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Physical activity is associated with less periodontitis and calculus in adults: A cross-sectional observational study

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Abstract

Aims: Physical activity (PA) may reduce periodontitis, but most studies have used non-validated methods to quantify PA and were conducted with Asian samples. This study assessed the association between PA, periodontitis and calculus in adults.

Materials and methods: 285 individuals participating in a population-based cohort study were analyzed. Probing depth (PPD) and clinical attachment loss (CAL) were recorded. PA was assessed by the International Physical Activity Questionnaire (IPAQ) determining physically inactive and active individuals. Multiple logistic regression was applied to estimate odds ratios (OR) and 95% confidence intervals (95%CI).

Results: After adjusting for calculus, smoking and diabetes physically active individuals had a significantly lower chance of severe periodontitis (OR=0.51; 95%CI 0.28-0.93). Reduction in odds was also observed for PPD ≥5mm in ≥1 tooth (OR=0.41; 95%CI: 0.21-0.79). When CAL alone was analyzed, no significant associations were found. Physically active individuals had 8.2% (95%CI -14.5 – -1.9; *p*=0.01) less sites with calculus than inactive individuals.

Conclusions: Physically active individuals had less periodontitis and calculus than inactive individuals.

Keywords: Physical activity, periodontal disease, periodontitis, risk factors, epidemiology

Introduction

Physical activity (PA) is defined as any body movement produced by skeletal muscles that results in energy expenditure (Caspersen *et al*., 1985; WHO, 2018). Benefits of regular PA include energy balance, increase of lean body mass, favorable changes in plasma lipids and lipoproteins, and enhancement of insulin sensitivity (Miles, 2007). Additionally, lack of PA lead to visceral fat accumulation, followed by infiltration of pro-inflammatory immune cells, increased release of adipokines and development of a state of low-grade systemic inflammation (Ouchi *et al*., 2011). Therefore, a prolonged inflammatory state resulting from lack of PA has health effects which are detrimental and associated with various chronic diseases and health conditions (Pradhan *et al*., 2001; Pedersen *et al*., 2006). Added to its biological benefits to the human body, PA is also related to healthier lifestyles and healthy aging (Daskalopoulou *et al*., 2017) by lower occurrence of chronic diseases.

There is irrefutable evidence of the benefits of routine PA in the prevention of a number of chronic diseases (Reiner *et al*., 2013; Warburton *et al*., 2017). Regular PA is considered an important modifiable risk factor which has protective effects on heart disease, diabetes, and some cancers (Koene *et al*., 2016). In this regard, some studies have also focused on the benefits of PA in the occurrence of periodontitis (Al-Zahrani *et*

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al., 2005a; Al-Zahrani *et al*., 2005b; Bawadi *et al*., 2011; Merchant *et al*., 2003; Park *et al*., 2015; Sanders *et al*., 2009; Shimazaki *et al*., 2010; Wakai *et al*., 1999). A recent systematic review found that PA was associated with a significant reduction on the prevalence of periodontitis in observational studies (Ferreira *et al*., 2019).

However, the great majority of previous observational studies assessed PA with alternative non-validated methods and applied partial periodontal recording protocols. These methodological drawbacks input important bias to the findings, mainly those related to incorrect diagnosis of periodontitis and misclassification of PA levels. Moreover, there is a very limited number of studies (Sanders *et al*., 2009) evaluating the beneficial effects of PA on periodontal diseases in populations other than those from Asia (Park *et al*., 2015; Bawadi *et al*., 2011; Shimazaki *et al*., 2010; Wakai *et al*., 1999) or United States as demonstrated in a recent systematic review (Ferreira *et al*., 2019), limiting the extrapolation of the associations. Moreover, the association between PA and oral hygiene standards has not been assessed.

Therefore, this study aimed to investigate the association between PA, periodontitis and dental calculus, controlling for important confounders, in a sample of adults applying an internationally validated questionnaire of PA.

Materials and methods

Study design and sample

This is a cross-sectional observational study nested to a population-based prospective cohort study. In 2011 during the baseline data collection, the Caries-Perio Collaboration Group from the Federal University of Rio Grande do Sul designed a survey by drawing a representative sample of adults living in Porto Alegre, Brazil. Detailed information regarding the sampling strategy at baseline was previously published (Wagner *et al*., 2016; Costa *et al*., 2014; Rios *et al*., 2014). In summary, a multistage probability sampling strategy was applied. The city was divided in 86 neighborhoods comprising the primary sampling units that were stratified in low and high income. The second stage consisted on a random selection of sectors, proportional to the total number of sectors in each PSU. The third stage consisted of selecting households consecutively according to the sector starting point until the sector sample size was reached. Gingival recession (GR) and other oral outcomes were assessed in 1023 individuals at that moment.

After an average time of four years, a follow-up examination took place with 414 (40.5%) individuals re-examined (Figure 1), recording periodontal probing depth (PPD) and GR, which allowed the diagnosis of periodontitis at this timepoint. This study was conducted with data collected in this follow-up examination of the cohort, which was conducted between January 2016 and March 2017. For the purposes of the present analysis, only individuals 38 to 64 years of age with more than 4 teeth were included.

Data collection, which included interviews and clinical examinations, was conducted into the households. Examinations were conducted using a medical headlight, a portable compressor and a bendable chair.

Ethical aspects

The study protocol was reviewed and obtained ethical approval from the Research Ethics Committee, Federal University of Rio Grande do Sul, Porto Alegre, Brazil. Prior to the interview, all patients read and signed a consent form.

Interview

Participants were interviewed using a structured questionnaire containing questions regarding important exposures evaluated in this study. Specifically, individuals were answered about their socioeconomic status, oral hygiene habits, previous history of dental assistance, and medical history. Three calibrated interviewers applied the questionnaire.

International Physical Activity Questionnaire (IPAQ)

IPAQ is a questionnaire approaching individuals' PA undertaken among a set of domains (leisure time, domestic activities, work-related and transport-related activities) (IPAQ, 2019; Hallal *et al*., 2004). It has been employed for national and regional surveillance, as well as for etiological research in many areas of medicine. Cross-cultural validation for Brazilian Portuguese was previously evaluated.

Energy expenditure rate is computed by weighting each type of activity by its energy requirements defined in METS (multiples of the resting metabolic rate) to yield a score in MET–minutes. An average MET score is derived for each type of activity (Ainsworth *et al*., 2000) as follows: Walking = 3.3 METs, Moderate PA = 4.0 METs and Vigorous PA = 8.0 METs. A continuous score is expressed in MET-min per week: MET level * minutes of activity * events per week. Using this total amount of MET-minutes per week, three levels of PA are proposed as defined bellow.

HIGH level of PA is defined when either of the following two criteria is met by an individual:

- vigorous-intensity activity on at least 3 days and accumulating at least 1500 MET-minutes/week
- 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 3000 MET-minutes/week.

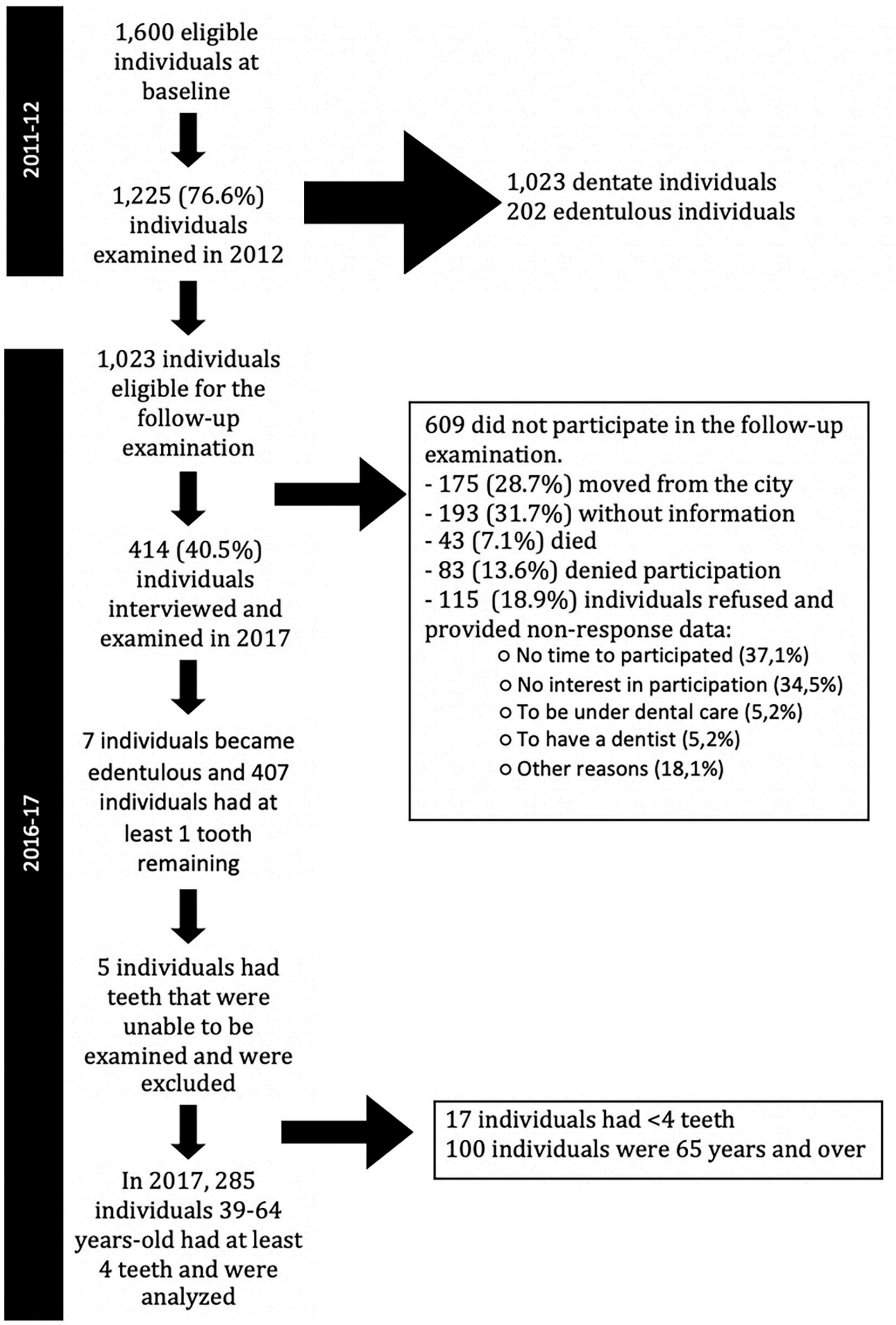

Figure 1. Flowchart of the study sample.

MODERATE level of PA is defined when either of the following three criteria is met by an individual:

- 3 or more days of vigorous activity of at least 20 minutes per day
- 5 or more days of moderate-intensity activity or walking of at least 30 minutes per day
- 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.

LOW level of PA is defined for an individual reporting no activity, or some activity is reported but not enough to meet the two categories “HIGH” or “MODERATE”.

Full access to the questionnaire and scoring protocol is available at the official web page of IPAQ. For analytical purposes, IPAQ categorization was dichotomized into physically inactive individuals (LOW category) and physically active individuals (aggregation of MODERATE and HIGH categories). This dichotomization is also based on the IPAQ research group statement that 30 minutes of moderate-intensity activity is low and broadly equivalent to the background or basal levels of activity adults would accumulate in a day. Thus, the physically active group in this study represents all PA levels over this basal level. Thus, it is possible to discriminate those inactive from those performing at least some amount of PA higher than the minimum recommended for a healthy lifestyle (Haskell *et al.*, 2007).

Periodontal examination

All permanent teeth were examined by four calibrated periodontists using a manual periodontal probe. A periodontal recording protocol of four sites per tooth (disto-buccal, mid-buccal, mesio-buccal, and disto-lingual/palatal) was used. The presence of supragingival calculus, gingival recession (GR), and periodontal probing depth (PPD) were recorded. Clinical attachment loss (CAL) was obtained by the sum of GR and PPD.

Reproducibility

Before the start of the study, intra and inter-examiner reproducibility for GR and PPD was assessed with duplicate measures conducted in a total of 16 patients (1,231 sites). This first assessment of the reproducibility was made at the University, however duplicate examinations were conducted using the same conditions that were faced in the field work of the study using a bendable chair and natural light. During data collection, 42 participants (2896 sites) allowed to perform the duplicate measurements. Weighted Kappa values for the four examiners range between 0.87 and 0.92.

Outcome variables

Periodontal status of the individuals was defined using three criteria. Individuals were dichotomized into those having or not severe periodontitis according to the AAP-CDC criteria (Eke *et al.*, 2012). Moreover, two additional definitions were used considering CAL and PPD separately: individuals were considered to have periodontal disease if they presented at least one tooth with (1) CAL ≥5mm and (2) PPD ≥5mm in one proximal site. Calculus was the clinical variable used to describe the oral hygiene standards of the individuals and was analyzed as a continuous variable.

Exposure variables

Physical activity (IPAQ) was the main exposure variable of the present study. Calculus was considered a secondary outcome. 2 shows two causal diagrams constructed based on previous literature to hypothetically describe the pathways linking PA, periodontitis and calculus. These direct acyclic graphs (DAG) were used to define the variables to be included in our analytical models.

The first pathway links PA to periodontitis by systemic inflammation, which is reduced by PA (Figure 2a). Age, sex, education and socioeconomic status are related to both PA and periodontitis. Obesity may influence and may be influenced by PA and is associated to systemic inflammation due to the pro-inflammatory effects of the adipose tissue. Diabetes and cardiovascular disease also have a bidirectional association with PA and lead to systemic inflammation. Smoking may be linked to PA since it may reduce the cardiorespiratory function, and is also associated with higher systemic inflammation and occurrence of periodontitis. Dental visits are related to periodontitis due to their preventive benefits. Tooth loss may lead to underestimation of periodontitis, since the most affected teeth may be lost and survival teeth be maintained. Additionally, two latent variables not assessed in this study (diet and other comorbidities) are related to PA and directly associated with changes in systemic inflammation. A second path linking PA and periodontitis has calculus as a mediator, for which associations are depicted in Figure 2b. The theoretical explanation for the association between PA and calculus is that these two variables describe behaviors, and physically inactive individuals may have worse oral hygiene as a result of lifestyle. Age, sex, education and socioeconomic status are related to both PA and calculus. Diet may influence PA and other behaviors related to lifestyle as a whole. Obesity may influence and may be influenced by PA and is also related to lifestyle. As mentioned before, smoking is a hazardous behavior and may negatively influence PA, and is also associated with higher accumulation of calculus. Going to the dentist is a beneficial behavior related to healthier lifestyle and directly may prevent calculus formation.

Age was categorized into two categories (35-49, 50-59). Educational level was defined according to years of education, using cut-offs of the Brazilian educational system, into low (≤8 years), middle (9-11 years) and high (≥12 years). Socioeconomic status was categorized using cut-off points adapted from a Brazilian classification system considering the amount of consumer goods and the educational level of the head of the family as follows. The use of interproximal cleaning devices was the variable used to describe the oral hygiene habits of the individuals and was categorized into never and yes. Also, individuals were dichotomized into those presenting <25% and ≥25% of sites with supragingival calculus.

Tobacco smoking was determined by calculating packyears (total number of packs of cigarettes consumed in a lifetime). Individuals were then categorized into never-smokers (0 packyears), light-moderate smokers (<20 packyears) and heavy smokers (≥20 packyears).

The height of the participants was obtained by self-reporting in centimeters, whereas the weight was assessed in kilograms using a mechanical scale. Body mass index (BMI) was categorized into: normal weight (BMI 18.5 – 24.9 kg/m^2), overweight (BMI 25 – 29.9 kg/m^2), and obese (BMI ≥ 30 kg/m^2).

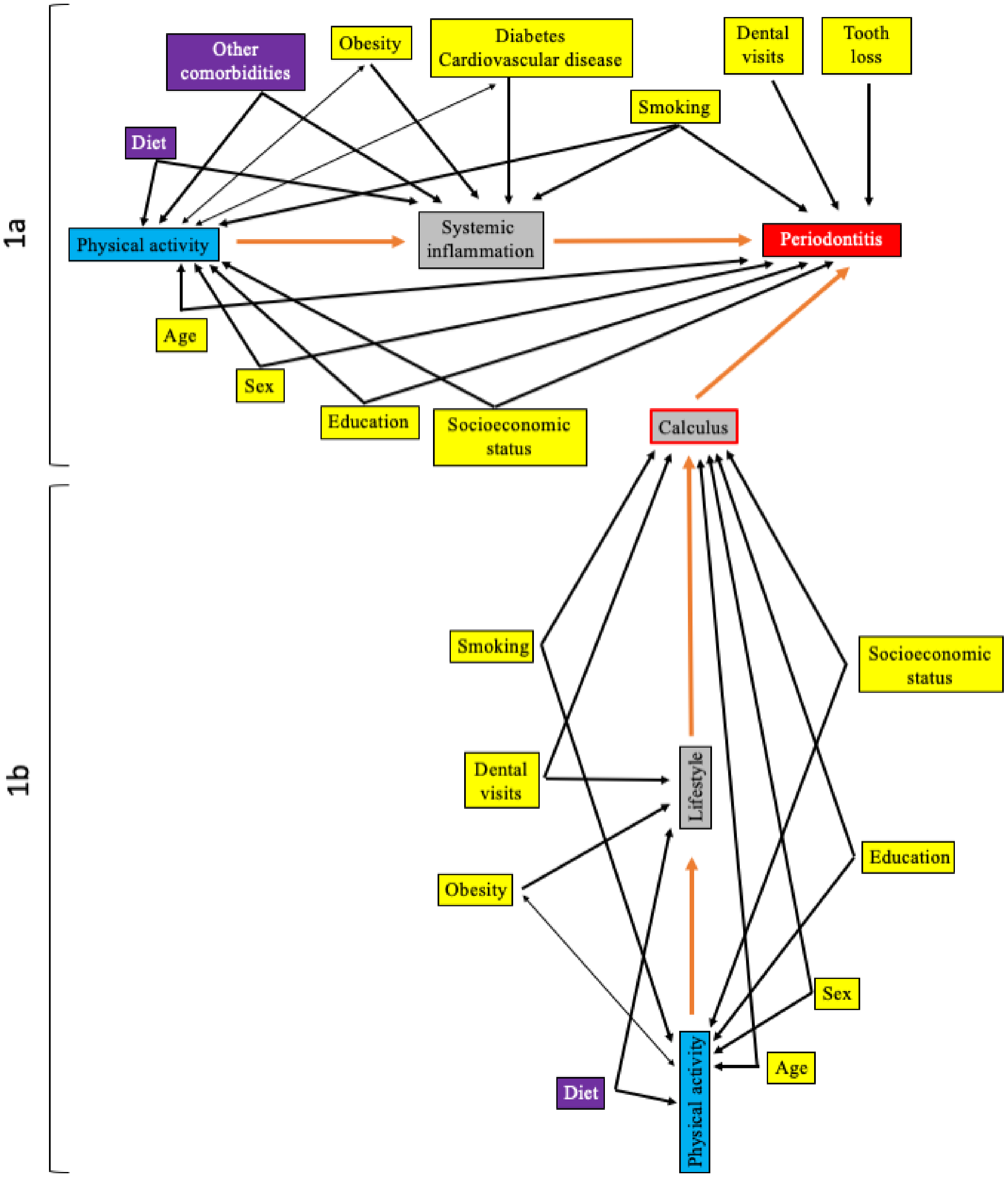

Figure 2. Direct acyclic diagrams illustrating the pathways linking physical activity to periodontitis by systemic inflammation (a) and lifestyle (b). The main exposure (physical activity) is indicated by blue boxes and the main outcome (periodontitis) by a red box. Grey boxes indicate the mediators. Calculus is both an outcome and a mediator, thus it is indicated by a grey box with a red outline. Yellow boxes indicate the measured exposures, whereas purple boxes indicate latent variables.

Statistical analyses

Fisher's exact or chi-square tests were applied to compare the distribution of individuals with or without periodontal disease according to each exposure variable. Multiple logistic regression models were fitted to estimate odds ratios (OR) and 95% confidence intervals (95%CI) for the associations between IPAQ and periodontal disease outcomes.

Model building was based on the two DAGs constructed based on theoretical causal relations between the main exposure (PA) and the outcomes (periodontitis and calculus). Model fit was guided by the purposeful approach

(Hosmer *et al.*, 2000). Modeling started by fitting simple models for each exposure variable, and all those variables presenting p-values <0.25 were entered in a first full multiple model. Removal and inclusion of each variable was performed iteratively to assess the effect of each variable in the model. After the final multiple model was defined, interactions between IPAQ and other variables (age, gender, BMI, cardiovascular disease, diabetes) were tested, but none was statistically significant. Three different models were fitted applying the same criteria described above for inclusion/exclusion of the exposures, also including age and number of missing teeth due to their relevant whole in the theoretical pathway linking PA and the outcomes. Thereafter, IPAQ was included in each final model which was reported.

The association between IPAQ and calculus was fitted using multiple linear regression. Model fitting followed the same approach as described above. However, according to Figure 2b and described above, variables eligible for modelling only included age, sex, education, socioeconomic status, obesity, dental visits and smoking.

Data analyses were performed using a statistical package (Stata 14 for Macintosh, STATA Corp., College Station, USA).

Sample power

Two sample power calculations were performed using G*Power software. First, the power of the sample of 285 individuals analyzed was calculated for a chi-square distribution, considering the observed prevalence of severe periodontitis in physically active (20.1%) and inactive (32.1%) individuals, resulting in 99% power to detect a true significant difference at 5% level. Second, the power of a multivariable logistic regression model with the same prevalence rates described above, significance level of 5%, sample size of 285, and R^2 equal to 0.3 for other confounders in the model was calculated and resulted in 94% power.

Results

The final sample of this study comprised 285 individuals (Figure 1). The percentage of individuals with severe periodontitis was significantly higher among those with higher percentage of calculus and with diabetes (Table 1). Variables associated with CAL ≥5mm were age, education, calculus and cardiovascular disease. Low socioeconomic status, education, calculus and diabetes were associated with higher percentages of individuals with PPD ≥5mm.

Figure 3a shows that 20.1% of the physically active individuals had severe periodontitis compared to 32.1% among those physically inactive (p=0.04). This finding was similar when PPD ≥5mm was evaluated (15% versus 28%), whereas no significant difference was observed for CAL ≥5mm (77% versus 81%).

In the univariable logistic regression models, socioeconomic status, education, calculus, smoking, and diabetes were associated with severe periodontitis (Table 2). Age, socioeconomic status, education, calculus and smoking were associated with CAL ≥5mm. Socioeconomic status, education, calculus, and diabetes were associated with PPD ≥5mm.

Simple and multiple logistic regression models of physical activity in relation to periodontal disease are shown in Tables 3 and 4. In the simple models, PA was associated with two periodontal outcomes (severe periodontitis and PPD ≥5mm). Noteworthy, during model building, PA always remained significantly associated with these two outcomes independently of the adjustments performed. When the outcome was presence of severe periodontitis, socioeconomic status, education, smoking, diabetes, cardiovascular disease and calculus were entered in the first full multiple model, whereas only smoking, diabetes and calculus remained in the final model together with age and number of missing teeth, in which the chance of having severe periodontitis was 50% significantly lower in active compared to inactive individuals (OR=0.50; 95%CI=0.20 – 0.98). The first full multiple model for PPD ≥5mm also included socioeconomic status, education, smoking, calculus, diabetes and cardiovascular disease. The final model ended with education, diabetes and calculus, together with age and number of missing teeth, and the reduction in the chance of PPD ≥5mm in ≥1 tooth was 55% for active than inactive individuals (OR=0.45; 95%CI=0.24 – 0.88). No significant association was found for the CAL ≥5mm in ≥1 tooth (p=0.39).

Physically active individuals had significantly lower percentage of sites with calculus compared to inactive individuals (Figure 3b). In the final multivariable linear regression model adjusted for age, smoking, interproximal cleaning, dental care, socioeconomic status and number of missing teeth, PA remained significantly associated with calculus. The beta coefficient was -7.3 (95%CI -13.4 – -1.2), indicating that physically active individuals had 7.3% less sites with calculus than inactive individuals.

Discussion

In this study, the presence of severe periodontitis, PPD ≥5mm in ≥1 tooth and calculus were lower in physically active than inactive individuals, independently of other co-factors. These findings suggest that PA may act as a possible protective factor for periodontal disease, potentially through an anti-inflammatory mechanism and healthier lifestyle.

These results corroborate previous findings from other observational studies. In Japan, poor physical fitness was associated with a higher Community Periodontal Index (CPI) in one study (Wakai *et al.*, 1999),

Table 1. Percentage of individuals with severe periodontitis, CAL ≥5mm in ≥1 tooth and PPD ≥5mm in ≥1 tooth according to traditional risk indicators.

	Whole sample	Severe periodontitis AAP-CDC		CAL ≥5mm in ≥1 tooth		PPD ≥5mm in ≥1 tooth	
Risk indicators	**n=285**	**n (%)**	**p-value**	**n (%)**	**p-value**	**n (%)**	**p-value**
Age (years)							
38-49 years	84	16 (19.1)		40 (47.6)		16 (19.0)	
50-64 years	201	51 (25.4)	0.29	132 (65.7)	0.01	39 (19.4)	1.00
Sex							
Females	101	27 (26.7)		74 (73.3)		21 (20.8)	
Males	184	40 (21.7)	0.38	98 (53.3)	0.001	34 (18.5)	0.64
Socioeconomic status							
Low	108	30 (27.8)		66 (61.1)		28 (25.9)	
Middle	101	26 (25.7)		66 (65.4)		21 (20.8)	
High	76	11 (14.5)	0.09	40 (52.6)	0.23	6 (7.9)	0.01
Education							
Low	132	37 (28.0)		88 (66.7)		33 (25.0)	
Middle	103	24 (23.3)		61 (59.2)		19 (18.4)	
High	50	6 (12.0)	0.08	23 (46.0)	0.04	3 (6.0)	0.01
Interproximal cleaning							
Yes	212	49 (23.1)		48 (65.8)		39 (18.4)	
No	73	18 (24.7)	0.87	124 (58.5)	0.33	16 (21.9)	0.50
Calculus							
<25%	87	8 (9.2)		36 (40.5)		9 (10.3)	
≥25%	198	59 (29.8)	<0.001	136 (69.4)	0.001	46 (23.2)	0.01
BMI							
Normal	77	16 (20.8)		48 (62.3)		12 (15.6)	
Overweight	115	28 (24.4)		70 (60.9)		23 (20.0)	
Obese	93	23 (24.8)	0.80	54 (58.1)	0.84	20 (21.5)	0.60
Smoking exposure							
Never smokers	128	22 (17.2)		67 (52.3)		18 (14.1)	
Moderate	90	25 (27.8)		57 (63.3)		20 (22.2)	
Heavy	67	20 (29.8)	0.07	48 (71.6)	0.03	17 (25.4)	0.11
Dental visits							
Irregular	113	26 (23.0)		61 (53.9)		23 (20.3)	
Regular	172	41 (23.8)	0.88	111 (64.5)	0.08	32 (18.6)	0.76
Cardiovascular disease							
Yes	130	37 (28.5)		85 (65.4)		30 (23.1)	
No	155	30 (19.4)	0.10	87 (56.1)	0.04	25 (16.1)	0.18
Diabetes							
Yes	40	15 (38.6)		28 (71.8)		13 (33.3)	
No	245	52 (21.2)	0.02	144 (58.8)	0.16	42 (17.1)	0.03

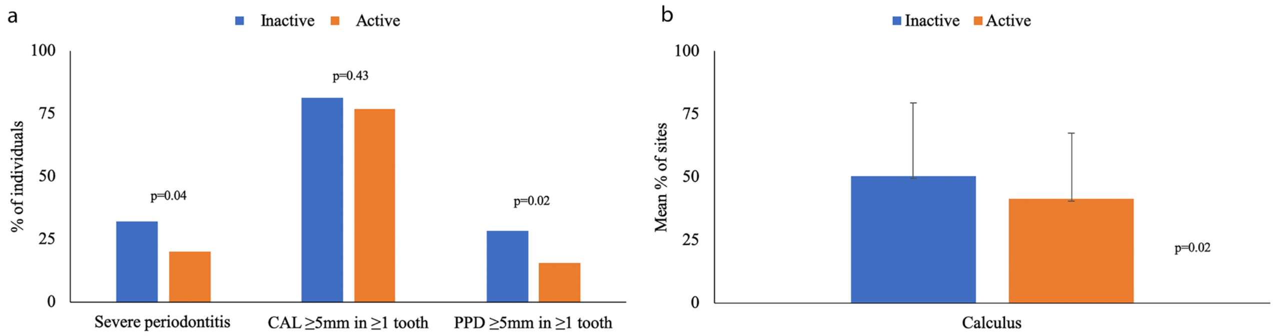

Figure 3. (a) Presence of periodontitis according to physical activity status. (b) Percentage of sites with calculus according to physical activity status.

and individuals with lower BMI and higher maximum oxygen uptake (VO2max) showed a significantly lower chance to present severe periodontitis in another study (Shimazaki *et al.*, 2010). A significant association has been demonstrated between increased level of PA and lower periodontitis prevalence using the NHANES data (Al-Zahrani *et al.*, 2005a). In another study using data from NHANES III (Al-Zahrani *et al.*, 2005b) it was shown that individuals who maintained normal weight, had a high-quality diet and had engaged in the recommended level of exercise were 40% less likely to have periodontitis when compared to individuals who maintained none of these health-enhancing behaviors. In a cohort study, Merchant *et al.* assessed the association of self-reported PA, walking and periodontitis, and found an inverse linear association between sustained physical activity and periodontitis (Merchant *et al.*, 2003). In another longitudinal study of 6 years of follow-up, the adherence to multiple healthy lifestyle factors including PA significantly lowers the risk of incidence or progression of periodontitis and tooth loss in older adults (Iwasaki *et al.*, 2018).

One of the benefits of exercise on general health is an anti-inflammatory effect resulting from physical activities. Reviews on the beneficial effects of exercise on inflammation (Petersen *et al.*, 2005; Flynn *et al.*, 2006; Mathur *et al.*, 2008) have indicated various possible mechanisms, including the reduction of visceral fat mass and increased production/release of anti-inflammatory cytokines from contracting skeletal muscle (Pedersen *et al.*, 2008), as well as a reduced expression of Toll-like receptors on monocytes and macrophages with subsequent inhibition of downstream responses, such as the production of pro-inflammatory cytokines (Gleeson *et al.*, 2006). In this regard, Sanders *et al.* (2009) observed a dose–response relationship of decreasing probability of detectable C-reactive protein in the gingival crevicular fluid with increasing levels of PA among cases of periodontitis. These anti-inflammatory effects of PA may explain, at least in part, the lower chances of periodontal disease observed in this study among active than inactive individuals. The lack of association between PA and CAL (destructive component of periodontal disease), added to a significant association between PA and PPD (inflammatory component of periodontal disease), reinforce that PA may act at the inflammatory cascade of periodontal disease.

In this study, PA was associated with better oral hygiene evaluated by the accumulation of calculus. This finding correlates with evidence demonstrating that PA is related to better and healthier lifestyle. In this way, behavioral factors may act as mediators in the relationship between PA and periodontitis, as it is the case of calculus (Figure 1). Both moderate- and vigorous-intensity PA are important for physical and mental health (Biddle *et al.*, 2015). Moreover, increased PA may have a positive and direct influence on self-esteem (Sani *et al.*, 2016). In the same way, there is some evidence showing associations of instability of self-esteem and perfectionism with oral health behaviors and oral health status (Dumitrescu *et al.*, 2012). A healthy lifestyle assembles a set of attributes and consequently may concur for the results of the present study.

Importantly, the models for the association between PA with clinical parameters of periodontitis were all adjusted for calculus. This indicates that the significant associations observed between PA with severe periodontitis and PPD are independent of calculus, strengthening the idea that PA may be related to periodontal disease prevention not only by healthier behaviors, but also by biological anti-inflammatory ways.

In the present study, PA was evaluated as a dichotomous variable. This approach was used considering cut-off points recommended by the IPAQ group. With this approach, active and inactive individuals can be clearly distinguished providing a clinically relevant differentiation in terms of levels of PA in the studied sample. Taking this into consideration, it may be argued that the findings of this study indicate that an amount of PA higher than that considered minimal for a healthy lifestyle (30 minutes of moderate exercise) may be beneficial for periodontal disease prevention.

One possible limitation of this study is that, although it was nested to a cohort study, data for PA and CAL

Table 2. Simple logistic regression models of traditional risk indicators for severe periodontitis, CAL ≥5mm in ≥1 tooth and PPD ≥5mm in ≥1 tooth.

	Severe periodontitis AAP-CDC		CAL ≥5mm in ≥1 tooth		PPD ≥5mm in ≥1 tooth	
Risk indicators	**OR (95%CI)**	**p-value**	**OR (95%CI)**	**p-value**	**OR (95%CI)**	**p-value**
Age (years)						
38-49 years	1		1		1	
50-64 years	1.44 (0.77-2.71)	0.25	2.05 (1.14-3.69)	0.02	1.02 (0.53-1.95)	0.94
Sex						
Females	1		1		1	
Males	0.76 (0.43-1.34)	0.34	0.56 (0.30-1.06)	0.07	0.86 (0.47-1.58)	0.63
Socioeconomic status						
Low	1		1		1	
Middle	0.90 (0.48-1.66)	0.74	0.67 (0.33-1.35)	0.26	0.75 (0.39-1.42)	0.38
High	0.44 (0.2-0.94)	0.03	0.43 (0.21-0.87)	0.02	0.24 (0.09-0.62)	0.003
Education						
Low	1		1		1	
Middle	0.78 (0.43-1.41)	0.41	0.55 (0.29-1.07)	0.08	0.67 (0.35-1.28)	0.23
High	0.35 (0.13-0.89)	0.03	0.34 (0.16-0.73)	0.006	0.19 (0.05-0.65)	0.009
Interproximal cleaning						
Yes	1		1		1	
No	0.92 (0.49-1.71)	0.80	0.64 (0.32-1.28)	0.20	0.80 (0.42-1.54)	0.51
Calculus						
<25%	1		1		1	
≥25%	4.19 (1.90 – 9.22)	<0.001	1.92 (1.07 – 3.43)	0.03	2.62 (1.22-5.63)	0.01
BMI						
Normal	1		1		1	
Overweight	1.23 (0.61-2.46)	0.57	0.90 (0.43-1.78)	0.71	1.35 (0.62-2.91)	0.44
Obese	1.25 (0.61-2.59)	0.54	0.78 (0.37-1.64)	0.51	1.48 (0.67-3.27)	0.33
Smoking exposure						
Never smokers	1		1		1	
Moderate	1.85 (0.96-3.55)	0.06	0.93 (0.50-1.73)	0.82	1.74 (0.86-3.52)	0.12
Heavy	2.05 (1.02-4.11)	0.04	2.35 (1.01-5.47)	0.04	2.07 (0.99-4.36)	0.05
Number of missing teeth	0.97 (0.94 – 1.00)	0.08	0.92 (0.89 – 0.96)	<0.001	1.02 (0.98 – 1.06)	0.25
Dental visits						
Irregular	1		1		1	
Regular	1.04 (0.59-1.83)	0.87	1.71 (0.97-3.03)	0.06	0.89 (0.49-1.62)	0.71
Cardiovascular disease						
No	1		1		1	
Yes	1.67 (0.96-2.87)	0.07	1.87 (1.03-3.36)	0.04	1.56 (0.87-2.82)	0.14
Diabetes						
No	1		1		1	
Yes	2.31 (1.13-4.73)	0.02	2.04 (0.75-5.39)	0.16	2.41 (1.14-5.08)	0.02

Table 3. Logistic regression models of physical activity as a protective factor for severe periodontitis, CAL ≥5mm in ≥1 tooth and PPD ≥5mm in ≥1 tooth.

	Severe periodontitis AAP-CDC		**CAL ≥5mm in ≥1 tooth**		**PPD ≥5mm in ≥1 tooth**	
Models	**OR (95%CI)**	**p-value**	**OR (95%CI)**	**p-value**	**OR (95%CI)**	**p-value**
Simple models						
Inactive	1		1		1	
Active	0.53 (0.29-0.94)	0.03	0.75 (0.39-1.45)	0.40	0.47 (0.25-0.86)	0.02
Multiple models						
Inactive	1*		1†		1‡	
Active	0.50 (0.20 – 0.98)	0.04	0.77 (0.42-1.40)	0.39	0.45 (0.24 – 0.88)	0.02

*Model adjusted for age, number of missing teeth, calculus, smoking and diabetes.
†Model adjusted for age, number of missing teeth, calculus, smoking and education.
‡Model adjusted for age, number of missing teeth, calculus, education and diabetes.

Table 4. Full final linear regression model for calculus.

Variable	**Beta**	**Std. Err.**	**p**	**95%CI**	
IPAQ	-7.30	3.09	0.02	-13.37	-1.22
Moderate smoking	1.53	3.24	0.64	-4.85	7.91
Heavy smoking	7.24	3.69	0.05	-0.03	14.51
Proximal cleaning	-13.12	3.37	0.00	-19.74	-6.49
Dentalvisits	5.34	3.05	0.08	-0.66	11.34
Middle SES	-5.86	3.35	0.08	-12.45	0.73
High SES	-10.54	3.76	0.01	-17.94	-3.14
Age	2.32	3.31	0.48	-4.19	8.83
Missing teeth	-1.20	0.23	<0.001	-1.65	-0.75

were only available at the follow-up examination, fact that did not allowed longitudinal evaluations at this moment. Although we included eleven possible confounding factors in our multivariable models, the absence of assessment of dietary behaviors and comorbidities other than diabetes and cardiovascular disease may be considered another possible limitation of this study. Noteworthy, the use of a reliable and valid questionnaire to measure PA (IPAQ) is unique in the literature and strengthens the findings of the present study. Moreover, the application of multivariable models accounted for possible confounding in the observed associations between PA and periodontal disease. Although the sample analyzed in this study can no longer be considered representative, it was derived from the population providing better generalizability than other studies in the same field.

In conclusion, PA was associated with lower chance of having severe periodontal disease defined by probing measures and CDC/AAP disease criteria. This is parallel to the benefits of PA for a number of other chronic diseases. Longitudinal prospective studies with population-based samples, as well as interventional studies, must be encouraged to allow the establishment of PA as a protective factor for periodontal diseases.

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