Concurrent determinants of blood pressure among adolescents: the 11-year follow-up of the 1993 Pelotas (Brazil) birth cohort study

Determinantes contemporâneos da pressão arterial em adolescentes: a visita de 11 anos da coorte de nascimentos de Pelotas, Rio Grande do Sul, Brasil, 1993

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Abstract

The aim of this study was to evaluate concurrent risk factors for high blood pressure in adolescents. This is a prospective cohort study including 4,452 adolescents born in Pelotas, Rio Grande do Sul State, Brazil, in 1993. Blood pressure was measured before and after the interview, and the mean value was used in the analyses. Mean systolic blood pressure was 101.9mmHg (SD = 12.3) and mean diastolic pressure was 63.4mmHg (SD = 9.9). Adolescents with black skin had higher blood pressure than those with white skin. Mean systolic pressure among subjects in the top quartile of body mass index (BMI) was 11.6mmHg higher than among those in the lowest quartile. Mean systolic pressure among postmenarcheal girls was 5.4mmHg higher than among premenarcheal girls. Similar trends were found for diastolic arterial pressure. Our findings suggest that blood pressure control must begin already in childhood and adolescence.

Blood Pressure; Adolescent; Cohort Studies

Introduction

High blood pressure during childhood and adolescence is an important risk factor for arterial hypertension in adult life, which in its turn is associated with cardiovascular disease [1,2]. In this context, the World Health Organization (WHO) underscores the importance of the periodic and routine measurement of arterial pressure in children and adolescents as a strategy to reduce morbidity and mortality in adult life [3].

Risk factors for high blood pressure among adolescents have been evaluated in a number of publications. Authors have highlighted the associations between menarche and arterial pressure [4,5], and physical activity and body mass index (BMI) [6]. There is also an extensive body of literature investigating the effects of skin color and race on blood pressure that suggests that individuals with dark skin have higher arterial pressure than those with fair skin [7,8,9].

The aim of the present analysis is to evaluate concurrent risk factors associated with high blood pressure among adolescents from the 1993 birth cohort carried out in the city of Pelotas, Southern Brazil. This analysis specifically explores the effects of skin color, BMI, physical activity, and menarche on blood pressure in early adolescence. Early determinants of this variable were reported in a previous publication [10].

Methods

All hospital births taken place in the city of Pelotas in 1993 were monitored. We administered a questionnaire to mothers and weighed and measured their newborn babies. Subsamples of this cohort were visited at ages 1, 3, and 6 months and 1, 4, 6, and 9 years of age. In 2004-2005 all participants of the cohort were traced in a further follow-up study, the details of which have been published elsewhere [11].

Arterial pressure was measured on the adolescent's wrist using a digital monitor (Omron, Beijing, China) with an error margin of 3mm/Hg. Measurements were taken immediately before and after the interview (with an interval of approximately 60 minutes). Measurements were taken with the subject seated. The mean of the two measurements was used for the present analysis. A previous study has found this digital monitor to be easy to use and to produce results that are very similar to those of a mercury sphygmomanometer [12].

The adolescent's BMI was calculated based on two measurements of weight and height, the mean value of which was used in the analysis. Weight was measured using a digital scale with 100g precision (SECA, Birmingham, UK). Height was measured using an aluminum stadiometer with 1mm precision. We chose to divide the BMI variable into quartiles. The same procedure was applied to a physical activity score based on a questionnaire that included means of transportation to school and participation in sports or structured or non-structured physical activity inside or outside school. Self-reported skin color was used in all analyses. We chose to evaluate the "black" category (*pretos/negros*) separately from the "mixed" category (*pardos/mulatos*), given that the literature suggests a specific effect of African descent on arterial pressure. Menarche was evaluated as a dichotomous variable (yes/no). An assets index was constructed based on the ownership of domestic goods, using principal component analysis. This index was classified into quintiles for analysis purposes.

We included the following confounders in the analysis: smoking, alcohol intake, family history of hypertension (father or mother), weight and length at birth, gestational age, maternal pre-gestational BMI, and maternal smoking during pregnancy. In addition, we also obtained information on the habit of adding salt to food after serving. However, this variable was not associated with arterial pressure, and was thus excluded from the analyses.

The descriptive analysis included calculating means and standard deviations (SD) for continuous variables and percentages for categorical variables. The percentage of hypertensives was calculated based on the cutoff points described in the *Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents* [13] (percentile > 95 according to sex, age, and height). We then carried out Pearson correlation analyses for systolic and diastolic arterial pressure, BMI, and physical activity score. In crude analysis, we compared mean arterial pressure between the subgroups defined by the independent variables, using the T test for menarche and analysis of variance for the remaining independent variables. In adjusted analysis, in addition to adjusting for confounders, we used a hierarchical model for entering independent variables into the model. The five independent variables were hierarchized into three levels. The first level included only skin color. The second included the assets index, and the third included BMI, physical activity score, and menarche.

The present study was approved by the Research Ethics Committee of the School of Medicine, Federal University in Pelotas. Parents or caretakers signed a term of free informed consent authorizing the youth to participate in the study.

Results

Of the 5,249 participants of the cohort, 4,452 were traced at the 11-year follow-up. When added to the 141 known to have died before this age, traced subjects represented 87.5% of the original cohort. Among those interviewed at 11 years, 67% were white, 23% were at risk of overweight or obesity, and only 42% reached the recommended level of 300 minutes per week of physical activity.

Mean systolic arterial pressure among adolescents was 101.9mmHg (SD = 12.3), being slightly higher (p = 0.08) among boys (102.2 ± 12.2mmHg) when compared to girls (101.5 ± 12.5mmHg). Mean diastolic pressure was 63.4mmHg (SD = 9.9), and was also slightly higher (p = 0.12) among boys (63.5 ± 9.8mmHg) than among girls (63.1 ± 9.9mmHg). The correlation coefficient between systolic and diastolic pressure was 0.78. Based on the cutoff points of the *Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents* [13], prevalence of arterial hypertension was 7% among boys and 7.2% among girls.

Table 1 presents the mean values of systolic pressure according to the five independent variables for the whole sample and for each sex in separate. Youths with white skin had slightly lower levels of systolic pressure when compared

Table 1

Mean and standard deviation (SD) of systolic arterial pressure according to skin color, body mass index (BMI) and physical activity score for the total sample and for boys and girls separately. 1993 Pelotas (Brazil) birth cohort, 2004-2005 follow-up.

Variables	Total sample		Boys		Girls	
	Mean (SD)	p-value *	Mean (SD)	p-value *	Mean (SD)	p-value *
Self-reported skin color		0.001		0.21		< 0.001
White	101.4 (12.2)		101.9 (12.1)		100.8 (12.3)	
Mixed	103.0 (12.2)		103.8 (12.7)		102.2 (11.6)	
Black	102.8 (12.6)		102.6 (12.2)		103.0 (12.9)	
Assets index (quintiles)		0.002		0.003		0.03
1st (poorest)	102.3 (13.0)		101.9 (12.8)		102.8 (13.1)	
2nd	100.4 (11.8)		100.2 (11.5)		100.5 (12.1)	
3rd	102.2 (12.3)		102.8 (12.1)		101.8 (12.4)	
4th	102.5 (12.5)		103.2 (12.3)		101.9 (12.6)	
5th (richest)	101.7 (11.9)		102.9 (11.9)		100.5 (11.9)	
BMI (quartiles)		< 0.001		< 0.001		< 0.001
1st (lowest)	96.9 (11.5)		97.8 (11.7)		96.1 (11.2)	
2nd	99.7 (11.2)		99.7 (11.2)		99.6 (11.3)	
3rd	102.6 (11.1)		103.1 (11.0)		102.1 (11.3)	
4th (highest)	108.3 (12.4)		108.4 (12.0)		108.2 (12.7)	
Physical activity score (quartiles)		0.03		0.03		0.12
1st (least active)	102.1 (12.3)		103.1 (11.9)		101.5 (12.5)	
2nd	102.6 (12.8)		102.7 (12.5)		102.5 (13.0)	
3rd	101.5 (12.5)		102.2 (12.6)		100.7 (12.3)	
4th (most active)	101.1 (11.6)		101.0 (11.5)		101.2 (11.8)	
Menarche						< 0.001
No	-		-		100.6 (12.3)	
Yes	-		-		106.1 (12.5)	

BMI: body mass index.

* p-values calculated using t test for menarche and analysis of variance for the other independent variables.

to those with black or mixed skin, but this difference was not statistically significant among boys. There was a significant association between the assets index and systolic arterial pressure in both the total sample and for each sex. However, there was no dose-response relationship between these two variables. BMI was directly and significantly associated with systolic arterial pressure, with a difference between extreme quartiles of 11.4mmHg for the total sample, 10.6mmHg among boys, and 10.1mmHg among girls. The Pearson correlation coefficient for systolic arterial pressure and BMI was 0.37 ($p < 0,001$). For diastolic pressure, this value was 0.29 ($p < 0.001$).

Physical activity was significantly associated with systolic pressure in the total sample and among boys. In both cases, systolic pressure was lower in the fourth (most active) quartile, though differences were moderate. Using the physical activity score as a continuous variable yielded Pearson correlation coefficients for systolic and diastolic pressure of -0.02 ($p = 0.15$) and -0.02 ($p = 0.11$), respectively. Menarche was strongly associated with systolic arterial pressure.

Table 2 presents mean diastolic arterial pressure according to independent variables. The association between skin color and diastolic pressure was very similar to that skin color and systolic pressure – i.e., white adolescents had lower pressure levels – but this association was not significant among boys. Once again, the association between assets index and arterial pressure showed no clear dose-response trend. BMI was positively and significantly associated with the outcome in all analyses, the difference between extreme quartiles being of 7.1mmHg for the total sample, 6.0mmHg among boys, and 8.0mmHg among girls. As in the case of systolic pressure, a large difference was found between the two lowest and the two highest BMI quartiles. The association between diastolic pressure and physical activity was also of moderate magnitude. The

Table 2

Mean and standard deviation (SD) of diastolic arterial pressure according to skin color, body mass index (BMI) and physical activity score for the total sample and for boys and girls separately. 1993 Pelotas (Brazil) birth cohort, 2004-2005 follow-up.

Variables	Total sample		Boys		Girls	
	Mean (SD)	p-value *	Mean (SD)	p-value *	Mean (SD)	p-value *
Self-reported skin color		< 0.001		0.30		< 0.001
White	62.9 (9.7)		63.4 (9.8)		62.5 (9.5)	
Mixed	63.6 (9.8)		64.0 (10.3)		63.2 (9.3)	
Black	64.3 (10.2)		64.1 (9.9)		64.6 (10.5)	
Assets index (quintiles)		0.006		0.10		0.05
1st (poorest)	63.8 (10.7)		63.6 (10.5)		64.0 (11.0)	
2nd	62.5 (9.7)		62.6 (9.5)		62.4 (9.9)	
3rd	63.6 (9.6)		64.1 (9.6)		63.2 (9.6)	
4th	64.0 (9.7)		64.3 (9.7)		63.7 (9.8)	
5th (richest)	62.9 (9.3)		63.4 (9.4)		62.4 (9.1)	
BMI (quartiles)		< 0.001		< 0.001		< 0.001
1st (lowest)	60.4 (9.5)		61.1 (9.6)		59.8 (9.3)	
2nd	61.9 (9.4)		62.1 (9.4)		61.7 (9.3)	
3rd	63.6 (9.3)		64.1 (9.4)		63.1 (9.2)	
4th (highest)	67.5 (9.9)		67.1 (9.8)		67.8 (9.9)	
Physical activity score (quartiles)		0.006		0.03		0.03
1st (least active)	63.4 (10.2)		63.9 (10.3)		63.1 (10.2)	
2nd	64.0 (10.3)		64.2 (10.2)		63.9 (10.4)	
3rd	63.0 (9.9)		63.6 (10.2)		62.2 (9.5)	
4th (most active)	62.6 (8.9)		62.6 (8.7)		62.6 (9.1)	
Menarche						< 0.001
No	-		-		62.6 (9.8)	
Yes	-		-		66.1 (10.0)	

BMI: body mass index.

* p-values calculated using t test for menarche and analysis of variance for the other independent variables.

strong positive association with age of menarche was also detected for diastolic pressure.

Table 3 presents the results of linear regression for systolic arterial pressure. Black and mixed adolescents showed similar coefficients among themselves, and higher pressure levels than white adolescents, although these associations were stronger for black adolescents due to higher numbers. Adjusted analysis confirmed the significant association, but without a dose-response effect, between assets index and arterial pressure. The direct association with BMI was confirmed in adjusted analysis, with those in the highest quartile showing a mean systolic pressure 11.6mmHg higher than those in the lowest quartile. The weak association with physical activity was confirmed in adjusted analysis, though these results were significant only for the total sample and among girls. The second quartile of physical activity showed the highest value of systolic pressure among girls, whereas among boys the highest value was found in the first quartile. Mean systolic pressure among postmenarcheal girls was 5.4mmHg higher than among the premenarcheal group.

Table 4 presents the results of multivariate analysis for diastolic arterial pressure. Black adolescents showed a diastolic pressure almost 2.0mmHg higher than that of white adolescents. Once again there was a significant association, though lacking a dose-response effect, between arterial pressure and assets index in the total sample. This association was not evident among either girls or boys separately. The positive association with BMI was confirmed after adjustment in all groups. Regarding physical activity, the second quartile consistently showed higher diastolic pressure, and magnitude of the associations remained moderate. Postmenarcheal girls had a mean diastolic pressure 3.6mmHg higher than premenarcheal girls.

Table 3

Linear regression coefficients (95% confidence interval – 95%CI) for systolic arterial pressure according to independent variables for the total sample and for boys and girls separately. 1993 Pelotas (Brazil) birth cohort, 2004-2005 follow-up.

Variables *	Total sample		Boys		Girls	
	Coefficient (95%CI)	p-value	Coefficient (95%CI)	p-value	Coefficient (95%CI)	p-value
Self-reported skin color		0.001		0.21		< 0.001
White	1.00		1.00		1.00	
Mixed	1.63 (-0.10; 3.36)		1.91 (-0.53; 4.35)		1.39 (-1.06; 3.83)	
Black	1.42 (0.61; 2.23)		0.64 (-0.52; 1.81)		2.17 (1.03; 3.31)	
Assets index (quintiles)		0.001		< 0.001		0.09
1st (poorest)	1.00		1.00		1.00	
2nd	-1.84 (-3.01; -0.67)		-1.54 (-3.18; 0.09)		-2.15 (-3.83; -0.48)	
3rd	0.11 (-1.06; 1.29)		1.10 (-0.56; 2.76)		-0.81 (-2.48; 0.86)	
4th	0.49 (-0.69; 1.67)		1.60 (-0.05; 3.24)		-0.59 (-2.27; 1.10)	
5th (richest)	-0.07 (-1.28; 1.13)		1.47 (-0.18; 3.13)		-1.67 (-3.41; 0.08)	
BMI (quartiles)		< 0.001		< 0.001		< 0.001
1st (lowest)	1.00		1.00		1.00	
2nd	3.62 (2.14; 5.11)		1.79 (0.33; 3.26)		3.81 (2.33; 5.28)	
3rd	5.54 (4.03; 7.06)		5.20 (3.70; 6.69)		6.08 (4.60; 7.56)	
4th (highest)	11.58 (10.03; 13.13)		10.74 (9.19; 12.29)		12.35 (10.86; 13.84)	
Physical activity score (quartiles)		0.03		0.07		0.02
1st (least active)	1.00		1.00		1.00	
2nd	1.19 (-0.15; 2.53)		-0.15 (-1.79; 1.50)		1.11 (-0.23; 2.45)	
3rd	-0.87 (-2.27; 0.53)		-0.44 (-2.01; 1.12)		-0.90 (-2.30; 0.51)	
4th (most active)	-0.52 (-2.06; -1.02)		-1.68 (-3.19; -0.16)		-0.60 (-2.14; 0.94)	
Menarche						< 0.001
No	-		-		1.00	
Yes	-		-		5.36 (3.97; 6.75)	

BMI: body mass index.

* Adjusted for smoking, alcohol intake, weight and length at birth, gestational age, mother's pre-gestational body mass index, reported maternal or paternal hypertension, and smoking during pregnancy. In addition, BMI, physical activity score, and menarche were adjusted for skin color and assets index, whereas the reverse adjustment was not performed.

Discussion

This is one of the few Brazilian studies to evaluate arterial blood pressure among adolescents in a population-based sample. Prevalence of hypertension in the sample – close to 7% – is similar to that detected in other Brazilian studies [14,15,16,17,18,19]. The age range in these studies was 6 to 18 years, and prevalence of hypertension ranged from 5% to 16.6%.

The study of arterial pressure becomes even more relevant if we consider that systolic and diastolic pressure levels have been rising among children and adolescents in a number of countries [20]. An analysis of surveys conducted in the United States between 1963 and 2002 showed that the arterial pressure of children and adolescents decreased between 1963 and 1988, after which it began to increase [20].

There is no data on trends in arterial pressure among Brazilian adolescents. However, given the increase in prevalence of obesity [21], it is reasonable to assume that a similar increase in blood pressure is also taking place in our settings.

Our results show a strong association between blood pressure and BMI, in addition to important effects of menarche and skin color on blood pressure. There was no clear dose-response relationship between physical activity and blood pressure.

The international literature provides convincing evidence that Blacks have higher levels of arterial pressure than Whites [7,8,9]. Both in the total sample and in analyses separated by sex, blood pressure was higher among adolescents with black skin, diastolic arterial pressure among black girls being on average 2mmHg higher than among white girls. Potential mechanisms for this

Table 4

Linear regression coefficients (95% confidence interval – 95%CI) for arterial arterial pressure according to independent variables for the total sample and for boys and girls separately. 1993 Pelotas (Brazil) birth cohort, 2004-2005 follow-up.

Variables *	Total sample		Boys		Girls	
	Coefficient (95%CI)	p-value	Coefficient (95%CI)	p-value	Coefficient (95%CI)	p-value
Self-reported skin color		< 0.001		0.30		< 0.001
White	1.00		1.00		1.00	
Mixed	0.67 (-0.72; 2.05)		0.65 (-1.32; 2.62)		0.70 (-1.23; 2.64)	
Black	1.43 (0.78; 2.09)		0.71 (-0.23; 1.65)		2.12 (1.23; 3.02)	
Assets index (quintiles)		0.008		0.06		0.15
1st (poorest)	1.00		1.00		1.00	
2nd	-1.15 (-2.08;-0.21)		-0.91 (-2.22; 0.41)		-1.36 (-2.69; -0.03)	
3rd	0.08 (-0.85; 1.02)		0.72 (-0.61; 2.05)		-0.48(-1.80; 0.84)	
4th	0.53 (-0.41; 1.47)		0.97 (-0.36; 2.29)		0.12 (-1.21; 1.45)	
5th (richest)	-0.36 (-1.32; 0.60)		0.17 (-1.17; 1.50)		-0.89 (-2.27; 0.49)	
BMI (quartiles)		< 0.001		< 0.001		< 0.001
1st (lowest)	1.00		1.00		1.00	
2nd	1.99 (0.78; 3.19)		0.88 (-0.31; 2.08)		2.10 (0.91; 3.30)	
3rd	2.93 (1.70; 4.16)		2.91 (1.69; 4.13)		3.33 (2.13; 4.52)	
4th (highest)	7.67 (6.41; 8.93)		6.07 (4.80; 7.34)		8.22 (7.02; 9.43)	
Physical activity score (quartiles)		0.02		0.04		0.03
1st (least active)	1.00		1.00		1.00	
2nd	0.61 (-0.47; 1.70)		0.64 (-0.70; 1.99)		0.54 (-0.54; 1.63)	
3rd	-1.14 (-2.28; 0.00)		0.20 (-1.08; 1.47)		-1.17 (-2.30; -0.03)	
4th (most active)	-0.75 (-2.00; -0.50)		-0.98 (-2.22; 0.25)		-0.82 (-2.07; 0.43)	
Menarche						< 0.001
No	-		-		1.00	
Yes	-		-		3.57 (2.46; 4.69)	

BMI: body mass index.

* Adjusted for smoking, alcohol intake, weight and length at birth, gestational age, mother's pre-gestational body mass index, reported maternal or paternal hypertension, and smoking during pregnancy. In addition, BMI, physical activity score, and menarche were adjusted for skin color and assets index, whereas the reverse adjustment was not performed.

association include less efficient excretion of sodium and fluids by Blacks, which would lead to a greater tendency to concentrate urine, and consequently greater susceptibility to hypertension [7]. Unlike most other health outcomes, the association between arterial pressure and skin color does not seem to be explainable by socioeconomic level, since adjustment for this variable did not affect the association between skin color and arterial pressure in the present study.

BMI showed the strongest association with blood pressure among all variables included in the analysis. Among girls, mean systolic pressure was 12mmHg higher in the uppermost quartile when compared to the lowest. A review study has shown that risk of developing arterial hypertension among obese children is three times higher than among the non-obese [22].

The absence of a linear association between physical activity and arterial pressure among adolescents is in agreement with a systematic review of the literature that concluded that there is no conclusive evidence for an association between these variables during adolescence [6]. A previous cross-sectional study carried out in Brazil [16] also failed to detect an association between blood pressure and physical activity among children and adolescents. Despite the absence of a linear trend, our results show that adolescents with lower physical activity scores had higher arterial pressure in both sexes. Prospective analyses will be required to investigate this association longitudinally.

Postmenarcheal girls showed the highest levels of arterial pressure. An analysis of the Guangzhou cohort study in China showed that girls whose menarche had occurred earlier were at

higher risk of hypertension [4]. An analysis of the Fels cohort in the United States also confirmed that earlier menarche was associated with higher arterial pressure [5]. Although earlier menarche is associated with body composition [23], the association between menarche and blood pressure was not affected by adjustment for BMI.

Effective strategies for controlling arterial pressure are necessary already during childhood and adolescence. In a previous publication, we showed that a number of early-life factors were associated with blood pressure in adolescence [10]. In the present article, we evaluate the association between blood pressure and concurrent variables. Future analyses using data from this same cohort will be able to determine the extent to which high blood pressure in adolescence is related to hypertension and other morbidities in adult life.

Resumo

O objetivo do presente artigo foi avaliar fatores associados com a pressão arterial de adolescentes. Trata-se de estudo de coorte prospectivo, incluindo 4.452 adolescentes nascidos em Pelotas, Rio Grande do Sul, Brasil, em 1993. A pressão arterial foi medida no início e final da entrevista com aparelho digital, sendo o valor médio utilizado nas análises. A pressão arterial sistólica média foi de 101,9mmHg (DP = 12,3) e a diastólica foi de 63,4mmHg (DP = 9,9). Adolescentes com pele preta apresentaram valores mais elevados de pressão arterial sistólica do que os de pele branca. Adolescentes no quartil superior do índice de massa corporal (IMC) apresentaram uma pressão sistólica média 11,6mmHg maior do que aqueles no quartil inferior. Meninas que já menstruaram apresentaram uma pressão sistólica média 5,4mmHg maior em comparação às demais. Os resultados foram similares para a pressão arterial diastólica. O controle da pressão arterial elevada deve ser iniciado desde a infância e adolescência.

Pressão Arterial; Adolescente; Estudos de Coortes

Contributors

A. M. B. Menezes coordinate the 1993 birth cohort and led the writing of the manuscript. P. C. Hallal led the data analysis, and approved the final version of the manuscript. C. L. Araújo and F. C. Barros coordinated the 1993 birth cohort and approved the final version of the manuscript. C. G. Victora coordinates all of the birth cohorts and approved the final version of the manuscript.

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