Original Article

Arterial Prehypertension and Elevated Pulse Pressure in Adolescents: Prevalence and Associated Factors

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Objective

To estimate the prevalence of prehypertension and elevated pulse pressure in adolescents and assess the association between those two conditions and sex, age, sexual development, obesity and physical activity.

Methods

Anthropometrical data and blood pressure were measured in and a questionnaire was applied to 456 adolescents (aged 12 to 17 years) recruited from public and private schools, in the Fonseca district, in the city of Niterói, state of Rio de Janeiro, Brazil, from 2003 to 2004.

Results

Thirty nine (8.6%) presented prehypertension (PH) and 13.4%, elevated pulse pressure (PP). At bivariate analysis, PH was significantly associated with sex, age and obesity, with more prevalent in boys aged between 15 and 17 years, and in the obese. Elevated PP was associated with gender only, as it was more prevalent in boys. Sexual maturation did not show an association with PH or elevated PP. Similar correlations were found at logistic regression. PH prevalence odds ratio was 7.7 for sex, 4.3 for age and 4.6 for obesity. Elevated PP prevalence odds ratio was 10.8 for sex. The correlation between PP and physical activity was positive and significant. The elevation of PP was attributable to systolic blood pressure.

Conclusion

PH and the elevated PP were shown to be present in adolescents from a population with a low prevalence of hypertension, mostly in boys. Further prospective studies are necessary to assess the persistence and the impact of those conditions.

Key words

Adolescents, prevalence, hypertension, obesity, pulse pressure.

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Cardiovascular diseases are currently accountable for 32% of all deaths in Brazil, and more than one million hospital admissions per year at the Sistema Único de Saúde (SUS) - the Brazilian governmental health agency, with arterial hypertension being one of its main risk factors[1]. In Brazil, approximately 44% of the population is overweight or obese, with the total of hypertensive individuals estimated as more than 16 million people[2], and obesity being one of the main risk factors for hypertension[3].

The association between systemic arterial hypertension and cardiovascular diseases steadily increases from 75 mmHg and 115 mmHg of diastolic and systolic pressures respectively, with no clear cutoff for a normal arterial pressure value[4]. Recently, the term prehypertension has been introduced[3]. American studies published in 2004 showed that this condition affects around 30% of the U.S. adult population[5], being directly responsible for 9.1% of the deaths, 6.5% of the home care cases and 3.4% of hospital admissions for people between 25 and 74 years of age[6]. In 2004, the National High Blood Pressure Education Program Working Group on Children and Adolescents published the fourth report on blood pressure control of children and adolescents[7]. It has defined that those individuals with a systolic pressure > 120 mmHg and a diastolic pressure > 80 mmHg, regardless of the age, must be considered prehypertensive and counseled to change their lifestyles[7,8].

In the most recent years, pulse pressure has been seen as a factor of cardiovascular risk, including the suggestion that it should be considered a marker of pre-clinical cardiovascular disease[9]. In the Dutch study ARYA, individuals who maintained higher levels of arterial pressure and pulse pressure, from adolescence to adult life, presented higher levels of carotid intimal-media thickening, which is a cardiovascular risk factor[10].

The concern regarding the prevention of future cardiovascular events has been translated into clear proposals made by specialists as well as governmental actions, such as restricting the sales of foods considered to be inadequate for children at schools (Municipal Law, RJ, #21,207 of April 1st, 2002) and the creation of programs that stimulate a more active lifestyle[11]. The choice and implementation of such measures can be further supported by the identification of higher-risk populations and the knowledge on the distribution of the different risk factors and their association since childhood and adolescence.

The objective of this study is to estimate the prevalence of prehypertension and elevated pulse pressure in schoolchildren and verify whether there is an association between these two conditions and gender, sexual development and two modifiable factors: obesity and physical activity intensity.

Methods

This study is part of a research conducted in the schools of Fonseca district in the city of Niterói, state of Rio de Janeiro, Brazil, from October 2003 to June 2004. It is a sectional study. Twelve to 17 year-old adolescents were evaluated, in a sample that was proportional to the number of students enrolled by age in all public and private schools of the district, which had 50 or more students within this age range. The sample of 480 students (400 + 20% of loss) was calculated for a statistical significance of 5%, to identify hypertension prevalence in 8% of the study population for a 25% precision. There were 24 losses, due to absenteeism (21 cases) or refusal to participate (3 cases). Two visits were carried out, for filling a questionnaire (visit 1) and anthropometrical data collection (visits 1 and 2). Two age groups were considered: 12 to 14 (group 1) and 15 to 17 (group 2). In order to determine the prevalence of obesity, the 95th percentile of body mass index (BMI) proposed for the Brazilian population was utilized[12].

Weight was measured using a Filizola® electronic scale (model PL18) and the procedures for weight, height and abdominal perimeter measurement were carried out as described by Fonseca et al[13] Boys who presented axillary hair and girls who had experienced menarche were considered sexually mature[13]. The measurement of arterial blood pressure was carried out in Omrom® automatic pressure monitors type Hem-711 and 705 CP, validated according to international protocols and calibrated before initiating the study[14]. The procedures followed the guidelines presented in the IV Brazilian Directives for Arterial Hypertension[15]. The mean of the six measurements - three per visit – was considered, with diastolic differences < 5 mmHg.

The adolescents were defined as being hypertensive when they presented systolic arterial pressure (SAP) or diastolic arterial pressure (DAP) means > 95th percentile for sex, age and height; those who presented systolic mean > 120 mmHg or diastolic mean > 80 mmHg were considered prehypertensive[7]. As a cutoff for pulse pressure (PP) was not found in the literature, an elevated PP was considered when the difference between the systolic and diastolic pressures was > 50 mmHg. This PP level showed to be associated with increased cardiovascular mortality in individuals younger than 50 years[16].

Leisure physical activity (LPA) was defined as any physical activity undertaken to improve health and/or physical condition with an esthetic objective or leisure, even those included in the curricular program, in the two weeks that preceded the application of the questionnaire[17]. In the quantification of the total activity volume, we utilized the metabolic equivalent (ME) index of each activity[18], regardless of body weight[17]. The time spent in each activity in hours was multiplied by each ME value, and the values of all activities practiced during the week was totalized as a weekly ME (WME). Each student's LPA was then determined by the summation of WMEs.

The whole team was trained previously, following a written protocol. All participants who were fifteen years of age or older signed an informed consent, and those 12 to 14 years asked their parents or tutors to sign it. The project was approved by the Ethics Committee of the Antonio Pedro University Hospital (Universidade Federal Fluminense).

Statistical Analysis - The prevalence was calculated for alterations in arterial pressure and their 95% confidence intervals according to gender, age (12 to 14 yrs and 15 to 17 yrs) as well as sexual development and BMI (obesity). The bivariate analysis between the dicotomic variables and the chi-square test was performed, for a level of significance set at 5%. Pearson's correlation coefficients were estimated for the continuous variables (BMI and WME), adjusted for gender, age and BMI with SAP, DAP and PP. Logistic regression was utilized to estimate the adjusted prevalence probability ratio, with a level of significance set at 5%. The statistical analyses were performed with Epiinfo (CDC) version 3.2 of January 2004.

Results

Of the total of 456 adolescents studied, 55.5% were girls and 44.5% were boys; 48.2% were between 12 and 14 years and 51.8% were 15 to 17 years; 13.2% were obese: 10.7% of the girls and 16.3% of the boys. Overall, 83.6% of the adolescents were considered sexually developed, being 88.1% of the girls and 78% of the boys.

Figure 1 represents the distribution of the prevalence of arterial pressure alterations by its components, SAP and DAP. Thirty-nine adolescents presented pre-hypertension (PH) (8.6%, 95%CI: 6.2% - 11.6%). Twenty-one adolescents presented arterial hypertension (4.6%, 95%CI: 2.9% - 7.1%); 11 presented isolated systolic hypertension (2.4%, 95%CI: 1.3 – 4.5); 7 presented isolated diastolic hypertension (1.5%, 95%CI: 0.7% - 3.2%); and 3 presented systolic and diastolic hypertension (0.7%, 95%CI: 0.2% - 2.1%).

Table 1 presents the prevalence of PH and elevated PP according to sex, age and obesity. Sexual development did not show a statistically significant association with the two arterial pressure alterations and thus, is not shown in the table. Thirty-nine adolescents (8.6%, 95%CI: 6.2% - 11.65) presented PH. The highest prevalence was observed among boys, when compared to the girls, among the adolescents aged 15 to 17 yrs of age, when compared to those aged 12 to 14 years, and among the obese (BMI>95th percentile) in relation to the non-obese (BMI≤95th percentile). There was a statistically significant association between PH and the three variables studied. Sixty-one adolescents (13.4%, 95%CI: 10.5% - 16.9%) had elevated PP. The elevated PP was not associated with obesity or age range, being higher among the boys when compared to the girls.

The distribution of the prevalence of SAP and DAP alterations among the adolescents with elevated PP is shown in Figure 2. Twenty-eight adolescents (45.9%,

Table 1 - Prevalence of pre-hypertension (PH) and elevated pulse pressure (PP) according to sex, age and obesity. Students attended schools in Fonseca, Niterói, Brazil, aged 12 to 17 yrs; 2003-2004

Arterial Pressure Alterations		PH	Elevated PP	Total
Total		39	61	456
	Prevalence% (CI 95%)	8.6 (6.2-11.6)	13.4 (10.5-16.9)	
Sex				
Boys		33	53	203
	Prevalence% (CI 95%)	16.3 (11.5-22.1)	26.1 (20.2-36.7)	
Girls		6	8	253
	Prevalence% (CI 95%)	2.4 (0.9-5.1)	3.2 (1.4-6.1)	
P-Value*		<0.001	<0.001	
Age				
15-17 yrs		31	35	236
	Prevalence% (CI 95%)	13.1(9.1-18.1)	14.8(10.6-20.0)	
12-14 yrs		8	26	220
	Prevalence % (CI 95%)	3.6(1.6-7.0)	11.8(7.9-16.8)	
P-Value*		<0.001	0.409	
Obesity				
Yes (BMI>95th percent.)		12	8	60
	Prevalence% (CI 95%)	20.0 (10.8-32.3)	13.3 (5.9-24.6)	
No (BMI<=95th percent.)		27	53	395
	Prevalence% (CI 95%)	6.8 (4.6-9.9)	13.4 (10.3-17.3)	
P-Valor*		0.001	1.000	

** P-Pearson's Chi-square value.*

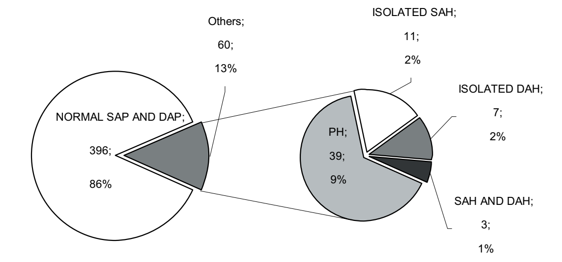

Fig. 1 – *Distribution of the prevalence of arterial blood pressure alterations through its components SAP and DAP. Students were from schools in Fonseca, Niterói, Brazil, aged 12 to 17 yrs; 2003-2004; SAP – systolic arterial pressure; DAP – diastolic arterial pressure; PH – pre-hypertension; SAH – Systolic arterial hypertension; DAH – diastolic arterial hypertension.*

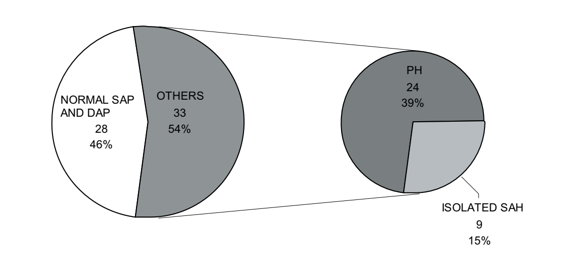

Fig. 2 – *Distribution of the prevalence of arterial blood pressure alterations in adolescents with elevated pulse pressure. Students were from schools in Fonseca, Niterói, Brazil, aged 12 to 17 yrs; 2003-2004; SAP – systolic arterial pressure; DAP – diastolic arterial pressure; PH – pre-hypertension; SAH – Systolic arterial hypertension; DAH – diastolic arterial hypertension.*

95%IC: 40.8% - 66.9%) were normotensive, and 33 adolescents (541%, IC 95%: 48.1% - 60.1%) presented arterial pressure alteration.

The SAP mean was significantly higher among adolescents with elevated PP when compared to those with normal PP, with no difference between DAP means. When comparing the group of adolescents with altered and normal PP, whether they had normal SAP and DAP or altered SAP and/or DAP, it was observed that the mean SAP was significantly higher and DAP was lower among the adolescents with altered PP (Table 2).

Pearson's correlation of the BMI with SAP (r = 0.3029) and DAP (r = 0.3480), adjusted for sex and age, were positive and statistically significant (P< 0.001). No correlation between BMI and PP was observed (r = 0.0533 and p = 0.240). Additionally, no correlation between WME and SAP was observed, adjusted for sex, age and BMI (r = 0.0063 and p = 0.894). The correlation was negative with DAP (r = -0.0967 and P= 0.041) and positive with PP (r = 0.0994 and P= 0.035), and statistically significant in both cases.

The logistic regression analysis is shown in Table 3, with probability ratios adjusted by the remaining variables included in the model. Sex, age and obesity were independently associated with PH. As in the bivariate analysis, only sex was associated with elevated PP.

Discussion

The presents study demonstrated that new forms of aberrant behavior of arterial pressure, PH and elevated PP, were present, respectively, in 8.6% and 13.4% of the studied adolescents. It is noteworthy that the prevalence of hypertension in the studied population was lower than that observed in Brazilian studies. According to the Task Force criterion of 1996[19], the prevalence of hypertension in the present study was 2.2% for both sexes, with 3.4% for boys and 1.2% for girls, whereas the results obtained for the state of Rio de Janeiro was 8.3% for both sexes, with 10.9% for boys and 7% for girls; a study carried out

Table 2 – Systolic arterial pressure (SAP) and diastolic arterial pressure (DAP) means according to the pulse pressure levels. Students attended schools in Fonseca, Niterói, Brazil, aged 12 to 17 yrs; 2003-2004

PP			Normal SAP and DAP		Altered SAP and/or DAP	
	SAP means	DAP means	SAP means	DAP means	SAP means	DAP means
Normal	105.18	65.53	104.00	64.43	121.29	80.55
Elevated	120.91	65.48	114. 32	61.57	126.51	68.80
P-Value*	<0.001	0.956	<0.001	0.013	<0.001	<0.001

*PP – pulse pressure; SAP – systolic arterial pressure; DAP – diastolic arterial pressure; * P-Value of Students' t test for the difference of means between normal PP and elevated PP.*

Table 3 – Prevalence odds ratio (POR) of pre-hypertension (PH) pulse pressure (PP) according to sex, age, obesity and physical activity. Students attended schools in Fonseca, Niterói, Brazil, aged 12 to 17 yrs; 2003-2004

Independent variables	PH		Elevated PP	
	Adjusted POR	P-Value	Adjusted POR	P-Value
Sex[1]	8.70	0.000	10.85	0.000
Dichotomic age[2]	4.80	0.001	1.17	0.593
Obesity[3]	5.30	0.000	0.811	0.628
Physical activity (WME)[4]	1.00	0.369	1.00	0.900

1 Girls –reference category and boys – risk category; 2 Dichotomic variable: 12-14 yrs – reference category and 15-17 yrs – risk category; 3 Dichotomic variable: BMI percentile < 95 – reference category and 95th percentile and over – risk category; 4 Continuous variable.

in São Paulo, with children aged 6 to 18 years, showed a prevalence of 6.9% for both sexes[20,21].

The chance of PH prevalence among boys, when adjusted for age, obesity and WME, was around 9-fold that of girls. A higher prevalence of hypertension in boys has been observed in national and international studies, but with lower intensity associations[22,23,24]. Sorof et al, in a recent study carried out with North-American schoolchildren, found a relative risk of 1.5 between hypertension and sex, with a higher risk for boys[25]. Despite the consistency of such observations, we did not find in Literature a discussion on the higher prevalence of pressure alteration in male adolescents when compared to females. In adults, this is a time-old discussion and includes hormonal and hemodynamic factors, favoring women[26].

PH did not show a strong and independent association with obesity, with a prevalence probability ratio of 5.3. In a review of the correlation between obesity and hypertension in children, the authors found a positive and consistent association, independent of age and ethnicity, with probability ratios varying from 2.5 and 3.7[27]. The mechanisms by which obesity leads to pressure elevation have not been completely clarified. In a recent review on the subject, Rahmouni et al point to central and peripheral alterations associated to obesity that can elevate the arterial pressure and maintain it elevated, citing the activation of the sympathetic nervous system, the rennin-angiotensin-aldosterone system, the endothelial dysfunction and renal function abnormalities[28].

The intensity of the practiced physical activity, measured through the weekly metabolic equivalent (WME), showed a negative and statistically significant correlation with DAP, regardless of age, weight and BMI. There was no association with WME, PH or SAP. Several epidemiological studies have observed an inverse correlation between the amount of physical exercise and arterial pressure level[29]. However, some studies have not observed such correlation. The CARDIA study, carried out in middle-aged adults, showed that physical activity was negatively associated to DAP, but not with SAP[30]. An Italian study with 6 to 18 year-old students showed that physical activity was not associated to pressure levels[31].

In the present study, sexual development was not associated with pressure alterations, dissimilarly to what has been presented in literature[32]. Two factors can explain such discordance. On the one hand, the indicator utilized here for sexual development might not have a good power of discrimination; on the other hand, only 16% of the adolescents studied were prepubertal, making the identification of the association difficult to perform.

We found a prevalence of elevated PP (>50 mmHg) of 13.3%. We considered a cutoff of 50 mmHg based on two studies that found an increased cardiovascular risk with this level of PP[16,33]. Although the positive association between PP and cardiovascular risk has been largely demonstrated[34], there are discordant results in literature, but the evidence points out to the existence of an increased risk in patients with elevated SAH and PP[35]. As observed by Lurbe et al[36], around 50% of the adolescents who presented elevated PP were normotensive, thus representing a lower risk[35]. The increase of PP in the studied population occurred from the increase of SAP, which is more common among adolescents[25].

The adolescents with elevated PP showed more elevated mean SAP when compared to those with normal PP, whether they were normotensive or not. DAP means were lower in the group with elevated PP, although with no statistical significance.

Pulse pressure is the result of the interaction of cardiac ejection and the properties of arterial circulation with the increased prevalence of left ventricular hypertrophy in hypertensive adults[37]. In elderly individuals, it has been associated with the stiffening of arteries and atherosclerosis of the great arteries, demonstrated as the intima-media thickening (IMT)[35,37]. The arterial stiffening as well as the IMT have shown to be associated with increased morbidity and mortality[38,39]. Recently, studies showing a correlation between SAH and PP observed in infancy and adolescence and the presence of arterial stiffening and IMT in young adults have been published[40-43], indicating that the processes identified in the elderly are also present in younger individuals. Studies with healthy young adults of both sexes also showed that the intima-media thickening (IMT) and aortic stiffening seem to reflect two different entities of vascular damage, with IMT alone being associated to LDL-cholesterol and BMI[44,45]. Despite the evidence associating elevated PP in adolescents to IMT in young adults, which in turn would be associated to increased BMI, we did not observe an association between elevated PP and obesity (dichotomic variable), or between PP and BMI, as continuous variables.

The association of PP with gender (higher in the male sex) has been observed in different studies[36,46], as well as the association with IMT[42,43,47], although the latter can be partially attributed to differences in lumen diameter and might not reflect differences in vascular damage[47]. In our study, the logistic regression showed that boys had a probability of elevated PP that was around 11-fold that of the girls.

In addition to age and the factors related to atherosclerosis, physical activity has been correlated to elevated PP, regarding a sedentary lifestyle as well as intense training, associated with arterial stiffening[37]. The intensity of physical activity measured by WME (continuous variable) did not show to be associated with elevated PP (dichotomic variable). However, the correlation between PP and WME (both as continuous variables) was positive and statistically significant.

The adopted PP criterion was estimated from adult values, as there are no studies showing cutoffs associated to increased morbidity and mortality in adolescents.

Pressure levels above the 95th percentile for the North-American children and adolescent populations, classified as hypertension for each age range, are lower than 140 X 80 mmHg, except for 17-year-old adolescents with height > 95th percentile. Based on this information, it is possible to suppose that the level of PP associated to increased morbidity and mortality in adolescents could be lower than that of adults. Anyhow, to adopt the adult cutoff is a study limitation and the results presented here must be interpreted with this reservation.

Our study is sectional; thus, we cannot establish the antecedence of modifiable factors (obesity and intensity of physical activity) in relation to pressure alterations. Nevertheless, the association between these factors with arterial hypertension and PP has been described in some longitudinal studies. Ben-Dov et al inform that PP, related to mechanical properties of great arteries, can be influenced by the "white coat effect", emphasizing that, in normotensive individuals, the effect is similar to what happens in the systolic pressure[48]. Our study utilized at least three measurements in two different occasions, and the adolescents themselves worked the device at the second and third measurements, which leads us to believe that the "white coat effect" might have been attenuated.

We utilized a student sample aged 12 to 17 years, which is an age range, according to the 2000 demographic census for Niteroi, that has 100% of students attending school, and the sampling was proportional to the number of adolescents enrolled at school, which decreases the possibility of study selection bias. The chosen district has adolescents from different social classes. Thus, the results of this study, considering its limitations, can possibly be extrapolated to districts of other cities from regions with similar social configuration and habits.

In conclusion, elevated PH and PP can already be observed in adolescents from a population that presented low hypertension prevalence. The association of obesity with PH is an extra alert factor regarding the need for control of this condition since childhood. Although it is not clear which are the PP determinants in adolescents, as well as the future risk that this alteration can represent, there is enough evidence to justify the study of this condition in adolescents. Our study showed that the chance of prevalence of this condition is much higher in boys, and that it occurs due to an increase in SAP, indicating the need for further studies with prospective designs to assess the persistence and impact of this condition.

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Potencial Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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