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Threshold-effect of income on periodontitis and interactions with race/ethnicity and education

Efeito limiar de renda na periodontite e interações com raça/etnia e educação

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ABSTRACT: ***Objectives:*** The aims of this study were to explore the shape of the relationship of income and education with periodontal health, and to assess the interactions between them and race/ethnicity. ***Method:*** Individual level data from the Brazilian National Oral Health Survey in 2010 (Pesquisa Nacional de Saúde Bucal—SB Brasil 2010) were obtained for 9,779 subjects. Relations between *per capita* income and education with periodontal health were smoothed using Locally Weighted Scatter-plot Smoother (Lowess) technique. Multivariable logistic regression was used to assess independent effects of income, education, race/ethnicity adjusted for age, sex and time since last dental appointment. ***Results:*** Prevalence of adults with moderate to severe and severe periodontitis was 17.6 and 6.5%, respectively. The relationship between periodontal health and income was curvilinear, showing a threshold of no relationship for income levels higher than US$ 600/month. In multivariable analysis, after controlling for covariates, only income was significantly associated with periodontal health. There was no significant interaction of income with race or education, neither between race and education. ***Conclusion:*** The relation between periodontal health and income was curvilinear and indicated the presence of a threshold, supporting income transfer programs. Beyond the threshold, only education presented a negative linear relationship with moderate to severe periodontitis.

Keywords: Income. Periodontal diseases. Educational status. Epidemiology. Dental health surveys.

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RESUMO: ***Objetivo:*** Os objetivos deste estudo foram explorar a relação entre renda e educação com doença periodontal e avaliar a interação entre eles e raça/etnia. ***Método:*** Dados individuais do inquérito epidemiológico de saúde bucal da Pesquisa Nacional de Saúde Bucal (SB Brasil 2010) foram obtidos para 9.779 indivíduos. A relação entre renda *per capita* e educação com saúde periodontal foi suavizada usando técnica de Locally Weighted Scatterplot Smoother (LOWESS). Utilizou-se regressão logística multivariável para avaliar os efeitos independentes de sexo, idade, renda, educação, raça/etnia, posse de bens, última visita ao dentista e número de pessoas por dormitório. ***Resultados:*** A prevalência de adultos com doença periodontal moderada e grave foi de 17,6 e 6,5%, respectivamente. A relação entre saúde periodontal e renda foi curvilínea, com limiar de R$ 1.050/mensais, a partir do qual não havia relação entre as variáveis. Na análise multivariavel, após ajuste por covariadas, apenas renda estava associada significativamente com saúde periodontal. Não foram encontradas interações significantes entre renda e educação ou raça/etnia, nem entre educação com raça/etnia. ***Conclusões:*** A relação entre saúde periodontal e renda foi curvilínea com a presença de efeito de limar, dando suporte para programas de transferência de renda. Além do limiar, apenas educação mostrou associação linear negativa com periodontite moderada a severa.

Palavras-chave: Renda. Doenças periodontais. Escolaridade. Epidemiologia. Inquérito de saúde bucal.

INTRODUCTION

A compromised periodontal health has high impact on the global burden of diseases[1]. In Latin America, the prevalence of periodontal diseases is high and its distribution is heterogeneous across different countries and regions[2-4]. Previous studies show that socioeconomic factors are associated with periodontal diseases as individuals with higher socioeconomic rankings present lower rates of the disease[5-11]. Common indicators of social position in epidemiology studies are education, income and occupation; they are also used in periodontal research[9,12]. While education indicates knowledge and skills in order to obtain economic resources and to understand useful information in daily life, income allows access to material resources such as housing and healthcare. Occupation represents a mix of education and income, and also reflects status and prestige in the society[13,14]. Accordingly, the investigation of multiple risk factors and their effects on oral health has been the focus of several studies in an effort to understand the underlying socioeconomic, cultural, and environmental determinants of oral diseases[6,9].

Although the existence of a universal social gradient in health[9] is generally claimed, some studies report a non-linear relationship between health and income[15-20]. In oral health, only a couple of studies have addressed such relation[21,22]; none, however, concerning periodontal disease. In particular, if there is a curvilinear relation, and assuming this association is causal, then reducing richer people's income to a certain value will barely affect their health, while increasing the income of the poorer in the same value can improve their health significantly. The curvilinear shape of income and health, then, can support income transfer programs and the establishment of minimum income values[23] to reduce health inequalities associated to income.

Distinct measures of socioeconomic status such as education and income, often considered to be interchangeable, were shown to be only moderately correlated[24-26]. Assuming that indicators of income and education have independent effects on health, this would imply that such effects might occur through different pathways. Nonetheless, they may interact with each other and with other socioeconomic indicators. For example, it was reported that high levels of income had a beneficial effect among white population, but a detrimental effect among black people in the United States.

However, this interaction has not been explored for other social factors, such as education. Some Brazilian studies have reported a non-significant association between race and periodontal disease and a few reversed association[7]. This may have occurred because race affects periodontal disease mainly through education and income, with small or no direct biological effect. An appropriate understanding of mechanisms is needed for adequate control. Also, it could be speculated that income decreases stress levels — that are associated with periodontal disease[27,28] — among people with white ethnicity, but not among people with black ethnicity, perhaps due to racial discrimination.

It is important to understand the relationship between social determinants and health outcomes not only for theoretical reasons, but also to provide the basis for broad social and health policies[14,29]. The aims of this study were to explore the shape of the relationship of income and education with periodontitis. In addition, the interactions between income, education and race/ethnicity were assessed.

METHOD

PARTICIPANTS AND SETTINGS

Sample data was obtained from the National Oral Health Survey (Pesquisa Nacional de Saúde Bucal — SB Brasil), conducted in 2010 by the Brazilian Ministry of Health. Multistage and stratified sampling methods were combined. As state capitals presented 100% probability of being selected, the first sampling stage was city level (if not a state capital) or census track (if state capital). Following, the second stage was census track among non-capital municipalities and households among state capitals. Non-capital municipalities presented household selection as third stage[30,31]. The sample was designed to be nationally representative within five age brackets (5, 12, 15–19, 35–44, 65–74 years). The sample size was calculated to estimate the prevalence of dental caries using estimates obtained in the 2003 survey and included 177 cities and 37,519 individuals. Institutionalized individuals were not included in this survey.

Oral examinations were conducted in the households. One dentist and one assistant composed a fieldwork team. The number of fieldwork teams in each city or municipality varied according to the region's sample size[31]. One person in each eligible age group was randomly chosen from selected households. Sampling weights were calculated to obtain weighted prevalence[30]. Selected individuals were interviewed with a questionnaire and clinically examined by a dentist according to World Health Organization's (WHO) criteria[32].

Bleeding on probing, dental calculus, shallow (4–5 mm) and deep (≥ 6 mm) pocket depths were registered for each sextant. Periodontal attachment loss (AL) was assessed in each sextant, according to the following categories: up to 3 mm, 4–5 mm, 6–8 mm, 9–11 mm, and > 12 mm. The sextant was excluded if less than two teeth were present or if it was not possible to examine the tooth due to calculus or other reasons[31,32]. Teams of dentists were trained in a 32-hour program, and disagreements were solved by consensus until a minimum inter-examiner kappa value of k > 0.65 was obtained[30,31]. Information was transcribed into a Personal Digital Assistant (PDA) using a software developed by the Brazilian Institute of Geography and Statistics (IBGE).

The present study included one of the two age groups for which periodontal attachment loss was collected: the 35–44-year-old group, whose sample size comprised 9,779 individuals. The 65–74 age group was not included in this study, due to a high number of missing teeth, and, therefore, lack of periodontal data.

Written informed consent was obtained, and the project was approved by the National Ethics Committee.

OUTCOME VARIABLES

The outcome variables of the present study were two dichotomous versions of periodontitis, defined as a combination of clinical attachment loss (CAL) and probing depth (PD) measured using WHO's probe[2,33]. Six index teeth, one in each sextant, were examined, and the highest score was used to represent individual disease history in each sextant. According to previous studies[2,33], we assessed two classifications for periodontitis: moderate to severe, and severe. Moderate to severe disease was defined as having at least one site with > 3 mm of CAL, and at least one site with probing depth > 3 mm. Severe disease was classified as having at least one site > 5 mm of AL, and at least one site with > 3 mm pocket depth. Sites for AL and PD were not necessarily the same, and this applied to both case definitions.

EXPOSURES AND COVARIATE VARIABLES

Information regarding total monthly disposable household income (earnings from all residents) was obtained during the questionnaire / interview as a categorical variable, divided in seven ordinal options:

- 250 Brazilian Reais (BRL) or less;
- 251 to 500 BRL;
- 501 to 1,500 BRL;
- 1501 to 2,500 BRL;
- 2501 a 4,500 BRL;
- 4501 to 9,500 BRL;
- > 9,500 BRL.

Based on that, a continuous *per capita* income variable was created using mid-point of income for closed categories and R$ 14,523 as median mid-point for open-ended category, according to the previously described methodology[34]. Following, those values were converted into US$ according to the exchange rate during data collection (August 2010 — US$ 1 = R$ 1.75 Brazilian Real).

Education was collected as a discrete variable in number of years of schooling and used as a continuous variable for dose-response analysis. Nonetheless, for descriptive tables, education was classified in three ordinal categories:

- elementary school (up to eight years of education);
- high school (between nine and eleven years of education);
- college/university (> 11 years of education).

Covariates used in multivariable logistic regression also included age and sex (male/female), and time since last dental appointment (< 1 year; 2 to 3 years; > 3 years; never). The sample's socioeconomic profile was also evaluated with the following variables: household density (persons per bedroom), number of household amenities (TV, refrigerator, micro-wave oven, audio player, computer, mobile, phone line, car, washing machine, and dishwasher).

STATISTICAL ANALYSIS

Descriptive data were provided using sampling weights to obtain representative prevalence and means. Sampling weights were calculated based on the sampling factions of each sample stage and were calibrated to correct for non-response[30]. To explore the shape of the relation between income (continuous variable) and CAL (binary variable), data were smoothed as described elsewhere[35] using Locally Weighted Ordinary Least Squares regression (LOWESS) technique, with unweighted running means and logit function for binary outcome. The graphs were then visually analysed to determine a smoothing parameter (bandwidth of 15 and 30%) to remove roughness. Based on the graph, income was dichotomized at the threshold (US$ 600) to evaluate whether education had a different magnitude of association above and below it. For that analysis, logistic regression was used to model the outcome. The effect of education and race/ethnicity was adjusted by age, sex and time since last dental appointment. For regression analysis, sampling weights were used with svy commands. Conclusions were not altered removing the weights. Interaction terms among income, education and race/ethnicity were tested in logistic regression models. All analyses were performed using statistical software (StataCorp, v.13.0, College Station, Texas, United States).

RESULTS

Sample size included 9,779 adults in the 35–44 years group, who participated in the survey. There were 290 edentulous individuals and 329 individuals with all sextants excluded

(less than two teeth per sextant). Therefore, the final sample comprised 9,160 individuals (93.7% response rate). However, due to missing values in different variables, regression analyses included 8,886 individuals.

Average monthly *per capita* income was US$ 299.5 (confidence interval of 95% — 95%CI 258.2 – 340.8), and mean number of years of education was 8.6 (95%CI 8.2 – 9.0). Average age was 38.9 (standard deviation — SD ± 3.03), mean number of missing teeth was 7.3 (95%CI 6.8 – 7.8; min = 0; max = 19; SD ± 3.6), and Decayed, Missing and Filled Teeth (DMFT) was 16.3 (95%CI 15.8 – 16.7; min = 0; max = 32; SD ± 6.2).

There was 82.4% of households with up to two persons/bedroom, and 41.1% with six or less amenities. Demographic characteristics of the sample are presented in Table 1.

Table 1. Sociodemographic characteristics and weighted prevalence of 35–44-year-old individuals with moderate (CAL > 3 mm and PD > 3 mm) to severe periodontitis (CAL > 5 mm and PD > 3 mm).

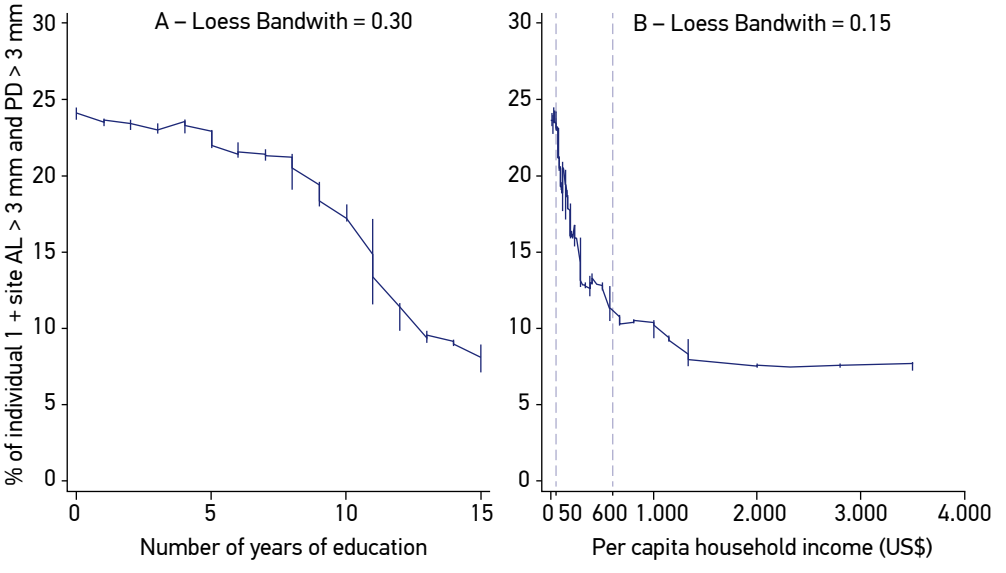
Variables	Total Sample		% of Periodontal Disease			
	n	%	Moderate to Severe	p-value*	Severe	p-value*
Total	9,160	100	17.8		6.6	
Household *per capita* Income (monthly)						
< US$ 50	646	5.9	22.8	< 0.01	6.2	< 0.01
US$ 50–150	3,675	40.4	21.6		9.1	
US$ 150–300	2,605	30.4	15.6		5.8	
US$ 300–600	1,277	15.5	12.7		4.2	
> US$ 600	879	7.7	8.9		1.7	
Sex						
Male	3,209	36.9	20.1	0.02	8.5	0.05
Female	6,101	63.1	16.2		5.3	
Ethnic Group						
White	3,967	50.3	15.9	0.13	5.7	0.52
Brown	4,156	37.5	18.9		7.4	
Black	962	10.5	20.7		6.7	
Yellow/Asian	155	1.0	33.6		11.4	
Indigenous	70	0.7	22.9		5	
Last dental appointment (years ago)						
Up to 1	4,406	46.4	17.3	0.04	7.1	0.03
1 to 3	2,357	25.4	14.2		4.3	
> 3	2,274	25.8	20.9		6.7	
Never	191	2.4	37.8		23.2	
Education						
Elem. School	4,098	48.3	23.9	< 0.01	10.4	< 0.01
High School	2,923	29.4	15.6		3.8	
College/University	2,216	22.3	7.1		1.8	

Note: some variables may not add up to 9,310 individuals due to missing data.
AL: attachment loss; PD: probing depth; *χ^2 test corrected for sampling design.

The prevalence of individuals with moderate to severe periodontitis (at least one site with AL > 3 mm and at least one site with > 3 mm of pocket depth) and severe (at least one site with AL > 5 mm and at least one site with > 3 mm of pocket depth) was 17.6% (95%CI 15.6 – 21.1) and 6.5% (95%CI 4.9 – 8.6), respectively. Further analyses for severe periodontitis were similar to moderate to severe, but with fewer cases, thus affecting the stratified analysis.

The relation between prevalence of periodontitis and both income and education is presented in Figure 1. The highest prevalence of moderate to severe periodontitis is associated with *per capita* household income value of US$ 50 per month. Individuals with income values higher than US$ 50 *per* month showed less probability of presenting moderate to severe periodontitis up to the threshold of US$ 600 *per* month. Beyond this threshold, income was no longer associated with decreased rates of moderate to severe periodontitis (*odds ratio* — OR = 0.99; p = 0.12).

Regarding education, treated as a continuous variable, a negative linear relationship with moderate to severe periodontitis was observed. The Spearman correlation coefficient between income and education was r = +0.44 (p < 0.01), the coefficient between income and the number of household amenities was r = +0.42 (p < 0.01), and the coefficient between education and number of amenities was r = +0.34 (p < 0.01). Number of household amenities was associated with moderate to severe periodontitis (p < 0.01) and severe periodontitis (p = 0.04). Persons/bedroom was not associated with moderate to severe periodontitis (p = 0.06) neither to severe periodontitis (p = 0.16). In regression analysis, after controlling for income, age, sex and time since last dental appointment, they were not significantly associated, and such data was not presented.



AL: attachment loss; PD: probing depth.

Figure 1. Relation between prevalence of moderate to severe periodontitis and both income and education between 35–44-year-old Brazilian individuals.

The stratified analysis of moderate to severe periodontitis prevalence according to two different income groups is presented in Table 2. When considering an income of less than US$ 600 *per* month, men more frequently presented the disease. Likewise, other variables, such as time since last dental appointment, education was significantly related to a higher prevalence of the disease. Among the individuals with higher income (> US$ 600 *per* month), only education was significantly ($p < 0.05$) related to differences in prevalence of moderate to severe periodontitis.

Table 2. Moderate to severe periodontitis weighted prevalence (attachment loss > 3 mm and probing depth > 3 mm), according to sociodemographic variables, stratified by monthly income for 35–44-year-old Brazilian individuals.

	Household per capita income			
	< US$ 600 (Month)		> US$ 600 (Month)	
	%	n	%	n
Total	29.9	8,077	8.9	868
Sex				
Male	20.9	2,734	12.2	337
Female	17.2	5,343	6.6	528
p-value	**0.05**		**0.30**	
Ethnic Group				
White	16.9	3,242	8.4	575
Brown	18.9	3,759	13.6	232
Black	21.6	876	2.1	45
Yellow/Asian	36.2	137	7.1	11
Indigenous	22.4	63	-	-
p-value	**0.20**		**0.29**	
Last dental appointment (year)				
Up to 1	18.2	3,635	10.2	623
1 to 3	14.7	2,114	3.2	164
More than 3	21.2	2,100	9.4	78
Never	38.2	167	-	-
p-value	**0.05**		**0.36**	
Education				
Elem. School	24.2	3,817	18.8	78
High School	15.7	2,672	18.2	165
College/University	7.8	1,541	4.4	619
p-value	< 0.01		< 0.01	

Note 1: some variables may not add up to 9,310 individuals due to missing data.
Note 2: p-values obtained from qui-square test for independence in bivariable analysis corrected for survey design.

Interaction between income and education was also assessed in regression models adjusted for age, sex, and time since last dental appointment (Table 3). Among those earning below US$ 600, having a college/university degree was associated with less chances (OR = 0.28; 95%CI 0.18 – 0.44) of presenting moderate to severe periodontitis compared to having elementary school. A similar result was found among those earning more than US$ 600 (OR = 0.23; 95%CI 0.06 – 0.89). The test for linear trend of education was significant ($p < 0.01$) in both groups, while the interaction between income and education was not ($p = 0.57$). There were no significant interactions between education and race/ethnicity ($p = 0.45$), neither between income and race/ethnicity ($p = 0.96$).

The model fit was tested using the Hosmer-Lemeshow goodness of fit test (GOF). The model without interactions showed better fit than the model with them. Pooled analysis showed that being white, having higher education and higher income was associated with less chance of periodontitis (Table 4), after controlling for age, sex and time since last dental appointment. However, only education remains statistically significant ($p < 0.05$) after inclusion of education, income and race/ethnicity in the same model.

DISCUSSION

While a non-linear relationship between income and dental caries/tooth loss has been previously reported[21,22], to the best of our knowledge this is the first study with such

Table 3. *Odds ratio* (OR) to moderate to severe periodontitis according to educational status and race/ethnicity, stratified by monthly income, and educational status stratified by race/ethnicity, for 35–44-year-old Brazilian individuals.

	OR1	(95%CI)	OR2	(95%CI)	Comparison OR1 × OR2
	< US$ 600 (Month)		> US$ 600 (Month)		
Race/ethnicity*					
White	1		1		p = 0.96
Brown/Black	1.21	(0.95 – 1.54)	1.24	(0.52 – 2.97)	
Education*					
Elementary School	1		1		p = 0.57
High School	0.60	(0.42 – 0.87)	0.96	(0.32 – 2.92)	
College/University	0.28	(0.18 – 0.44)	0.23	(0.06 – 0.89)	
	Brown/Black		White		
Education*					
Elementary School	1		1		p = 0.45
High School	0.64	(0.40 – 1.00)	0.60	(0.38 – 0.94)	
College/University	0.39	(0.19 – 0.79)	0.18	(0.09 – 0.36)	

*Adjusted by age, sex and time since last dental visit.
95%CI: confidence interval of 95%.

approach regarding periodontal health. In addition, few studies[21,22] have addressed the use of socioeconomic position indicators as continuous variables to investigate the shape of this relationship. Main findings of this study indicate the existence of an income threshold for moderate to severe periodontitis in a large and nationally representative survey in Brazil. The only variable associated with a protective effect in the richer group was years of education. This indicates that income and education might influence periodontitis through independent and distinct mechanisms.

A materialistic approach explains differences in health among individuals based on absolute standard of life, so having a minimum income provides access to oral care materials, *e.g.*, toothbrush and toothpaste, in addition to housing, sanitation, and healthcare. Another interpretation arises from the influence of chronic stress on individual living conditions in a process called allostasis[27,28]. Income not only provides individuals access to resources, but it also allows them to focus on other aspects of life, as their self-awareness regarding health. It has been suggested that, while income influences health through materialistic mechanisms, social position affects health through psychosocial pathways as well[18,19,21,36]. Data of the present study support both contentions, assuming the effects of education as a psychosocial influence.

Education and income were once thought to similarly contribute to disease prevention. However, recent evidence suggests that these measures are not interchangeable[24-26]. In fact, this study shows that income presents a non-linear relationship with moderate to severe periodontitis with the presence of a threshold. While other socioeconomic indicators only presented an effect with individuals below the cut-off point, education

Table 4. *Odds ratio* (OR) to moderate to severe periodontitis in 35–44-year-old Brazilian individuals.

	OR*	(95%CI)	p-value	OR**	(95%CI)	p-value
Race/ethnicity						
White	1		0.05	1		0.75
Brown/Black	1.26	(1.00 – 1.59)		1.04	(0.82 – 1.32)	
Education						
Elementary School	1		<0.01	1		< 0.01
High School	0.62	(0.44 – 0.88)		0.66	(0.45 – 0.96)	
College/University	0.25	(0.17 – 0.38)		0.29	(0.17 – 0.50)	
Household *per capita* Income (monthly)						
< US$ 50	1		<0.01	1		0.44
US$ 50–150	0.99	(0.63 – 1.55)		1.16	(0.72 – 1.87)	
US$ 150–300	0.64	(0.39 – 1.04)		0.88	(0.52 – 1.49)	
US$ 300–600	0.48	(0.31 – 0.76)		0.84	(0.52 – 1.35)	
> US$ 600	0.32	(0.13 – 0.77)		0.68	(0.26 – 1.80)	

*Adjusted by age, sex and time since last dental visit; **adjusted by race/ethnicity, education, income, age, sex and time since last dental visit.

showed a direct and independent effect at all income levels, even above the cut-off. This highlights the importance of focusing on the independent effect of socioeconomic indicators on oral and periodontal health. Studies aiming at a general socioeconomic effect may indeed use a combined composite index. However, for causality, tracking specific pathways is important, and different socioeconomic indicators should not be mixed given that they might cause disease through different mechanisms[37]. Education can influence health outcomes either directly, as employment status and earned income, or indirectly, through healthy behaviours. In addition, the influence of education can also be seen across generations[10].

We observed no association between race/ethnicity and periodontitis after controlling for education and income, differently from other studies[7,10,33]. Contrary to anticipated, we also did not find as interaction between income and race/ethnicity[38]. Contrasting results with regards to these variables have been previously reported[7]. After controlling for other socioeconomic variables, any residual effect of race/ethnicity has been attributed to some genetic or biological mechanism[10], but we believe the presence of residual (socioeconomic) confounding factors or other pathways, mainly linked to stress, such as racial discrimination and smoking, should be considered.

This study used data from a large epidemiological survey conducted in Brazil, in which six sites in six index teeth were measured per person. Thus, disease prevalence may be underestimated[39]. Our findings showed that severe periodontitis had much lower prevalence, as expected, but all associations were in the same direction as moderate to severe. We could not present detailed stratified analysis for severe periodontitis due to the lower number of cases. In addition, analyses considering more complex outcomes of periodontal disease, based on full mouth examinations, were not possible to be calculated.

The use of standardized measures to report findings is an important approach to improve the grouping of different studies[39], and should be encouraged. Smoking is an important behaviour when investigating socioeconomic indicators and periodontal disease. However, as a mediator, it should not be used as adjustment for the total effect of socioeconomic factors[7].

In addition, smoking data was not collected in the survey used in this study (SB Brasil 2010)[30]. It must also be highlighted that any smoothing method is exploratory in nature and does not provide a definite answer regarding the cut-off-point. Finding a threshold with such techniques is a visual exercise with some subjectivity; as a result, the value of US$ 600 was the best cut-off point for the graph presented in our study. Other selected cut-off points would likely not be far from this estimation.

CONCLUSION

The current study demonstrated that higher income was associated with decreased prevalence of moderate to severe periodontitis, until a threshold of US$ 600 *per* month. The only variable that influenced prevalence of periodontitis beyond the threshold was education,

presented by a negative linear relationship. Such findings indicate that income and education might influence periodontal health through independent pathways.

From the public health perspective, these findings shed light on the understanding of the complex interrelationship between socioeconomic variables such as income and education. Future research is necessary to investigate the causality of socioeconomic pathways that lead to periodontitis and up to what extent independent socioeconomic components are influencing disease onset and progression. Importantly, for chronic diseases, such as most forms of periodontal disease, a life-course approach with prospective comprehensive cohort studies would offer great benefit in the investigation of different etiologic and modulatory disease factors.

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REFERENCES

1. Petersen PE, Ogawa H. The global burden of periodontal disease: Towards integration with chronic disease prevention and control. Periodontol 2000 2012; 60(1): 15-39. https://doi.org/10.1111/j.1600-0757.2011.00425.x
2. Vettore MV, Marques RA, Peres MA. Social inequalities and periodontal disease: Multilevel approach in sbbrasil 2010 survey. Rev Saúde Pública 2013; 47 (Suppl. 3): 29-39. http://dx.doi.org/10.1590/S0034-8910.2013047004422
3. Sanders AE, Campbell SM, Mauriello SM, Beck JD, Jimenez MC, Kaste LM, et al. Heterogeneity in periodontitis prevalence in the hispanic community health study/study of latinos. Ann Epidemiol 2014; 24(6): 455-62. https://doi.org/10.1016/j.annepidem.2014.02.018
4. Oppermann RV, Haas AN, Rösing CK, Susin C. Epidemiology of periodontal diseases in adults from latin america. Periodontol 2000 2015; 67(1): 13-33. https://doi.org/10.1111/prd.12061
5. Klinge B, Norlund A. A socio-economic perspective on periodontal diseases: A systematic review. J Clin Periodontol 2005; 32 (Suppl. 6): 314-25. https://doi.org/10.1111/j.1600-051X.2005.00801.x
6. Borrell LN, Burt BA, Warren RC, Neighbors HW. The role of individual and neighborhood social factors on periodontitis: The third national health and nutrition examination survey. J Periodontol 2006; 77(3): 444-53. https://doi.org/10.1902/jop.2006.050158
7. Bastos JL, Boing AF, Peres KG, Antunes JL, Peres MA. Periodontal outcomes and social, racial and gender inequalities in brazil: A systematic review of the literature between 1999 and 2008. Cad Saúde Pública 2011; 27 (Suppl 2): S141-53. http://dx.doi.org/10.1590/S0102-311X2011001400003
8. Boillot A, El Halabi B, Batty GD, Rangé H, Czernichow S, Bouchard P. Education as a predictor of chronic periodontitis: A systematic review with meta-analysis population-based studies. PLoS One 2011; 6(7): e21508. https://doi.org/10.1371/journal.pone.0021508
9. Thomson WM, Sheiham A, Spencer AJ. Sociobehavioral aspects of periodontal disease. Periodontol 2000 2012; 60(1): 54-63. https://doi.org/10.1111/j.1600-0757.2011.00405.x

10. Borrell LN, Crawford ND. Socioeconomic position indicators and periodontitis: Examining the evidence. Periodontol 2000 2012; 58(1): 69-83. https://doi.org/10.1111/j.1600-0757.2011.00416.x
11. Schuch HS, Peres KG, Singh A, Peres MA, Do LG. Socioeconomic position during life and periodontitis in adulthood: A systematic review. Community Dent Oral Epidemiol 2017; 45(3): 201-8. https://doi.org/10.1111/cdoe.12278
12. Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). J Epidemiol Community Health 2006; 60(1): 7-12. https://doi.org/10.1136/jech.2004.023531
13. Mueller CW, Parcel TL. Measures of socioeconomic-status - alternatives and recommendations. Child Dev 1981; 52(1): 13-30. https://doi.org/10.2307/1129211
14. Watt RG. From victim blaming to upstream action: Tackling the social determinants of oral health inequalities. Community Dent Oral Epidemiol 2007; 35(1): 1-11. https://doi.org/10.1111/j.1600-0528.2007.00348.x
15. Backlund E, Sorlie PD, Johnson NJ. The shape of the relationship between income and mortality in the united states. Evidence from the national longitudinal mortality study. Ann Epidemiol 1996; 6(1): 12-20; discussion 21-2.
16. Gravelle H. How much of the relation between population mortality and unequal distribution of income is a statistical artefact? BMJ 1998; 316(7128): 382-5.
17. Wolfson M, Kaplan G, Lynch J, Ross N, Backlund E. Relation between income inequality and mortality: Empirical demonstration. BMJ 1999; 319(7215): 953-7.
18. Adler NE, Newman K. Socioeconomic disparities in health: Pathways and policies. Health Aff (Millwood) 2002; 21(2): 60-76. https://doi.org/10.1377/hlthaff.21.2.60
19. Marmot M. The influence of income on health: Views of an epidemiologist. Health Aff (Millwood) 2002; 21(2): 31-46.
20. Fritzell J, Nermo M, Lundberg O. The impact of income: Assessing the relationship between income and health in sweden. Scand J Public Health 2004; 32(1): 6-16. https://doi.org/10.1080/14034950310003971
21. Sanders AE, Slade GD, Turrell G, John Spencer A, Marcenes W. The shape of the socioeconomic-oral health gradient: Implications for theoretical explanations. Community Dent Oral Epidemiol 2006; 34(4): 310-9. https://doi.org/10.1111/j.1600-0528.2006.00286.x
22. Celeste RK, Nadanovsky P. Income and oral health relationship in brazil: Is there a threshold? Community Dent Oral Epidemiol 2009; 37(4): 285-93. https://doi.org/10.1111/j.1600-0528.2009.00474.x
23. Morris JN, Wilkinson P, Dangour AD, Deeming C, Fletcher A. Defining a minimum income for healthy living (mihl): Older age, england. Int J Epidemiol 2007; 36(6): 1300-7. https://doi.org/10.1093/ije/dym129
24. Macintyre S, McKay L, Der G, Hiscock R. Socio-economic position and health: What you observe depends on how you measure it. J Public Health Med 2003; 25(4): 288-94.
25. Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, et al. Socioeconomic status in health research: One size does not fit all. JAMA 2005; 294(22): 2879-88. https://doi.org/10.1001/jama.294.22.2879
26. Geyer S, Hemstrom O, Peter R, Vagero D. Education, income, and occupational class cannot be used interchangeably in social epidemiology. Empirical evidence against a common practice. J Epidemiol Community Health 2006; 60(9): 804-10. https://doi.org/10.1136/jech.2005.041319
27. McEwen BS, Wingfield JC. The concept of allostasis in biology and biomedicine. Horm Behav 2003; 43(1): 2-15.
28. Sterling P. Allostasis: A model of predictive regulation. Physiol Behav 2012; 106(1): 5-15. https://doi.org/10.1016/j.physbeh.2011.06.004
29. Marmot M, Allen J, Bell R, Bloomer E, Goldblatt P, Consortium for the European Review of Social Determinants of Health and the Health Divide. WHO european review of social determinants of health and the health divide. Lancet 2012; 380(9846): 1011-29. https://doi.org/10.1016/S0140-6736(12)61228-8
30. Silva NN, Roncalli AG. [Sampling plan, weighting process and design effects of the brazilian oral health survey]. Rev Saúde Pública 2013; 47 (Suppl. 3): 3-11.
31. Roncalli AG, Silva NN, Nascimento AC, Freitas CH, Casotti E, Peres KG, et al. [Relevant methodological issues from the sbbrasil 2010 project for national health surveys]. Cad Saúde Pública 2012; 28 (Suppl.): s40-57. http://dx.doi.org/10.1590/S0102-311X2012001300006
32. World Health Organization. Oral health surveys: Basic methods. 4ª ed. Geneva: ORH/EPID; 1997. 93p.
33. Peres MA, Antunes JL, Boing AF, Peres KG, Bastos JL. Skin colour is associated with periodontal disease in brazilian adults: A population-based oral health survey. J Clin Periodontol 2007; 34(3): 196-201. https://doi.org/10.1111/j.1600-051X.2006.01043.x
34. Celeste RK, Bastos JL. Mid-point for open-ended income category and the effect of equivalence scales on the income-health relationship. Rev Saúde Pública 2013; 47 (Suppl. 3): 168-71.

35. Hastie T, Tibshirani R. Exploring the nature of covariate effects in the proportional hazards model. Biometrics 1990; 46(4): 1005-16.
36. Link BG, Phelan J. Social conditions as fundamental causes of disease. J Health Soc Behav 1995; Spec No: 80-94.
37. Celeste RK. Contextual effect of socioeconomic status influences chronic periodontitis. J Evid Based Dent Pract 2007; 7(1): 29-30. https://doi.org/10.1016/j.jebdp.2006.12.006
38. Borrell LN, Burt BA, Neighbors HW, Taylor GW. Social factors and periodontitis in an older population. Am J Public Health 2008; 98 (Suppl.): S95-101. https://doi.org/10.2105/AJPH.98.Supplement_1.S95
39. Holtfreter B, Albandar JM, Dietrich T, Dye BA, Eaton KA, Eke PI, et al. Standards for reporting chronic periodontitis prevalence and severity in epidemiologic studies: Proposed standards from the joint eu/USA periodontal epidemiology working group. J Clin Periodontol 2015; 42(5): 407-12. https://doi.org/10.1111/jcpe.12392

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