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The association between periodontal disease, physical activity and healthy diet among adults in Jordan

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Background and Objective: Physical inactivity and an unhealthy diet have been implicated as risk factors for several chronic diseases that are known to be associated with periodontitis, such as cardiovascular diseases, obesity and diabetes. Studies investigating the relationship between periodontitis and physical activity and diet are limited. Therefore, this study was conducted to determine the relationship between physical activity, healthy eating habits and periodontal health status.

Material and Methods: A systematic random sample of 340 persons, 18–70 years of age, was selected from persons accompanying their relative patients who attended the outpatient clinics in the medical center of Jordan University of Science and Technology in north of Jordan. Data collected included socio-demographic and clinical characteristics, anthropometric measurements, physical activity level and dietary assessment.

Results: Individuals who were highly physically active had a significantly lower average plaque index, average gingival index, average clinical attachment loss (CAL) and percentage of sites with CAL ≥ 3 mm compared to individuals with a low level of physical activity and individuals with a moderate level of physical activity. Those who had a poor diet had a significantly higher average number of missing teeth and an average CAL compared with those who had a good diet. In the multivariate analysis, a low level of physical activity and a poor diet (diets with a healthy eating index score of < 50 points) were significantly associated with increased odds of periodontitis.

Conclusions: A low physical activity level and a poor diet were significantly associated with increased odds of periodontal disease. Further studies are needed to understand this relationship in greater detail.

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Regular physical activity enhances health in general and improves quality of life (1). The risk of several noncommunicable chronic diseases, including cardiovascular diseases (2), hypertension (3), Type 2 diabetes mellitus (4), osteoporosis (5), obesity, colon cancer, breast cancer (6), and anxiety and depression (7), is inversely related to regular physical activity. Recently, it was proposed that physically active individuals may have a lower risk of periodontitis (8–10). However, studies investigating this association are limited.

Healthy eating habits go hand-in-hand with physical activity in preventing the chronic diseases mentioned in

the previous paragraph. An unhealthy diet has also been implicated as a risk factor for several chronic diseases, such as cardiovascular diseases (11,12), hypertension (13,14), diabetes (15,16) and certain types of cancers (17–19). Historically, nutrition has been linked to periodontal disease through scurvy (i.e. vitamin C deficiency disease). However, more associations have been documented between nutrition and periodontal disease as an inflammatory disease, including the effect of vitamin C, vitamin E and carotenoids as dietary antioxidants in inflammation modulation (20–22), and the impact of obesity on modulating the host's immune and inflammatory system, leaving the patient with a greater risk of periodontitis (23). The relationship between dietary components and periodontitis is not clear and needs further research (24). This study aimed to determine the association between quality of the diet (as measured using the healthy eating index), physical activity and periodontitis.

Material and methods

Participants

A total of 4203 patients attended the outpatient clinics in the medical center of Jordan University of Science and Technology, in north of Jordan in the period between April and October 2007. Of those, 3564 were accompanied by a relative of ≥ 18 years of age. A systematic random sample of 340 persons between 18 and 70 years of age was selected from persons accompanying their relative patients in the study period. In systematic random sampling, first a number within the sampling interval was chosen. We chose a random number between 1 and 10 using random number tables. Then, every 10th person of ≥ 18 years of age following the first number chosen was selected each day for the whole study period. Selection of every 10th person allowed participants to be interviewed and examined without delay. Participants were informed about the objective of the study. Based on their approval, participants were asked to read carefully and sign a consent form. None of the patients had received periodontal treatment within the previous 6 mo. One person diagnosed with cancer and three persons diagnosed with osteoporosis were excluded. Pregnant women and those who required antibiotic prophylaxis for dental examinations were also excluded. None of the patients had autoimmune conditions.

Questionnaire

The questionnaire was completed through a structured interview with a trained interviewer. Socio-demographic characteristics, including age, gender, marital status, income and years of education, were collected. Participants' self-reported history of chronic conditions, including history of diabetes, hypertension and dyslipidemia, were collected. Participants were asked if they were ever diagnosed and told by the physician that they had one of the previously mentioned diseases. They were also asked if they were on regular medication at the time of data collection. Smoking status was recorded as current smoker, past smoker or nonsmoker.

Anthropometric measurements

Weight and height were taken by a nutritionist while the participants were wearing light clothing and no shoes. Body mass index (BMI) was calculated as the ratio of weight (in kg) to the square of height (in m). Methods of measurements and definition of obesity are detailed elsewhere (23).

Physical activity

Level of physical activity was evaluated using the short form of the International Physical Activity Questionnaire (IPAQ) – a standardized questionnaire used to estimate habitual practice of physical activities of populations from different cultural and socio-economic backgrounds. The questionnaire is a 7-d recall of physical activity and includes seven questions to estimate the time spent performing physical activities. The questionnaire includes questions like 'During the last 7 d, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?' and 'How much time did you usually spend doing vigorous physical activities on one of those days?'. The IPAQ classifies subjects into three categories (low, moderate, and high physical activity) based on a scoring protocol (25). The protocol provides several criteria for classification. Full access to the questionnaire and scoring protocol is available at the official web page of the international physical activity questionnaire (http://www.ipaq.ki.se/ipaq.htm).

Dietary assessment and the healthy eating index

Dietary assessment was conducted through an interviewer-administered semiquantitative food frequency questionnaire (FFQ). The semiquantitative FFQ has been shown to be a valid and reliable tool for dietary assessment both in the USA and internationally (26–28). For each item, a serving size was provided. Participants were asked to provide the best answer of how often, on average, they had had eaten each food item listed in the FFQ during the last year. Answer choices were: 'more than once a day', 'once every day', '5–6 days a week', '3–4 days a week', '1–2 days a week', 'at least once a month', 'less than once a month' or 'rarely or never'. The last two answers were treated as zero intake of that item. Food consumption and nutrient intake reported by the participants were calculated by multiplying the number of servings consumed from each food item by the frequency of consumption. Dietary consumption data were then treated using Food Processor software (V. 7.71; ESHA, ESHA Research, Salem, OR, USA) to obtain the daily consumption of food groups (grain, vegetable, fruit, milk and meat), the intake of cholesterol and sodium, and the daily contribution of total fat and saturated fat relative to daily calories consumed (29).

The healthy eating index (HEI) score was calculated for each completed FFQ based on the United States Department of Agriculture (USDA)

HEI (30). The HEI is a single, summary measure of overall diet quality defined in terms of adequacy, moderation and variety (31). It is a 100-point analytic scoring tool used to measure compliance with dietary recommendations and guidelines (32). The HEI determines adherence to the Food Guide Pyramid's serving recommendation for the five major food groups – grains, vegetables, fruit, milk and meat. The HEI also assesses the intake of total fat and saturated fat as a percentage of the total energy intake. It measures the intake of dietary cholesterol and sodium, and evaluates the variety in a person's diet. Scores for the 10 components can range from 0 to 10 (a score of 10 indicates that the recommendations were fully met, a score of 0 indicates that dietary behavior was not at all practiced, and a score between 0 and 10 was assigned proportionately to indicate intermediate intakes of the recommended amounts), giving a maximum total score of 100 points (31). An HEI score of > 80 points implies a good diet; an HEI score of 51–80 suggests that the diet is fair; and an HEI score of < 50 points suggests a poor diet (32).

Clinical examination

All participants underwent a clinical periodontal examination that was carried out by a professional dental hygienist. The oral hygiene of six selected teeth and the periodontal status of all teeth, excluding third molars, were assessed using the plaque index of Silness & Loe (33), the gingival index of Loe & Silness (34), probing pocket depth and clinical attachment loss (CAL). The six teeth chosen were the Ramfjord teeth, which include the maxillary right first molar, the maxillary left central incisor, the maxillary left first premolar, the mandibular left first molar, the mandibular right central incisor and the mandibular right first premolar. Sterile dental mirrors and explorers were used to assess plaque accumulation and gingival status, and Williams' periodontal probes were used to measure probing pocket depth and CAL. Six representative teeth, and four surfaces (mesio-facial, mid-facial, disto-facial and mid-lingual) of each tooth studied, were assessed and scored for plaque index. Probing pocket depth and CAL were measured at six sites (mesio-facial, mid-facial, disto-facial, mesio-lingual, mid-lingual and disto-lingual) per tooth for all teeth, excluding third molars. The number of decayed teeth, number of filled teeth and number of missing teeth for each participant were recorded according to World Health Organization criteria (35). The mean plaque index, gingival index, probing pocket depth and CAL over all examined surfaces or sites, as well as the percentages of sites with CAL ≥ 3 mm, CAL ≥ 4 mm, probing pocket depth ≥ 3 mm and probing pocket depth ≥ 4 mm were calculated for each participant. The percentage of sites meeting the severity criteria for probing pocket depth and CAL was calculated for each subject by dividing the number of sites meeting the criteria by the total number of sites measured. Periodontitis was defined as the presence of four or more teeth with one site or more with a probing pocket depth of ≥ 4 mm and CAL of ≥ 3 mm. The clinical examiner was trained and calibrated for the clinical examinations 15 d before the start of the study. Intra-examiner reproducibility assessments were carried out in probing pocket depth and CAL examinations, and were assessed by double recordings in 23 subjects. The repeat recordings were made 7 d after the first clinical examination. The intraclass correlation coefficients for the intra-examiner reproducibility were 0.87 for mean probing pocket depth and 0.93 for mean CAL. Considering the intra-rater agreement on the diagnosis of periodontitis, the overall intra-rater percentage of agreement and kappa statistics were 0.91 and 0.81 respectively, indicating a very good agreement.

Statistical analysis

The Statistical Package for Social Sciences software (version 11.5; SPSS Inc., Chicago, IL, USA) was used for data processing and data analysis. Characteristics of subjects' variables were described using frequency distribution for categorical variables, and mean and SD for continuous variables. Chi-square tests were used to assess the association between categorical variables. The multivariate analysis of the differences in periodontal parameters (average probing pocket depth, average CAL and percentage of surfaces with probing pocket depth ≥ 3, probing pocket depth ≥ 4 and CAL ≥ 3), according to HEI groups and physical activity categories, was conducted using the General Linear Model Multivariate procedure. This procedure provided regression analysis and analysis of variance for multiple dependent variables (periodontal parameters) by different explanatory variables and covariates. Multivariate binary logistic regression was conducted to determine the association between physical activity and HEI and the prevalence of periodontal disease after adjusting for statistically important variables in the main-effects model. Variables in the main-effects model were reached using a forward stepwise logistic regression model. The statistical significance of the two-way interactions between independent variables was assessed using forward stepwise regression. The two-way interaction terms, one at a time, were added in the model containing all the main effects and were assessed for their significance using the likelihood ratio test. Crude and adjusted odds ratios and their 95% confidence intervals were calculated. A p-value of < 0.05 was considered statistically significant.

Results

Participants' characteristics

This study included a total of 340 participants (168 men and 172 women; mean age $\pm$ SD: 36.4 ± 14.9 years; range: 18–70 years). Table 1 shows their socio-demographic, anthropometric and relevant characteristics. According to the BMI results, 33.8% were overweight and 30.5% were obese. Half of the participants were not physically active, 31.8% were moderately active and 17.9% were highly active. According to the HEI, 20.3% were classified as having a good diet, 63.8%

Table 1. Socio-demographic, anthropometric and relevant characteristics of participants

Variable	*n* (%)
Gender	
Male	168 (49.4)
Female	172 (50.6)
Age (years)	
≤ 25	127 (37.4)
26–45	113 (33.2)
46–77	100 (29.4)
Years of education	
≤ 12	133 (39.1)
> 12	207 (60.9)
Marital status	
Single	155 (45.6)
Married	185 (54.4)
Monthly family income (JD)[a]	
≤ 400	187 (55.2)
> 400	152 (44.8)
Body mass index	
< 25 kg/m^2	121 (35.6)
Overweight (25–29.9 kg/m^2)	115 (33.8)
Obese (≥ 30 kg/m^2)	104 (30.5)
Healthy eating index	
Good	69 (20.3)
Fair	217 (63.8)
Poor	54 (15.9)
Physical activity	
Low	171 (50.3)
Moderate	108 (31.8)
High	61 (17.9)
Smoking	
Current	69 (20.3)
Past	29 (8.5)
No	242 (71.2)
Brushing	
Daily brushing (at least once daily)	223 (65.6)
No daily brushing	89 (26.2)
No brushing	28 (8.2)
Self-reported conditions	
History of diabetes mellitus	61 (17.9)
History of elevated total cholesterol level	37 (10.9)
History of hypertension	46 (13.5)

[a] JD, The Jordanian Dinar = $1.41.

as having a fair diet and 15.9% as having a poor diet. The dental and periodontal status of participants is shown in Table 2.

Periodontal parameters according to physical activity status

Table 3 shows the dental and periodontal parameters according to physical activity status. Individuals who were highly physically active had a significantly lower average gingival index, average CAL and percentage of sites with CAL > 3 mm compared to individuals with a low level of physical activity and individuals with a moderate level of physical activity.

Table 2. Dental status and periodontal status of participants

Variable	Mean (SD)
Average plaque index	1.44 (0.57)
Average gingival index	1.57 (0.55)
Average PPD	2.00 (0.27)
Average CAL	2.59 (1.01)
Percentage of sites with:	
PPD ≥ 3	26.86 (11.42)
PPD ≥ 4	0.36 (1.86)
CAL ≥ 3	16.93 (21.99)
Number of decayed teeth	2.12 (2.59)
Number of filled teeth	2.03 (2.57)
Number of missing teeth	1.47 (2.91)

CAL, clinical attachment loss; PPD, probing pocket depth.

Periodontal parameters according to the HEI

When categorized according to the HEI, subjects differed in the average number of missing teeth and average CAL (Table 4). Those who had a poor diet had a significantly higher average number of missing teeth and average CAL compared to those who had a good diet.

Prevalence of periodontal disease

The prevalence of periodontal disease according to socio-demographic, oral health parameters, clinical and relevant characteristics are shown in Table 5. Of the 340 subjects examined, 30.9% had periodontal disease. Periodontal disease was present in 17.4% of those who had a good diet, 30.9% of those

Table 3. Dental status and periodontal status according to physical activity

	Physical activity (mean ± SD)			
	Low (*n* = 171)	Moderate (*n* = 108)	High (*n* = 61)	*p*-value
Average plaque index	1.42 ± 0.57	1.53 ± 0.55	1.32 ± 0.58	0.060
Average gingival index	1.61 ± 0.54	1.61 ± 0.56	1.36 ± 0.49	0.005
Average PPD	2.01 ± 0.26	2.04 ± 0.28	1.94 ± 0.26	0.093
Average CAL	2.69 ± 1.04	2.62 ± 1.12	2.18 ± 0.46	0.002
Percentage of sites with:				
PPD ≥ 3	26.51 ± 0.12	28.02 ± 0.12	25.83 ± 0.09	0.431
PPD ≥ 4	0.27 ± 0.01	0.51 ± 0.03	0.32 ± 0.02	0.594
CAL ≥ 3	19.36 ± 0.23	17.75 ± 0.25	8.83 ± 0.10	0.006
Number of decayed teeth	2.01 ± 2.49	2.42 ± 2.75	1.92 ± 2.56	0.367
Number of filled teeth	2.18 ± 2.75	1.77 ± 2.27	2.07 ± 2.54	0.442
Number of missing teeth	1.60 ± 2.67	1.44 ± 2.92	1.14 ± 3.50	0.569

CAL, clinical attachment loss; PPD, probing pocket depth.

Table 4. Dental status and periodontal status according to the healthy eating index (HEI)

	Healthy eating index (mean ± SD)			
	Poor (*n* = 54)	Fair (*n* = 217)	Good (*n* = 69)	*p*-value
Average plaque index	1.41 ± 0.59	1.46 ± 0.56	1.37 ± 0.60	0.512
Average gingival index	1.55 ± 0.59	1.57 ± 0.54	1.55 ± 0.54	0.932
Average PPD	2.01 ± 0.25	2.01 ± 0.27	1.98 ± 0.27	0.783
Average CAL	2.76 ± 1.00	2.65 ± 1.08	2.29 ± 0.67	0.017
Percentage of sites with:				
PPD ≥ 3	27.48 ± 0.11	26.57 ± 0.12	27.33 ± 0.10	0.821
PPD ≥ 4	0.23 ± 0.01	0.37 ± 0.02	0.39 ± 0.02	0.881
CAL ≥ 3	21.09 ± 0.21	17.97 ± 0.24	10.55 ± 0.16	0.211
Number of decayed teeth	2.12 ± 2.48	2.14 ± 2.62	2.08 ± 2.60	0.985
Number of filled teeth	1.72 ± 2.23	2.12 ± 2.65	1.97 ± 2.54	0.601
Number of missing teeth	2.14 ± 3.04	1.58 ± 3.05	0.61 ± 2.13	0.012

CAL, clinical attachment loss; PPD, probing pocket depth.

Table 5. Prevalence of periodontal disease according to socio-demographic, oral health parameters, clinical parameters and relevant characteristics

Variable	Periodontal disease		Total	*p*-Value
	No *n* (%)	Yes *n* (%)		
Gender				
Male	114 (67.9)	54 (32.1)	168	0.619
Female	121 (70.3)	51 (29.7)	172	
Age (years)				
≤ 25	117 (92.1)	10 (7.9)	127	< 0.005
26–45	64 (56.6)	49 (43.4)	113	
46–77	54 (54)	46 (46)	100	
Marital status				
Single	131 (84.5)	24 (15.5)	155	< 0.005
Married	104 (56.2)	81 (43.8)	185	
Monthly family income (JD)[a]				
≤ 400	126 (67.9)	61 (32.6)	187	0.467
> 400	108 (71.1)	44 (28.9)	152	
Years of education				
≤ 12	75 (56.4)	58 (43.6)	133	< 0.005
> 12	160 (77.3)	47 (22.7)	207	
Brushing				
Regular	154 (69.1)	69 (30.9)	223	0.809
Irregular	63 (70.8)	26 (29.2)	89	
No	18 (64.3)	10 (35.7)	28	
Average plaque index				
≤ 1	83 (84.7)	15 (15.3)	98	< 0.005
1–2	119 (63.3)	69 (36.7)	188	
> 2	19 (47.5)	21 (52.5)	40	
Diabetes mellitus				
Yes	34 (55.7)	27 (44.3)	61	0.013
No	201 (72.0)	78 (28.0)	279	
Missing teeth				
No	146 (77.2)	43 (22.8)		< 0.005
Yes	75 (54.7)	62 (45.3)		
Elevated cholesterol level				
Yes	23 (62.2)	14 (37.8)	37	0.332
No	212 (70)	91 (30.0)	303	
Hypertension				
Yes	28 (60.9)	18 (39.1)	46	0.134
No	207 (70.6)	86 (29.4)	293	
Smoking				
Current	46 (66.7)	23 (33.3)	69	0.346
Past	17 (58.6)	12 (41.4)	29	
No	172 (71.1)	70 (28.9)	242	
Physical activity				
Low	105 (61.4)	66 (38.6)	171	0.001
Moderate	77 (71.3)	31 (28.7)	108	
High	53 (86.9)	8 (13.1)	61	
Healthy eating index				
Good	57 (82.6)	12 (17.4)	69	0.001
Fair	150 (69.1)	67 (30.9)	217	
Poor	28 (51.9)	26 (48.1)	54	
Body mass index				
< 25 kg/m^2	104 (86.0)	17 (14.0)	121	< 0.005
Overweight (25–29.9 kg/m^2)	81 (70.4)	34 (29.6)	115	
Obese (≥ 30 kg/m^2)	50 (48.1)	54 (51.9)	104	

[a] JD, The Jordanian Dinar = $1.41.

who had a fair diet and 48.1% of those who had a poor diet. The percentage of participants with periodontitis decreased with increased physical activity (38.6% in those with low physical activity, 28.7% in those with moderate physical activity and 13.1% in those with high physical activity).

Periodontal disease in relation to physical activity and the HEI

In the univariate analysis, people who had a fair diet and those who had a poor diet were more likely to have periodontal disease compared to those who had a good diet. Moderate or low levels of physical activity were associated with increased odds of periodontal disease in the univariate analysis (Table 6). Multivariate analysis revealed that, after adjusting for gender, age, marital status, years of education, BMI, diabetes mellitus, plaque index and number of missing teeth, only subjects who had a low level of physical activity (odds ratio = 3.8) were more likely to have periodontal diseases compared with those who had a high level of physical activity (Table 5). Only subjects who consumed a poor diet had a significantly higher odds of having periodontal disease (odds ratio = 3.5) compared with those who consumed a good diet.

Discussion

Healthy eating has been linked to disease prevention, including heart disease, cancer, diabetes, blood pressure and, most importantly, obesity. More focus was given to obesity because it is not only a disease that affects one's physical and psychological health, but also a risk factor for, and an underlying cause of, many chronic diseases. Very few studies have examined the risk of periodontitis relative to the HEI; rather, most studied individual components of the HEI in relation to the risk of periodontitis. In our study, poor diet was significantly associated with increased odds of periodontal disease. A cross-sectional study conducted by Al-Zahrani *et al*., in which they used secondary data from the third National Health and Nutrition Examination Survey, aimed to investigate the impact of consuming a high-quality diet, undertaking regular exercise and maintaining a healthy weight on the risk reduction of periodontal disease in Americans. Data on 12,110 individuals were retrieved and used in the analysis (24). It was found that individuals who maintained

Table 6. Univariate and multivariate analysis of the association between periodontitis and both physical activity and healthy eating index (HEI)

		Univariate analysis		Multivariate analysis[a]	
	n	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Physical activity					
High	61	1		1	
Moderate	108	2.7 (1.1, 6.3)	0.024	2.0 (0.8, 5.8)	0.091
Low	171	4.2 (1.9, 9.3)	< 0.005	3.8 (1.6, 9.0)	0.005
Healthy eating index					
Good	69	1		1	
Fair	217	2.1 (1.1, 4.2)	0.032	1.1 (0.5, 2.7)	0.488
Poor	54	4.4 (1.9, 10.0)	< 0.005	3.5 (1.3, 8.8)	0.010

[a]Adjusted for gender, age, marital status, years of education, body mass index (BMI), diabetes mellitus, plaque index and number of missing teeth.

healthy eating practices were less likely to have periodontitis compared with individuals who did not. Another study by the same researchers in 2004 aimed to examine the association between the HEI and extent of dental calculus deposits using data on 12,405 individuals who participated in the third National Health and Nutrition Examination Survey (36). After controlling for age, gender, race, education, poverty income ratio, smoking, diabetes, history of vitamin and mineral use, BMI, time elapsed since last dental visit and gingival bleeding, it was found that diet quality correlated with calculus formation. The study revealed that having a poor-quality diet is associated significantly with calculus formation (odds ratio = 1.54) (36). Healthy eating may be associated with lower levels of periodontal disease, either by its impact on obesity or by the higher consumption of whole grains, fruits and dairy products, and lower consumption of cholesterol. One prospective study examined the relationship between wholegrain consumption and periodontal disease (37). Male US health professionals (n = 34,160) were followed up biennially with questionnaires on diet every 4 years by using a validated food-frequency questionnaire. The study found that those who consumed high amounts of whole grains were 23% less likely to have periodontitis, but this association was not significant in the case of refined grain. Milk and dairy products were also tested if they were related to periodontitis risk (38). Al-Zahrani *et al*. showed that the prevalence of periodontitis was 20% lower for participants in the highest quintile of dairy product intake compared to those in the lowest quintile (p = 0.024). Fruit intake appeared to have an impact on periodontal health; Grobler & Blignaut (39) conducted a cross-sectional study of workers on apple-producing, grape-producing (treatment) and grain-producing (control) farms. The researchers found that, after controlling for age, participants in the control group, who had a lower consumption of apples and grapes, had the highest number of dentate sextants with advanced periodontitis (p < 0.01). Low cholesterol content is also a characteristic of healthy diet. In rats, it was found that rats fed high-cholesterol diets had a higher risk of periodontal disease when compared with other groups in the study (40).

Using the HEI as a dietary quality-assessment tool in this study has several benefits. First, unlike the traditional approach of testing the effect of a single nutrient or an individual food on the risk of a disease, the HEI allows a more comprehensive approach. Hence, it is possible to examine nutrient interactions and their combined effect on health outcomes. Second, the HEI has been used in different non-US populations, such as Japan (41), France (42) and Greece (43), like the population in the present study. Moreover, previous investigations of the relationship between the risk of periodontal disease and diet quality used the HEI (24,36). Using the same tools makes the discussion of our results in light of the literature more valid. However, the most appropriate tool for diet quality-assessment is an issue of controversy. Researchers at the Harvard School of Public Health reported an association between HEI scores and reduction in risk of cardiovascular disease and no association with the risk of cancer (44–46). By contrast, others found a strong correlation between HEI scores and plasma antioxidant levels, a strong contributor to cancer prevention (32).

The limitations of the HEI stem from the limitations of the USDA food guide pyramid and the dietary guidelines for Americans, especially with issues raised by nutrition scientists who are debating whether the existing dietary guidelines describe an optimal diet (44,45). Others guidelines, such as the Healthy Eating Pyramid (which focuses on whole grains, plant oils, fruits and vegetables) may provide a more promising tool for predicting the risk of diseases.

In regard to the association between periodontal disease and physical activity, our results were consistent with the results of Al-Zahrani *et al*. (24). They conducted a study on health-enhancing behaviors (i.e. maintaining a normal weight, being physically active and eating a high-quality diet). It was found that individuals who maintained those behaviors were 40% less likely to have periodontitis compared to individuals who performed none of these behaviors. They also concluded that having a healthy lifestyle is associated with a lower prevalence of periodontitis.

In another study, the same investigators studied the relationship between periodontal disease and physical activity solely (9). They used secondary data from individuals (n = 2521) who were engaged in the third National Health and Nutrition Examination Survey. They included participants who were ≥ 18 years of age, had a periodontal examination and were reported to have had a similar physical activity (or inactivity) level for 10 years or longer. After controlling for gender, race, education, smoking, BMI, poverty index, vitamin use, healthy eating index, time since last dental visit, gingival bleeding and dental calculus, the

prevalence of periodontitis was higher among inactive individuals (25.2%) than among partially active individuals (16.9%) and those who met the recommended level of exercise (13.0%). The pathophysiological mechanism of action between physical activity and periodontal disease has not been clearly elucidated. However, this relationship may be explained by the underlying adiposity and insulin resistance in individuals with a low level of physical activity. The association between insulin resistance and periodontal disease is a matter of conflict in the scientific community. The direction of the relationship between insulin resistance and periodontal disease is controversial (47). In a cross-sectional study conducted on a convenience sample of 12 obese men with untreated Type 2 diabetes mellitus and six obese controls (matched in age and BMI), the serum concentration of tumor necrosis factor-α (TNF-α) was analyzed. It was found that the serum levels of TNF-α were higher in patients with insulin resistance than in patients without insulin resistance (48). Another study investigated this relationship using three groups of participants; the treatment group consisted of obese patients with Type 2 diabetes mellitus ($n = 12$), the control group consisted of normal subjects ($n = 12$) and another control group consisted of nonobese patients with Type 2 diabetes mellitus ($n = 12$). Patients with Type 2 diabetes mellitus were assigned to a 4-wk program of diet and exercise. At baseline, the serum levels of TNF-α in the treatment group were higher than those observed in the control groups ($p < 0.01$). The serum levels of TNF-α were significantly lower in the obese patients with Type 2 diabetes mellitus after the treatment ($p < 0.01$), while those in the nonobese patients with Type 2 diabetes mellitus were unchanged (49). Another study documented declining TNF levels following a weight-loss regimen and improved insulin sensitivity (50). The study was conducted on 19 obese and 10 lean men. Obese participants were given an energy-restricted diet. The plasma levels of TNF-α were analyzed and insulin sensitivity was assessed. During the intervention, the plasma levels of TNF-α and interleukin-6 decreased by 25–30% ($p < 0.001$).

Unexpectedly, our results showed that the association between periodontal disease and smoking was not significant. This finding might be explained by the fact that categorizing subjects as smokers or nonsmokers, which is often used in clinical studies, may not be sufficient to evaluate the role of smoking in the prevalence and severity of periodontal disease. This is because smokers represent a highly heterogeneous group of subjects. Therefore, a quantitative and more objective method to describe such a group provides a better analytical tool with which to evaluate the association between smoking and periodontal disease.

There are some limitations inherent in this study. The cross-sectional studies have their own limitations, because little information is available about the pattern of disease progression during the short period of the study; nevertheless, periodontal disease progresses in a chronic pattern. Our cross-sectional study design lacked information on the time sequence of events and so did not permit identification of the causal relationship. To evaluate, in greater detail, the relationship between periodontal disease and physical activity and quality of diet, prospective longitudinal studies are needed. Finally, the problem of imperfect measurement of confounders can exist. However, it is not a serious problem because adjustments were made for the major confounders.

In conclusion, a low level of physical activity and a poor diet were significantly associated with increased odds of periodontal disease. Further studies are needed understand this relationship in greater detail.

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