Hyperbolic Relationship between Blood Pressure and Body Mass Index in a Nigerian Adolescent Population

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Abstract

Objective
Hypertension is a leading killer in the world, and is known to begin in childhood/adolescence, and to track into adulthood. Traditionally, blood pressures are said to be associated positively with body mass index (BMI), even in adolescents. This study investigated the relationship between blood pressures and BMI in a population of Nigerian adolescents stratified along three blood pressure (BP) phenotypes.

Methods
Four hundred and eighty three adolescents from Ajaokuta – a low income semi-urban town in Nigeria – were studied. Their blood pressures and anthropometric parameters (from which BMI was calculated) were measured using standard protocol. Based on international recommendations each was classified as hypertensive, prehypertensive or normotensive depending on his/her age, sex and height. Age at last birth day was recorded per subject. Plots of BP versus BMI were generated for each BP phenotype, and Pearson’s correlation coefficients calculated for each.

Results
The mean ages of the subjects, irrespective of sex or BP phenotype were largely similar (p>0.05). Blood pressures correlated positively with BMI only in normotensive subjects. This correlation was attenuated in prehypertensive subjects and literally disappeared in the hypertensive subjects.

Conclusion
Increase in BMI may not affect normotensive and hypertensive adolescents alike. A reassessment of management priorities for hypertensive adolescents is required.

Introduction
Hypertension is a major risk factor for cardiovascular disease. [1] It is the third leading killer in the world,[2] and a key component of the metabolic syndrome, often accompanied by metabolic disorders like dyslipidemia, insulin resistance and obesity.[3-5] In fact, data from the US National Health and Nutrition Examination Survey 1999 to 2004 show that the prevalence of hypertension is about 20% in normal weight Americans and more than 50% in their obese counterparts.[6] Hypertension has been reported in children and adolescents of different populations [7-9] and is believed to track into adulthood.[10] This is worrisome especially in developing countries like Nigeria where the co-existence of both adolescent under- and over-nutrition has been reported,[11] and where communicable diseases still present a monumental health care challenge.[12,13]

Consequently studies aimed at understanding the dynamics of hypertension and other CVD risk factors in children and adolescents (in developing countries) are required as they would help provide tools for the disruption of CVD risk factors, thereby offsetting both the risk of CVD in adulthood and the potential burden it would place on the health systems of developing countries.

Traditionally, hypertension is known to be associated with obesity in both adults and adolescents.[6,14] However, whether this relationship between hypertension and obesity is linear for all the blood pressure phenotypes – normotensive, prehypertensive and hypertensive – or not, has not yet been investigated, especially in African adolescents who are currently facing the nutrition transition and the health challenges that come with it. This paper studies the said relationship in a semi-urban-dwelling Nigerian adolescent population. The results are expected to broaden the present understanding of pediatric hypertension and possibly guide its management.

Methods
A total of 483 adolescents from a low income semi-urban town in Nigeria were recruited for this study. The study site, population, and sampling methods have been described previously.[9,11,14] Only adolescents who attended public schools in Ajaokuta, Kogi State, Nigeria, and who were between 13 and 18 years of age (determined from the students
records as age at last birth day) were included for analysis in this study. The subjects gave an oral informed consent after consulting with their parents/guardians before being allowed to participate in the study. The study design, prepared according to the Helsinki declaration, was approved by the Board of the Department of Biochemistry, Kogi State University, Anyigba, Nigeria.

Subjects were asked to seat and relax for 10 minutes before three separate blood pressure (BP) readings were taken (per subject), at two minutes intervals, using an automated digital monitor (Omron HEM-741 CINT), and appropriate cuff sizes. The device has an error of measurement of ± 3 mmHg, according to the manufacturers. The average of the last two readings was recorded for both systolic and diastolic blood pressures of each student. The same trained personnel took all blood pressure measurements.

The weight of each subject was measured using an electronic weighing balance, to the nearest 0.1kg. Each adolescents’ height was measured (to the nearest 0.5cm) using a non-elastic measuring tape, fastened to a vertical wall. Weights and heights were measured with the student on bare feet and with light clothing. From the heights and weights got, Body Mass Index (BMI) was calculated using the formula $\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$. All the equipments were calibrated each morning according to the manufacturer’s instructions. All anthropometric variables were measured by the same trained personnel.

Three BP phenotypes were defined for this study, thus: normotensive phenotype is taken as systolic and diastolic blood pressure that is < 90th percentile for gender, age and height; prehypertensive phenotype is taken as systolic and diastolic blood pressure ≥ 90th percentile, but < 95th percentile for gender, age and height or ≥ 120/80 mmHg; hypertensive phenotype is taken as systolic and diastolic blood pressure ≥ 95th percentile for gender, age and height.[15]

Based on the above BP phenotypes, we plotted a curve of BP versus BMI for the general, normotensive, prehypertensive and hypertensive populations (each divided into three sub groups thus: all subjects, male subjects and female subjects) and calculated the Pearson’s product moment correlation coefficients for each sub group. The mean ages of the subjects in the different BP phenotypes were calculated and differences between means were checked for significance using the Student’s T test (2-tailed, unequal variances assumed). A significant threshold of $p \leq 0.05$ was employed for all analyses.

Results

The mean age for the male subjects was 14.8 years (15.0 ± 1.9 years, 14.6 ± 1.8 years and 14.8 ± 1.8 years for hypertensives, normotensives and prehypertensives respectively); while for the females, it was 15.1 years (15.0 ± 1.8 years, 15.1 ± 1.8 years and 15.3 ± 1.7 years for hypertensives, normotensives and prehypertensives respectively). Comparing between the sexes for each BP phenotype showed that only the differences in the mean ages of normotensive males and females were significant ($p<0.05$) mean ages for both sexes. Also comparing within each sex, for the three BP phenotypes showed no significant difference ($p>0.05$) in the mean ages of the male and female adolescents (Illustration 1).

From Illustration 2, it is seen that in the general population, the plot of both SBP and DBP (each) versus BMI gave an ascending pattern, indicative of a positive correlation. These positive correlations were seen to be significant ($p<0.05$). For normotensive adolescents, the plots of SBP and DBP (each) versus BMI also gave an ascending pattern. The positive correlations were significant ($p<0.05$). From Illustration 4, it is seen that the SBP plots for prehypertensive subjects showed an ascending pattern for all the subjects irrespective of sex and for male subjects only. That of the female subjects showed a slightly descending pattern. However, none of these correlations were significant ($p>0.05$). The DBP plots all had descending patterns that were also not significant ($p>0.05$).

For hypertensive adolescents, the SBP versus BMI plot for all subjects irrespective of sex was virtually a parallel to the vertical axis (though the plots for the males descended slightly, while that for the females ascended slightly). The correlations were all insignificant ($p>0.05$). The DBP plots showed slight ascending patterns for all subjects irrespective of sex, and for male subjects, while that of the females was more or less a parallel to the vertical axis. The values were however found to be insignificant ($p>0.05$) (Illustration 5).

Discussion

Blood pressure and BMI have been shown to be correlated (positively) in some adolescent populations.[14,16,17] It is however known that the exact mechanism for this relationship is poorly understood. In adult populations similar relationships have been reported.[18-20] Other adult studies show
that cardiovascular mortality from hypertension may vary between lean, normal weight, and obese hypertensives.[21-23] These findings buttress the insufficiently explored relationship between BP and BMI in humans.

Data from this study show that BP correlates positively and significantly in the entire population irrespective of BP phenotype. However, when the population is stratified by BP phenotypes, it becomes clear that this relationship exists only in the normotensive population; is significantly attenuated in the prehypertensive population and disappears in the hypertensive phenotype. This therefore gives a hyperbolic curve that rises in the normotensive phenotype and plateaus in the hypertensive phenotype.

Though age is a major risk factor for hypertension, even in adolescents (for which adolescent BP is tied to age and other factors)[15], age differences may not be responsible for the observed patterns since the differences in the mean ages of the adolescents stratified by BP phenotypes and sex were largely similar.

Increasing BMI is thought to increase salt retention, physical inactivity and lead to the development of metabolic abnormalities like dyslipidemia, insulin resistance etc, that are known to result in increased BP and risk of CVDs.[24-26] Though BMI is used as a measure of overall obesity, it is known to be a poor indicator of actual fat, muscle, bone and tissue proportions. It is also known that metabolic abnormalities that usually co-present with obesity are more important than ‘fatness’ as predictors of cardiovascular disease morbidity and mortality.[27] BMI may therefore be a poor surrogate for determining hypertension risk or risk for other CVDs in adolescents. Despite limitations like not assessing pubertal maturation, salt intake, family history of hypertension and other such factors that are known to affect BP elevation, these data show that the relationship between BP and BMI is not linear throughout the different BP phenotypes. It therefore calls for a reassessment of management priorities especially for hypertensive adolescents whose blood pressures (apparently) do not increase with increasing BMI.

**Conclusion(s)**

This paper studied the relationship between BP and BMI in an adolescent population stratified along BP phenotypic lines. The findings show that the said relationship is hyperbolic, rising from the normotensive phenotype and tapering at the hypertensive phenotype. Increase in BMI may therefore not affect hypertensive and normotensive adolescents alike.

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**Authors Contribution(s)**

CECCE was responsible for design, data analysis and interpretation and writing of the manuscript. CEU was responsible for design, data collection and collation. Both authors read and approved the final version of the manuscript.

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Illustrations

Illustration 1

Mean ages of the studied adolescents stratified by sex and blood pressure phenotype

<table>
<thead>
<tr>
<th></th>
<th>Hypertensive</th>
<th>Normotensive</th>
<th>p</th>
<th>Prehypertensive</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>15.0 ± 1.9</td>
<td>14.6 ± 1.8</td>
<td>0.73</td>
<td>14.8 ± 1.8</td>
<td>0.92</td>
</tr>
<tr>
<td>female</td>
<td>15.0 ± 1.8</td>
<td>15.1 ± 1.8</td>
<td>0.30</td>
<td>15.3 ± 1.7</td>
<td>0.68</td>
</tr>
<tr>
<td>p</td>
<td>0.95</td>
<td>0.02</td>
<td></td>
<td>0.16</td>
<td></td>
</tr>
</tbody>
</table>
Illustration 2

Relationship between blood pressure and body mass index in the adolescent population

Female

\[ r = 0.26, \quad r = 0.21, \quad r = 0.36, \quad r = 0.18, \quad r = 0.11, \quad r = 0.21, \]
Illustration 3

Relationship between blood pressure and body mass index in the normotensive adolescent population
Illustration 4

Relationship between blood pressure and body mass index in the prehypertensive adolescent population

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>0.06, p</td>
<td>0.12, p</td>
<td>-0.03,</td>
</tr>
<tr>
<td>r</td>
<td>-0.16,</td>
<td>-0.19,</td>
<td>-0.11,</td>
</tr>
</tbody>
</table>
Illustration 5

Relationship between blood pressure and body mass index in the hypertensive adolescent population

All Male Female

$r = 0.06, p$

$r = -0.36,$

$r = 0.37, p$

$r = 0.16, p$

$r = 0.09, p$

$r = 0.35, p$
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