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The relationship between body mass index and body fat percentage and periodontal status in Mexican adolescents

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Abstract

Objective. To assess the association between obesity indicators and the periodontal status of high school students. ***Materials and methods.*** High school students (15-year-olds) in Mexico City participated in the survey (n = 257). International Obesity Task Force cut-off values (ISO-BMI) were applied to identify overweight and obesity. Also, bioelectrical impedance analysis was performed to estimate body fat percentage (BF%). The simplified detritus index (DI-S) was used to evaluate oral hygiene. The periodontal community index (CPI) was obtained to assess the periodontal status of the participants. ***Results.*** Overweight/obesity was identified in 30.0% of the students. BF% was 37.5% in women and 21.2% in men and 16.7% of the participants smoked and 33.5% of the students presented DI-S >1. Based on CPI, 59.5% of the participants showed good periodontal status (CPI = 0); bleeding on probing without further periodontal involvement was found in 13.6% of the participants (CPI = 1), 23.8% showed a CPI = 2 (dental calculus) and a CPI = 3 (shallow periodontal pockets) was detected in 3.1% of the participants. The results of the multinomial logistical regression model fitting CPI ≥2 identified an association BF% (OR = 1.06), having poor oral hygiene (OR = 20.09) and smoking (OR = 2.49). Similarly, overweight/obesity was associated with CPI ≥2 (OR = 1.78) adjusting for school attended (public school OR = 0.35), oral hygiene (DI-S >1, OR = 23.92) and tobacco consumption (smoker OR = 1.81). ***Conclusions.*** Excess body fat indicators were associated with bleeding on probing and dental calculus in adolescents. The relationship between overweight/obesity and periodontal status in adolescents should be considered in oral health preventive programs.

Key Words: *Overweight, obesity, periodontal disease, gingival bleeding, oral hygiene*

Introduction

Obesity is an epidemic that affects millions of people throughout the world. Mexico has the second highest obesity prevalence, ranking only after the US [1]. In the 2006 Mexican National Health Survey, researchers reported a prevalence of 21.6% overweight and 9.3% obesity in 10–19-year old adolescents [2]. Obesity is associated with several risk factors for the later development of heart disease, early onset atherosclerosis and hypertension [3].

The relationship between obesity and periodontitis has been the subject of numerous studies. In a meta-analysis of 57 independent populations, a trend of increasing risk of periodontal disease with increasing body mass index (BMI) was recognized [4]. In another systematic review, a total of 526 titles were screened and 19 studies provided sufficient information to be considered in the meta-analysis. A significant association was obtained between obesity and periodontal disease, with an OR of 1.3 for overweight and 1.8 for obesity, suggesting a dose–response relationship [5].

The association between obesity and periodontal disease is biologically plausible; however, the causal pathways are not fully understood. It has been suggested that similar pathways are involved in the physiopathology of obesity and periodontal disease [6]. The adipose tissue secretes pro-inflammatory cytokines and hormones and the obese patient shows a

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chronic low-grade systemic inflammatory state, endothelial dysfunction and increased products of reactive oxygen species [5,6]. Obesity has an impact on the periodontal blood vessels; also, excessive fat tissue deregulates immune response. Cytokines function in networks; they are essential mediators in the immune response and an imbalance between anti-inflammatorily and pro-inflammatory cytokines result in periodontal tissue destruction [7].

The results of epidemiological studies on the relationship between obesity and periodontal status are heterogeneous. In Japanese adults a higher BMI and body fat were associated with periodontal status. In a multivariate regression analysis adjusted for age, sex, oral hygiene and smoking, a dose–response relationship was found between BMI and periodontitis [8]. In the US Third National Health and Nutrition Examination Survey (NHANES III), the association between obesity and periodontal disease was inconsistent among the different adult and elderly groups that were examined [9]. A study carried out in Korea applied three obesity-related measures (visceral fat area, BMI and waist circumference), to the 45–50-year-old group and an association was detected between visceral fat area and periodontitis; this was true only in the male group; however, in females only weight circumference was associated with periodontitis [10]. Moreover, follow-up studies have also shown inconsistent results; a longitudinal study of employed Japanese found a higher risk of development periodontal disease as BMI increased, adjusting for smoking status, diabetes mellitus and age. Also, a study in US veterans found that overweight men who gained weight most rapidly during the 40 years of follow-up developed more periodontal pockets than those in the lowest tertile of weight gain [11]. On the other hand, a study in European men found that the BMI identified at 21 years old did not predict periodontitis development at 60–70 years of age [12].

Body mass index is a conventional indicator for assessing overweight status and obesity. Nevertheless, this index is an indirect measurement of obesity and does not distinguish between body fat mass and body lean mass. Assessing obesity is a difficult task, which involves the study of body composition. Several methods are available to estimate body fat mass. Bioelectrical impedance analysis (BIA) is a non-invasive method and it has been applied in epidemiological studies [13].

The health condition of adolescents has an impact upon their adulthood and it is an ideal age to acquire or reinforce health behavior. Periodontitis increases with age and the recognition of risk factors early in life could contribute to the identification of preventive strategies. However, there is little information regarding the impact of obesity in the periodontal status of adolescents [14–16]. An analysis of a US representative sample found an association between body weight and periodontitis in the 17–21-year-old group; however, no relationship was identified in younger adolescents [17]. In addition, a study in a group of Italian patients of 10–17 years of age did not identify an association between obesity and periodontal status [16]. On the other hand, in Turkish 10–12 year-old children, Cinar and Murtomaa [18] analyzed the relationship between obesity, lifestyle factors and oral disease (dental caries, gingival bleeding and calculus) and a cluster of children with oral disease and obesity was identified, applying principal component analysis. Also, Modéer et al. [19] studied Swedish adolescents, comparing normal weight and obese participants and found higher bleeding on probing (BOP) sites, calculus and periodontal pockets in the obese group compared with their normal weight counterparts [19].

An increase in obesity, diabetes mellitus type 2 and metabolic syndrome has been observed in Mexican adolescents [20]. It is possible that, even with the young adolescents, there is an association between overweight/obesity and periodontal status. Our hypothesis was that the prevalence of periodontal disease is greater in high body fat percentage or overweight/obese adolescents as compared to adolescents with normal weight.

Materials and methods

Study group

A cross-sectional study was performed in a convenience sample. Students attending high schools located in middle-income neighborhoods in the southern part of Mexico City were selected. The number of high school students in this area was ~30,000 students distributed through 62 schools; 67.3% of the students attended public schools and 32.7% attended private schools. Two private and two public schools were randomly selected, using a list of schools in the area listed by the Ministry of Education. Only 15-year-old students were included in the study. This is a World Health Organization (WHO) indicator age for oral health comparisons [21].

Based on a calculation of sample size, 240 students were needed considering an OR = 2.3, $\alpha = 0.05$ and power 0.80, assuming a prevalence of overweight/obesity of 30% and dental calculus of 30% [22]. To offset for the possibility of the students' non-response and the application of the study's exclusion criteria, the sample was increased by 30%; resulting in 312 students being selected. Students were randomly selected from alphabetical lists of the groups enrolled in the 2010–2011 academic year of the participating high schools. Twenty-three students (7.4%) were excluded due to the presence of an orthodontic appliance or previous orthodontic treatment 25 (8.0%) did not return the letter of informed consent to be signed by their parents and 7 (2.2%) students record were incomplete. A total of 257 students were included; 161 student who attended a public school and 96 who attended a private institution. Some of the students participating in the present study were also included in a previous report regarding malocclusions [23].

Anthropometric evaluation

A standardized dietitian performed the anthropometric procedures. The participants were asked to remove their shoes, wear minimal clothing and unbraided hair that could interfere with height measurement. The anthropometric measurements were performed following standard procedures [24]; weight (kg) and height (m) were measured using a portable digital electronic scale and a stadiometer (accuracy of 100 g and 1 mm, respectively).

Age- and sex-specific *Z*-score for anthropometric data were obtained [25]. The International Obesity Task Force (IOTF) ISO-BMI age- and sex-specific cut-off points were used to identify normal weight, overweight (OW) and obese (OB) participants. IOTF proposed that the adult cut-off points (25 kg/m^2 for overweight and 30 kg/m^2 for obesity) be linked to body mass index percentiles for children and adolescents aged 2–18 years old. The IOTF database consists of data of large national representative samples of six countries, in order to obtain the percentile curves of ISO-BMI, and developed specific cut-off off points for age and sex. In the case of the 15.5-year-olds, the BMI cut-off points for being overweight were 23.6 and 24.17 in males and females, respectively, and for obese, 28.6 and 29.29 in males and females, respectively [26].

Bioelectrical impedance analysis

Tetrapolar leg–leg bioelectrical impedance analysis (BIA) (Tanita TBF-215™, Tokyo, Japan) was performed and body fat percentage (BF%) was recorded. Students had refrained from any intense physical activity for 4 h prior to BIA evaluation. Such activity can affect the distribution of bodily fluids and electrolytes, thereby affecting the BIA body composition assessment [13].

Oral examination

The Community Periodontal Index (CPI) and loss of periodontal attachment (LOA) following WHO criteria [21] were applied. The CPI has five categories: 0, normal; 1, bleeding on probing (BOP); 2, supragingival or subgingival calculus; 3, shallow periodontal pocket (4–5 mm); and 4, deep pockets (≥6 mm). The periodontal loss of attachment index was applied only if the CEJ (Cemento-Enamel Junction) was clinically visible.

In accordance with WHO, the teeth examined in 15-year-olds were first molars, then right upper central and right lower central incisors. The WHO periodontal probe was used for the periodontal evaluation; the pressure recommended during periodontal examination is 50 N/cm^2, (20 g force applied on the probe/area at the tip end) [27]. Two dentists were trained to exert gentle pressure while probing. The periodontal probe was placed on the distobucal surface of the teeth that were examined, parallel to the longitudinal exe and moved slowly up and down, all around the tooth, following the tooth anatomy. To detect the presence of bleeding, the examiner waited 10 s after probing and rechecked the gingival tissue, looking for bleeding sites.

The two dentists who completed the periodontal assessment were calibrated (inter-examiner consistency kappa = 0.78, intra-examiner >0.81, for CPI = 1, and inter-examiner consistency kappa = 0.82, intra-examiner >0.85 for CPI = 2). Ten per cent of the exams were repeated during the course of the survey and good examiner consistency was maintained.

The presence of dental plaque deposits was assessed according to the Simplified Debris Index (DI-S). This index considers six indicator teeth to be examined and one surface is coded on each tooth. There are four codes: 0, if no soft debris or stain is present; 1, if less than one third of the tooth surface examined has soft debris; 2, if more than a third but less than two thirds of the tooth surface is covered with soft debris; and 3, if more than two thirds of the tooth surface is covered with debris [28]. The examiners did not have access to the students' data regarding smoking or anthropometric evaluations prior to performing oral examinations.

Interview

Students were asked about their smoking habits. This process was carried out by a young interviewer trained not to have a judgmental attitude while obtaining an honest answer from the students. Those students who smoke a cigarette at least twice a month were classified as smokers. Former smokers were placed in the smokers group. The participants were asked about the duration of their habit and the number of cigarettes smoked per week. Then the number of pack-years was calculated. Parents signed an informed consent allowing the participation of their son/daughter; 92% of the forms were signed. Furthermore, the students verbally expressed their consent to participate in the study. Health education activities were carried out after the students were evaluated. This study was reviewed and approved by the committee for the protection of human subjects in research from the Universidad Autónoma Metropolitana.

Statistical analysis

A bivariate analysis was performed for obesity indicators (body fat percentage, overweight/obesity and

Table I. Mean for height, weight and body mass index for age Z-score (NHI), body fat percentage, overweight and obesity by sex.

Sex	Height* (cm), Mean (SD)	Weight* (kg), Mean (SD)	BMI (kg/m^2), Mean (SD)	Weight/age Z-score, Mean (SD)	BMI/age Z-score, Mean (SD)	Body fat percentage*, Mean (SD)	Overweight (IOTF),† n (%)	Obesity (IOTF),† n (%)
Women (n = 120)	158.4 (6.0)	56.2 (10.6)	22.4 (3.3)	0.06 (1.0)	0.389 (0.9)	37.5 (5.0)	25 (20.8)	4 (3.3)
Men (n = 137)	168.3 (5.9)	63.3 (12.0)	22.3 (3.5)	0.19 (0.9)	0.402 (1.0)	21.2 (7.5)	38 (27.7)	10 (7.3)
Total (n = 257)	163.6 (6.0)	60.0 (11.1)	22.3 (3.4)	0.14 (1.0)	0.394 (0.9)	28.9 (10.4)	63 (24.5)	14 (5.5)

NHI, National Health Institute, Z-score for age and sex.
† Overweight and obesity categories based on the International obesity task force (IOTF) cut-off points of Body Mass Index (ISO-BMI).
* Statistically significant differences by sex ($p < 0.001$).

obesity) and the dependent variable was CPI using three categories (CPI = 0, CPI = 1 and CPI ≥2). No statistically significant differences between the two private schools or between the two public schools were detected in reference to the main variables of interest. Therefore, in the data analysis, the students were classified into two groups according to the attending school, public or private. Multinomial logistic regression models obtaining odd ratios (OR) and 95% confidence intervals (CI) were constructed for the CPI categories and obesity indicators (body fat percentage, ISO-BMI overweight/obesity and obesity), controlling for sex, school type, detritus score (DI-S) and tobacco use. The multinomial logistic regression models can be thought of as simultaneous, estimating binary logistic models for the comparisons among the alternatives [29]. The outcome variables in the study was CPI, which was considered as a categorical variable with three levels (0, no periodontal sings (CPO = 0); 1, bleeding on probing (CPI = 1); and 2, dental calculus and 3, periodontal pockets (CPI ≥2). Robust standard errors were obtained, which allows for intra-group correlation, considering that the students selected were clustered into schools. A value of $p < 0.05$ was considered statistically significant. Possible effect modifications by smoking and obesity indicators were analyzed by interactions terms in the models. STATA statistical package was used for the data analysis (StataCorp, 2007, Stata Statistical Software: Release 10. StataCorp, College Station, TX).

Results

Obesity indicators

The study group included 120 (46.7%) females and 137 (53.3%) males. Table I shows the anthropometric results by sex. The percentage of students showing overweight/obesity based on the ISO-BMI cut-off value was 30.0%. The percentage of students showing overweight/obesity in the public school group was 25.7% and 34.7% in the private school students (p = 0.14). As expected, females had a higher body fat percentage than males ($p < 0.01$). Adjusting for sex, BF% was higher in the private school students (BF% = 25.1) compared with those attending a public school (BF% = 22.1) (p = 0.0011).

Tobacco use

Smoking was reported by 16.7% of the students; no student indicated a practice of chewing tobacco. Among the smokers, the mean pack/years was 1.43 (SD = 1.78). No significant difference in smoking was detected by sex (p = 0.08) and between normal-weight and overweight/obese participants (p = 0.09). The private school students (22.2%) smoked more than those students who attended a public school (10.9%) (p = 0.013).

Oral hygiene

The results of the oral examination for dental plaque indicated that 61.2% of the students had good oral hygiene, with a DI-S mean score between 0–0.6, 25.3% had fair oral hygiene (DI-S mean between 0.7–1.8) and 13.6% of the students showed poor oral hygiene (DI-S between 1.9–3). About one third (32.7%) of the students had DI-S >1. A lower percentage of females (22.8%) presented a DI-S >1 compared with males (42.3%, $p < 0.001$). Smoking was not associated with dental plaque level; high DI-S was detected in 31.3% and in 41.0% of non-smokers and smokers (p = 0.230), respectively; 43% of the public school participants and 57% of the private school students showed DI-S >1 ($p < 0.0001$).

Periodontal status

Based on the CPI, 59.5% of the students showed good periodontal status (CPI = 0) and 40.5% of the participants had CPI >0; bleeding on probing, without further periodontal involvement, was detected in 13.6% (CPI = 1), 23.8% showed a CPI score of 2 (gingival calculus) and a CPI score of 3 (shallow periodontal pockets) was detected in 3.1% of the participants, CPI ≥2 was found in 26.9% of the participants (Table II); none of the students examined

Table II. Community periodontal index by selected variables and crude odds ratios of the multinomial logistic regression model

	Healthy CPI = 0 (*n* = 153; 59.5%)	Bleeding on probing CPI = 1 (*n* = 35; 13.6%)			Dental calculus and periodontal pockets CPI ≥2 (*n* = 69; 26.9%)		
	n (%)	*n* (%)	OR	*p*	*n* (%)	OR	*p*
Sex							
Female (*n* = 120)	78 (51.0)	20 (57.1)	reference		22 (31.9)	reference	
Male (*n* = 137)	75 (49.0)	15 (42.9)	0.78	0.57	47 (68.1)	2.20	0.07
School							
Private (*n* = 96)	40 (26.1)	12 (34.3)	reference		44 (63.8)	reference	
Public (*n* = 161)	113 (73.9)	23 (65.7)	0.68	0.33	25 (36.2)	0.20	< 0.01
Detritus I-S							
0–1 (*n* = 173)	137 (89.5)	19 (54.3)	reference		17 (24.6)	reference	
2–3 (*n* = 84)	16 (10.5)	16 (45.7)	7.20	0.02	52 (75.4)	26.20	< 0.01
Tobacco							
No (*n* = 214)	131 (85.6)	31 (88.6)	reference		52 (75.4)	reference	
Yes (*n* = 43)	22 (14.4)	4 (11.4)	0.97	0.86	17 (24.6)	2.50	0.02
Body fat percentage (mean (SD))	28.8 (10.6)	31.1 (7.9)	1.06	0.05	28.0 (11.0)	1.01	0.68
OW/obesity[†]							
No (*n* = 180)	111 (72.5)	24 (68.6)	reference		45 (65.2)	reference	
Yes (*n* = 77)	42 (27.5)	11 (31.4)	1.20	< 0.01	24 (34.8)	1.41	< 0.01
Obesity[†]							
No (*n* = 243)	149 (97.4)	31 (88.6)	reference		63 (91.6)	reference	
Yes (*n* = 14)	4 (2.6)	4 (11.4)	4.80	< 0.01	6(8.7)	3.50	< 0.01

Crude (OR) odds ratios of the multinomial logistic regression model, CPI = 0 is the reference category for CPO = 1 and CPO ≥2. Robust standard errors cluster (school).
Detritus I-S, sum of detritus index score; Tobacco, Yes (included smoker and ex-smoker).
[†] OW/obesity, Overweight/obesity and obesity categories based on the International obesity task force (IOTF) cut-off points of Body Mass Index (ISO-BMI).

had deep pockets (≥6 mm). The clinical exposure of the CEJ was observed only in one student (LOA code 1). Table II shows the distribution of the CPI score by selected variables, for CPI = 1, no statistically significant association was detected by sex, type of school attended or smoking, while DI-S, overweight and obese were associated with CPI = 1, using CPI = 0 as the reference category; CPI ≥2 school type, DI-S tobacco use, overweight and obesity were also associated by using CPI = 0 as the reference category.

Table III presents a multinomial logistic regression analysis for CPI and selected variables and Table IV presents two more models fitted for the same outcome variable. The first model included body fat percentage among the independent variables and the second by using the categories of overweight/obesity and the third by using the obesity category defined according with the ISO-BMI cut-off points. In the first model for the CPI = 1 category including in the independent variables body fat percentage, only DI-S showed a strong association (OR = 9.20) with CPI = 1 and sex, school type and tobacco use were not significant; for CPI ≥2 body fat percentage was significant (OR = 1.06), males were ~3-times (OR = 2.97) as likely to have CPI ≥2 than females, attending a public school was protective and tobacco use increased the likelihood (OR = 2.49) of having calculus and shallow periodontal pockets (CPI ≥2).

Table IV presents a second model, for CPI = 1, adolescents who were overweight/obese were more likely (OR = 1.54) to have CPI = 1; also higher plaque accumulation (DI-S >1) (OR = 8.31) was associated with CPI = 1 and smoking (OR = 0.80) decreased the likelihood of CPI = 1. For the category CPI ≥2 overweight/obesity was also associated with periodontal status (OR = 1.78), debris index showed a strong association (OR = 23.92), attending a public school (OR = 0.34) was protective and smokers (OR = 1.81) were more likely to have CPI ≥2 than non-smokers. Finally, in the third model, using obesity as an independent variable, this condition was associated with CPI = 1 (OR = 7.07), controlling by sex, school type DI-S and tobacco use; for CPI ≥2 obesity also showed a strong association (OR = 5.56) controlling by sex, school type, DI-S

Table III. Multinomial logistic regression results for community periodontal index and independent variables (Model 1).

	Bleeding on probing†		Calculus and periodontal pockets†	
	Adjusted OR (CI 95%)*	*p*	Adjusted OR (CI 95%)*	*p*
Body fat percentage	1.03 (0.97, 1.07)	0.21	1.06 (1.05, 1.07)	< 0.01
Sex				
Female	reference		reference	
Male	0.72 (0.16, 2.07)	0.66	2.97 (1.07, 5.07)	< 0.01
School type				
Private	reference		reference	
Public	0.88 (0.49, 1.51)	0.65	0.44 (0.35, 0.56)	< 0.01
Debris Index-S				
DI-S ≤1	reference		reference	
DI-S >1	9.20 (1.78, 46.65)	< 0.01	20.9 (6.46, 67.83)	< 0.01
Tobacco use**				
No	reference		reference	
Yes	0.96 (0.83, 1.10)	0.55	2.49 (1.46, 4.21)	< 0.01

† Reference category: healthy, no signs or symptoms of periodontal disease (CPI = 0).
* Adjusted OR by variables in table. Body fat percentage (continuous variable). DI-S (Debris Index-Simplify).
** Tobacco use (yes: includes smokers and former smokers).

and tobacco use (Table IV). In the models, interactions between smoking and obesity indicators were not statistically significant (data not shown).

Discussion

In the adolescents studied, being overweight or obese was associated with periodontal status (BOP and calculus); also high body fat percentage was associated with dental calculus. Accordingly, a recent meta-analysis identified an association between obesity and periodontitis (OR = 1.35); this association was stronger in younger adults as compared with older age groups [4]. In addition, a higher risk of rapidly progressing periodontitis with high BMI was detected in a VA Dental Longitudinal Study [11].

In reference to adolescents and data from the NHANES III, in the 13–16 year-old group no association was detected between body weight and periodontitis [17]. Probably due to the definition of periodontitis applied that included both one or more periodontal sites with loss of tissue attachment of 3 mm and a probing depth of 3 mm. In the present study, earlier signs of periodontal deterioration were associated with obesity indicators. Other studies of obese adolescents had also identified a relationship between obesity and periodontal status. In a cross-sectional study, in Swedish adolescents, obesity was associated a high percentage of BOP sites and a reduced stimulated salivary flow rate [15]. Also in Swedish adolescents, higher BOP sites, dental calculus and periodontal pockets were observed in the obese group compared with their normal weight counterparts. No association was found between levels of pro-inflammatory cytokines interleukins (IL-8 and IL1 β) in the gingival cervicular fluid and periodontal pockets; nevertheless, an association between these interleukins and obesity was detected. As pointed out by the authors, this suggestd that the link between obesity and periodontal pockets may be related to the deregulation of the immune system that deteriorates the response to periodontal pathogens in the obese subjects [19,30]. In line with this observation, Zeigler et al. [14] evaluated the microbiota in the oral subgingival biofilm of obese and normal weight adolescents, a higher sum of bacterial cells was found in the obese participants compared with their normal weight counterparts (OR = 1.05). In addition, traditional periodontitis bacteria (*a. actinomycetemcomitans*, *P gingivales* and *P. micra*) were present in an ~3-fold increase in the dental biofilm of obese adolescents compared with the normal weight participants [14]. These findings suggest that a deregulation of the immune system in obese adolescents is a key factor in the development of periodontal disease.

A population-based birth cohort study of young adults was carried out in Brazil, aiming to investigate the association between obesity and periodontal disease. Records of body weight were available for several years from 15–23 years of age. This study revealed that the risk of dental calculus was 10% higher in obese participants compared with normal weight counterparts. Also, episodes of obesity were associated with the presence of dental calculus [31]. Interestingly, when controlling for oral hygiene or C-reactive protein, the association between BOP and obesity was no longer significant; however, the association with calculus remains significant after

Table IV. Multinomial logistic regression results for community periodontal index and independent variables (Model 2 and Model 3).

	Bleeding on probing[†]		Calculus and periodontal pockets[†]			Bleeding on probing[†]		Calculus and periodontal pockets[†]	
	Adjusted OR* (95% CI)	*p*	Adjusted OR* (95% CI)	*p*		Adjusted OR* (95% CI)	*p*	Adjusted OR* (95% CI)	*p*
Overweight/obesity**					Obesity				
No	reference		reference		No	reference		reference	
Yes	1.54 (1.45, 1.63)	< 0.01	1.78 (1.51, 2.10)	< 0.01	Yes	7.07 (2.74,18.24)	< 0.01	5.56 (5.39, 5.74)	< 0.01
Sex					Sex				
Female	reference		reference		Female	reference		reference	
Males	0.51 (0.33, 0.79)	< 0.01	0.89 (0.44, 1.78)	0.73	Males	0.49 (0.34, 0.70)	< 0.01	0.87 (0.43,1.79)	0.72
School type					School type				
Private	reference		reference		Private	reference		reference	
Public	0.79 (0.33, 0.79)	< 0.01	0.34 (0.27, 0.44)	< 0.01	Public	0.79 (0.53,1.16)	0.24	0.34 (0.27, 0.44)	< 0.01
Debris Index-S					Debris Index-S				
DI-S ≤1	reference		reference		DI-S ≤1	reference		reference	
DI-S >1	8.31 (1.62, 42.56)	0.02	23.92 (10.1, 56.7)	< 0.01	DI-S >1	8.82 (1.64, 47.41)	0.01	24.80 (11.14, 52.06)	< 0.01
Tobacco use***					Tobacco use				
No	reference		reference		No	reference		reference	
Yes	0.80 (0.73, 0.87)	< 0.01	1.81 (1.62, 2.04)	< 0.01	Yes	0.88 (0.68, 1.15)	0.35	1.98 (1.95, 2.01)	< 0.01

[†] Reference category: healthy, no signs or symptoms of periodontal disease (CPI = 0).
* Adjusted OR by variables in table.
** Overweight/obesity defined in accordance with International Obesity Task Force cut-off points (ISO-BMI). Obesity defined in accordance with International Obesity Task Force cut-off points (ISO-BMI). DI-S (Debris Index-Simplify).
*** Tobacco use (yes: includes smokers and former smokers).

controlling for these variables. It is possible that several pathways interact in the relationship between obesity and periodontal diseases.

The results herein showed an association between being overweight or obese and CPI in 15-year-olds, probably due to the early presence of risk factors, such as insulin resistance and fat intake [20]. A study of obese Mexican children and adolescents showed that 51% presented insulin resistance and 20% metabolic syndrome [20]. A high intake of free fatty acids may induce apoptosis in the pancreatic β cells, altering glucose metabolism [32]. Insulin resistance has been found to be associated with gingival inflammation in Italian young age groups; however, no significant association was detected between gingival inflammation and overweight/obesity status. The authors concluded that it is not simply the presence of obesity that is related to periodontal status, but the metabolic disorders that high body fat causes in the human body [16]. In addition, psychological stress associated with a high BMI may also play a role in periodontitis etiology [33].

The presence of BOP, calculus and pockets observed in the Mexican adolescents were probably related to both metabolic and local risk factors.

Consistent with the literature, the results of the present study showed that the presence of dental plaque had a strong association with periodontal status [34]. A study in Italian children and adolescents found that the strongest predictor of gingivitis was plaque accumulation [16]. Dental plaque growth and gingival tissue inflammation have shown a strong relationship in different populations and age groups [35]. The relatively low prevalence of bleeding on probing found in the population studied could be related to the low dental debris index identified in more than half of the students.

Approximately one third of the participants were overweight or obese, similar to national figures [2]. In addition, body fat percentage was higher among the private school students compared with the public school participants. Accordingly, in the National Health and Nutrition Survey, Mexican adolescents belonging to higher socioeconomic status showed a higher prevalence of obesity [36].

Body fat percentage was obtained using bioelectrical impedance analysis in the present study; this indicator was associated with periodontal status in the adolescents. Some studies applying bioimpedance analysis in adults have identified an association between BF% and periodontitis [37–39]. Also, body composition assessed by BIA and periodontal status was investigated in 30–60-year-old Iranian men. A significant association was detected between body fat percentage and established periodontitis, BF % was 21.1% in the healthy group and 26.8% in the periodontitis group; however, no association was detected between body fat percentage and mild forms (gingivitis) or initial periodontitis adjusting for age, diabetes and socioeconomic status [37].

In the present study, BF% was not associated with BOP; however, overweight/obesity showed an association with this indicator. Accordingly, in a study in young Japanese adults, BMI was associated with periodontitis and no association was detected with body fat percentage that was obtained by BIA [39]. In addition, BMI has been shown to be a better risk indicator of type 2 diabetes than BIA-determined body fat mass [40]. Furthermore, it has been suggested that the BIA equations are population-specific; however, because there are not equations available for Mexican adolescents, we used the manufacturer's equations [41]. Better methods to assess body composition, for example using dual X-ray absorptiometry, could be useful in exploring the relationship between body fat mass and periodontal status in young population groups. Obesity and periodontal disease have common risk determinants [4]. To control for excess body fat and periodontal disease, a comprehensive multidisciplinary approach by medical, dental and dietician healthcare professionals is required.

The association between smoking and CPI = 1 was significant in the multinomial logistic regression model, showing a lower likelihood of bleeding on probing among smokers, adjusting for overweight/obesity, sex, school type and debris index. Accordingly, studies have identified fewer bleeding sites among smokers as compared with non-smokers; the opposite relationship has been identified between smoking and calculus [42,43]. This information is consistent with the findings of the present study, using a cut-off value of CPI ≥2; smokers were more likely to show this condition. Other research in adults has had similar findings. A case-control study in India, comparing smokers and non-smokers, showed higher calculus deposits in the group of smokers [43].

The percentage of students with periodontal pockets (3.1%) was similar to the value observed in NHANES III, where 3.3% of 13–21-year-olds experienced this condition [17]. More than one quarter of the participants exhibited gingival calculus. In Swedish adolescents, alveolar bone loss was associated with subgingival calculus [44]. The presence of calculus on the tooth surface is a risk factor of periodontal pocket formation [45].

The relationship between socioeconomic status, obesity and oral health is complex. Frequently better oral health conditions are found in groups with higher socioeconomic status [18,46]. A study of Turkish school children, using the CPI, identified that 62% of the public school students had calculus compared with 37% of the private school participants and the reversed trend was observed for obesity, as 25% of public school participants were obese and 40% of the private school students [18]. In the present study the private high school participants showed considerably higher periodontal involvement and more plaque deposits, as well as a higher prevalence of smoking than their public school counterparts. As far as it was possible to investigate, there are no Mexican studies carried out in high school students comparing periodontal status between public and private school students. In Mexico City, the students in the public school system participate in health promotion activities (e.g. health fairs, annual medical check-ups). In particular, the public schools visited had a health team working in educational and promotion activities and these teams included dental personnel; this probably had a positive effect on the public school students' oral health status and a lower frequency of tobacco smoking compared with their private school counterparts. Furthermore, it is possible that the association found between type of school and periodontal conditions was the result of the rigorous selection process for public high school students.

The study has the limitations inherent with a cross-sectional design. The oral examiners were blind to the smoking and body composition status of the students; however, obesity is a condition that the examiner cannot be blind to, so this could increase the risk of examiner bias. The study had a high response rate, which reduces the risk of selection bias. In the present study, it was not possible to obtain information about blood glucose level, insulin resistance and lipids profile. It would be useful for further studies to gather information about the cardio-metabolic risk factors of the adolescents, particularly those with obesity.

In the statistical analysis bleeding on probing, dental calculus and periodontal pockets were used as risk indicators of periodontal diseases [19]. The multinomial model applied allows the simultaneous comparison of the different categories of the outcome variable. However, these subrogate indicators do not fully evaluate periodontal status. In addition, the application of the CPI does not require the examination of all of the teeth, which decreases the sensitivity of the index; this index had shown an acceptable specificity [47]. The periodontal probe was moved all around the index teeth selected in each sextant to improve the sensitivity of the index. A study aimed to assess the validity of partial protocols to evaluate the prevalence of periodontal outcomes in adolescents showed that CPI under-estimates the prevalence of BOP by 16.2% [48]. In spite of the limitation of the CPI index, an association between CPI and obesity indicators was observed.

It can be concluded that an association of obesity-related measures and periodontal status could appear as early as adolescence. The early identification of active disease and high risk groups for destructive periodontal conditions are important elements of treatment planning and should impact oral health policy. Prevention of periodontal problems should be emphasized in young patients. Dentists could be important agents in promoting a healthy lifestyle among their patients.

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