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# The Contribution of Linear Growth Components to Hypertension in Secondary School Adolescents in an Urban Setting in Cameroon

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## Abstract

**Background:** Components of height have been found to be positively associated with blood pressure (BP) both in developed and developing nations. However, amongst Cameroon secondary school adolescents, the relationship between heights, SH and SH/H with BP has rarely been studied. The purpose of this study was to determine the proportion of secondary school adolescents with elevated BP and high BP and to evaluate the relationship between the different components of linear growth with BP. **Methods:** An institution-based cross-sectional study involving 602 adolescents (399 girls and 203 boys, mean age 14.9 ± 2.3 years) attending some public and private secondary schools in the Bamenda municipality of the North West Region of Cameroon. Anthropometric and BP measurements were carried out following standard procedures. Pearson correlation and linear regression were used to determine the relationship between the various components of height (height, SH, SH/H) with BP amongst the children. **Results:** The overall prevalence of elevated BP and hypertension amongst the study participants was 21.9% and 15.6% respectively (with 8.3% and 7.3% of the hypertensive children in Stage I and Stage II respectively). However, there were no significant gender differences in the prevalence of elevated BP and high BP ($p = 0.497$). Girls had a significantly ($p < 0.05$) higher mean SH/H compared to boys. There was a significant correlation ($p < 0.001$) between systolic BP (SBP) with height (r = 0.311), SH (r = 0.276), and SH/H (r = −0.181). Linear regression indicated a significant association ($p < 0.001$) between height ($\beta = 0.48$; 95% CI = 0.31, 0.53), SH ($\beta = 0.10$; 95% CI = 0.56, 0.99) and SH/H ($\beta = -47.35$; 95% CI = −70.11, −24.59) with SBP for the unadjusted. Adjusting for age, gender, BMI and school type, SBP showed a positive significant association ($p < 0.001$) with height ($\beta$ = 0.048; 95% CI = (0.28, 0.69). **Conclusion:** This study has demonstrated that height was positively associated with SBP amongst children and adolescents. Thus, height can be used in predicting adolescents with a high risk of developing high BP in our setting.

## Keywords

Linear Growth, Components, Hypertension, Secondary School, Adolescents, Cameroon

## 1. Introduction

The upturn in the prevalence of high blood pressure (BP) in the paediatric population is becoming an emerging public health issue [1] [2], affecting about 4% of children and adolescents worldwide [3] [4] [5]. Moreover, it is considered a major risk factor for mortality, accounting for about 12.8% of global deaths [6]. A systematic review by Chen and Wang in 2008 [7], as well as a meta-analysis by Toschke *et al.* [8] in 2010 have demonstrated that BP levels persist from childhood to adulthood, with hypertension in puberty being a strong predictor of adult hypertension [9]. In addition, a WHO report [10] in 2005 found that sustained high BP in childhood was associated with cardiovascular risk factors in adults in sub-Saharan Africa. A recent study in Yaoundé, Cameroon, among primary school pupils in 2019 reported an overall prevalence of hypertension of 1.6% (with 1.5% and 0.1% of the children being in stage I and stage II respectively) and that of elevated BP was 8.1% [11]. The rising prevalence of high blood pressure in sub-Saharan African children could be attributed to the shift toward western lifestyle and urbanization [12]. Again, evidence suggests that an increase in the incidence of elevated BP in childhood mirrors the obesity epidemic and physical inactivity trends worldwide [13] [14]. Recent studies have shown that in the paediatric population, elevated blood pressure is associated with pathological changes such as atherosclerosis, left ventricular hypertrophy, cognitive function disorders and an increase in the carotid intima-media thickness [15] [16].

Evidence suggests that in children and adolescents being taller is associated with high BP [17] [18] [19]. However, there are only a few studies that have studied the effect of the components of height on blood pressure in the paediatric population [18] [19] [20] [21]. In addition, components of height which are key in the assessment of linear growth, have been found to be positively associated with high blood pressure in children and adolescents [19] [20] [21]. For instance, children with a higher height-for-age tend to accumulate more adiposity [22], a risk factor for elevated BP in this group. In the North West Region (NWR) of Cameroon, the highest prevalence of overweight/obesity has been recorded among the tallest children [22] [23]. Despite evidence of childhood obesity rise in Cameroon [22], there is limited data on the association between paediatric hypertension and components of height in children and adolescents in the country. This has made early diagnosis, control and management of elevated BP and HTN in this vulnerable group difficult.

Linear growth proportions are usually represented by standing height (H), sitting height (SH) and sitting height/standing height (SH/H) ratio. Therefore, a small SH/H indicates relatively long legs to the total height and a high SH/H indicates relatively shorter legs for total height [24]. Sitting height (SH) which is a key parameter in the evaluation of childhood growth and pubertal disorders. It has also been considered an important biomarker of cardiovascular risk in adulthood, especially among adults with longer trunks [18]. Moreover, data from both industrialized and developing countries have reported that BP is closely associated with growth proportion in children. For instance, studies among Brazilian [19], South African [21] and Indian [25] children found that SH was associated with BP. Furthermore, a study by Dong *et al.* [17] in Chinese children and adolescents found that SH correlated positively with BP. In addition, a previous study in rural South African children reported that SH is significantly associated with systolic BP (SBP) and diastolic BP (DBP) [20] [21]. Moreover, if the distance from the heart to the vertex of the head determines the blood pressure in the arteries, a child with a longer trunk will require a higher BP to overcome gravity for the brain to be adequately perfused. This explains the positive association between standing height and BP in the paediatric population.

Thus, height components may play a vital role in predicting childhood hypertension [26]. Nevertheless, it is unclear whether the relationship between the components of linear growth and BP exists across all age and height ranges given that the current guidelines for defining hypertension in children and adolescents are based on age, sex and height [4]. Some studies have demonstrated that components of height can be used in identifying children and adolescents with a high risk of developing high blood pressure [9] [24] [27], but it is currently unclear if these measures of linear growth are associated with BP in children and adolescents in a limited resource setting like Cameroon. An understanding of the association between the various components of height and BP may contribute to the early identification of children at risk of elevated BP thus reducing the risk of hypertension and adverse cardiovascular outcomes in later life.

This study, therefore, set out to determine the proportion of secondary school adolescents with elevated BP and high blood pressure and to evaluate the relationship between the different components of linear growth with blood pressure in the Bamenda municipality of the North West Region of Cameroon.

## 2. Materials and Methods

### 2.1. Study Design and Study Participants

This study was an institution-based cross-sectional study involving 602 secondary school adolescents (399 girls and 203 boys) aged 10 to 19 years attending four secondary schools (2 private and 2 public) in the North West Region of Cameroon in 2022. However, adolescents with any form of physical disability that does not permit weight, height or BP to be taken or those on medications for lowering BP were excluded from the study. This study made use a 2-stage sampling technique: Firstly, from a list of secondary schools obtained from the Regional Delegation of Secondary Education of the NWR, four secondary schools (2 private and 2 public) were randomly selected and asked to participate in the study. Secondly, within the schools, a quota sampling technique was used to select students from each class in the different study levels.

### 2.2. Ethical Considerations

Approval to carry out this study was obtained from the Institutional Review Board (IRB) of the Faculty of Health Sciences of The University of Bamenda (Ref: 2022/0421H/UBa/IRB).Administrative clearance was obtained from the Regional Delegation of Public Health of the North West Region and Regional Delegation for Basic Education of the North West Region.

(Ref. No.G649/1188/MINSEC/RDSE/NW/SDGA of 13 Jan 2022). Written informed consent and verbal assent were obtained from all principals/parents/guardians/ and the children respectively, before any data collection procedure commenced.

## 3. Data Collection

### 3.1. Anthropometry

All measurements were made on the school campuses between 9.00 am and 1.00 pm by well-trained nurses recruited to assist in the data collection process. Components of height and weight were measured by the nurses ensuring standard protocols were respected. Standing height was measured to the nearest 0.1 cm without shoes using a portable stadiometer (Seca 213, Germany) while sitting height (SH) was measured with the participant comfortably seated with their back and buttocks positioned against the stadiometer postensuring legs were 90˚ degree with the ground from the vertex of the head to the sitting surface. SH/H was calculated by dividing the sitting height (cm) by standing height (cm). Body weight was measured with a digital scale (Omron BF511, Japan) to the nearest 0.1 kg. The body mass index (BMI) was then calculated for each child as weight (kg)/[height $(cm)^2$] [28].

### 3.2. Blood Pressure

Using an automated device (SANITAS SBM21, Hamburg, Germany), the systolic and diastolic blood pressure levels of the children were obtained. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured three times at 3-minute intervals on the same day. The measurements were taken with the participant sitting in a relaxed position with the arm resting and the palm facing upwards. The average of the three (3) measurements was recorded.

### 3.3. Statistical Analysis

Statistical analysis was carried out using IBM-SPSS for Windows version 23.0. Continuous variables were checked for normality using the Kolmogorov-Smirnov (K-S) test. Anthropometric variables (height, sitting height, weight and BMI) were standardized for age and gender (z scores) using the WHO LMS Growth software [29]. This package has different growth reference data including WHO 2006, WHO 2007, UK-CDC and the British 1990 growth reference data for children and adolescents. The prevalence of elevated BP and hypertension were calculated and presented with their corresponding 95% confidence intervals. In addition, the association between categorical variables was assessed using Chi square test. Means of continuous variables were assessed using an independent student t-test and ANOVA as appropriate. Pearson correlation was used to assess the association between the various components of height with blood pressure (SBP and DBP). Finally, linear regression models (unadjusted and adjusted for age, gender, BMI and school type) were used to assess the relationship between the components of height (height, SH, SH/H) with blood pressure (SBP and DBP). Statistical significance was set at $p$-value of < 0.05.

## 4. Results

### 4.1. Descriptive Characteristics of the Study Participants

**Table 1** shows the descriptive characteristics of the children by gender. Half of the study participants were in the age group 14 to 17 years with more boys (52.2%) being in the age category than girls (48.9%). More than 15% of all the children were overweight/obese. More than one-third (38.4%) of the boys were in the first two quartiles of height, while 44.6% of girls were in the third and fourth quartiles of height. With respect to SH quartiles, more than half (57.6%) of the girls were in the first 2 quartiles of height, while 56.7% of boys were in the third and fourth quartiles of height.

### 4.2. Prevalence of Elevated Blood Pressure and Hypertension

The overall prevalence of elevated BP and hypertension in the study population was 21.9% and 15.6% respectively (with 8.3% and 7.3% of the hypertensive children in Stage I and Stage II respectively). **Figure 1** shows the prevalence of hypertension by gender. Comparing the prevalence of elevated BP and hypertension by gender, a higher proportion of girls had elevated BP and high BP (38.9%) compared to boys (35%). However, the gender differences were not significant ($X^2 = 1.046$, $p = 0.497$). In the whole sample, there was a 2.7% increase in the prevalence of hypertension between children aged 18 to 19 years compared to those aged 10 to 13 years. However, this was not significant ($X^2 = 4.995$, $p = 0.288$). In addition, among the boys, there was a 17.2% and 10.4% increase in the prevalence of elevated BP and hypertension between boys aged 10 to 13 years

**Table 1.** Descriptive characteristics of the study population (N = 602).

| Variable | All children (N = 602) | Boys (N = 203) | Girls (N = 399) | *p*-value |
|---|---|---|---|---|
| | n (%) | n (%) | n (%) | |
| Age categories (yrs) | | | | **0.007** |
| 10 - 13 | 198 (32.9) | 52 (25.6) | 146 (36.6) | |
| 14 - 17 | 301 (50.0) | 106 (52.2) | 195 (48.9) | |
| 18 - 19 | 103 (17.1) | 45 (22.2) | 58 (14.5) | |
| BMI category (kg/m$^2$) | | | | **0.006** |
| Underweight | 68 (11.3) | 35 (17.2) | 33 (8.3) | |
| Healthy weight | 430 (71.4) | 149 (73.4) | 281 (70.4) | |
| Overweight/Obese | 104 (17.3) | 19 (9.4) | 85 (21.3) | |
| Height quartiles | | | | |
| First quartile | 171 (28.4) | 54 (26.6) | 117 (29.3) | **<0.001** |
| Second quartile | 128 (21.3) | 24 (11.8) | 104 (26.1) | |
| Third quartile | 153 (25.4) | 30 (14.8) | 123 (30.8) | |
| Fourth quartile | 150 (24.9) | 95 (46.8) | 55 (13.8) | |
| SH quartiles | | | | **<0.001** |
| First quartile | 141 (23.4) | 52 (25.6) | 89 (22.3) | |
| Second quartile | 177 (29.4) | 36 (17.7) | 141 (35.3) | |
| Third quartile | 147 (24.4) | 48 (23.6) | 99 (24.8) | |
| Fourth quartile | 137 (22.8) | 67 (33.1) | 70 (17.5) | |
| SBP (mmHg) | | | | 0.593 |
| Normal | 376 (62.5) | 132 (65) | 244 (61.2) | |
| Elevated BP | 132 (21.9) | 40 (19.7) | 92 (23.1) | |
| Hypertension | 94 (15.6) | 31 (15.3) | 63 (15.8) | |
| DBP (mmHg) | | | | 0.939 |
| Normal | 510 (84.7) | 173 (85.2) | 377 (84.5) | |
| Elevated BP | 69 (11.5) | 22 (10.8) | 47 (11.8) | |
| Hypertension | 23 (3.8) | 8 (3.9) | 15 (3.8) | |

BP: Blood Pressure, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, SH: Sitting Height.

and those aged 18 to 19 years respectively ($X^2 = 6.349$, $p = 0.012$). On the contrary, this study found that more girls aged 14 to 17 years had elevated BP (26.7%) compared to those aged 18 to 19 years (20.7%). Still among the girls, it was observed that 17.2% of girls aged 18 to 19 years were hypertensive compared to 13.8% in those 14 to 17 years. However, it was not significant ($X^2 = 3.295$, $p = 0.510$). Furthermore, 24.7% of girls that were overweight/obese were hypertensive compared to 10.5% of boys.

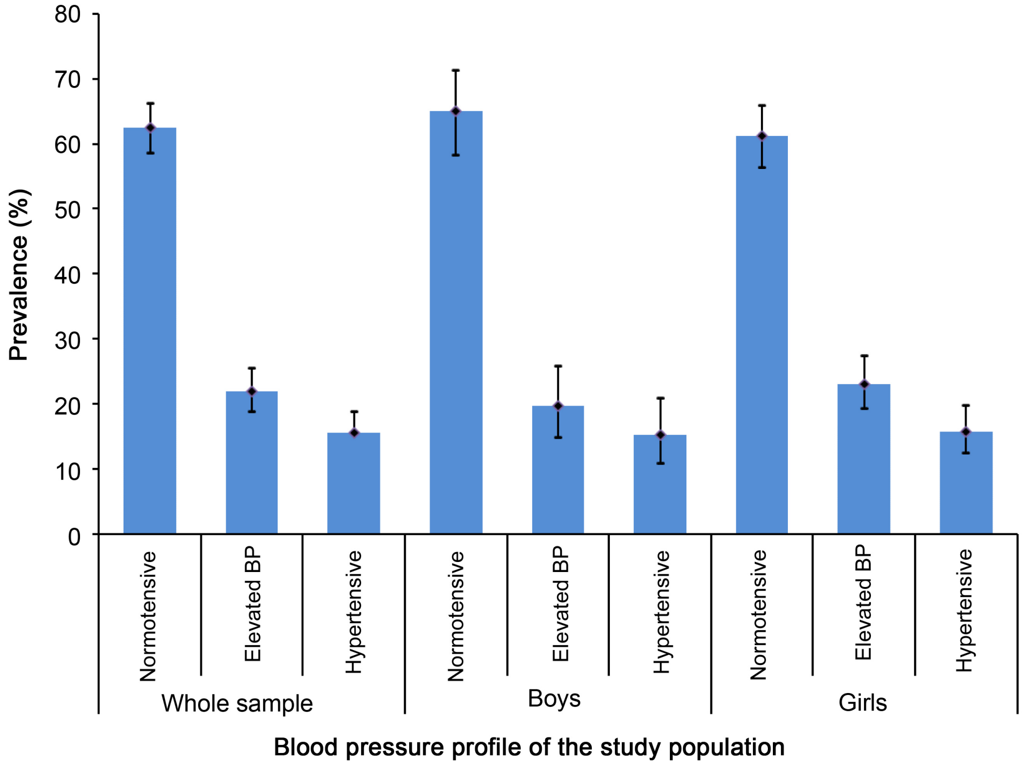


**Figure 1.** The prevalence of blood pressure amongst the study participants by gender.

### 4.3. Mean Clinical Characteristics of the Children

**Table 2** shows the differences in the mean clinical parameters of the children. On average males were significantly ($p < 0.05$) older and taller than females. In addition, boys had a significantly ($p = 0.025$) higher mean SH than girls. On the contrary, girls had a significantly ($p < 0.05$) higher mean SH/H ratio, BMI and diastolic blood pressure than boys. There was no significant ($p > 0.05$) difference in weight between boys and girls.

**Table 3** shows the mean systolic and diastolic blood pressure profiles of the study participants according to height and SH quartiles. There was on average a 19 mmHg significant ($p < 0.001$) difference in the mean SBP between the first and fourth quartiles of height for both boys and girls. Additionally, a significant difference ($p < 0.05$) was observed in the mean SBP between the quartiles of SH in both genders. On the contrary, no significant difference ($p = 0.969$) was observed in the mean DBP in the quartiles of standing height and SH for boys as opposed to girls where a significant difference ($p < 0.05$) was observed.

**Table 4** shows the Pearson correlation coefficients between the different components of height with blood pressure (SBP and DBP). In the present study, we found a significant positive correlation ($p < 0.001$) between systolic BP (SBP) with height (r = 0.311) and SH (r = 0.276) and a significant ($p < 0.001$) negative relationship between SH/H (r = −0.181) with systolic blood pressure. However, no significant association was observed between the different height components with diastolic BP ($p > 0.05$).

Table 2. Mean clinical characteristics of the study participants by gender [mean (±SD)].

| Variable | Whole sample n = 602 | Boys (n = 203) | Girls (n = 399) | *p*-value |
|---|---|---|---|---|
| | Mean (SD) | Mean (SD) | Mean (SD) | |
| Age (years) | 14.9 (2.3) | 15.3 (2.4) | 14.7 (2.2) | **0.001** |
| Height (cm) | 158.9 (11.0) | 162.3 (13.3) | 157.2 (9.2) | **<0.001** |
| Height SDS+ | −0.35 (1.41) | −0.58 (1.45) | −0.23 (1.49) | **0.004** |
| SH (cm) | 77.2 (5.7) | 77.9 (6.5) | 76.8 (5.2) | **0.025** |
| SH/H | 0.49 (0.05) | 0.48 (0.04) | 0.49 (0.06) | **0.005** |
| SH SDS+ | −2.07 (1.33) | −2.13 (1.28) | −2.04 (1.35) | 0.396 |
| Weight (kg) | 56.6 (11.2) | 56.5 (12.1) | 56.7 (10.7) | 0.882 |
| Weight SDS+ | 0.45 (1.02) | 0.05 (0.99) | 0.65 (0.96) | **<0.001** |
| BMI (kg/m$^2$) | 22.3 (3.7) | 21.4 (3.8) | 22.8 (3.6) | **<0.001** |
| BMI SDS+ | 0.70 (0.94) | 0.55 (0.98) | 0.94 (0.91) | **<0.001** |
| SBP (mmHg) | 115.5 (15.9) | 114.1 (15.9) | 116.2 (15.9) | 0.127 |
| DBP (mmHg) | 66.8 (11.9) | 64.4 (12.4) | 68.1 (11.4) | **<0.001** |

+Based on WHO 2007 reference data, SH: Sitting Height, SH/H: Sitting height to height ratio; WHtR: Waist-to-height ratio, SBP: Systolic Blood Pressure.

### 4.4. Associations between Components of Linear Growth with Blood Pressure

Table 5 shows the linear regression (unadjusted and adjusted for age, gender and BMI) for the association between height, SH, SH/H and blood pressure in the study population. There was a significant positive association ($p < 0.001$) between height ($\beta = 0.48$; 95% CI = 0.31, 0.53), SH ($\beta = 0.10$; 95% CI = 0.56, 0.99) and a negative association between SH/H ratio ($\beta = -47.35$; 95% CI = −70.11, −24.59) with systolic blood pressure for the unadjusted analysis. After adjusting for age, gender, BMI and school type, only height ($\beta = 0.048$; 95% CI = (0.28, 0.69) showed a positive significant association ($p < 0.001$) with systolic blood pressure. However, there was no significant association ($p > 0.05$) between the components of height and diastolic blood pressure.

## 5. Discussion

Being taller has been shown to be positively associated with high BP in children and adolescents. However, very little attention has been focused on the influence of the different height components on blood pressure in children and young adults by researchers [18]. Early detection, control and management of high blood pressure in children and adolescents is essential for the prevention of short and long-term adverse cardiovascular outcomes. The aim of this study was to determine the proportion of secondary school adolescents with elevated BP and high blood pressure and to evaluate the relationship between the components of linear growth (height, SH and SH/H) with blood pressure in an urban

**Table 3.** Mean systolic BP and diastolic BP profile of the study participants according to standing height and sitting height quartiles (N = 602).

| Variables | N | Blood Pressure status | | | | | |
|---|---|---|---|---|---|---|---|
| | | SBP (mmHg) | | *p*-value | DBP(mmHg) | | *p*-value |
| | | Mean | (95% CI) | | Mean | (95% CI) | |
| **Whole sample** | | | | | | | |
| Height quartiles | | | | **<0.001*** | | | **0.008** |
| First quartile | 171 | 107.6 | (105.4 - 109.9) | | 64.6 | (62.8 - 66.5) | |
| Second quartile | 128 | 116.9 | (114.0 - 119.7) | | 67.6 | (65.8 - 69.4) | |
| Third quartile | 153 | 118.5 | (116.0 -120.9) | | 69.0 | (67.3 - 70.7) | |
| Fourth quartile | 150 | 120.1 | (117.8 - 122.4) | | 66.5 | (64.3 - 68.6) | |
| SH quartiles | | | | **<0.001** | | | **0.013** |
| First quartile | 141 | 106.5 | (104.1 - 108.9) | | 63.9 | (62.0 - 65.9) | |
| Second quartile | 177 | 116.8 | (114.5 - 119.1) | | 67.9 | (66.5 - 69.4) | |
| Third quartile | 147 | 119.9 | (116.9 - 122.8) | | 67.7 | (65.6 - 69.8) | |
| Fourth quartile | 137 | 118.1 | (116.0 - 120.3) | | 67.4 | (65.2 - 69.6) | |
| **Boys** | | | | | | | |
| Height quartiles | | | | **<0.001** | | | 0.969 |
| First quartile | 54 | 101.6 | (98.2 - 104.9) | | 64.7 | (61.5 - 67.8) | |
| Second quartile | 24 | 111.2 | (105.7 - 116.7) | | 64.8 | (60.5 - 69.2) | |
| Third quartile | 30 | 118.6 | (112.4 - 124.9) | | 64.9 | (61.3 - 68.5) | |
| Fourth quartile | 95 | 120.5 | (117.7 - 123.3) | | 63.9 | (61.1 - 66.8) | |
| SH quartiles | | | | **<0.001** | | | 0.107 |
| First quartile | 52 | 102.2 | (98.4 - 106.1) | | 61.8 | (58.9 - 64.6) | |
| Second quartile | 36 | 114.3 | (109.2 - 119.3) | | 68.1 | (64.2 - 72.0) | |
| Third quartile | 48 | 119.3 | (114.3 - 124.3) | | 65.2 | (61.6 - 68.8) | |
| Fourth quartile | 67 | 119.4 | (116.5 - 122.3) | | 63.4 | (60.4 - 67.2) | |
| **Girls** | | | | | | | |
| Height quartiles | | | | **<0.001** | | | **<0.001** |
| First quartile | 117 | 110.4 | (107.6 - 113.3) | | 64.6 | (62.3 - 66.9) | |
| Second quartile | 104 | 118.2 | (114.9 -121.5) | | 68.2 | (66.2 - 70.2) | |
| Third quartile | 123 | 118.4 | (115.8 - 121.1) | | 70.0 | (68.1 - 71.9) | |
| Fourth quartile | 55 | 119.5 | (115.4 - 123.5) | | 70.9 | (68.1 - 73.8) | |
| SH quartiles | | | | **<0.001** | | | **0.017** |
| First quartile | 89 | 109.1 | (106.1 - 112.0) | | 65.3 | (62.7 - 67.9) | |
| Second quartile | 141 | 117.5 | (114.9 - 120.0) | | 67.8 | (66.3 - 69.4) | |
| Third quartile | 99 | 120.2 | (116.6 - 123.8) | | 68.9 | (66.4 - 71.5) | |
| Fourth quartile | 70 | 116.9 | (113.8 - 120.1) | | 70.9 | (68.3 - 73.6) | |

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; SH: Sitting Height; CI: Confidence Interval.

**Table 4.** Pearson correlation between the components of height with blood pressure.

| Components of height | Pearson's coefficient (*r*) | *p*-value |
|---|---|---|
| **Systolic blood pressure** | | |
| Height (cm) | 0.311 | <0.001 |
| Sitting height (cm) | 0.276 | <0.001 |
| SH/H | −0.181 | <0.001 |
| **Diastolic blood pressure** | | |
| Height (cm) | 0.061 | 0.137 |
| Sitting height (cm) | 0.074 | 0.071 |
| SH/H | −0.031 | 0.451 |

**Table 5.** Linear regression analysis (unadjusted and adjusted) for the association between the components of linear growth and blood pressure among the children.

| Exposure | Unadjusted | | | Adjusted | | |
|---|---|---|---|---|---|---|
| | Estimate (β) | (95% CI) | *p*-value | Estimate (β) | (95% CI) | *p**-value |
| **Systolic BP (mmHg)** | | | | | | |
| Height (cm) | 0.42 | (0.31, 0.53) | **<0.001** | 0.48 | (0.28, 0.69) | **<0.001** |
| Sitting Height (cm) | 0.78 | (0.56, 0.99) | **<0.001** | 0.10 | (−0.21, 0.42) | 0.523 |
| SH/H | −47.35 | (−70.11, −24.59) | **<0.001** | 7.67 | (−22.26, 37.58) | 0.615 |
| **Diastolic BP (mmHg)** | | | | | | |
| Height (cm) | 0.05 | (−0.04, 0.14) | 0.252 | - | - | - |
| Sitting Height(cm) | 0.15 | (−0.01, 0.32) | 0.071 | - | - | - |
| SH/H | −2.62 | (−19.76, 14.52) | 0.764 | - | - | - |

SH: Sitting Height, BP: Blood Pressure; BMI: Body Mass Index, SH/H: Sitting Height to Height Ratio; *adjusted forage, gender, BMI and school type.

setting in Cameroon. This study has shown that height is positively associated with blood pressure and itself an independent predictor of blood pressure in children and adolescents. SH was also found to positively correlate with systolic blood pressure in this vulnerable group. To the best of our knowledge this is the first study in Cameroon describing the influence of the components of height (standing height, SH, SH/H) on blood pressure in secondary school adolescents.

This study found a high prevalence of hypertension (37.5%) in the investigated adolescent study population with 15.8% of girls having hypertension compared to 15.3% of boys. These findings are similar to those obtained in Tanzania [30] and Pakistan [31] but higher than those reported in Portugal [32], Brazil [33], India [34] and other developed nations [35] [36] [37]. The high prevalence in our study population can be attributed to the fact that adolescents are a group of people with unique lifestyle challenges including socio-cultural barriers, high levels of physical inactivity and unhealthy nutrition due to less parental supervision compounded by the obesity epidemic, all of which are risk factors associated with hypertension. Moreover, the higher prevalence in girls compared to boys might be as a result of pubertal hormones from the rapid biological changes associated with the onset of puberty and psychosocial factors in this age group. These findings highlight the necessity for cost-effective measures for creating awareness, early identification, effective control and management of hypertension in the paediatric population in order to reduce the complications resulting from hypertension in childhood and later life. This study also found a higher prevalence of elevated BP and hypertension in children 14 years and older, a finding which concurs with other studies in Africa [38] [39].

Boys were significantly taller than girls, a finding similar to that reported in Brazil [33]. Nonetheless, there was no significant difference in weight according to gender contrary to that reported by de Almeida *et al.*[33].

Obesity has been shown to be a major risk factor for hypertension in the paediatric population with an obese child being four-times more at risk of developing HTN than a child with normal BMI [33] [34] [40] [41]. In this study, we found that obese children had a higher mean systolic and diastolic blood pressure compared to their normal weight counterparts. Studies carried out in Hungary [41], Brazil [33] and India [36] [37] indicated that boys had higher mean BMI and systolic BP compared to girls. This is in contrast with the current study in which it was observed that girls had a significantly higher mean BMI and systolic blood pressure compared to boys.

In this present study, boys had a significantly higher mean SH compared to girls. Again, this study reveals that height and SH were significantly and positively correlated with SBP. SH/H ratio was significantly and negatively correlated with SBP, but not DBP. Greater height, SH and SH/H in children and adolescents have been shown to positively influence blood pressure. Studies performed in China [17], Brazil [19] and rural South Africa [21] indicated that height, SH and SH/H ratio are associated with blood pressure. This is in line with our study, where it was observed that height, SH and SH/H were significantly associated with SBP in the unadjusted analysis, and height alone was significantly associated with SBP in the adjusted analysis. However, this current study did not observe any significant association between the components of height and diastolic BP. These findings can be attributed to the fact that BP at the level of the heart must exceed the hydrostatic pressure induced by the distance between the heart and the apex of the head, to ensure adequate perfusion of a child's brain.

## 6. Study Limitations

This study had limitations worth mentioning. The tanner staging to assess the level of puberty in the children and adolescents in this present study was not assessed and this could have affected the relationship between standing height, SH and SH/H with blood pressure especially in girls. Also, the influence of genetics on height cannot be completely ruled out. Finally, this study was carried out only in one region in one municipality thus; the findings might not be a true reflection of the blood pressure profile of all secondary school adolescents in the country. Finally, the difference in the ratio of boys to girls in this study could have resulted in bias in the results on gender differences in the study.

Despite the limitations of this study, the study is innovative as it has provided for the first-time data from the North West Region of Cameroon on the influence of components of height on the blood pressure profile of secondary school adolescents.

## 7. Conclusion

This study among secondary school adolescents in Cameroon has demonstrated that height is positively associated with high BP in children and adolescents. Therefore, height can be used to identify children and adolescents at high risk of hypertension in early life. Further research needs to be conducted in other regions of the country to assess the relationship between standing height and other risk factors for cardiovascular diseases in children and adolescents in order to reduce the risk of cardiovascular diseases in later life.

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## Availability of Data

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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This study was funded by the authors.

## Authors' Contributions

LLN was responsible for the conception and design of the study, directed data collection and organization, statistical analysis and drafting of the manuscript. LKN contributed to the conception and design of the study, participated in data collection, analysis of data and interpretation of data as well as drafting of the manuscript. AAT contributed to the conception and design of the study, participated in data collection as well as interpretation and drafting of the manuscript. MBA contributed to the conception and design of the study, participated in data collection, analysis of data as well as interpretation and drafting of the manuscript. All authors read and approved the final version of the manuscript for submission.

## Conflicts of Interest

The authors declare no conflict of interest in this publication.

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## Abbreviations and Acronyms

The following abbreviations were used in this manuscript;

| ANOVA | Analysis of Variance |
|---|---|
| BMI | Body Mass Index |
| BP | Blood Pressure |
| DBP | Diastolic Blood Pressure |
| H | Standing Height |
| SH | Sitting Height |
| SBP | Systolic Blood Pressure |
| SDS | Standard Deviation Score |