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*Association between sleep and severe periodontitis in
a nationally representative adult US population.*

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Summary

Drs. Hend Alqaderi, J. Max Goodson, and Israel Agaku conducted a cross-sectional national study of a U.S. population that would show if there is an association between the duration of sleep and severe periodontal disease. This study used data from a 2013-2014 U.S NHANES survey; using 3,624 participants, 30 years and older with and without a pre-existing systemic disease (diabetes), has no history or is a current smoker and sleeps ≥ 7 hours a night without difficulty and those that sleep < 7 hours a night. Participants risk indicators of race, sex, education level, and socioeconomical status varied. This study concludes that participants with who had a shorter sleep duration due to sleeping troubles had severe periodontitis, and the presents of diabetes increased the likelihood of periodontal disease, whereas participants with longer sleep duration were less likely to have severe periodontal disease. Participants with diabetes that had long sleep duration decreased their risk of severe periodontal disease; Other risk indicators were also contributors to periodontal disease. Healthy subjects are too at risk for periodontal disease when sleep is decreased.

Impression

I found this article very interesting, I wanted to know if there was a significant link between a lack of sleep and periodontal disease. This study mostly showed a stronger link to sleep duration to periodontal disease with those who have diabetes, but there is an association of sleep duration and its effects on the circadian rhythm and that ultimately could disrupt the ones release of melatonin, hormones secretion, and systemic inflammation. The conductors of this study would like to continue with more longitudinal studies and one question I'd like answered would be does the severity of brushing and flossing before bed have a difference in the outcome of the extent of Periodontal disease on healthy and diabetic individuals.

[Journal of Periodontology](#)

ORIGINAL ARTICLE

Full Access

Association between sleep and severe periodontitis in a nationally representative adult US population

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Abstract

Background

Poor sleep behavior appears to have adverse effects on health by metabolic disruption and immunity suppression. Sleep disturbance is strongly associated with diabetes, cardiovascular diseases, and some cancers. This study aimed to evaluate the association between sleep duration and periodontal disease in a national US population study in a National Health and Nutrition Examination Survey (NHANES).

Methods

The data were collected from individuals aged ≥ 30 years and included 3,624 participants in the United States NHANES 2013 to 2014. A weighted multivariable logistic regression modeling

quantified the association between sleep and severe periodontal disease. We tested for diabetes as an effect modifier, adjusting for potential confounders such as smoking status, sex, age, education level, and dental visit.

Results

Individuals who sleep >7 hours/night with no trouble sleeping are 40% less likely to have severe periodontal disease (odds ratio [OR] = 0.6, $P < 0.05$), adjusting for age, sex, smoking status, FPL, education level, and dental visit. Additionally, diabetes was a significant positive effect modifier of the relationship between sleep and severe periodontal disease (OR = 4.8, $P < 0.05$).

Conclusions

Findings of this cross-sectional representative study of an adult US population revealed a statistically significant association between sleep duration and severe periodontitis. In this study, individuals who slept >7 hours/night were less likely to exhibit severe periodontal disease. It also seems that this relationship was stronger among individuals with diabetes compared with individuals without diabetes.

1 INTRODUCTION

Insufficient sleep is a well-established risk factor that negatively affects daytime functioning and contributes to the progression of several chronic conditions **1 such as diabetes, cardiovascular, and other inflammatory disorders.2-4**

Recent studies show that healthy sleep behavior supports the immune system by regulating the defense mechanism against pathogens. **5 Additionally, sleep curtailment is associated with insulin resistance and glucose intolerance due to hormonal disruption.6 Glucose intolerance is a causal risk factor for endothelial inflammation in both diabetic and non-diabetic individuals, compromising microvasculature and impairing wound healing.7 A study of 30 sleep-deprived adults who slept at 3 am to 7 am found significantly higher levels of monocyte production of interleukin-6 and tumor necrosis factor-alpha.8 Another study on healthy subjects found that one night of sleep loss stimulates interleukin-1 beta and interleukin-1 receptor antagonist.9 It seems that short sleep duration has a potential systemic inflammatory effect that might subject endothelial tissue to bacterial infection.**

We hypothesize that adequate sleep duration could be protective from severe periodontal disease as influenced by metabolic regulation and host immune response.

We also hypothesize that the effect of sleep duration could affect both individuals with and without diabetes differently, giving the fact that diabetes can intensify the

association between sleep and severe periodontal disease. In addition, we examined whether smoking status is related to the association between sleep duration and periodontal disease.

A substantial body of evidence reports that adequate night sleep regulates insulin balance through circadian system processes **10 and that sleep deprivation is strongly related to glucose intolerance.7, 11**

There is an active link between sleep disorder, glucose intolerance, and systemic inflammation in patients without diabetes. **7, 11 Periodontal destruction is associated with an inflammatory process of the supporting tooth structure, and is a product of bacterial infection and immune host response.12 Periodontal disease is characterized by gingival inflammation, periodontal pocket formation, loss of connective tissue attachment, and alveolar bone destruction, ultimately resulting in tooth loss.13, 14**

Evidence over the years shows that periodontal disease is strongly related to diabetes mellitus due to compromised microvasculature and inadequate host immune response. **15 Studies showed that the existing cell-mediated immune responses in the periodontium are critical to causing damage to host tissue via immune or inflammatory interactions.16 Both hormonal and cell-mediated immune responses play important roles in the host defense against microbial infectious disease such as periodontal diseases.17**

The purpose of this analysis was to investigate the cross-sectional association between sleep duration and severe periodontitis, mediated by diabetes. We used the National Health and Nutritional Examination Survey (NHANES, 2013 to 2014), to obtain a representative sample of the US population. The reason we used the 2013 to 2014 data set is that this is the latest data that included a periodontal examination.

It is important to note that a study published by Wiener used the NHANES data set of 2011 to 2012 and failed to detect a significant relationship between sleep duration and periodontal disease. **18 Our study is different because we restricted our analysis to subjects with severe periodontitis, while the analysis of Wiener included subjects with any level of periodontal disease.18 In addition, we aimed to determine the effect of diabetes on the relationship between sleep duration and severe periodontitis.**

2 MATERIALS AND METHODS

2.1 Study population

This study used the public-use NHANES cross-sectional survey for years 2013 to 2014, in compliance with the Data Use Restrictions for data collected by the National Center for Health Statistics, Centers for Disease Control and Prevention.¹⁹ **The NHANES is a rich source of health/disease and risk factor data representative of the US population, obtained from a well-designed and well-conducted study starting from 1999. NHANES is a complex, multistage, stratified, clustered sample of the civilian, non-institutionalized US population, representing the US population. The NHANES includes a questionnaire, laboratory assays, and clinical examination measures of health outcomes and explanatory variables.**

Nearly 5,000 participants of all ages were interviewed in their homes and received a health examination in Mobile Examination Centers. Dental surveys, including full-mouth periodontal examination involving participants' aged ≥ 30 years, were conducted by calibrated dental providers on the mobile examination centers.

Details on NHANES methodology, the oral health exams and questionnaires, and related data quality assurance can be found elsewhere.¹⁹

2.2 Description of the dependent variable

2.2.1 Periodontal examination

The NHANES study of 2013 to 2014 was conducted using a full-mouth periodontal examination (FMPE) among individuals aged ≥ 30 years who did not have a health condition that required antibiotic prophylaxis before periodontal testing. The FMPE was conducted with the intent to produce gold-standard assessments for clinical attachment loss (AL). For this reason, direct measurements of both the distance between the cemento-enamel junction and the free gingival margin (CEJ-FGM) and the probing depth (PD) were measured at each site. All measurements were taken at six sites (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual) of all teeth with the exclusion of third molars. All calculations were rounded to the lower whole millimeter. Clinical AL was calculated based on these two measurements.

2.2.2 Definition of the dependent variable: Severe periodontal disease

The outcome variable was defined as any individual with severe periodontal disease.²⁰ **Severe periodontal disease was defined and coded as an individual having ≥ 2**

interproximal sites with ≥ 6 mm of loss of attachment not on the same tooth, and ≥ 1 interproximal sites with probing depths of ≥ 5 mm.

2.2.3 Description of independent and potentially confounding variables

Sleep duration

The primary exposure variable, sleep duration, was defined as a binary variable, and was coded using two sleep habit questions: 1) How much sleep do you usually get at night on weekdays or workdays? Also, 2) Have you ever been told by a doctor that you have trouble sleeping.

The recommended daily sleep hours for adults are ≥ 7 hours per night.**21, 22 If the subjects answered that they usually get >7 hours/night, and if the subjects responded that they never told their doctor of their difficulty in sleeping, they were placed in the category of "sleep duration >7 hours/night," otherwise, they would be placed in the category of "sleep duration ≤ 7 hours/night."**

2.2.4 The potential confounding or effect modifier variables

Diabetes

This variable was binary. Each was asked; have you ever been told by a doctor or health professional that you have diabetes or sugar diabetes? The responses were one of the following: no, yes, or borderline. Each response was dichotomized to one of two categories: "no" and either "yes" or "borderline." Given the fact that "borderline" might indicate a pre-diabetic status.

Smoking status

From participants' responses to the smoking questions administered in the household interview, smoking status was defined as current and never smokers.**23 Current smokers were defined as adults who reported that they smoked ≥ 100 cigarettes in their lifetime, and they currently smoke every day or some days. Non-smokers were defined as adults who reported that they have never smoked 100 cigarettes in their lifetime.**

Age in years was categorized into four groups: 30 to 34 years, 35 to 49 years, 50 to 64, and ≥ 65 years. Sex was a binary variable as males and females. Education level variable was categorized as 0 to 11th grade, high school graduates, or equivalent, and high school or above.

Race variable was categorized as Mexican-American, white, black, or others. We used the ratio of income to federal poverty level (FPL) to indicate the financial status; this

variable was categorized as <100% FPL, 100% to 199% FPL, 200% to 399% FPL, and \geq 400% FPL. Dental visit variable includes four categories of the responses of the question: About how long has it been since you last visited a dentist? Include all types of dentists, such as orthodontists, oral surgeons, and all other dental specialists, as well as dental hygienists. The responses were one of the following: \leq 6 months, >6 months but not >1 year ago, >1 year but not >2 years ago, >2 years ago or never.

2.3 Statistical methods

We conducted multivariate binary logistic regression modeling to test the hypotheses that sleeping >7 hours might be protective from severe periodontal disease, adjusting for smoking status, age, sex, dental visits, and education level. To determine the effect of diabetes on the relationship between sleep and severe periodontal disease, we created an interaction term variable of the main effect of "sleep" variable with "diabetes" variable to examine the effect of diabetes on the relationship between sleep and periodontal disease. Similarly, we created an interaction term variable of "sleep" variable with "smoking" variable. We also compared the crude and the adjusted odds ratio of both diabetes and smoking status. By this comparison, we assess whether these factors are confounding factors in the relationship between severe periodontitis and sleep duration. Analyses were conducted using survey weights and to account for the sampling design to produce representative estimates for the United States. All analyses were performed using STAT 12 software, considering the significance level of 0.05.

3 RESULTS

Table [1 demonstrates the descriptive summary of the population characteristic comparing individuals with severe periodontal disease to individuals with no severe periodontal disease](#) (*P* values determined using the Chi-square test). Among the 3,624 individuals in the sample, 317 (8.7%) had severe periodontal disease; 73.2% of the individuals who exhibited severe periodontal disease reported short sleep duration (\leq 7 hours) with a problem sleeping. Ninety percent (90.2%) of those who did not demonstrate severe periodontal disease did not have diabetes. Forty-nine percent of individuals classified with severe periodontitis were current smokers, whereas 52% of individuals classified as having no severe periodontitis were non-smokers.

Table 1. Descriptive summary of the population characteristics with and without severe periodontal disease

Group	Independent variable	Severe active periodontal disease (n = 317)		No severe active periodontal disease (n = 3,307)		Total (n = 3,624)	P value
Sleep duration	>7 hours/night	85	26.8%	1,013	30.6%	1,098(30.3%)	0.1
	≤7 hours/night	232	73.2%	2,294	69.4%	2,526(69.7%)	
Diabetes	Diabetic or borderline	35	11%	325	9.8%	360(9.9%)	0.4
	Not diabetic	282	89%	2,978	90.2	3,260(90.1%)	
Smoking status	Current smokers	58	49%	572	47.3%	630(47.4%)	0.6
	Non-smokers	60	51%	638	52.7%	698(52.6%)	
Age	30 to 34	13	4.1%	440	13.3%	453(12.50)	<0.001
	35 to 49	71	22.4%	1,186	35.9%	1,257(34.69)	
	50 to 64	160	50.4%	963	29%	1,123(30.99)	
	≥65	73	23.1%	718	21.7%	791(21.83)	
Sex	Males	216	68.1%	1,539	46.5%	1,755(48.43)	<0.001
	Females	101	31.9%	1,768	53.5%	1,869(51.57)	
Race	Mexican-American	86	27.1%	727	22%	813(22.4%)	<0.001
	White	193	29.3%	1,472	44.5%	1,565(43.2)	
	Black	105	33.1%	602	18.2%	707(19.5%)	
	Other	33	10.4%	506	15.3%	539(14.87)	
Federal poverty level	<100%	95	33.3%	543	17.7%	638(19.1%)	<0.001
	100% to 199%	81	28.4%	735	24%	816(24.4%)	
	200% to 399%	75	26.3%	833	27%	908(27.1%)	

	≥400%	34	11.9%	951	31.1%	985(29.4%)	
Dental visit frequency. Last dental visit is:	≤6 months	161	50.7%	1,577	47.7%	1,738(48%)	0.6
	>6 months but not >1 year ago	47	14.8%	481	14.5%	528(14.6%)	
	>1 year but not >2 years ago	32	10.1%	326	9.9%	358(10%)	
	Last dental visit: >2 years, or never	77	24.3%	917	27.8%	994(27.4%)	
Education level	0 to 11th grade	116	36.5%	599	18%	715(19.7%)	<0.001
	High school graduate/GE D	97	30.6%	689	21%	786(21.7%)	
	High school or above	104	33%	2017	61%	2,121(58.5%)	

- Sleep duration = sleep >7hours/night with no problem with sleeping, or otherwise. FPL = federal poverty level. Current smokers = smoked 100 cigarettes and they currently smoke every day or some days.

Males exhibited greater severity of periodontal disease (68.1%) compared with females (31.9%). Individuals aged 50 to 64 years had the highest prevalence of severe periodontal disease (50.4%) compared with other age groups. Other demographic characteristics are presented in Table [1](#).

The present study (Table [2](#)) **indicates that individuals who slept >7 hours/night with no trouble sleeping are 40% less likely to have severe periodontal disease (odds ratio [OR] = 0.6, P < 0.05)**. Additionally, there is a significant positive effect of diabetes on the relationship between sleep and severe periodontal disease (OR = 4.8, P = 0.01), that is, diabetes is a significant effect modifier that intensifies the relationship between

sleep and severe periodontal disease. There was no difference between the crude and the adjusted OR for diabetes, indicating that diabetes is not a confounding factor in the relationship between severe periodontitis and sleep duration.

Table 2. Multiple logistic regression model for the association between severe periodontal disease with sleep duration: The United States, 2013 to 2014

Independent variables	Adjusted odds ratio (<i>P</i> value)	95% confidence interval
Sleep duration	0.6 (0.008)* <u>‡</u>	0.3 to 1.3
Diabetes	0.9 (0.8)	0.5 to 1.8
Sleep diabetes (interaction term) <u>‡</u>	4.8 (0.01)* <u>‡</u>	1.4 to 15.8
Smoking status (reference: non-smoker)	0.1 (0.8)	0.5 to 1.9
Sex (reference: male)	0.4 (<0.001)* <u>‡</u>	0.2 to 0.6
Age, years (reference: age 30 to 34)		
35 to 49	2.6 (0.02)* <u>‡</u>	1.2 to 5.7
50 to 64	6.1 (0.001)* <u>‡</u>	2.5 to 14.8
≥65	3.0 (0.01)* <u>‡</u>	1.2 to 7.3
Education level (reference: 0 to 11th grade)		
High school graduate or equivalent	0.7 (0.3)	0.4 to 1.3
High school or above	0.2 (<0.001)* <u>‡</u>	0.1 to 0.4
Last dental visit (reference: ≤6 months)		
>6 months but not >1 year ago	0.8 (0.5)	0.5 to 1.4
>1 year but not >2 years ago	0.9 (0.8)	0.5 to 1.6
>2 years or never	0.8 (0.4)	0.5 to 1.3
FPL (Reference: <100% FPL)		
100% to 199%	0.8 (0.4)	0.6 to 1.2
200% to 399%	0.5 (0.04)* <u>‡</u>	0.3 to 0.9
400%	0.2 (0.002)* <u>‡</u>	0.1 to 0.5

- **P* value <0.05.
- †The interaction variable between sleep duration and diabetic status.

When testing for smoking effect, smoking status was not an effect modifier nor a confounding factor in the relationship between periodontal diseases and sleep duration.

Individuals with a high school degree and above were less likely to exhibit severe periodontitis than those with less education (OR = 0.2, $P < 0.001$).

Older individuals were more likely to demonstrate periodontal disease than individuals' aged 30 to 34 years (OR = 2.6, $P = 0.02$), individuals aged 50 to 64 (OR = 6.1, $P < 0.01$), and individuals ≥ 65 years (OR = 3.0, $P = 0.01$).

Individuals living at extreme FPL also had significantly greater periodontal disease. Although those with an FPL of 100% to 199% did not have significantly higher periodontal disease (OR = 0.8, $P = 0.4$), those with an FPL of 200% to 399% (OR = 0.5, $P = 0.04$) and $\geq 400\%$ (OR = 0.2, $P < 0.01$) both had significantly greater periodontal disease. Frequency of dental visits was not significantly related to periodontal disease.

4 DISCUSSION

In this study, we have shown that individuals who sleep >7 hours/night and who have never reported having trouble sleeping were less likely to exhibit severe periodontal disease (OR = 0.6, $P < 0.05$). More importantly, when we tested diabetes as an effect modifier on the relationship between sleep and severe periodontal disease, we found that diabetes modifies this association. The result of the assessment of effect modification by diabetes status shows that individuals with diabetes who slept longer had decreased risk of developing severe periodontitis. The clinical motivation behind the evaluation of effect modification is to identify whether the impact of sleep duration is different in diabetic versus non-diabetic individuals, given the link between sleep, diabetes, and periodontal disease.**7, 11, 15, 24 By obtaining a significant positive odds ratio (OR = 4.8, $P = 0.01$) due to interaction between sleep and diabetes, we found that the likelihood of exhibiting severe periodontitis was five times higher among individuals with diabetes than the likelihood expressed among those without diabetes. Findings of this study indicate that sleep duration could be related to periodontal disease through glucose intolerance, particularly in individuals with diabetes, due to compromised immune response. Night sleep deprivation disrupts circadian rhythm, which ultimately results in significant delays of melatonin secretion.² The melatonin hormone is released by the pineal gland during night sleep and is responsible for regulating insulin secretion.² Insufficient night sleep reduces melatonin and insulin secretion, resulting in consequent insulin resistance and glucose intolerance.²⁴ This suggests that increased glucose levels could cause complications, especially in individuals with diabetes. There is considerable evidence that diabetes is strongly related to periodontal disease,¹⁵ and that sleep**

disturbance is a causal risk factor for diabetes.²⁵ Insufficient night sleep influences insulin resistance and glucose intolerance, resulting in compromised microvasculature and endothelial damage.^{15, 24} Inflammation is enhanced in patients with hyperglycemia indexed by the higher level of inflammatory mediators. Specifically, the cytokine TNF-alpha has been demonstrated to play a major role in the process of periodontal destruction.²⁶ These mediators reduce the ability of the host cells to kill bacteria, which may explain the lower capacity of tissue healing and repair in patients with glucose intolerance⁷ that might result in gingival inflammation and consequent periodontal diseases. Periodontitis is a multifactorial disease; dental plaque, oral hygiene habits, socioeconomic status, and the systemic/immune condition can influence the severity of periodontitis.²⁷ Periodontal disease is a treatable and reversible disease that shares common risk factors with systemic disease conditions.²⁸ Sleep can be one of the other risk factors of gingival inflammation triggered by glucose intolerance.²⁹ Evaluation of the risk factors for diabetes reveals that the risk of developing diabetes associated with sleep disturbances is comparable with that of conventional risk factors such as diet and physical activity, and should be considered a clinical guideline for type 2 diabetes screening.³⁰ Recent evidence suggests the role of diminished sleep in promoting inflammation and tissue damage through compromising immunity and disturbing glucose metabolism.⁵

A study among healthy subjects showed that intentionally delaying night sleep and disturbing circadian rhythm resulted in hyperglycemia.³¹ **Moreover, considerable evidence indicates that insufficient sleep can trigger inflammation in different body organs due to hormonal disruption.³² Experimental trials found that night sleep deprivation suppresses immunity, observed by increased cytokines inflammatory markers, with a dose-response relationship.⁵ Immune impairment by insufficient night's sleep is suggested by the poor antibody response to flu and hepatitis vaccines observed in subjects deprived of sleep.^{33, 34}**

A recent longitudinal study has shown that children who slept fewer night hours, and children with higher glucose levels were more susceptible to develop gingival inflammation. This observation suggests that reduced sleep seems to be associated with gingival inflammation triggered by hyperglycemia.²⁹

The relationship between high blood glucose levels and increased gingivitis has been observed by others.¹¹ **It follows that sleep disturbance can produce hyperglycemia**

that creates glucose intolerance, augmented gingival inflammation, and tissue damage that may precede periodontitis. Our present study supports these findings of the protective effect of healthy sleep habit on periodontal disease, mediated by the level of diabetes.

Several investigators have reported the relationship between sleep and periodontal disease. A study conducted in India with 60 subjects revealed a statistically significant relationship between the level of sleep deprivation and the severity of periodontal disease.**35 Another study of 99 subjects conducted in Turkey showed that the grade of periodontitis was associated with short sleep duration and low sleep quality.36 On the other hand, three cross-sectional studies were published using the Korean NHANES (KNHANES) 2012, failed to detect a relationship between short sleep duration and periodontal disease, instead these three studies reported that long sleep duration was associated with periodontal disease.18, 37, 38 It is worth mentioning that these three KNHANES studies used different measurements of periodontitis. The presence of periodontitis in the KNHANES was defined as at least two interproximal sites with an attachment loss of at least 3 mm and at least two interproximal sites with probing depths of at least 4 mm, which are not on the same tooth or at least one site with a probing depth of at least 5 mm. In our study, we restricted the analysis to only severe periodontal disease.**

Additionally, a meta-analysis published in 2015 showed some evidence of the association, but not a causal effect, between periodontal disease and Obstructive Sleep Apnea (OSA).**39 In addition to the studies included in the meta-analysis, and regardless of the variation in measuring periodontitis and OSA, recent studies reported consistent results that OSA is associated with periodontal disease.40, 41 Because both conditions are related to systemic inflammation, it is plausible that OSA influences the activation of inflammatory pathways in periodontal inflammation or vice versa.40 Sleep behavior has a critical influence on metabolic health and immunity.42 There is a strong link between periodontal disease with immune reaction and metabolic regulation.**

4.1 Smoking, sleep, and periodontal disease

In this analysis, we failed to detect a significant effect of smoking status on the relationship between severe periodontal disease and sleep duration. Lack of sleep quality data might contribute to this finding. Most of the published studies on the relationship between smoking and sleep used sleep quality data along with the sleep

quantity data. A study among 6,400 participants of the Sleep Heart Health Study (the United States, 1994 to 1999) found no differences in sleep architecture between former and never smokers; however, they suggested that acute withdrawal from nicotine in cigarette smoke may contribute to disturbances in sleep architecture.⁴³ **Compared with non-smokers, Jaehne et al., 2012 reported that smokers showed insomnia-like sleep impairments, but no differences in sleep disorder parameters, as well as in the sleep efficiency measured by polysomnography between smokers and non-smokers.**⁴⁴ **A cohort of 10th graders in the United States shows that the associations between smoking and sleep problems exist, but these associations were different between non-Hispanic black and non-Hispanic white youth, and they recommend that sleep problems intervention studies should include smoking as a secondary outcome to better understand how intervening on one behavior could influence other behavior.**⁴⁵ **There is emerging evidence showing that poor sleep quality is associated with smoking status.**^{46, 47} **A study of adults aged ≥20 years from the 2005 to 2006 National Health and Nutrition Examination Survey, found that current smokers reported significantly more sleep difficulties than non-smokers.**²³ **Similarly, a study among Chinese adolescents found that adolescents with poor sleep quality were more likely to smoke.**⁴⁷

On the other hand, the evidence on the relationship between smoking and periodontal disease is clear and well-established. Cigarette smoking increases the incidence, severity, and progression of periodontal diseases,^{37, 48} **indexed by the nicotine and chemicals effect that diminish the attachment and augmentation of gingival fibroblasts and periodontal ligament cells.**^{49, 50}

5 Conclusions

This study suggests a protective effect of healthy sleep hours (>7 hours/night) on severe periodontal disease, and this relationship is stronger among individuals with diabetes. It appears that individuals with diabetes benefit more from the protective effect of healthy sleep on periodontal disease.

These understandings may help in the development of new preventive and therapeutic approaches against periodontal disease by enhancing the quality of sleep behavior. However, further prospective longitudinal studies are needed for better assessment of the protective effect of sleep behavior on periodontal disease.

The self-reported questions might be susceptible to reporting bias. The cross-sectional design of the current study allows only measuring the association but not the causation between sleep duration and severe periodontal disease. Moreover, the relationship between sleep duration and periodontal disease could be influenced by other factors such as medical conditions, body weight, and certain hormones. Finally, the findings of this study apply to only the adult US population in 2014. Future studies should consider collecting data on sleep quality and not only sleep quantity to understand the effect of sleep on oral health better. Future studies should also consider prospective intervention and longitudinal data collection to infer the causal relationship of sleep quantity and quality on periodontal health, using objective, unbiased measures and accounting for smoking and other possible confounding factors.

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AUTHOR CONTRIBUTION

Hend Alqaderi designed the study, contributed to data analysis, took the lead in writing the manuscript, and were in charge of overall direction and planning; J. Max Goodson contributed to data analysis, contributed to the interpretation of the results, and critically revised the manuscript; Israel Agaku contributed in the study design, carry out the statistical coding, and verified the analytical methods. All authors provided critical feedback and helped shape the research, analysis and manuscript, and gave final approval and agreed to be accountable for all aspects of the work.

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