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Racial differences in the association between early socioeconomic position, birth weight, and arterial stiffness in adults from ELSA-Brasil

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ABSTRACT

Purpose: We investigated the association between social and nutritional adversities in childhood and increased arterial stiffness in adulthood, according to race/skin color.
Methods: We used baseline data (2008–2010) from 13,365 adults (aged 34–75 years) from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). Arterial stiffness was assessed by carotid-femoral pulse wave velocity (cfPWV). Childhood social and nutritional adversities were assessed by maternal education and birth weight. Race/skin color was self-reported.
Results: The lower the maternal education, the higher the cfPWV in adulthood in Whites, Browns, and Blacks. This association was no longer significant after adjusting for the participant's education level in Whites, but it persisted after full adjustment among Browns (low vs. high maternal education: $\beta = 0.18$, 95% confidence interval: 0.01; 0.34) and Blacks (low vs. high maternal education: $\beta = 0.44$, 95% confidence interval: 0.18; 0.70). On the other hand, the association between low birth weight and higher cfPWV was found only among Whites.
Conclusions: Our findings regarding the association between maternal education and arterial stiffness are consistent with the disproportionate burden of cardiovascular disease-related morbidity and mortality in Blacks and Browns. The fact that the association between birth weight and arterial stiffness was only present in Whites may have reflected a survival bias.

Introduction

Arterial stiffness is considered to be an independent predictor of cardiovascular events [1,2], arterial hypertension incidence, target organ damage [3–4], and all-cause mortality [1]. Exposure to low socioeconomic position and intrauterine and childhood nutritional deficiencies is associated with increased cardiovascular risk in adulthood, regardless of current socioeconomic position (SEP) [5,6]. However, studies investigating the association between social and nutritional adversities in early life and greater arterial stiffness in adulthood are scarce and have reported inconsistent results.

Low birth weight, an important indicator of social and nutritional adversities in early life, was associated with increased arterial stiffness in adulthood in some studies [7,8], but not in others [9,10]. Low parental education, low household income, and living in neighborhoods with limited resources and opportunities during childhood are factors that have been associated with increased arterial stiffness in adolescents [11]. In adults, low household income in childhood was associated with increased arterial stiffness during a 26-year follow-up period, even when current SEP was accounted for [12]. However, low parental social class was associated to increased arterial stiffness in adult life only in the cross-sectional analysis of the Whitehall study II, but not in the 5-year follow-up [13].

Historically, in Brazil and in most countries, subjects who self-reported their race/skin color as Black tend to have lower SEP throughout life [14,15,16] than Whites. Previous studies have shown that Blacks also presented higher arterial stiffness than

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Whites [17,18]. These two findings may partially account for the higher prevalence of arterial hypertension and increased cardiovascular risk among Blacks. However, whether the association between SEP and arterial stiffness is modified by race/skin color remains uncertain. In a study with North American adolescents, low household income was associated with increased arterial stiffness only in African Americans [11]. However, in a study carried out with North American adults, the association between current SEP and arterial stiffness did not differ according to race/color, after all analysis adjustments was carried out [19]. Indeed, despite the evidence suggesting that race/skin color–related differences in arterial stiffness arise during adolescence [11,20], studies investigating the association between social and nutritional adversities in early life and arterial stiffness in adults according to race/skin color are still lacking.

The present study set out to investigate a cross-section association between indicators of social and nutritional adversities in early life and arterial stiffness in adult life, according to race/skin color among middle-aged civil servants living in Brazil. We hypothesized that individuals exposed to social and nutritional adversities early in life have increased arterial stiffness in adulthood, and that the magnitude of this association is higher among Blacks and Browns than in Whites.

Methodology

This study used baseline data (2008–2010) from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multicenter prospective study involving 15,105 volunteers, aged between 35 and 74 years, including civil servants from universities and research institutions located in six Brazilian capital cities (São Paulo, Belo Horizonte, Porto Alegre, Salvador, Vitória, and Rio de Janeiro). Detailed information regarding study design and recruitment methods were published elsewhere [21]. The ELSA-Brasil study was approved by the ethics committee of each organization involved; all participants have signed an informed consent.

We excluded from the analysis participants with nonvalidated arterial stiffness data ($n = 380$), those with missing data on maternal education ($n = 356$) or self-reported race/skin color data ($n = 172$), and individuals who reported themselves as Asian descents ($n = 357$) or Brazilian indigenous ($n = 146$), as they were under-represented in the ELSA-Brasil cohort. Participants reporting low birth weight associated with preterm births ($n = 329$) were also excluded as this condition is more often because of gestational conditions (e.g., previous preterm delivery, multiple second-trimester abortions, maternal stature and body mass, infertility history, placental abnormalities, preeclampsia, among others) than social and nutritional factors [22], and might also be related with specific health problems. Therefore, the final sample comprised 13,365 subjects.

Variables

Outcome

Arterial stiffness—carotid-femoral pulse wave velocity

Arterial stiffness was measured in m/s via carotid-femoral pulse wave velocity (cfPWV) and was assessed using a validated automatic device (Complior SP; Artech Medicale, France), with the subject lying down in a temperature-controlled room (20°C–24°C). Before cfPWV assessment, blood pressure was measured on the right arm using an oscillometer (Omron HEM 705 CP), with the subject in the supine position. The distance from the suprasternal notch to the right femoral pulse was assessed with a measuring tape; the abdominal circumference was not considered. Pulse sensors were placed on the right carotid and femoral arteries to allow pulse wave visualization on a computer screen. High-quality pulse wave recordings were detected using the devices' software (Complior SP). Pulse wave velocity was calculated by dividing the distance between the sternal notch and the femoral pulse by the time delay between the carotid and femoral pulses. Measurements of the cfPWV were averaged over ten consecutive cardiac cycles at regular cardiac rhythm. For quality control, all cfPWV tests were recorded in each of the six investigative centers by trained and certificated technicians and sent to a central reading center, which was responsible to verify and exclude the unsuited examinations of all ELSA-Brasil participants [23].

Exposure

Maternal education

Maternal education assessment was based on the survey question "*What is the level of education of your mother?*" Answers were classified into four categories as follows: high school, complete elementary school, incomplete elementary school, and never attended school.

Birth weight

For birth weight assessment, participants were asked the question "*According to the information you have, what was your birth weight?*", with the following response options: under 2.5 kg; between 2.5 kg and 4 kg; and over 4 kg.

Race/skin color

Race/skin color assessment was based on the following question: "The Brazilian census (IBGE) describes people's color or race as "Black", "Brown", "White", "Asian descendant" or "Brazilian indigenous". If you were to answer the IBGE census today, how would you describe your own color or race?" The following response options were given: Black, Brown, White, Asian descendant, and Brazilian indigenous.

Covariates

The following covariates were defined as adjustment variables because they are associated with both exposure and outcome: sex, age, participants' own education (university degree, high school, complete elementary school, incomplete elementary school), physical activity (weak, moderate, strong, according to the International Physical Activity Questionnaire) [24], smoking (smoker, former smoker, never smoked), excessive alcohol consumption (≥210 g or ≥140 g of alcohol per week, for men and women, respectively), current body weight (kg), height (s), mean arterial pressure (systolic blood pressure at the time of cfPWV assessment + [diastolic blood pressure at the time of cfPWV determination*2] ÷ 3), heart rate, diabetes (self-reported, use of antidiabetic drugs, fasting glucose ≥126 mg/dL, glucose tolerance test ≥200 mg/dL, or glycated hemoglobin ≥6.5%), total cholesterol–high-density lipoprotein (HDL-C) ratio (total cholesterol divided by HDL-C) and use of antihypertensive drugs. Laboratory measurement techniques used in the ELSA-Brasil study have been described elsewhere [21].

The relation between age and cfPWV is not linear [25,26]. Therefore, subjects were divided into eight 5-year–interval age groups (from 35–39 to 70–74 years).

Data analysis

The descriptive analysis of the study population was stratified by race/skin color subgroups and expressed as median and interquartile ranges for continuous variables, and frequencies for categorical variables. The Kruskal–Wallis and χ^2 tests were used to assess differences in the distributions of the studied variables according to race/skin color.

Associations between maternal education and cfPWV were investigated using linear regression models. Sequential adjustments were made by adding the following variables to multivariate models: maternal education, sex and age (model 1); physical activity, smoking, excessive alcohol consumption, body weight, and height (model 2); diabetes, total cholesterol–HDL-C ratio, use of antihypertensive drugs, mean arterial pressure, and heart rate (model 3); and the participants' own education (model 4). Variables with P-value $\geq .05$ in the final model (excessive alcohol consumption and total cholesterol–HDL-C ratio) were not retained in the analyses.

Associations between birth weight and cfPWV were also investigated using linear regression models, as described previously. However, in this investigation, the model 4 also included the adjustment by maternal education as this variable is associated with birth weight. Regression coefficients β and respective 95% confidence intervals were assessed and represent cfPWV differences in m/s associated with each explanatory variable category.

Additive interactions between race/skin color and maternal education were investigated by including interaction terms in the fully adjusted regression model (model 4). Evidence of additive interaction between maternal education and race/skin color was found (P-value: never attended school*Black race/skin color = 0.001; never attended school*Brown race/skin color = 0.037); therefore, analyses were presented separately for Whites, Blacks, and Browns.

Multivariate imputation by chained equations [27] was used to impute missing birth weight values ($n = 1712$). Twenty data copies, with the missing values properly imputed, were independently assessed using multivariate linear regression models. Estimates of β coefficients were averaged across the 20 copies to obtain a single mean estimate, and standard errors were adjusted according to Rubin's rules [27]. The variables in the imputed model were age, race, sex, maternal education, cfPWV, and the participants' own education. Sensitivity analyses conducted in the complete case analysis without imputation yielded a similar result.

All analyses were performed using Stata 14 (StataCorp, 2015, College Station, TX: StataCorp LP) and a level of significance of 5%.

Results

The characteristics of the study population, according to race/skin color, are presented in Table 1. Although most subjects were born to mothers with no education or incomplete elementary school (56.5%), more than half (53.5%) had a university degree. Blacks were more frequently born to mothers with no education or incomplete elementary school (72.8%) compared with Browns (64.8%) and Whites (47.2%). Low birth weight was higher among Browns and Blacks than Whites. Blacks and Browns had also higher mean arterial pressure and higher prevalence of physical inactivity, current smoking habits, diabetes and use of antihypertensive drugs than Whites.

Median cfPWV was higher among Blacks (9.2 m/s ± 2.3) than Browns (9.0 m/s ± 2.1) and Whites (8.9 m/s ± 2.0) (Table 1). Age- and sex-adjusted mean cfPWV increased as maternal level of

Table 1
Descriptive characteristics of participants from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), 2008–2010

Characteristics	Total ($n = 13.365$)	White ($n = 7.335$)	Brown ($n = 3.843$)	Black ($n = 2.187$)	P-value
Age (y), median (IQR)	51.0 (45.0–58.0)	52.0 (45.0–59.0)	50.0 (45.0–57.0)	51.0 (45.0–57.0)	<.001
Sex, %					
Men	45.7	46.0	48.2	39.0	<.001
Women	54.3	54.0	51.8	61.0	
Maternal education, (%)					
High school	24.1	32.2	16.9	9.7	<.001
Complete elementary school	19.4	20.5	18.3	17.4	
Incomplete elementary school	42.6	39.1	45.5	49.2	
Never attended school	13.9	8.1	19.3	23.6	
Participants' own education, (%)					
University degree	53.5	67.7	41.3	27.7	<.001
High school	34.8	25.5	42.9	51.9	
Complete elementary school	6.4	4.0	8.2	11.7	
Incomplete elementary school	5.2	2.9	7.6	8.7	
Birth weight, %					
<2.5 kg	5.6	4.5	6.7	6.4	<.001
≥ 2.5 kg e ≤ 4 kg	86.7	87.1	86.2	86.4	
>4 kg	7.6	8.4	7.1	7.2	
Height, median (IQR)	164.6 (158.1–172.0)	165.4 (158.6–173.0)	164.1 (157.7–171.0)	163.4 (157.1–170.3)	<.001
Current body weight, median (IQR)	72.6 (63.4–83.2)	72.4 (63.0–83.3)	72.0 (63.2–81.9)	74.1 (65.2–85.0)	<.001
Smoking, %					
Never smoked	57.5	56.6	58.2	59.5	<.001
Former smoker	29.7	31.3	28.6	26.2	
Smoked	12.7	12.0	13.2	14.3	
Physical activity, %					
Weak	76.7	73.7	79.0	82.5	<.001
Moderate	16.2	18.3	14.4	12.6	
Strong	7.1	8.4	6.6	5.0	
Diabetes, %					
No	81.2	84.0	80.3	73.2	<.001
Yes	18.8	16.0	19.7	26.7	
Antihypertensive drugs, %					
No	71.3	73.6	71.5	63.0	<.001
Yes	28.7	26.4	28.5	37.0	
Mean arterial pressure, median (IQR)	92.0 (84.7–100.0)	90–3 (83.3–98.0)	93.0 (85.7–101.3)	95.0 (87.7–104.3)	<.001
Heart rate, median (IQR)	69.5 (63.0–76.5)	70.0 (63.5–77.0)	69.0 (62.5–76.0)	69 (62.0–76.0)	<.001
Carotid-femoral pulse wave velocity (cf-PWV), median (IQR)	9.0 (8.1–10.2)	8.9 (8.0–10.0)	9.0 (8.1–10.2)	9.2 (8.2–10.5)	<.001

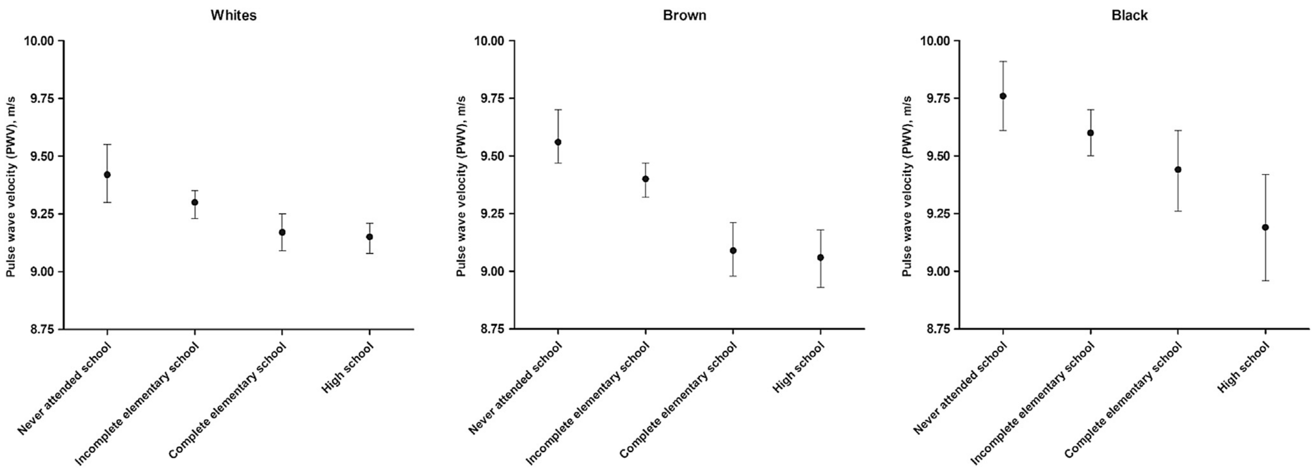

Fig. 1. Age- and sex-adjusted mean (95% CI) of carotid-femoral pulse wave velocity according to categories of maternal education in Whites (n = 7.335), Browns (n = 3.843), and Blacks (n = 2.187). Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), 2008–2010.

education decreased, with more pronounced differences in Blacks (Fig. 1).

In the minimally adjusted model, the lower the maternal education, the higher the cfPWV in adult life in all three race/skin color subgroups (Table 2). Adjustments had little impact on such association in Blacks, but produced a strongly attenuated association in Browns. However, this association was eliminated after the adjustment for the participants' own education in Whites.

Low birth weight was associated with cfPWV only in White subjects and remained significant after the full model adjustment (P = .039) (Table 3).

Discussion

The present study was based on a large multiracial population of Brazilian adults and showed that the lower the level of maternal education, the higher the arterial stiffness in adult life in Whites, Browns, and Blacks. These findings suggest that low SEP in childhood is associated with a less favorable vascular profile in adult life, regardless of race. We observed that this association was no longer statistically significant in a multivariate analysis after adjustment for the participants' own education in Whites. However, this association remains statistically significant among Browns and Blacks after full model adjustment, suggesting that in these groups, other mechanisms, unrelated to the adjustment of variables, may be involved in potentiating an unfavorable vascular profile. We also observed that low birth weight was associated with increased arterial stiffness in Whites, but not in Blacks or Browns.

To our knowledge, this is the first study investigating the association between social and nutritional adversities in early life and cfPWV stratified by race/skin color. However, there is robust evidence that Blacks are more intensely exposed to social and nutritional adversities throughout life [14,15,16,28] and tend to have increased arterial stiffness [17,18]. Parental education is thought to be a proxy for household SEP and context in which a child is born and raised. It is also related to educational opportunities and

Table 2
Association between maternal education and carotid-femoral pulse wave velocity in adulthood: Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), 2008–2010

Maternal education	Model 1	Model 2	Model 3	Model 4
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Whites				
Maternal education				
High school	REF	REF	REF	REF
Complete elementary school	0.02 (−0.08; 0.12)	0.02 (−0.08; 0.12)	−0.04 (−0.13; 0.04)	−0.06 (−0.15; 0.03)
Incomplete elementary school	0.15 (0.06;0.22)**	0.14 (0.06;0.22)**	0.08 (0.00;0.15)*	0.05 (−0.03; 0.13)
Never attended school	0.27 (0.14;0.41)***	0.27 (0.14;0.41)***	0.08 (−0.05; 0.20)	0.01 (−0.12; 0.15)
Browns				
Maternal education				
High school	REF	REF	REF	REF
Complete elementary school	0.04 (−0.13; 0.21)	0.02 (−0.15; 0.19)	−0.07 (−0.22; 0.08)	−0.09 (−0.24; 0.06)
Incomplete elementary school	0.33 (0.19;0.48)***	0.31 (0.17;0.46)***	0.12 (−0.01; 0.25)	0.08 (−0.05; 0.21)
Never attended school	0.53 (0.36;0.70)***	0.50 (0.33;0.67)***	0.29 (0.13;0.44)***	0.18 (0.01;0.34)*
Blacks				
Maternal education				
High school	REF	REF	REF	REF
Complete elementary school	0.24 (−0.04; 0.53)	0.25 (−0.03; 0.54)	0.25 (−0.01; 0.50)	0.24 (−0.01; 0.49)
Incomplete elementary school	0.40 (0.15;0.66)**	0.42 (0.16;0.67)**	0.37 (0.15;0.59)**	0.35 (0.13;0.57)**
Never attended school	0.56 (0.28;0.85)***	0.59 (0.31;0.88)***	0.49 (0.24;0.74)***	0.44 (0.18;0.70)**

Significance level: *<0.05, **<0.01, ***<0.001.
Model 1: sex and age.
Model 2: Model 1 + smoker, physical activity, current body weight, and height.
Model 3: Model 2 + mean arterial pressure, heart rate, use of antihypertensive, and diabetes.
Model 4: Model 3 + participants' own education.
β = Regression coefficients; CI = confidence intervals.

Table 3
Association between birth weight and pulse wave velocity in adulthood: Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), 2008–2010

Birth weight	Model 1	Model 2	Model 3	Model 4
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Whites				
Birth weight				
≥ 2,5 kg e ≤ 4 kg	REF	REF	REF	REF
<2,5 kg	0.17 (−0.01; 0.35)	0.22 (0.03;0.40)*	0.19 (0.02;0.35)*	0.17 (0.01;0.34)*
>4 kg	0.01 (−0.12; 0.15)	−0.08 (-0.22; 0.05)	0.00 (−0.12; 0.12)	0.00 (−0.12; 0.12)
Browns				
Birth weight				
≥ 2,5 kg e ≤ 4 kg	REF	REF	REF	REF
<2,5 kg	−0.00 (−0.22; 0.22)	0.03 (−0.19; 0.26)	−0.03 (−0.22; 0.16)	−0.06 (−0.25; 0.13)
>4 kg	−0.12 (−0.34; 0.09)	−0.13 (−0.36; 0.09)	−0.09 (−0.28; 0.11)	−0.09 (−0.28; 0.11)
Blacks				
Birth weight				
≥ 2,5 kg e ≤ 4 kg	REF	REF	REF	REF
<2,5 k	−0.12 (−0.46; 0.21)	−0.10 (−0.44; 0.23)	−0.15 (−0.45; 0.14)	−0.17 (−0.46;0.12)
>4 kg	0.12 (−0.19; 0.43)	0.03 (−0.29; 0.35)	0.16 (−0.11; 0.44)	0.18 (−0.09; 0.46)

Significance level: *<0.05, **<0.01, ***<0.001.
Model 1: sex and age.
Model 2: Model 1 + smoker, physical activity, current body weight, and height.
Model 3: Model 2 + mean arterial pressure, heart rate, use of antihypertensive, and diabetes.
Model 4: Model 3 + maternal education + participants' own education.
β = Regression coefficients, CI = confidence intervals.

cultural environment at home [29]. Maternal education in particular has been strongly associated with child health and nutrition [30,31], given the positive relationship with parental care, greater use of health services and prevention of diseases in childhood [30]. This supported the argument that maternal education plays a more significant role in child health than paternal SEP indicators [32]. Thus, maternal education is an indicator of social adversity in childhood and may have different meaning and impacts in Browns and Blacks compared with Whites.

The findings of this study suggest that the association between low maternal education and arterial stiffness is greater among Blacks and Browns than Whites, which may reflect greater suffering and stress in the former race/skin color subgroups, particularly in Black populations. Some studies have shown that the social environment to which Black children are exposed to is permeated by racial discrimination against the subjects themselves and their families, potentially contributing to and amplifying the effects of a low maternal level of education [33]. Furthermore, upward social mobility, which may offset health damage associated with lower SEP in early life, is also less common in Blacks and Browns than in Whites [34]. This may explain the persistence and greater robustness of associations between maternal education and arterial stiffness in Blacks and Browns after adjustment for the participants' own education in this study. In the ELSA-Brasil population, upward educational mobility rates (children who were born to mothers with incomplete elementary school but that achieve a university degree) were 16.5%, 20.2%, and 24.4% in Blacks, Browns, and Whites, respectively ($P < .05$, data not shown).

Brazil has a highly admixed, with self-reported mixed or Brown subjects accounting for 43% of the population in the country [35]. This reality is very different from that in the United States, whose society presents a Black-White division because of the strict racial segregation policies that restricted the growth of the mixed heritage population throughout their history [36]. Subjects who self-report a Brown race/skin color in Brazil generally show socioeconomic indicators that are slightly better than those of Blacks, but much worse than those of Whites [37]. In the present study, we also found that the association between maternal education and arterial stiffness was stronger in Browns than in Whites, but weaker than in Blacks. This intermediate position of Browns compared with Blacks and Whites is consistent with many previous studies that investigated racial inequalities in other health outcomes in Brazil [38,39].

Mean cfPWV was 0.44 m/s higher in Blacks born to mothers who never attended school after full model adjustment. This apparently modest increase in the mean cfPWV is equivalent to that produced by 2.7 additional life years, as previous studies have shown that the cfPWV increases by 0.16 m/s per year, on average [40]. In a meta-analysis of 17 longitudinal studies, a 1 m/s increase in cfPWV led to a rise by 14% in the risk of cardiovascular events, during a 7.7-year follow-up period [1]. If the results of this meta-analysis apply to the population in this study, we would estimate that the increase of 0.42 m/s in the cfPWV observed in Blacks born to mothers who never attended school would result in an increase of about 6.2% in cardiovascular risk.

Associations between low birth weight and increased arterial stiffness were limited to White subjects in this study. Low birth weight is associated with higher mortality throughout life [41,42] and disproportionately affects Blacks and Browns [43]. Therefore, considering the cross-sectional design of this study, it may be argued that Blacks and Browns with low birth weight were underrepresented in our sample because of a survival bias. It is possible that only a few Blacks and Browns born with low birth weight achieved adulthood and met the ELSA-Brasil inclusion criteria.

This study has some potential limitations. We do not have information about paternal education, which is a limiting factor in the identification of SEP in childhood in the present study. Moreover, some participants may have incorrectly informed their birth weight or maternal education as this information was obtained retrospectively by self-reports. If this error is nondifferential, the association of maternal education and birth weight with arterial stiffness might be underestimated. In addition, subjects with increased arterial stiffness and low SEP are more prone to early CVD-related death and this may have translated into underestimated associations of birth weight and maternal education with cfPWV, particularly in Blacks, who have higher CVD-related mortality rates [44]. Thus, longitudinal studies are required to confirm our findings. It should also be noted that although we controlled for a variety of important covariates, it is not possible to rule out bias because of model misspecification and unmeasured or unknown confounders.

This study was based on a sample comprising voluntary civil servants with stable jobs at universities and research institutes, with an average schooling level above that of the general Brazilian population. The ELSA-Brasil population is not representative of the Brazilian population. It is important to note that, although sampling representativeness is necessary when we aim to estimate the prevalence of a condition in a given population (which was not the objective of the present study), sampling representativeness is not required to draw valid scientific inferences for associations found in well-conducted epidemiological studies [45,46], in the absence of interaction. However, the absence of the very poor and the very rich population in the ELSA-Brasil cohort may have contributed to reduce the magnitude of the association between social/nutritional adversities and arterial stiffness. This is owing to the fact that the difference in the exposure to social adversities between the excluded groups is likely to be also extreme.

Our findings suggest that exposure to social and nutritional disadvantages in childhood, as indicated by low maternal education, is associated with increased cfPWV. This association was stronger and independent of current SEP in Blacks and Browns, contributing to the disproportionate burden of cardiovascular morbidity and mortality in these groups. If confirmed, our results indicate that strategies to deal with racial inequality must be integrated with policies aimed to reduce socioeconomic inequalities, as well as reduce the disproportionate burden of cardiovascular morbidity and mortality in Black subjects.

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References

[1] Vlachopoulos C, Konstantinos A, Christodoulos S. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. J Am Coll Cardiol 2010;55:1318–27.
[2] Ben-Shlomo Y, Spears M, Boustred C, May M, Anderson SG, Benjamin EJ, et al. Aortic pulse wave velocity improves cardiovascular event prediction: an individual participant meta-analysis of prospective observational data from 17,635 subjects. J Am Coll Cardiol 2014;63:636–46.
[3] Kaess BM, Rong J, Larson MG, Hamburg NM, Vita JA, Levy D, et al. Aortic stiffness, blood pressure progression, and incident hypertension. JAMA 2012;308:875–81.
[4] King KS, Chen KX, Hulsey KM, McColl RW, Weiner MF, Nakonezny PA, et al. White matter hyperintensities: use of aortic arch pulse wave velocity to predict volume independent of other cardiovascular risk factors. Radiology 2013;267:709–17.
[5] Lee M, Khan MM, Wright B. Is childhood socioeconomic status related to coronary heart disease? evidence from the health and retirement study (1992-2012). Gerontol Geriatr Med 2017;3:1–9.
[6] Kauhanen L, Lakka HM, Lynch JW, Kauhanen J. Social disadvantages in childhood and risk of all-cause death and cardiovascular disease in later life: a comparison of historical and retrospective childhood information. Int J Epidemiol 2006;35:962–8.
[7] Mzayek F, Sherwin R, Hughes J, Hassig S, Srinivasan S, Chen W, et al. The association of birth weight with arterial stiffness at mid-adulthood: the bogalusa heart study. J Epidemiol Community Health 2009;63:729–33.
[8] Murray LJ, Gallagher AM, Boreham CA, Savage M, Smith GD. Sex specific difference in the relation between birth weight and arterial compliance in young adults: the young hearts project. J Epidemiol Community Health 2001;55:665–6.
[9] Miles KL, McDonnell BJ, Maki-Petaja KM, Cockcroft JR, Wilkinson IB, McEniery CM. The impact of birth weight on blood pressure and arterial stiffness in later life: the enigma study. J Hypertens 2011;29:2324–31.
[10] Batista MS, Mill JG, Pereira TSS, Fernandes CDR, Molina VMDCB. Fatores associados ao aumento da rigidez arterial em crianças de 9 e 10 anos. Rev Saúde Pública 2015;49:1–8.
[11] Thurston RC, Matthews KA. Racial and socioeconomic disparities in arterial stiffness and intima media thickness among adolescents. Soc Sci Med 2009;68:807–13.
[12] Puolakka E, Pahkala K, Laitinen T, Magnussen CG, Hutri-Kähönen N, Kähönen M, et al. Childhood socioeconomic status and arterial stiffness in adulthood. Hypertension 2017;70:729–35.
[13] Trudel X, Shipley MJ, McEniery CM, Wilkinson IB, Brunner EJ. Socioeconomic status, education, and aortic stiffness progression over 5 years: The Whitehall II prospective cohort study. J Hypertens 2016;34:2038–44.
[14] Instituto Brasileiro de Geografia e Estatística. Diretoria de Pesquisas, Coordenação de Trabalho e Rendimento, 2018, Pesquisa Nacional por Amostra de Domicílios Contínua. Rio de Janeiro: IBGE; 2018.
[15] Instituto Brasileiro de Geografia e Estatística. Diretoria de Pesquisas, Coordenação de Trabalho e Rendimento, 2016, Pesquisa Nacional por Amostra de Domicílios Contínua. Rio de Janeiro: IBGE; 2016.
[16] Semega JL, Fontenot KR, Kollar MA. U.S. Census Bureau, Current Population Reports, P60-259, Income and Poverty in the United States: 2016. Washington, DC: U.S. Government Printing Office; 2017.
[17] Goel A, Maroules CD, Mitchell GF, Peshock R, Ayers C, McColl R, et al. Ethnic difference in proximal aortic stiffness: an observation from the Dallas heart study. JACC Cardiovasc Imaging 2017;10:54–61.
[18] Ferreira AV, Viana MC, Mill JG, Asmar RG, Cunha RS. Racial differences in aortic stiffness in normotensive and hypertensive adults. J Hypertens 1999;17:631–7.
[19] Wendell CR, Waldstein SR, Evans MK, Zonderman AB. Distributions of subclinical cardiovascular disease in a socioeconomically and racially diverse sample. Stroke 2017;48:850–6.
[20] Shah AS, Dolan LM, Gao Z, Kimball TR, Urbina EM. Racial differences in arterial stiffness among adolescents and young adults with type 2 diabetes. Pediatr Diabetes 2012;13:170–5.
[21] Aquino EM, Barreto SM, Bensenor IM, Carvalho MS, Chor D, Duncan BB, et al. ELSA-Brazil (Brazilian Longitudinal Study of Adult Health): objectives and design. Am J Epidemiol 2012;175:315–24.
[22] Institute of Medicine (US) Committee on Understanding Premature Birth and Assuring Healthy Outcomes. In: Behrman RE, Butler AS, editors. Preterm Birth: Causes, Consequences, and Prevention. Washington (DC): National Academies Press (US); 2007. B, Prematurity at Birth: Determinants, Consequences, and Geographic Variation, https://www.ncbi.nlm.nih.gov/books/NBK11386/.
[23] Mill JG, Pinto K, Griep RH, Goulart A, Foppa M, Lotufo PA, et al. Aferições e exames clínicos realizados nos participantes do ELSA-Brasil. Rev Saúde Pública 2013;47:54–62.
[24] International Physical Activity Questionnaire. Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ): short and long forms [Internet]. IPAQ Web site: IPAQ group. www.institutferran.org/.../scoring_short_ipaq_april04.pdf. [Accessed 9 September 2016].
[25] Mitchell GF. Arterial stiffness: insights from Framingham and Iceland. Curr Opin Nephrol Hypertens 2015;24:1–7.
[26] Mitchell GF, Parise H, Benjamin EJ, Larson MG, Keyes MJ, Vasan RS, et al. Changes in arterial stiffness and wave reflection with advancing age in healthy men and women: the Framingham heart study. Hypertension 2004;43:1239–45.
[27] White IR, Royston P, Wood AM. Multiple imputation using chained equations: issues and guidance for practice. Stat Med 2011;30:377–99.
[28] Williams DR, Priest N, Anderson NB. Understanding associations among race, socioeconomic status, and health: patterns and prospects. Health Psychol 2016;35:407–11.
[29] Galobardes B, Lynch J, Smith GD. Measuring socioeconomic position in health research. Br Med Bull 2007;81:21–37.
[30] Boyle MH, RacineY, Georgiades K, Snelling D, Hong S, Omariba W, et al. The influence of economic development level, household wealth and maternal education on child health in the developing world. Soc Sci Med 2006;63:2242–54.
[31] Shmueli A, Cullen MR. Birth weight, maternal age, and education: new observations from connecticut and Virginia. Yale J Biol Med 1999;72:245–8.
[32] Cleland J. The benefits of educating women. Lancet 2010;376:933–4.
[33] Sanders-Phillips K, Settles-Reaves B, Walker D, Brownlow J. Social inequality and racial discrimination: Risk factors for health disparities in children of color. Pediatrics 2009;124(e-supp 3):e3.

[34] Ribeiro CAC. Racial continuum, social mobility and “whitening”. Rev Bras Ci Soc 2017;32:1–25.
[35] Instituto Brasileiro de Geografia e Estatística. Censo demográfico: 2010: características gerais da população, religião e pessoas com deficiência. Rio de Janeiro; 2010.
[36] Burgard S, Castiglione DP, Lin KY, Nobre AA, Aquino EML, Pereira AC. Differential reporting of discriminatory experiences in Brazil and the United States. Cad Saude Publica 2017;33Suppl 1(Suppl 1):e00110516.
[37] Daflon VT, Carvalhaes F, Feres Júnior J. Sentindo na Pele: Percepções de Discriminação Cotidiana de Pretos e Pardos no Brasil. Dados 2017;60: 293–330.
[38] Oliveira BLCAD, Thomaz EBAF, Silva RAD. The association between skin color/race and health indicators in elderly Brazilians: a study based on the Brazilian National Household Sample Survey (2008). Cad Saude Publica 2014;30: 1438–52.
[39] Barros MBA, Francisco PMSB, Zanchetta LM, Cesar CLG. Tendências das desigualdades sociais e demográficas na prevalência de doenças crônicas no Brasil, PNAD: 2003-2008. Ciênc Saúde Coletiva 2011;16:3755–68.
[40] Redheuil A, Yu WC, Wu CO, Mousseaux E, de Cesare A, Yan R, et al. Reduced ascending aortic strain and distensibility: earliest manifestations of vascular aging in humans. Hypertension 2010;55:319–26.
[41] Risnes KR, Vatten LJ, Baker J, Jameson K, Sovio U, Kajantie E, et al. Birthweight and mortality in adulthood: a systematic review and meta-analysis. Int J Epidemiol 2011;40:647–61.
[42] Wilcox AJ. On the importance - and the unimportance - of birthweight. Int J Epidemiol 2001;30:1233–41.
[43] Nyarko KA, Lopez-Camelo J, Castilla EE, Wehby GL. Explaining racial disparities in infant health in Brazil. Am J Public Health 2013;103:1675–84.
[44] Lariscy JT. Black–white disparities in adult mortality: implications of differential record linkage for understanding the mortality crossover. Popul Res Pol Rev 2017;36:137–56.
[45] Rothman KJ, Gallacher JEJ, Hatch E. Why representativeness should be avoided. Int J Epidemiol 2013;42:1012–4.
[46] Richiardi L, Pizzi C, Pearce N. Commentary: representativeness is usually not necessary and often should be avoided. Int J Epidemiol 2013;42(4): 1018–22.