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Associations between physical activity domains and oral health: an analysis of a Brazilian population–based study

Stefany Duarte dos ANJOS[a]
Rafael Milani FERRO[b]
Bernardo Novak LASKAWSKI[b]
Alex Nogueira HAAS[c]
Rodolfo Coelho PRATES[d]
Joao Paulo STEFFENS[a]

[a]Universidade Federal do Paraná–UFPR, Postgraduate Program in Dentistry, Curitiba, PR, Brazil.

[b]Universidade Federal do Paraná–UFPR, School of Dentistry, Department of Stomatology, Curitiba, PR, Brazil.

[c]Universidade Federal do Rio Grande do Sul–UFRGS, School of Dentistry, Department of Periodontology, Porto Alegre–RS–Brazil.

[d]Universidade da Região de Joinville–Univille, Postgraduate Program in Health and Environment, Joinville, SC, Brazil.

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Corresponding Author:
Joao Paulo Steffens
E-mail: joao.steffens@ufpr.br

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Abstract: Physical activity comprises four domains (leisure, transportation, domestic, and work activities) that may be differently associated with oral health. The aim of this study was to assess the association between each physical activity domain and oral health conditions in Brazilian adults. A total of 38,539 participants in the 2019 Brazilian Health Survey aged 30 years or older were analyzed. The outcomes were self-perceived oral health (dichotomous) and self-reported number of missing teeth (counts). The presence, frequency, and time of activity in each domain and their combination were analyzed as main exposures. Odds ratios (OR) and mean ratios (MR) were estimated by fitting multivariable models. Higher leisure time physical activity was the only domain associated with better self-perception of oral health (OR = 1.32; 95%CI 1.26–1.38) and lower tooth loss (MR=0.88; 95%CI 0.86–0.90). Higher levels of work, transportation, and household activities were significantly associated with worse self-perception of oral health, while higher levels of work– and transportation–related physical activities were also associated with greater tooth loss. When the total recommended weekly physical activity time was analyzed, no significant associations were found. Sensitivity analysis suggested that this pattern persists in potential periodontitis–related cases, such as when selecting older age or excluding individuals with no tooth loss. In conclusion, leisure physical activity was the only domain with the potential of reflecting the benefits of physical activity on oral health. The inclusion of other domains can confound this association.

Keywords: Tooth Loss; Oral Health; Cross-sectional Studies; Brazil; Exercise.

Introduction

Physical activity is defined by the World Health Organization (WHO) as any bodily movement produced by skeletal muscles that involves energy expenditure.[1] It can be performed in four domains: work, sport/leisure, transport, and household. According to the WHO, there is moderate evidence that physical activity undertaken in different domains can provide health benefits, although it is not possible to differentiate the effect of the different domains on several health outcomes.[1] Physical activity leads to decreased risk of chronic

non–communicable diseases such as hypertension, stroke, diabetes, and colon and breast cancer, and has been associated with a lower prevalence of periodontal diseases and tooth loss.[1–5]

Exercise, a component of leisure time physical activity, is characterized by planned, structured, and repetitive activities with the final or intermediate objective of improving or maintaining physical fitness.[6] It has been shown to decrease inflammatory markers, such as tumor necrosis factor (TNF)–α in healthy adults and C–reactive protein and interleukin (IL)–6 in older persons,[7,8] which are also associated with periodontitis.[9] Periodontitis is a ubiquitous multifactorial chronic inflammatory disease associated with dysbiotic biofilm and is characterized by progressive destruction of tooth-supporting tissues.[10] It affects approximately 50% of adults over 30 years of age,[11,12] being the leading cause of tooth loss in older adults,[13,14] and negatively affects self-perception of oral health.[15] Besides periodontitis, caries is also a highly prevalent noncommunicable disease that shares common social and behavioral risk factors and contributes to the so-called 'chronic oral diseases burden', which was demonstrated to connect these two major causes of tooth loss.[16]

Not only might inflammation-related biomarkers be related to the favorable impact of physical activity on general (and oral) health, but depression symptoms might also be improved.[17] Therefore, it is plausible to assume that leisure time activities (exercise) are inversely associated with tooth loss, while work, transportation, and domestic activities seem to be related to unfavorable socioeconomic status, especially in developing countries such as Brazil.[18] Consequently, these three domains may be associated with increased risk of oral diseases rather than having a protective effect. For instance, when all four domains are considered, the prevalence of physical inactivity in low-income countries is about half that in high income countries in 2016.[19] This may explain why the risk of mortality and several noncommunicable diseases attributable to physical inactivity is consistently higher in high-income countries than in low- and middle-income countries.[20] Therefore, the objective of this study was to explore the associations between physical activity domains and tooth loss–the endpoint of periodontitis and chronic oral diseases burden– and self-perception of oral health in Brazilian adults.

Methodology

The Second Brazilian National Health Survey (Pesquisa Nacional em Saúde– PNS) was a study carried out to estimate access and use of health services, family, lifestyle, chronic diseases, self-perception of health status, oral health status, anthropometric information, and primary health care. The study had a cross-sectional design and was carried out in 2019 by the Brazilian Institute of Geography (IBGE, Rio de Janeiro, RJ, Brazil) in collaboration with the Ministry of Health and the Ministry of Economy. A three-stage cluster sampling was used. All participants signed an informed consent. Research protocols were approved by the National Research Ethics Committee of the National Health Council (Conep, Brasília, DF, Brazil) under #3.529.376. This study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013, and complied with the Strengthening the Reporting of Observational Studies in Epidemiology–STROBE–guidelines.

The three-stage sampling involved, sequentially, census sectors, households, and residents. Simple randomization was applied to select households and any resident aged 15 years or older for individual interviews. First, the agent described the study to the person responsible for the household or one of the residents who answered a household questionnaire and recorded all residents aged 15 years or older in a mobile device. Then, one of the 15-year-old or older residents was selected through the mobile devices and answered the individual interview with scheduled times, with two or more visits expected. More details about the methodology can be found elsewhere.[21]

Dependent and independent variables

For the present study, the dependent variables used were self-perception of oral health and self-reported number of lost teeth. For the first one, the answer to the question "In general, how do you rate your oral health (teeth and gums)?" was

dichotomized in 0–very poor, poor, or fair; and 1–good or very good. For the calculation of tooth loss, the answer to the question "Did you lose any upper permanent teeth?" was considered. If the answer was "no", the number "0" was recorded. If the answer was "yes, I lost all my upper teeth", the number "16" was recorded. If the answer was "yes", participants answered the question "How many permanent upper teeth did you lose?". The same approach was followed for the lower teeth, and the total number of missing teeth was the sum of missing upper and lower teeth.

The main independent variables were the physical activity domains, as follows: a) leisure, considering 'any type of exercise or sport' in the last 3 months; b) work and c) household activities, including 'long walk' (to work) or 'performing heavy cleaning, carrying weight, or performing any other heavy activity that requires intense physical effort (at work and at home); and d) transport, taking into account walking or biking to/from work or on frequent activities. The presence, weekly frequency, and weekly time of activities in each domain were analyzed, using the thresholds defined by the WHO and the U.S. Department of Health and Human Service as references.[1,3] A variable composed of the sum of weekly activity times in the different domains, called "total physical activity", was also created. Individuals also answered a question related to the physical activity or sport they practiced most often. The intensity of this leisure activity was then defined using its metabolic equivalent (MET)[22] and categorized as follows: Light = MET up to 3; Moderate = MET between 3 and 6; Vigorous = MET greater than 6.

Statistical analysis

Logistic regression models were built to obtain the odds ratios (OR) for the variable self-perception of oral health. For tooth loss, negative binomial regression models were fitted to calculate the mean ratio (MR). Model building was based on the purposeful approach.[23] Briefly, potential variables were defined *a priori* and included sex, age, skin color, education, oral health care, smoking, body mass index, alcohol consumption, vegetable consumption, and monthly income (calculated as all earnings received in the analyzed month, including work–related wage/salary, pension, alimony, child maintenance, and profits from property rentals or investments). Each variable was included in the model with self-perception of oral health or tooth loss, and those that had a p–value < 0.25 were entered in the first model. Then, a multivariate model was built, and retention of the variable in the next step depended on a combination of a p–value <0.05, confounding, and interactions. Thereafter, each domain of physical activity was separately included in the model, and the variables with nonsignificant associations (p > 0.05) or no confounding modification (25% change in the estimate of other variables) were excluded from the final model. The final adjusted model included sex, age, skin color, education, tooth brushing frequency, smoking, vegetable consumption, and income. Individuals with missing data for any of those variables were excluded. Sensitivity analyses were conducted to estimate the influence of income (using the median as cutoff) or periodontitis–related factors–age (cutoff ≥ 55 years) and number of lost teeth (> 0 or < 32) in the models.

All analyses were performed using Stata 13.0 software (Stata Corp., College Station, USA). Associations are presented with a 95% confidence interval (CI). Statistical significance was set at 5%.

Results

Data from a total of 38,539 subjects were included and analyzed (Figure). Table 1 shows the sociodemographic characteristics of the sample. The majority of the sample consisted of men (56.4%) with a mean age of 46.3 ± 10.9 years, reported brushing their teeth more than twice a day, never having smoked, and eating vegetables 4 to 7 days a week. The average income was 2,807 ± 5,449 Brazilian reals (BRL). Self-perception of oral health was more often positive, being classified as good or very good by 68.67% of the sample. The mean number of missing teeth was 6.6 ± 8.9.

Table 2 shows the association between the domains of physical activity, self-perception of oral health, and tooth loss. Higher scores for leisure-time physical activity was the only domain

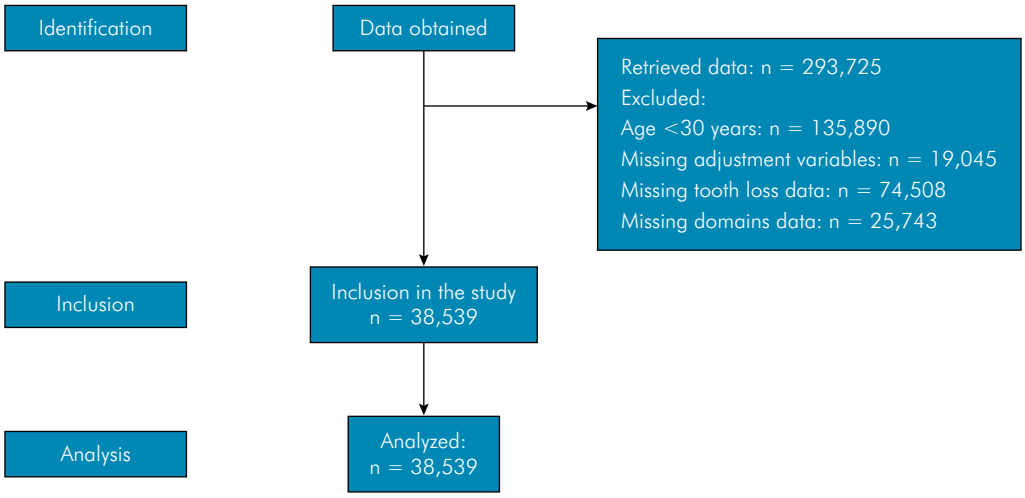

Figure. Flowchart of subjects in each phase of the study.

Table 1. Sociodemographic characteristics of the study sample (n = 38,539).

Characteristics	Mean ± SD or Percentage
Sex (Men, %)	56.37%
Age (years)	46.3±10.9
Race/Ethnicity:	
White	38.12%
Black	11.62%
Other	50.26%
Education	
College or higher	24.24%
Toothbrushing	
≥ 2 times/day	95.38%
Smoking	
Never	86.76%
Former	0.72%
Current	12.52%
Vegetables	
4–7 d/wk	62.89%
Total income (BRL)	2,807 ± 5,449
Physical activity	
Leisure	42.06%
Work	48.91%
Transportation	51.68%
Household	15.29%
Oral health self-perception	
(Very) Poor /Fair	31.33%
Good/Very Good	68.67%
Tooth loss (mean number)	6.6 ± 8.9
No lost teeth	25.71%
All teeth lost	5.40%

significantly associated with better self-perception of oral health (adjusted OR = 1.32) and lower tooth loss (adjusted MR = 0.88). On the other hand, higher scores for work and transport domains in the adjusted model were significantly associated with worse self-perception and increased tooth loss, while a higher score for the household domain was significantly associated only with a worse self-perception. A higher overall physical activity, independently of domain, showed a statistically significant association with higher tooth loss and worse self-perception in the adjusted model.

Higher leisure activity was significantly associated with better self-perception of oral health and lower tooth loss, independently of frequency, intensity, and meeting the WHO recommendation (Table 3). For weekly time, similar associations were observed, except for the lowest category of leisure time (1– < 75 min/wk) and tooth loss.

Vigorous work–related physical activity was significantly associated with worse self-perception of oral health and higher tooth loss independently of frequency and weekly time, except for the lowest category of weekly time. Higher walking or cycling transport was consistently significantly associated with worse self-perception and increased tooth loss, although the lower confidence limit for 1–2 d/wk in tooth loss analysis was very close to 1. Higher household activities was significantly

Table 2. Association between the domains of physical activity, self-perception of oral health and tooth loss.

Domain	Crude Analysis				Adjusted Model*			
	Self-perception		Tooth Loss		Self-perception		Tooth Loss	
	OR (CI)	p–value	MR (CI)	p–value	OR (CI)	p–value	MR (CI)	p–value
Leisure	1.73 (1.66–1.81)	**< 0.001**	0.64 (0.62–0.65)	**< 0.001**	1.32 (1.26–1.38)	**< 0.001**	0.88 (0.86–0.90)	**< 0.001**
Work	0.65 (0.63–0.68)	**< 0.001**	1.19 (1.16–1.22)	**< 0.001**	0.78 (0.75–0.82)	**< 0.001**	1.18 (1.15–1.21)	**< 0.001**
Transportation	0.73 (0.70–0.76)	**< 0.001**	1.23 (1.20–1.27)	**< 0.001**	0.82 (0.78–0.85)	**< 0.001**	1.10 (1.07–1.12)	**< 0.001**
Household	0.83 (0.78–0.88)	**< 0.001**	0.93 (0.89–0.97)	**< 0.001**	0.78 (0.73–0.83)	**< 0.001**	1.03 (0.99–1.06)	0.125
Physical activity (Total)	0.88 (0.83–0.94)	**< 0.001**	0.94 (0.90–0.98)	**0.004**	0.85 (0.80–0.91)	**< 0.001**	1.07 (1.03–1.10)	**< 0.001**

OR: Odds ratio; MR: Mean ratio; *Adjusted for sex, age, skin color, education, tooth brushing frequency, smoking, vegetable consumption, and income; Bold numbers indicate statistically significant associations.

Table 3. Association between weekly frequency, time, intensity, and recommended World Health Organization (WHO) time of leisure activities and oral health self-perception and tooth loss.

Leisure	Self-perception		Tooth Loss	
	OR	p–value	MR	p–value
Frequency				
0	REF.		REF.	
1–2 d/wk	1.32 (1.24–1.42)	**< 0.001**	0.87 (0.85–0.91)	**< 0.001**
3–5 d/wk	1.35 (1.27–1.44)	**< 0.001**	0.88 (0.85–0.91)	**< 0.001**
6–7 d/wk	1.32 (1.19–1.47)	**< 0.001**	0.86 (0.81–0.91)	**< 0.001**
Weekly time				
0	REF.		REF.	
1–<75 min/wk	1.21 (1.09–1.34)	**< 0.001**	0.97 (0.92–1.02)	**0.269**
75–150 min/wk	1.27 (1.17–1.38)	**< 0.001**	0.89 (0.86–0.93)	**< 0.001**
>.150–300 min/wk	1.33 (1.24–1.42)	**< 0.001**	0.86 (0.84–0.89)	**< 0.001**
> 300 min/wk	1.53 (1.40–1.67)	**< 0.001**	0.83 (0.79–0.86)	**< 0.001**
Intensity				
None	REF.		REF.	
Light	1.22 (1.14–1.30)	**< 0.001**	0.93 (0.90–0.97)	**< 0.001**
Moderate	1.16 (1.03–1.32)	**0.019**	0.87 (0.82–0.93)	**< 0.001**
Vigorous	1.51 (1.41–1.61)	**< 0.001**	0.82 (0.79–0.85)	**< 0.001**
WHO target				
None	REF.		REF.	
Below	1.22 (1.15–1.30)	**< 0.001**	0.94 (0.91–0.97)	**< 0.001**
Within	1.25 (1.13–1.39)	**< 0.001**	0.87 (0.83–0.92)	**< 0.001**
Above	1.62 (1.50–1.75)	**< 0.001**	0.77 (0.74–0.80)	**< 0.001**

WHO recommendation: 75 to 150 minutes of vigorous physical activity, or an equivalent combination of vigorous and moderate activity throughout the week; or 150 to 300 minutes of moderate–intensity aerobic physical activity weekly. Abbreviations: OR: odds ratio; MR: mean ratio; REF: reference. Adjusted for sex, age, skin color, education, tooth brushing frequency, smoking, vegetable consumption, and income. Bold numbers indicate statistically significant associations.

associated with worse self-perception independently of frequency and weekly time, except for the lowest category of weekly time. On the other hand, there were no statistically significant associations with tooth loss. When physical activity was defined as the sum of the four domains, all associations disappeared, except for the highest category of weekly time (> 300 min/wk), which was significantly associated with worse self-perception and higher tooth loss (Table 4).

In order to assess the influence of income and potential periodontitis–related cases, based on age and tooth loss, on the findings for total physical activity, stratified analyses were conducted (Table 5). For income and tooth loss, results were comparable between the two strata, with only the highest category of weekly time being significantly associated with increased tooth loss. However, in the lowest income group, meeting the WHO recommendation for weekly time of physical activity (75–150 and 150–300 min/wk) was also significantly associated with worse self-perception. The youngest age group (< 55 years) showed a significant association with both worse self-perception and higher tooth loss only in the highest weekly time category. When edentulous individuals were excluded, the pattern remained–only the highest physical activity time was significantly associated with higher tooth loss and worse self-perception. On the other hand, when individuals with no tooth loss were excluded, a significant association was observed for lower tooth loss in the 75–150 min/wk group (although the upper confidence limit was close to 1).

Discussion

It is biologically plausible that the physical activity domains that are related to a lower income, such as work, housework, and transport activities, have unfavorable effects on health status. This topic is relevant since some physical activity assessment instruments (not used in this specific study), such as the long form of the International Physical Activity Questionnaire (IPAQ), which considers the four domains of physical activity, have been used to monitor physical inactivity and activity in population studies.[24,25] Importantly, those questionnaires have been extrapolated to verify the association of physical activity with oral[26] and other systemic diseases.[27,28] This study demonstrated that when oral health is analyzed within the context of different domains of physical activity, only higher levels of leisure activities were statistically associated with better oral health self-perception and lower tooth loss–the final endpoint of periodontitis. On the other hand, those associations were inversed when work and transportation domains or total physical activity were analyzed, even after adjustment for confounders.

The WHO recommends, for adults between 18 and 64 years old, 75 to 150 minutes of vigorous physical activity, or an equivalent combination of vigorous and moderate activity throughout the week, or 150 to 300 minutes of moderate–intensity aerobic physical activity weekly.[1] When those references were applied to total physical activity, there was no statistically significant association with tooth loss or self-perception (although above–target weekly time was significantly associated with higher tooth loss and worse self-perception). Sensitivity analysis suggested that this pattern remains even when analyzing subgroups of potential periodontitis–related cases, such as older age and when excluding edentulous individuals. It is also relevant to highlight that we have included in this study only individuals aged 30 and over, since this age group is especially affected by periodontitis.[11,12] A cutoff of 55 years was selected for sensitivity analysis since periodontitis is the leading cause of tooth loss after this age.[13,14] Accordingly, exclusion of individuals with no tooth loss may theoretically reflect a sample of individuals with increased severity of periodontitis, while exclusion of edentulous patients could reflect a sample of individuals with current periodontitis. However, we cannot rule out caries and other causes of tooth loos when interpreting the results.

Our results show that the target for recommended physical activity reached in work and transport domains are associated with increased tooth loss and worse self-perception. Physical activity at work or for transport may indicate a lack of financial

Table 4. Association between weekly frequency and time of activities in the work, transportation, housework domains and total physical activity and oral helath self-perception and tooth loss.

Domain	Self-perception		Tooth Loss	
	OR	p–value	MR	p–value
Work				
Frequency				
0	REF.		REF.	
1–2 d/wk	0.78 (0.72–0.85)	**< 0.001**	1.16 (1.11–1.21)	**< 0.001**
3–5 d/wk	0.80 (0.76–0.84)	**< 0.001**	1.17 (1.14–1.21)	**< 0.001**
6–7 d/wk	0.76 (0.71–0.81)	**< 0.001**	1.20 (1.16–1.24)	**< 0.001**
Weekly time				
0	REF.		REF.	
1–< 75 min/wk	0.89 (0.77–1.02)	0.085	1.06 (0.98–1.14)	0.134
75–150 min/wk	0.84 (0.75–0.95)	**0.007**	1.10 (1.03–1.18)	**0.003**
> 150–300 min/wk	0.83 (0.75–0.92)	**< 0.001**	1.14 (1.08–1.20)	**< 0.001**
> 300min/wk	0.77 (0.73–0.80)	**< 0.001**	1.20 (1.17–1.24)	**< 0.001**
Transportation				
Frequency				
0	REF.		REF.	
1–2 d/wk	0.83 (0.77–0.90)	**< 0.001**	1.06 (1.01–1.10)	**0.009**
3–5 d/wk	0.82 (0.77–0.86)	**< 0.001**	1.10 (1.06–1.13)	**< 0.001**
6–7 d/wk	0.81 (0.76–0.86)	**< 0.001**	1.12 (1.08–1.16)	**< 0.001**
Weekly time				
0	REF.		REF.	
1–<75 min/wk	0.88 (0.82–0.93)	**< 0.001**	1.09 (1.05–1.12)	**< 0.001**
75–150 min/wk	0.83 (0.77–0.88)	**< 0.001**	1.08 (1.04–1.12)	**< 0.001**
> 150–300 min/wk	0.77 (0.70–0.83)	**< 0.001**	1.13 (1.08–1.18)	**< 0.001**
> 300min/wk	0.74 (0.66–0.82)	**< 0.001**	1.20 (1.13–1.28)	**< 0.001**
Household				
Frequency				
0	REF.		REF.	
1–2 d/wk	0.79 (0.74–0.84)	**< 0.001**	1.02 (0.98–1.06)	0.331
3–5 d/wk	0.73 (0.62–0.86)	**< 0.001**	1.07 (0.98–1.17)	0.120
6–7 d/wk	0.74 (0.58–0.95)	**0.018**	1.05 (0.92–1.21)	0.452
Weekly time				
0	REF.		REF.	
1–< 75 min/wk	0.95 (0.82–1.11)	0.536	1.01 (0.93–1.09)	0.791
75–150 min/wk	0.76 (0.66–0.86)	**< 0.001**	1.02 (0.95–1.09)	0.636
> 150–300 min/wk	0.79 (0.72–0.88)	**< 0.001**	1.02 (0.96–1.07)	0.588
> 300min/wk	0.71 (0.64–0.78)	**< 0.001**	1.05 (1.0–1.11)	0.072
Total Physical Activity				

Continue

Continuation				
Weekly time				
0	REF.		REF.	
1–< 75 min/wk	0.92 (0.83–1.03)	0.155	1.01 (0.96–1.07)	0.664
75–150 min/wk	0.94 (0.86–1.04)	0.253	0.98 (0.93–1.03)	0.348
> 150–300 min/wk	0.95 (0.87–1.03)	0.212	1.00 (0.95–1.04)	0.869
>300min/wk	0.81 (0.76–0.87)	**< 0.001**	1.10 (1.06–1.14)	**< 0.001**

OR: odds ratio; MR: mean ratio; REF: reference. Adjusted for sex, age, skin color, education, tooth brushing frequency, smoking, vegetable consumption, and income. Bold numbers indicate statistically significant associations.

Table 5. Sensitivity analyses for the association between weekly time of total physical activity and oral health self-perception and tooth loss, stratified by income, age, and number of lost teeth.

Total Physical Activity	Self-perception		Tooth Loss		Self-perception		Tooth Loss	
	OR	p–value	MR	p–value	OR	p–value	MR	p–value
Income	≤1,500BRL* (n = 19,769)				>1,500BRL* (n=18,770)			
Weekly time								
0	REF.		REF.		REF.		REF.	
1–<75 min/wk	0.89 (0.77–1.03)	0.134	0.99 (0.92–1.07)	0.828	0.98 (0.83–1.15)	0.792	1.02 (0.93–1.11)	0.694
75–150 min/wk	0.83 (0.73–0.95)	**0.006**	0.97 (0.90–1.04)	0.357	1.13 (0.97–1.31)	0.105	0.96 (0.90–1.04)	0.350
> 150–300 min/wk	0.87 (0.77–0.98)	**0.018**	1.00 (0.94–1.06)	0.116	1.08 (0.95–1.22)	0.237	0.97 (0.91–1.04)	0.378
>300min/wk	0.77 (0.70–0.84)	**< 0.01**	1.09 (1.04–1.15)	**<0.01**	0.90 (0.82–0.99)	**0.034**	1.09 (1.03–1.14)	**0.002**
Age	< 55 (n = 29,353)				≥55 (n = 9,186)			
Weekly time								
0	REF.		REF.		REF.		REF.	
1–<75 min/wk	0.89 (0.78–1.02)	0.089	1.00 (0.93–1.07)	0.950	0.99 (0.82–1.21)	0.958	1.06 (0.97–1.15)	0.202
75–150 min/wk	0.92 (0.82–1.04)	0.186	0.96 (0.90–1.03)	0.269	1.01 (0.84–1.21)	0.952	0.99 (0.91–1.07)	0.736
> 150–300 min/wk	0.90 (0.82–1.00)	0.051	1.00 (0.95–1.06)	0.978	1.08 (0.92–1.26)	0.364	0.97 (0.91–1.04)	0.440
>300min/wk	0.78 (0.72–0.84)	**<0.01**	1.10 (1.06–1.15)	**< 0.01**	0.96 (0.85–1.09)	0.551	1.04 (0.98–1.09)	0.213
Tooth Loss	> 0 (n = 28,631)				< 32 (n = 36,457)			
Weekly time								
0	REF.		REF.		REF.		REF.	
1–<75 min/wk	0.97 (0.86–1.09)	0.614	0.99 (0.94–1.03)	0.601	0.91 (0.81–1.02)	0.112	1.04 (0.98–1.11)	0.152
75–150 min/wk	1.00 (0.90–1.12)	0.985	0.94 (0.91–0.98)	**0.006**	0.96 (0.86–1.06)	0.398	1.00 (0.95–1.06)	0.896
> 150–300 min/wk	0.99 (0.90–1.09)	0.910	0.98 (0.94–1.01)	0.246	0.94 (0.86–1.03)	0.171	1.02 (0.98–1.07)	0.367
> 300min/wk	0.88 (0.82–0.95)	**< 0.01**	1.02 (0.99–1.05)	0.190	0.81 (0.75–0.86)	**< 0.01**	1.13 (1.09–1.17)	**< 0.01**

OR: odds ratio; MR: mean ratio; REF: reference. *Median monthly income. Adjusted for sex, age, skin color, education, tooth brushing frequency, smoking, vegetable consumption, and income. Bold numbers indicate statistically significant associations.

or social condition related to peripherality to services of interest, combined with a financial condition that makes it impossible to use less exhaustive means of transport. In the domain of household activities, significant associations were observed for self-perception, but not for tooth loss. One possible explanation is that people with higher incomes subcontract the housework. The performance of these moderate or vigorous tasks would naturally be delegated by individuals with higher purchasing power, education, income, among others, to people with lower purchasing power who perform these less profitable and qualified professions.

It is also noteworthy that above–target weekly total physical activity was relatively consistently associated with worse oral health status, as shown by increased tooth loss and worse self-perception. Previous published data support a 'U'–shaped relationship between physical activity and oral health status, since poor oral health has been frequently reported in elite athletes.[29,30] However, our results show that even above–target leisure time is associated with positive outcomes, suggesting that the results observed for total physical activity are strongly influenced by the potential negative impact of household, work, and transportation domains.

In this study, the statistical models were adjusted for income, which means that the associations observed were independent of the economic status. Furthermore, sensitivity analysis showed that the pattern for the association between tooth loss and total weekly physical activity remain the when stratified for median income. On the other hand, there was a significant association between WHO targets and worse self-perception only in the lowest income group. In fact, low income has been described as a risk factor for oral health, being associated with lower toothbrushing frequency and higher consumption of sugary drinks, higher rates of caries and periodontal diseases, higher rates of tooth loss, and worse self-perception of oral health.[31–33] In addition, a pro–inflammatory profile was also associated with worse socioeconomic indices and may reflect poorer oral health. The inflammatory markers C–reactive protein and interleukin–6, which are associated with periodontitis,[9] were found at significantly higher levels in individuals with worse socioeconomic indices.[34]

Therefore, the income factor only partially explains the association between the physical activities related to lower social classes (work, transport and household activities) and worse oral health conditions. Interestingly, it was shown in an adult Brazilian population that low income at birth, regardless of income at the time of examination, had an important effect on dental caries–related tooth loss, which may help explain our results.[35] In addition, another possible explanation is stress, which causes changes in the individual's immune response[36] and has been associated with chronic diseases such as periodontitis.[37]

In the present study, tooth loss was used as an indicator of oral health, being considered the final outcome of highly prevalent diseases, especially periodontitis in older adults, and reflecting the chronic burden of oral diseases throughout life.[38–40] In a previous study by our group, a statistically significant association was found between exercise (leisure-time activity) and less tooth loss, especially for activities performed at least 75 minutes per week.[40] Accordingly, a recent study in the US population observed that individuals with higher leisure-time physical activity had lower periodontal disease prevalence.[41] On the other hand, they showed that total physical activity was also associated with lower periodontal disease prevalence, while we found that the protective effect of leisure-time physical activity disappeared when the other WHO physical activity domains were included. Accordingly, a very recent study has shown that leisure time and occupational physical activity have divergent associations with periodontitis in a US population.[42]

The main strength of this study is that, to our knowledge, it is the first to explore the association of oral health status with all four domains of physical activity, providing insights for both public health policies and clinical practice. Also, beyond tooth loss, we evaluated self-perception of oral health as a patient-centered measure, which should be encouraged in dental research. Limitations include the cross-sectional design, which makes it impossible

to verify cause-and-effect relationships and the direction of the association. In fact, a systematic review suggests that poor oral health may negatively impact physical fitness and performance.[43] Also, all outcomes were self-reported, which may influence the observed associations. However, the professional anamnesis also depends on the participant's memory, which has clinical relevance. Additionally, this study did not focus on periodontal parameters, and tooth loss may have different causes. Sensitivity analysis was a statistical approach to try to overcome this limitation. Future longitudinal clinical studies are suggested to establish the cause-and-effect relationship between the different domains of physical activity and oral health status.

Conclusions

When considering physical activity as the combination of four domains, as defined by the WHO, the association between oral health status and physical activity is mitigated. Among the domains, only leisure-time physical activity was associated with better oral health conditions.

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