Income at birth and tooth loss due to dental caries in adulthood: The 1982 Pelotas birth cohort

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Abstract

Objective: To estimate the effect of income at birth on adulthood tooth loss due to dental caries in 539 adults from the 1982 Pelotas birth cohort.

Methods: Family income was collected at birth. Tooth loss was clinically assessed when individuals were aged 31. Dental visit and oral hygiene at age 25 were considered mediators. Confounders included maternal skin color, and individual’s skin color, sex, and income in adulthood. Marginal structural modeling was used to estimate the controlled direct effect of income at birth on tooth loss due to dental caries that was neither mediated by the use of dental service nor oral hygiene.

Results: Forty-three percent of the individuals of low income at birth lost one/two teeth, and 23% lost three or more; among those non-poor, the prevalence was 30% and 14%, respectively. Poor individuals at birth had a 70% higher risk for missing teeth in adulthood than those non-poor. The risk of losing one/two (risk ratio 1.68) and three or more teeth (risk ratio 3.84) was also higher among those of low income at birth.

Conclusions: Economic disadvantage at birth had an effect on tooth loss due to dental caries at age 31 not mediated by individual risk factors.

Keywords: cohort studies, edentulism, epidemiology, income, oral health
Introduction

In life-course epidemiology, the critical period theory considers the time window as a key factor (Nicolau, Thomson, Steele, & Allison, 2007). Thus, according to this theory, exposures that occurred early in life will program the development of adult conditions (Barker, 1998). Evidence suggests that childhood socioeconomic position (SEP) directly impacts on health outcomes in adulthood (Kuh & Ben-Shlomo, 2004), such as diabetes, stroke, and cardiovascular diseases (Nandi, Glymour, Kawachi, & VanderWeele, 2012). In oral health, adverse early-life SEP has been associated with oral cancer, caries, and periodontitis (Krishna Rao et al., 2015; Peres, Peres, Thomson, et al., 2011; Schuch et al., 2019).

Tooth loss is a public health problem that negatively affects the quality of life (Kassebaum et al., 2014; Peres et al., 2019; Thomson, 2012), and has been associated with adverse health outcomes such as malnutrition, hypertension, and obesity (De Marchi, Hugo, Hilgert, & Padilha, 2012; Nascimento et al., 2016; Peres, Tsakos, Barbato, Silva, & Peres, 2012). Severe tooth loss affected 2% of the world population and was ranked in the 36th position among the most prevalent chronic diseases that affect life expectancy (Marcenes et al., 2013). This condition is influenced by several factors, including educational level, family income, oral hygiene habits, dietary habits, and access and utilization of dental care services (Barbato, Peres, Hofelmann, & Peres, 2015; Thomson, Poulton, Kruger, & Boyd, 2000). In a meta-analysis, we found that individuals of low income had greater odds of losing teeth (Seerig, Nascimento, Peres, Horta, & Demarco, 2015).

Despite the rising evidence on the topic, there are still gaps that need to be filled in. The available source of evidence is mainly originated from high-income countries (Blane, Netuveli, & Stone, 2007), and as the patterns of socioeconomic inequalities differ from high- to the low–middle-income countries, the effects of early-life SEP on adult health outcomes may differ significantly according to the setting where the study was conducted (Lima-Costa, De Oliveira, Macinko, & Marmot, 2012). In light of the preceding discussion and based on the critical period model, we hypothesize that relative poverty at birth has a direct effect on tooth loss in adulthood, independent of adult socioeconomic conditions. In order to identify possible causal pathways, we developed a directed acyclic graph (DAG; Figure 1). As oral hygiene and dental services mediate the association between income and tooth loss, collider bias might be created if conventional regression is employed (Robins & Greenland, 1992). Furthermore, as adult income is affected by family income at birth, additional bias might occur (Robins & Greenland, 1992). In order to overcome these issues, marginal structural modeling, which accounts for time-dependent confounders and mediators, can be employed under a counterfactual framework (Robins, Hernan, & Brumback, 2000). Accordingly, the aim of this study was to estimate the controlled direct effect of family income at birth on adult tooth loss due to dental caries not mediated by oral habits occurring in later life using marginal structural modeling.

Methods

As this a human observational longitudinal study, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used to guide the reporting of the study. The study was performed in accordance with the Declaration of Helsinki; all follow-up assessments were approved by the Ethics Committee of the Federal University of Pelotas (IRB#19551713.9.0000.5317), and a signed consent form was collected either from the parents of participating children or the adult participants.

2.1 The 1982 Pelotas birth cohort

In 1982, all maternity hospitals of the city of Pelotas were visited daily. All live births whose mothers lived in the urban area of the city were examined and their mothers interviewed. These individuals have been followed up for several times during the life course (Horta et al., 2015). In 1997, 900 individuals were randomly selected for the Oral Health Study (OHS)-97, and in 2006 (OHS-06) and 2013 (OHS-13), they were contacted for new oral examinations. Information regarding dental caries, missing teeth, and periodontal disease among others was elicited. In 2013, six dentists previously trained and calibrated performed oral examination at the individuals’ home. Examiners underwent theoretical and practical training on 20 individuals with similar age but not enrolled in the cohort. Examiner reliability was assessed using weighted kappa, which ranged from 0.89 to 0.95 for tooth loss.
Methodological details of the Oral Health Studies nested to the 1982 Pelotas birth cohort can be found elsewhere (Peres, Peres, Demarco, et al., 2011).

2.2 | Outcome: tooth loss at age 31

Tooth loss was assessed through a full-mouth examination. Only teeth lost due to dental caries were considered for this study. In order to assure that, we used the code 4 of the DMF index, and in the absence of evident signs of multiple caries lesions, participants were asked, during the clinical examination, the reason for tooth loss (e.g., presence of pain or abscess prior to extraction). In cases of doubt, we used data from the previous dental examinations (e.g., presence of dental caries). Thus, teeth lost for other reasons (code 5 of the DMF index), such as periodontal disease, trauma, or due to orthodontic treatment, were not included in the outcome variables.

Two different variables were defined as the outcome:

1. Number of missing teeth: Discrete variable that considered the number of missing teeth;
2. Categories of missing teeth: Three categories were created from the discrete variable. The reference category comprised those individuals that have never lost a tooth until the age of 31; the next category included those individuals that have lost at most two teeth; and finally, the last category comprised individuals that have lost 3 or more teeth. These categories were created based on the mean number of missing teeth.

2.3 | Exposure: family income at birth

The main exposure for this study was family income at birth. Family income was collected at birth through a face-to-face interview and categorized according to the Brazilian minimum wage units (the mid-year value of the minimum wage in 1982 was 16 608 cruzeiros) in five categories: less than 1 minimum wage unit (21.9% of the entire cohort), 1.1–3 units (47.4%), 3.1–6 (18.5%), 6.1–10 units (6.5%), and more than 10 units (5.7%). Unfortunately, information on income was not collected as a continuous variable. Thus, due to the unequal numbers of individuals in each income category, a principal component analysis was conducted in order to classify family income into tertiles (Barros et al., 2006). For this study, the exposure was included as a binary variable; thus, the middle and last tertiles were merged into the category “Non-poor,” while the first tertile comprised the category “Poor.”

2.4 | Mediators and confounders

Maternal skin color was considered as a baseline confounder. This variable was dichotomized into “white”/“brown and black.” Adult income was collected as a continuous variable and later categorized into tertiles. Self-reported individuals’ skin color at age 23 (“white”/“brown and black”) and gender were also included as confounders in the model.

The mediator “dental service utilization in the last year” was collected as a binary variable “Yes”/“No.” Dental flossing at age 25 (“do you often floss your teeth?”) was also collected as a binary variable “Yes/No.”

For a better understanding of the relationship between those variables in the model, Figure 1 displays possible causal pathways assumed in order to estimate the controlled direct effect of income at birth on adult tooth loss not mediated by dental service or use of dental floss.

2.5 | Statistical analyses

In order to estimate the controlled direct effect (CDE) of income at birth on tooth loss in adulthood that was not mediated by dental service utilization and use of dental floss at age 25, marginal structural modeling was used. As hypothesized in the DAG, adult income, influenced by family income at birth, confounded the mediator-outcome relation. According to VanderWeele, (2009), the presence of a causal intermediate that confounds the mediator-outcome relation allows the estimation of the controlled direct effect of the exposure on the outcome. As the controlled direct effect may be equal to natural direct effect in the absence of an interaction between exposure and mediator, multiplicative interaction was tested (De Stavola & Daniel, 2012). This interaction was examined, including the cross-product term in the analytical model. As no interaction was detected, the cross-product term was omitted in the subsequent analyses (Tables S1 and S2).

Stabilized weights were calculated for exposure (1) and mediators (2) in separate according to the following formulas:

\[
SW_1 = \frac{P(X=x)}{P(X=x|C_1)}, \quad (1)
\]

\[
SW_2 = \frac{P(M_x=E=e)}{P(M_x=E=e|M_y=M_y,C_2,C_3,C_1)}, \quad (2)
\]

Stabilized weight for each model is given by \(SW = SW_1 \times SW_2\). Stabilized weights were calculated separately for the two mediators (dental service use and dental floss) \((M_x, M_y)\) for the two outcome models that considered individual mediators. For calculating the weight of each mediator, the other one was included as confounder of the mediator-outcome relation. For the marginal structural model that adjusted for both mediators, the final stabilized weight was obtained by multiplying the stabilized weights of family income at birth, dental service use, and dental floss.

The distribution stabilized weights were as follows: final stabilized weight: mean = 1.01; range = 0.22–5.24; IQR = 0.64–1.18; “Dental service use” stabilized weight: mean = 1.00; range = 0.33–3.40; IQR = 0.77–1.10; “Dental floss” stabilized weight: mean = 1.01;
2.6 | Sensitivity analyses

2.6.1 | Unmeasured confounder

In order to test the assumption of no unmeasured confounder (U), a sensitivity analysis was performed. For conducting this analysis, we assumed that the relative excess risk due to interaction between X and U is equal to 0. The parameters of U, such as $\gamma$ (conditional increase in risk for tooth loss), $P_1$ (prevalence in those exposed to the mediators), and $P_2$ (prevalence in those non-exposed to the mediators), were specified. We used the following model given by VanderWeele (2010) to calculate the bias introduced by U that could invalidate the controlled direct effect:

$$\text{Bias CDE} = \frac{1+\gamma-1}{1+\gamma-1} \cdot \frac{P_1}{P_2}$$

3 | RESULTS

In the Oral Health Study-13 (OHS-13), 539 individuals were examined, representing 60.1% of those examined in the OHS-97. Socioeconomic and demographic indicators of the participants enrolled in the OHS-13 were comparable to those of the original cohort study (data not shown). About 51% of the sample lost at least one tooth; 34% lost at most two teeth, whereas 17% lost three or more teeth. The mean number of missing teeth was 1.25. Among those of low income at birth, the prevalence of 1 or 2 lost teeth was 43%, while the prevalence of losing more than 3 teeth was 23%, while among those non-poor at birth the prevalence was 30% and 14%, respectively.

Table 1 displays the descriptive analysis. The crude analyses indicated that low income at birth, brown/black maternal skin color, no use of dental floss at age 25, and low income at age 23 increased the risk of tooth loss in adulthood.

Table 2 presents the controlled direct effect of income at birth on tooth loss not mediated by dental service use (Model A), dental floss (Model B), and by both mediators (Model C). Model A shows that individuals considered “poor” at birth presented 73% higher risk of losing 1 or 2 teeth (risk ratio [RR] 1.73; 95% CI 1.02–2.95), and 3 times higher risk of having 3 or more missing teeth (RR 3.13; 95% CI 1.67–5.90) compared with those that were “non-poor” at birth. The counterfactual relative risk for missing teeth was 61% higher among those “poor” compared to those who presented a better economic condition at birth (RR 1.61; 95% CI 1.19–2.20). When the effect was controlled for dental floss at age 25, individuals that were “poor” at birth presented 93% greater risk for having 1 or 2 teeth lost at age 31 (RR 1.93; 95% CI 1.12–3.32), and almost 4 times higher risk for missing 3 or more teeth (RR 3.84; 95% CI 2.03–7.26). Considering the

### Table 1

<table>
<thead>
<tr>
<th>Total sample</th>
<th>Categories of teeth lost</th>
<th>Number of teeth lost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage</td>
<td>Crude RR (95% CI)</td>
</tr>
<tr>
<td></td>
<td>1–2 teeth (%)</td>
<td>≥3 teeth (%)</td>
</tr>
<tr>
<td><strong>Income at birth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-poor</td>
<td>70.2</td>
<td>30.3</td>
</tr>
<tr>
<td>Poor</td>
<td>29.8</td>
<td>42.8</td>
</tr>
<tr>
<td><strong>Mother’s skin color</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>31.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Brown/Black</td>
<td>45.9</td>
<td>2.2 (1.3–3.7)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50.6</td>
<td>36.6</td>
</tr>
<tr>
<td>Female</td>
<td>49.4</td>
<td>33.2</td>
</tr>
<tr>
<td><strong>Income at age 23</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-poor</td>
<td>70.7</td>
<td>31.8</td>
</tr>
<tr>
<td>Poor</td>
<td>29.3</td>
<td>37.2</td>
</tr>
<tr>
<td><strong>Dental service utilization in the last year at age 25</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>41.9</td>
<td>37.8</td>
</tr>
<tr>
<td>Yes</td>
<td>58.1</td>
<td>30.9</td>
</tr>
<tr>
<td><strong>Dental floss at age 25</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>29.0</td>
<td>36.0</td>
</tr>
<tr>
<td>No</td>
<td>71.0</td>
<td>32.3</td>
</tr>
</tbody>
</table>
number of teeth lost, those “poor” at birth presented 78% increased risk for losing teeth than those “non-poor” at birth (RR 1.78; 95% CI 1.30–2.40). Finally, Model C presents the direct effect controlled for both mediators simultaneously. Individuals that were born in a disadvantaged family showed 68% higher risk for losing 1 or 2 teeth (RR 1.68; 95% CI 1.00–2.92), while the risk was almost 4 times higher when the outcome was set as losing more than 3 teeth (RR 3.84; 95% CI 1.97–7.26). Individuals “poor” at birth had 70% greater risk of losing teeth than those “non-poor” (RR 1.71; 95% CI 1.25–2.33).

Sensitivity analysis for unmeasured confounder U is presented in Table S3. This table presents hypothetical scenarios where the controlled direct effect of income at birth on tooth loss would be eliminated. Considering the prevalence among exposed and non-exposed to mediators combined with the strong association between U and outcome, no unmeasured variable seems to eliminate the CDE.

### Discussion

This study presents evidence that individuals of low socioeconomic position at birth presented a higher risk of losing teeth due to dental caries in adulthood. Our findings support our previous hypothesis that low income at birth has a long-term effect on tooth loss due to dental caries in adulthood independent of adult socioeconomic circumstances. Our findings are corroborated by previous studies, which showed that disadvantaged economic conditions in childhood impact on general and oral health conditions in adulthood (Nandi et al., 2012; Schuch et al., 2019).

In a previous study conducted in this cohort, Peres, Peres, Thomson, et al. (2011) found that poor individuals at birth had a higher risk of having more unsound teeth at age 24. According to the authors, subjects that experienced poverty in early life had less access to oral hygiene items (such as dental floss) so as to dental care service, which led to neglected oral hygiene habits in childhood (Oliveira et al., 2013). Since habits developed in early life influence habits in adulthood, it is expected that neglected habits established in childhood will follow a similar pattern during the life course (Sheiham et al., 2011). In addition, dental caries is a cumulative disease whose neglected treatment will eventually lead to tooth extraction. The combination of those factors might have predisposed individuals to dental caries in adulthood; the only cause to tooth loss considered for our study.

Our findings shed light on the importance of public health interventions to prevent dental caries and tooth loss. We demonstrate that there is a direct effect of income at birth on tooth loss in adulthood that is not mediated by adulthood individual risk factors. In our analysis, the two risk factors that are most directly related to the outcome were the use of dental services and oral hygiene, which was accounted for using the information on dental flossing. Our decision to use dental flossing as a proxy for oral hygiene attempts to circumvent report bias, as individuals tend to report a higher frequency of tooth brushing due to social desirability, and therefore, such a measure may not accurately reflect the oral hygiene habits. Based on ours and similar findings (Peres, Nascimento, Peres, Demarco, & Menezes, 2018), we advocate that solving oral health inequalities is beyond the capacities of individual measures since individual risk factors by themselves are not able to compensate the effect of income inequalities on oral health. Public health strategies need to be implemented, focusing on the societal and commercial determinants of health. Policies such as optimal community water
In conclusion, those individuals of low income at birth had higher risk of losing teeth in adulthood, independent of adult income, use of dental service, and oral hygiene. Our findings reinforce the relevance of developing public policies to reduce the existing early-life socioeconomic vulnerability, especially in low- and middle-income countries.

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AUTHOR CONTRIBUTION

Gustavo Giacomelli NASCIMENTO: Data curation; Formal analysis; Investigation; Methodology; Project administration; Writing-original draft; Writing-review & editing. Lenise M. Seerig: Data curation; Investigation; Methodology; Writing-original draft; Writing-review & editing. Helena S Schuch: Investigation; Methodology; Writing-review & editing. Bernardo L. Horta: Conceptualization; Methodology; Project administration; Writing-review & editing. Karen Glazer Peres: Conceptualization; Funding acquisition; Methodology; Writing-review & editing. Marco Aurélio Peres: Conceptualization; Funding acquisition; Project administration; Writing-review & editing. Marcos Britto Correa: Funding acquisition; Methodology; Writing-review & editing. Flavio Fernando


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Additional supporting information may be found online in the Supporting Information section.