevalence of overweight population and co-morbidities. Obesity and hypertension have been recognized as an important factor behind

causation of cardiovascular diseases(1). Children and adolescents who are overweight are more likely to grow up to become obese adults which puts them at the risk of various health problems (2). The risk factors for development of hypertension are many, which include lack of physical activity, diet, stress, family history and presence of obesity, etc(1). The root cause of hypertension being prevalent is that it usually goes undetected during adolescent period and hence increased blood pressure during adolescence leads to adults being hypertensive later on in their life(3). Age, weight, height, sex, family history, socio-economic status, dietary habits and Body Mass Index (BMI) all have an influence on blood pressure. It has also been recommended that blood pressure should be recorded along will all other anthropometric measurements among children more than 6 years of age at least once in a year, but this practice has not been implemented in our country as of yet (4). Additionally, there have been a lot of research regarding the relationship between BMI and blood pressure among adults, however, not among adolescents. Hence this study was done to address the research gap regarding the relationship of blood pressure and BMI among school going adolescents. Th e objectives of the study were: To find out the mean Body Mass Index (BMI) of school going adolescents, to find out mean systolic and diastolic blood pressure of school going adolescents, to analyze the effect of BMI on blood pressure of study population and to suggest ways through which we can prevent the emergence of hypertension among adolescents.

Material & Methods

Study design & setting: The cross sectional study was carried out at Aligarh Muslim University's (AMU) high school, Aligarh, a city in North India, from July 2018 to June 2019. Selected schools had recess during the working days, along with physical education classes in their curriculum. The AMU currently maintains six high schools, including three male and three female schools.

Selection of participants: The participants were selected using simple random sampling with a table of random numbers which students could choose. The selected students were aged between 12 to 14 years and had to be present on the day of examination and had willingness to participate in the examination. Whereas, the exclusion criteria were children aged less than 12 years and more than 15 years, not willing to participate, absent on the day of examination, uncooperative, and suffering from chronic illness, endocrine problems, physical and mental problems.

The study was carried out after getting the approval of the Institutional Ethical Committee, Faculty of Medicine, Aligarh Muslim University, Aligarh (D. No. 1006/FM; Dated: 13.7.2018). Written consent was obtained prior to the research from the principals of the relevant schools through the School Education Directorate of AMU, along with consent from at least one of the students' wards. The respondents informed their assent for participation orally. Those who did not give their assent were excluded from the research. Students were assured about the confidentiality of the information and their identity during the examination and interview. The questionnaire consisted of three sections: information regarding their socio demographic factors (part 1) and anthropometric measurements including record of Body Mass Index(5) (part 2), and blood pressure (part 3). Body Mass Index was Defined as a person's weight in kilograms, divided by person's height in meters squared.

Blood pressure (6) was measured by an aneroid meter calibrated before taking the readings with an age appropriate cuff with an inflatable bladder; at least 40 percent of the arm circumference at a point midway between Olecranon and Acromion processes. Blood pressure was recorded in the sitting position in the right arm to the nearest 1mm Hg using an electronic machine. Two readings were taken 5 minutes apart and the mean of the two was taken as the blood pressure. Taking absolute allowable error as 3% with a confidence level of 95%, the sample size was calculated as per the formula: $n=Z^2PQ/L^2$ Where, n = sample size, Z=Value of the standard normal variable at 0.05 level of significance (1.96) P= Prevalence of physical inactivity among school going children as 21% (7), Q= 1-P, L= Absolute

allowable error as 3% Along with 10% non-response rate, The sample size (n) came out to be 709, which was rounded off to 800. During collection of data, if a medical problem was diagnosed, the respondents received appropriate medical advice. Health education and advice were provided to all respondents.

Data analysis:

The statistical analysis was done in IBM SPSS version 20.0. The mean age of the male and female population in the study was determined using mean values and frequency tables. The association between adolescent blood pressure and BMI were analyzed using the correlation and chi square tests. The variables mentioned above were added to simple linear regression in order to predict the trends in adolescent blood pressure.

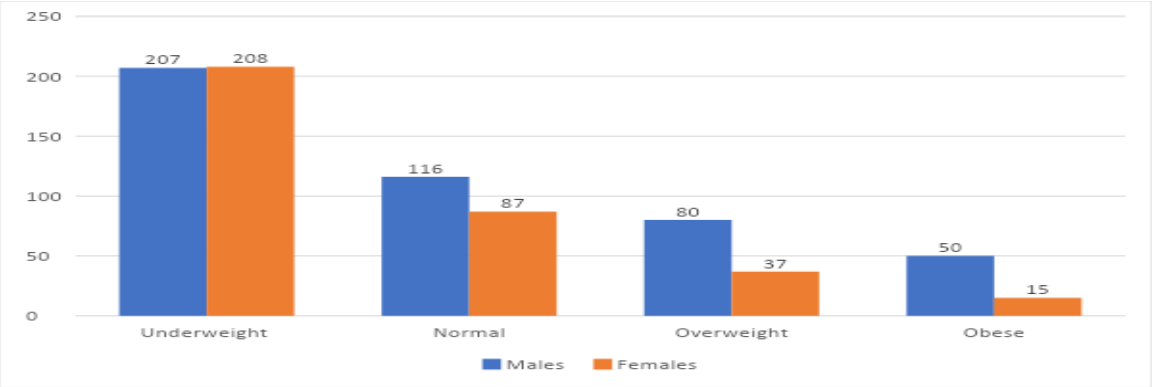
RESULTS

Table 1 shows that the majority (42.6%) of the respondents was in the 12- year age group as a new academic session just started at the time of study. The mean age of the respondents was between 12±0.81 years. Figure 1 shows that in 45.7% of cases, male students are classified as underweight, in 25.6% as normal weight, in 17.7% as overweight, and in 11.0% as obese. The majority of female students- 59.9% - were found to be underweight, with normal weight students (25.1%), overweight students (10.7%) and obese students (4.3%) following in proportion. Overall, there are 51.9% of pupils who are underweight, 25.4% normal weight, 14.6% overweight, and 8.1% obese.

TABLE 1: Socio Demographic Distribution of Study Population

Characteristics	Frequency (N)	Percentage (%)
Age (in years)		
12	341	42.6
13	244	30.5
14	215	26.9
Sex		
Male	453	56.6
Female	347	43.4
Father's education		
Illiterate	72	9
Primary	70	8.8
High school	112	14
Intermediate	138	17.3
Graduate	408	51
Mother's education		
Illiterate	137	17.1
Primary	88	11
High school	163	20.4
Intermediate	131	16.4
Graduate	281	35.1
Father's occupation		
Unskilled	242	30.3
Semi- skilled	27	3.4
Skilled	164	20.5
Semi- professional	234	29.3
Professional	133	16.6
Mother's occupation		
Housewife	740	92.5
Employed	60	7.5
Total	800	100

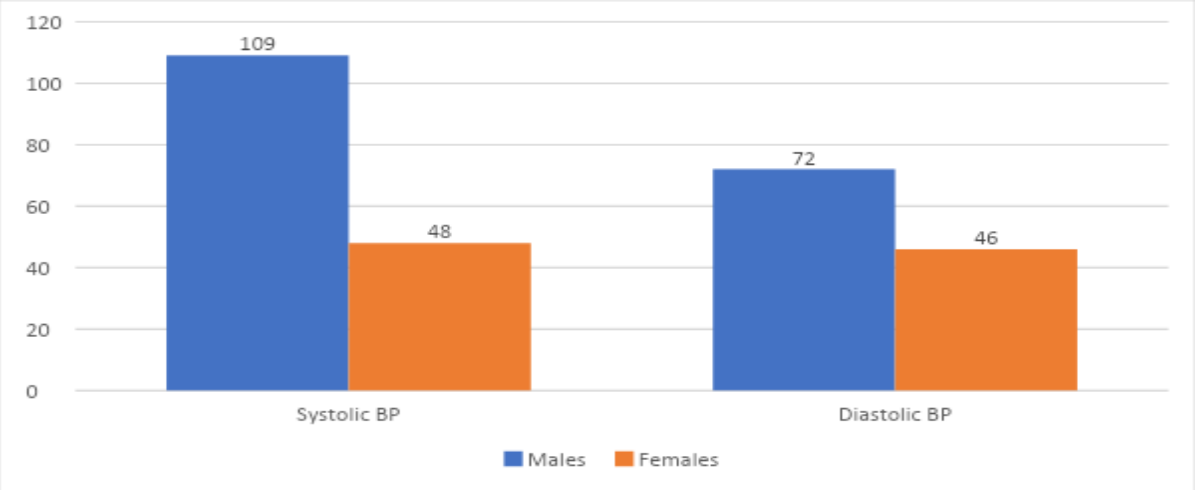
FIGURE 1: SEX WISE DISTRIBUTION OF BMI AMONG STUDY POPULATION



The mean BMI of the study population was found to be 18.89±3.9 kg/m^2. The mean BMI among males was 19.3±3.8 kg/m^2, while among females it was found to be 18.3±4.02 kg/m^2. Of the total 453 male students and 347 female students, 109 (24.06%) and 48 (13.83%)

males and female students respectively were found to have higher than normal (more than 120 mmHg) and 72 (15.89%) and 46 (13.25%) male and female students were reported to have higher than normal diastolic (more than 80 mmHg) blood pressure as depicted in Figure 2.

FIGURE 2: SEX WISE DISTRIBUTION OF MORE THAN NORMAL SYSTOLIC (>120 mmHg) AND DIASTOLIC (>80 mmHg) BLOOD PRESSURE IN STUDY POPULATION



In the present study, the majority of adolescents had normal blood pressure, i.e. <120 mmHg systolic and <80 mmHg diastolic (7). Overall, 80.38% of the students had normal systolic blood pressure while 85.25% of the students reported normal diastolic blood pressure. The overall mean systolic blood pressure was recorded as 110±12 mm Hg, while mean diastolic blood pressure was recorded as 72±9 mmHg. The average systolic blood pressure among males was recorded as 113±12 mm Hg, while the same in females was recorded to be 106±13 mm Hg. The mean diastolic blood pressure among males and females was the same and was to be 72±8 mmHg.

Using a statistical test to assess the association between blood pressure and BMI among adolescents enrolled in school, it was found that there was a very weak positive correlation (r = 0.00) between the students' systolic and diastolic blood pressure and their BMI. However, the association was found to be highly statistically significant among the study variables (p <0.05). Along with this, a simple linear regression was calculated to predict systolic and diastolic blood pressure based on the body mass index of the study population. A significant regression was found (R^2 = 0.130, p< 0.00) with an in case of systolic and (R^2 0.047, p< 0.00) with an in case of diastolic blood pressure respectively (Table 2).

TABLE 2: Association Between Bmi and Blood Pressure Among Study Population

SBP	**BMI STATUS**						**Total**
	UNDERWEIGHT		NORMAL		OVERWEIGHT		
Less than 120	363	24.4	157	24.4	123	19.1	643 (100%)
More than 120	52	33.1	47	29.9	58	36.9	157 (100%)
Total	415	51.9	181	22.6	181	22.6	800(100%)
χ2 =32.450, df= 2, p <0.05, r = 0.00							
DBP	BMI STATUS						TOTAL
	UNDERWEIGHT		NORMAL		OVERWEIGHT		
	n	%	n	%	n	%	N
Less than 80	370	54.3	170	24.9	142	20.8	182 (100%)
More than 80	45	38.1	34	28.8	39	33.1	118 (100%)
Total	415	51.9	204	25.5	181	22.9	800 (100%)
χ2 = 12.283, df= 2, p <0.05, r= 0.00							

Regression analysis results (Table 3) show a significant correlation between BMI and both systolic and diastolic blood pressure. Each unit increase in BMI is related to a roughly 1.169 unit rise in systolic blood pressure and a roughly 0.449 unit increase in diastolic blood pressure. These results imply a favorable correlation between higher BMI levels and higher blood pressure levels. It's crucial to keep in mind that these connections are only associations and do not imply causality.

TABLE 3 Regression Analysis Table for Blood Pressure

For diastolic blood pressure								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	63.772	1.436		44.421	.000	60.954	66.590
For systolic blood pressure								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	88.193	2.053		42.965	.000	84.164	92.222
	BMI of student	1.169	.106	.363	10.996	.000	.960	1.378

DISCUSSION

In the current study, we have evaluated the association between BMI and blood pressure among school going adolescents in the city of Aligarh. We have shown that a statistically significant association is present between the SBP and DBP with BMI (8). However, a weak positive correlation was found between the systolic and diastolic blood pressure and the BMI. Interpreting the blood pressure–BMI relationship is further complicated by the suggestion from some studies of a threshold effect below there appears to be no correlation between the variables.(9) The majority of pediatric research has concentrated on examining three key pathophysiological mechanisms: anomalies in vascular structure and function, insulin resistance, and alterations in autonomic function. Overlapping or a mixture of these factors are probably to blame for obesity-induced hypertension. We have shown that there is a correlation between BMI and blood pressure in both sexes. (10,11,12,13). In our study, significant regression results were found between SBP and DBP with BMI, which means that their blood pressure would increase progressively with increase in BMI among the adolescent population which was a consistent finding in various other studies. (14). Variations in blood pressure may be caused by additional elements that our regression model does not account for. These findings however highlight the significance of BMI monitoring as it seems to be a strong predictor of blood pressure levels.

In context to prevention of emergence of high blood pressure among adolescents, early childhood interventions to encourage healthy behaviors and prevent harmful exposures may have a significant impact on reducing abnormal BP levels in children. Currently, there are various evidence- based guidelines for primordial prevention of high blood pressure, which include statements regarding dietary habits, physical activity, screen time and sleep disorders among adolescents. Parental education, counseling, and supportive reinforcement could be some strategies to stop the development of risk factors. Additionally, a supportive environment in the form of resources for safe physical activity of the children and adolescents, and economical and wholesome dietary options could also help in this regard. (15)

The study has its own limitations. Firstly, long term follow up is not available in our study. Secondly, it is not known from our study if

interventions focusing on dietary habits and physical activity could bring about a change in results. Finally, the significant association between BMI and blood pressure found in our study does not indicate a causal relationship between the two. Despite these drawbacks, our retrospective analysis offers insightful data that captures current, actual practice.

Conclusion

To conclude, it can be said that there is significant association between Blood pressure and BMI among the school going adolescents, with a significant linear regression among the values. This is important with the perspective of application of primordial prevention in the context of increasing prevalence of non-communicable diseases, particularly in a developing country like India, which is battling with the double burden of malnutrition. This can be done by making children understand the importance of eating healthy, through various Information, Education and Communication activities among themselves and through the parents, with active involvement from the teachers. Alternatively, awareness can be increased among them through various role plays and interactive sessions which highlight the importance of a healthy lifestyle and good eating habits.

Recommendation

High BMI values are responsible for causation of high blood pressure, particularly in case of adolescents where high BP usually goes undetected and hence preventive measures could not be applied at an earlier stage.

Relevance of the Study

The association between BMI and Blood pressure among adolescents highlights the importance of application of preventive methods at primordial level itself, where school children are best audiences to apply the same and follow a healthy lifestyle.

Authors Contribution

All authors have contributed equally.

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Nil

Conflict of Interest

There are no conflicts of interest.

Declaration Of Generative Ai And Ai Assisted Technologies In The Writing Process

Chat GPT and Quilt were used for refinement and editing of the draft manuscript.

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