BMC Oral Health

RESEARCH

Open Access

Association between the indicators of insulin resistance and periodontitis: a study using data from the National Health and Nutrition Examination Survey 2009–2014

Yiyuan Lang[1,2*†], Xin Song[1†], Yan Chen[1], Han Mei[1,2], Chengyu Wu[1], Rui Zhang[1*] and Changao Xue[1,2*]

Abstract

Background The rising obesity rates are accompanied by an increasing prevalence of insulin resistance (IR) associated with obesity. To ascertain the best index for replacing IR, this study aimed to investigate the possible association between IR, which was assessed using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), and the triglyceride–glucose (TyG) index and its derived indexes and periodontitis.

Methods The association between the indicators of IR and periodontitis was assessed via multivariate-adjusted logistic regression analyses using data from the National Health and Nutrition Examination Survey (NHANES) 2009–2014. In addition, subgroup analyses and receiver operating characteristic curve analyses were conducted to explore possible influencing factors.

Results Our study encompassed 1,588 participants, and 41.0% were diagnosed with periodontitis. Based on the multivariate logistic regression analysis, a higher TyG-waist-to-height ratio (WHtR) (odds ratio [OR] = 1.14, 95% confidence interval [CI]: 1.02–1.27, P = 0.0244) and HOMA-IR score (OR = 1.00, 95% CI: 1.00–1.00, P = 0.0028) were associated with an increased risk of periodontitis. Conversely, the TyG index, TyG-adjusted for body mass index, and TyG-adjusted for waist circumference (WC) were not associated with periodontitis. According to further subgroup analyses and interaction result analyses, sex affected the association between the TyG index, TyG-WC, and TyG-WHtR and periodontitis (P < 0.05 for interaction). Moreover, the influence of age regulated the association between periodontitis and both TyG and HOMA-IR score. In terms of diagnostic accuracy, the area under the receiver operating characteristic curve analysis revealed that HOMA-IR score and TyG-WHtR slightly outperformed the TyG index, TyG-body mass index, and TyG-WC. Thus, they can be robust markers for assessing IR-related periodontitis risk.

Conclusion A consistent and positive association was found between HOMA-IR score and TyG-WHtR and the odds of periodontitis prevalence. Hence, HOMA-IR score and TyG-WHtR were significantly associated with periodontitis

†Yiyuan Lang and Xin Song contributed equally to this work.

*Correspondence:
Yiyuan Lang
dentistyylang@gmail.com
Rui Zhang
dentistzr@163.com
Changao Xue
xuechangao@162.com
Full list of author information is available at the end of the article

in this cross-sectional study. However, prospective studies are needed to determine whether higher TyG-waist-to-height ratio and HOMA-IR score can predict the occurrence of periodontitis.

Keywords TyG-related indicators, Periodontitis, NHANES, Relationship, A cross-sectional study

Introduction

Periodontal diseases are among the most prevalent chronic inflammatory conditions affecting the oral cavity worldwide [14, 39]. According to the Global Burden of Disease 2015 study, the prevalence rate of severe periodontitis is approximately 7.4%. The prevalence of milder types of periodontitis can be as high as 50% [41]. Periodontitis can lead to tooth loss, pronunciation disorders, and aesthetic issues [35] and can significantly affect a person's quality of life [23]. Therefore, early periodontitis diagnosis and treatment are essential.

As far as the current research is concerned, patients and physicians only notice periodontitis until after symptoms such as loose teeth and tooth loss have occurred [37]. Further, there is still a significant challenge in establishing reliable and universally accepted biomarkers for early diagnosis [13]. Blood tests and body mass index measurement are part of routine medical examinations. Diabetes has been established as a risk factor for the development of periodontitis [34]. Insulin resistance (IR), a precursor to diabetes, contributes to periodontitis by increasing pro-inflammatory cytokines such as interleukin-6 and tumor necrosis factor-alpha [44, 51]. IR, which is characterized by decreased sensitivity and responsiveness to insulin, is a hallmark of type 2 diabetes, and it even precedes disease onset [12, 3]. The hyperinsulinemic–euglycemic clamp is the gold standard for evaluating IR [45]. However, it is complex and time-consuming. In recent years, a series of novel indicators such as the TyG index and HOMA-IR score have been proposed to be simpler, more cost-effective methods for assessing IR [36]. Several studies have shown that the accuracy of the TyG index in assessing IR is comparable to that of the hyperinsulinemic–euglycemic clamp [21, 31].

Obesity is prevalent worldwide and is strongly associated with various health risks. Previous studies have reported that the combined use of TyG index and obesity-related measures can improve IR detection [10, 17]. By integrating fasting triglyceride levels and glucose concentrations, the TyG index can be a surrogate marker of IR. Moreover, to offer a more comprehensive assessment of an individual's metabolic status, it can be used along with obesity indicators such as body mass index and waist circumference (WC).

To facilitate early periodontitis detection by enhancing the management and control of IR indicators, a cross-sectional study was conducted using data from NHANES 2009–2014. The current study aimed to identify optimal markers for assessing the close association between IR and periodontitis among adult populations in the United States.

Materials and methods

The cross-sectional data were obtained from NHANES, which is a survey conducted by the National Center for Health Statistics to evaluate nutrition and health in the United States. The questionnaire we used was taken from NHANES. All details regarding the study designs and data of NHANES are publicly available at www.cdc.gov/nchs/nhanes/.

Participants

As the Fig. 1 showed, this study utilized data from NHANES 2009–2014, with 30,468 participants completing the demographic survey, laboratory examination, and health condition questionnaire. The exclusion criteria were as follows [48]:

(1) Individuals with missing data on periodontitis ($n=19,804$)
(2) Individuals with missing data on fasting triglyceride ($n=4,951$), fasting glucose ($n=4,045$), and insulin ($n=26$) levels
(3) Individuals with missing data on weight ($n=3$) and WC ($n=40$)
(4) Individuals with missing data on diabetes ($n=4$), hypertension ($n=16$), fasting glucose levels ($n=10$), and alcohol intake ($n=2$)
(5) Pregnant women (n = 9)

Finally, 1,588 participants were enrolled in this research.

Definitions of the TyG index, TyG-WC, TyG-WHtR, TyG-BMI, and HOMA-IR score

The indices used in the current study were defined as follows [10, 28]:

(1) WHtR = WC/height
(2) TyG index = Ln (fasting triglyceride level [mg/dL] × fasting glucose level [mg/dL] / 2).
(3) TyG-BMI = TyG × BMI
(4) TyG-WHtR = TyG × WHtR
(5) TyG-WC = TyG × WC

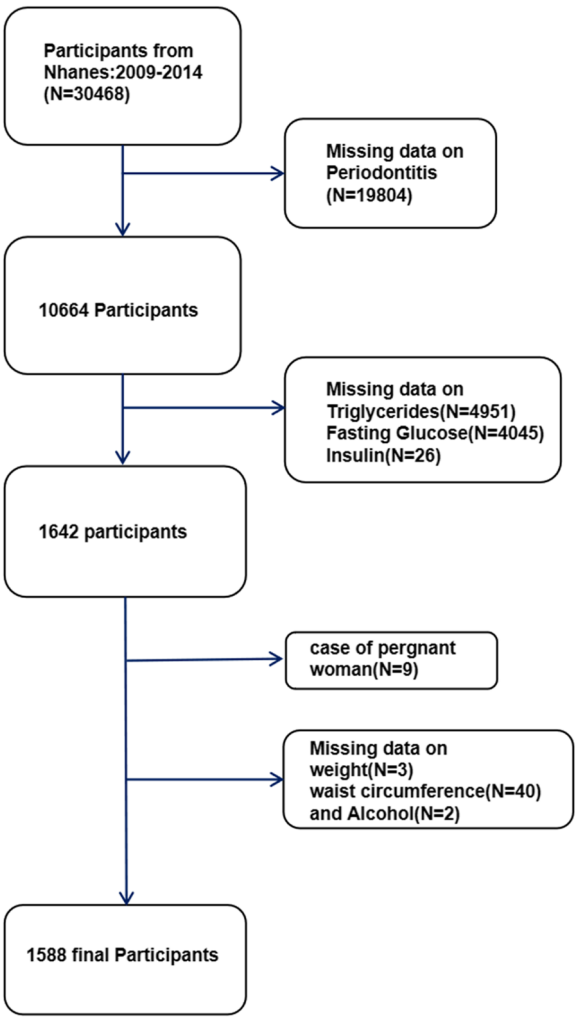

Fig. 1 Flowchart of the sample selection from NHANES 2009–2014

(6) HOMA-IR = fasting insulin level (μU/mL) x fasting glucose level (mmol/L) / 22.5

Definitions of periodontal disease

Periodontitis data were obtained from Oral Health-Periodontal in Examination Data of NHANES 2009–2014 [32]. To define periodontitis, the researchers adopted the Disease Control and Prevention and the American Academy of Periodontology classification [7, 15]. Based on attachment loss (AL) and pocket depth (PD) measurements at four interproximal sites per tooth, the conditions were defined as follows: mild periodontitis, ≥ 2 sites with AL ≥ 3 mm and ≥ 2 sites (nonadjacent) with PD ≥ 4 mm or 1 site with PD ≥ 5 mm; moderate, ≥ 2 sites (nonadjacent) with AL ≥ 4 mm or ≥ 2 sites (nonadjacent) with PD ≥ 5 mm; and severe, ≥ 2 sites (nonadjacent) with AL ≥ 6 mm and ≥ 1 site with PD ≥ 5 mm. In this study, the periodontitis category encompasses mild, moderate, and severe cases.

Covariates

Covariates including age, sex, race/ethnicity, alcohol use, diabetes, and hypertension were selected based on the relevant literature [5, 19]. Alcohol use was defined as the consumption of at least 12 alcoholic drinks per year. Diabetes, smoking status and hypertension were based on self-reported diagnosis by a physician.

Statistical analysis

EmpowerStats version 2.0 (http://www.empowerstats.net/analysis) was used to analyze data from the NHANES 2009–2014 database. Periodontitis was categorized as a dichotomous variable, with or without periodontitis. TyG indicators were expressed as a continuous variable divided into three categories.The continuous covariates were reported using the mean ± standard deviation, while the categorical variables were presented as percentages. The chi-square test or the Student's *t*-test was used to evaluate the P value of the distribution. Multivariate linear regression models were used. One-way and multifactorial logistic regression analyses were performed to assess the odds ratio (OR) and 95% confidence intervals (95% CIs) for the association between HOMA-IR score, TyG index, TyG-WHtR, TyG-WC, and TyG-BMI and periodontitis. Model I was not adjusted for any covariates. Model II was adjusted for age, sex, and race/ethnicity. Model III was adjusted for all factors in Model II, alcohol status, diabetes, smoking status and hypertension. Finally, the receiver operating characteristic (ROC) curves were obtained to assess the diagnostic accuracy of the association between the indicators of IR and the risk of developing periodontitis.

Results

Baseline characteristics of the participants

The current study included 1,588 participants. Approximately 49.62% were men, and 50.38% were women. Further, 56.30% presented with periodontitis, and the average age of the patients was 51.9 years. The participants were categorized based on periodontitis status. Notably, patients with periodontitis had higher TyG indexes and fasting glucose levels and a higher likelihood of cigarette smoking than those without periodontitis (Table 1).

Associations between the indicators of insulin resistance and periodontitis

Our study assessed the association between the five indicators of IR and the risk of developing periodontitis (Table 2). Results revealed a significant association

Table 1 Baseline characteristics of the study population according to periodontitis status

Variables	Patients with NPD (n = 936)	Patients with PD (n = 652)	Total	P value
Age (years, mean ± sd)	49.83 ± 13.80	55.02 ± 13.78	51.96 ± 14.02	< 0.001
Sex, n (%)				< 0.001
Male	414 (44.23%)	374 (57.36%)	788 (49.62%)	
Female	522 (55.77%)	278 (42.64%)	800 (50.38%)	
Weight (kg, mean ± sd)	82.59 ± 21.57	82.93 ± 22.23	82.73 ± 21.84	0.903
Height (cm, mean ± sd)	167.91 ± 9.99	167.50 ± 10.01	167.74 ± 9.99	0.468
BMI (kg/m^2, mean ± sd)	29.20 ± 7.00	29.47 ± 7.15	29.31 ± 7.06	0.456
RACE, n (%)				< 0.001
Mexican American	96 (10.26%)	112 (17.18%)	208 (13.10%)	
Other Hispanics	73 (7.80%)	62 (9.51%)	135 (8.50%)	
NonHispanic White	494 (52.78%)	226 (34.66%)	720 (45.34%)	
NonHispanic Black	128 (13.68%)	169 (25.92%)	297 (18.70%)	
Other race including multiracial	145 (15.49%)	83 (12.73%)	228 (14.36%)	
Diabetes, n (%)				< 0.001
Yes	74 (7.91%)	107 (16.41%)	181 (11.40%)	
No	832 (88.89%)	519 (79.60%)	1,351 (85.08%)	
Borderline	30 (3.21%)	26 (3.99%)	56 (3.53%)	
Alcohol use, n (%)				0.968
Yes	660 (73.66%)	450 (73.65%)	1,110 (73.66%)	
No	234 (26.12%)	160 (26.19%)	394 (26.14%)	
Hypertension, n (%)				0.001
Yes	326 (34.83%)	280 (42.94%)	606 (38.16%)	
No	610 (65.17%)	372 (57.06%)	982 (61.84%)	
Smoking status, n (%)				< 0.001
Current	96 (27.83%)	155 (43.79%)	251 (35.91%)	
Sometimes	18 (5.22%)	27 (7.63%)	45 (6.44%)	
Never	231 (66.96%)	172 (48.59%)	403 (57.65%)	
TyG-BMI, mean ± sd	250.85 ± 67.26	256.07 ± 71.07	252.99 ± 68.88	0.137
TyG-WC, mean ± sd	854.20 ± 170.98	876.49 ± 181.58	863.35 ± 175.70	0.013
TyG-WHtR, mean ± SD	5.09 ± 1.00	5.24 ± 1.09	5.15 ± 1.04	0.005
WC, mean ± SD	99.45 ± 16.03	100.95 ± 16.24	100.07 ± 16.13	0.069
HOMA-IR,mean ± sd	5.78 ± 1.44	6.38 ± 2.35	6.03 ± 1.89	< 0.001

Abbreviations: *NPD* Non-Periodontitis, *PD* Periodontitis, *TyG* triglyceride–glucose, *BMI* body mass index, *WC* waist circumference, *HOMA-IR* Homeostatic Model Assessment of Insulin Resistance, *WHtR* waist-to-height, *SD* standard deviation

Normally distributed continuous variables are described as means ± SD; categorical variables are presented as numbers (percentages). The t-test was used for continuous variables and the χ test for categorical variables

between HOMA-IR score and TyG-WHtR and periodontitis development. In particular, higher HOMA-IR scores and TyG-WHtR were associated with the odds of periodontitis prevalence. This association persisted across the crude (model I), minimally adjusted (model II), and fully adjusted models. In the fully adjusted models (III), TyG-WHtR exhibited the strongest association with periodontitis (OR = 1.14, 95% CI: 1.02–1.27, P = 0.0244), indicating a 14% increased risk per unit increase. Further, HOMA-IR score (OR = 1.00, 95% CI: 1.00–1.00, P = 0.0028) was positively associated with the prevalence of periodontitis. Meanwhile, the association between TyG (OR = 1.15, 95% CI: 0.97–1.35, P = 0.1066), TyG-BMI (OR = 1.00, 95% CI: 1.00–1.01, P = 0.1449), and TyG-WC (OR = 1.00, 95% CI: 1.00–1.00, P = 0.1599) and periodontitis was not statistically significant.

Diagnostic value of the indicators of insulin resistance in periodontitis

The ROC curves were used to assess the diagnostic utility of several IR indicators in relation to periodontitis (Fig. 2). Results showed that the area under the curves

Table 2 Association between the Indicators of insulin resistance and periodontitis

Exposure	Model 1 β (95% CI), P value	Model 2 β (95% CI), P value	Model 3 β (95% CI), P value
HOMA-IR score	1.00 (1.00–1.00), 0.0001	1.00 (1.00–1.00), 0.0004	1.00 (1.00–1.00) 0.0028
TyG index	1.19 (1.03–1.37), 0.0162	1.18 (1.01–1.38), 0.0328	1.15 (0.97–1.35) 0.1066
TyG-WHtR	1.15 (1.04–1.26), 0.0047	1.16 (1.04–1.29), 0.0057	1.14 (1.02–1.27), 0.0244
TyG-BMI	1.00 (1.00–1.00), 0.1376	1.00 (1.00–1.00), 0.0635	1.00 (1.00–1.01), 0.1449
TyG-WC	1.00 (1.00–1.00), 0.0131	1.00 (1.00–1.00), 0.0589	1.00 (1.00–1.00), 0.1599

Abbreviations: CI confidence interval, *TyG* triglyceride–glucose, *BMI* body mass index, *WC* waist circumference, *HOMA-IR* Homeostatic Model Assessment of Insulin Resistance, *WHtR* waist-to-height

Model 1: no covariates were adjusted

Model 2: adjusted for sex, age, and race

Model 3: adjusted for sex, age, race, hypertension, diabetes, smoking status and alcohol use

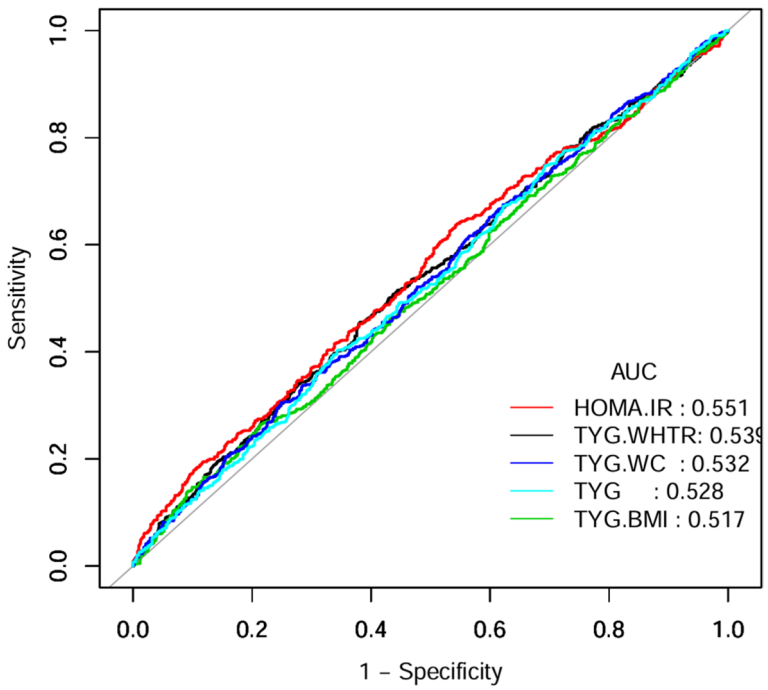

Fig. 2 The ROC curves of the indicators of insulin resistance for diagnosing periodontitis

(AUCs) for HOMA-IR score and TyG-WHtR were 0.551 and 0.539, respectively. Hence, they slightly surpassed the AUCs of TyG (AUC = 0.528) and TyG indexes combined with different anthropometric measures (TyG-WC, AUC = 0.532; TyG-BMI, AUC = 0.517).

Subgroup analysis

To assess the consistency of the association between periodontitis and the various indicators of IR in the overall population and to identify potentially different population characteristics, subgroup analyses and interaction tests stratified by age, sex, drinking status, diabetes status, and hypertension status were performed. As shown in Table 3, sex affected the association between periodontitis and TyG, TyG-WC, and TyG-WHtR (p values < 0.05 for the interactions). Age emerged as another important factor that regulates the associations between periodontitis and both TyG and HOMA-IR score. In contrast, the influence of alcohol consumption, diabetes status, and hypertension status on these associations was not statistically significant.

Table 3 Subgroup analysis of the association between periodontitis and TyG-related indices

	HOMA-IR					**TyG-WHtR**				
Subgroup	OR (95% CI)			P value	P interaction	OR (95% CI)			P value	P interaction
Sex					0.4181					0.0393
Male	1.00 (1.00–1.00)			0.1428		0.94 (0.79–1.12)			0.4847	
Female	1.00 (1.00–1.00)			0.0341		1.19 (1.03–1.39)			0.0202	
Age (years)					0.0082					0.2289
≤ 60	1.00 (1.00–1.00)			0.0016		1.12 (0.99–1.27)			0.0747	
> 60	1.00 (1.00–1.00)			0.8799		0.96 (0.77–1.20)			0.7245	
Drinking					0.9976					0.7504
Yes	1.00 (1.00–1.00)			0.0397		1.08 (0.95–1.23)			0.2503	
No	1.00 (1.00–1.00)			0.1404		1.12 (0.91–1.39)			0.2779	
Diabetes					0.9882					0.1064
Yes	1.00 (1.00–1.00)			0.1140		1.30 (0.96–1.75)			0.0063	
No	1.00 (1.00–1.00)			0.1399		1.07 (0.95–1.22)			0.0002	
Borderline	1.00 (1.00–1.01)			0.5932		0.65 (0.36–1.19)			0.9368	
Hypertension					0.9334					0.9502
Yes	1.00 (1.00–1.00)			0.0591		1.10 (0.92–1.30)			0.3013	
No	1.00 (1.00–1.00)			0.1541		1.10 (0.95–1.28)			0.1854	
	TyG				TyG-WC			TyG-BMI		
Subgroup	OR (95% CI)	P value	P interaction		OR (95% CI)	*P* value	P interaction	OR (95% CI)	*P* value	P interaction
Sex			0.0075				0.0130			0.0788
Male	0.81 (0.65–1.01)	0.0557			1.00 (1.00–1.00)	0.1016		1.00 (1.00–1.00)	0.4742	
Female	1.26 (0.99–1.61)	0.0626			1.00 (1.00–1.00)	0.0618		1.00 (1.00–1.00)	0.0581	
Age (years)			0.0331				0.2303			0.5023
≤ 60	1.10 (0.92–1.33)	0.2903			1.00(1.00–1.00)	0.4926		1.00(1.00–1.00)	0.3626	
60	0.73 (0.53–1.02)	0.0666			1.00(1.00–1.00)	0.3293		1.00(1.00–1.00)	0.7970	
Drinking			0.0697				0.6320			0.4816
Yes	0.92 (0.76–1.11)	0.3807			1.00 (1.00–1.00)	0.9056		1.00 (1.00–1.00)	0.4926	
No	1.29 (0.94–1.78)	0.1151			1.00(1.00–1.00)	0.5250		1.00 (1.00–1.01)	0.2062	
Diabetes			0.2543				0.0962			0.0996
Yes	1.27 (0.85–1.90)	0.2514			1.00(1.00–1.00)	0.1042		1.00 (1.00–1.01)	0.0448	
No	0.96 (0.80–1.16)	0.6620			1.00(1.00–1.00)	0.8882		1.00 (1.00–1.01)	0.5837	
Borderline	0.67 (0.32–1.38)	0.2761			1.00 (0.99–1.00)	0.1758		1.00 (0.99–1.00)	0.3074	
Hypertension			0.8461				0.6767			0.5384
Yes	0.99 (0.77–1.28)	0.9651			1.00(1.00–1.00)	0.4941		1.00 (1.00–1.00)	0.1832	
No	1.03 (0.83, 1.27)	0.8008			1.00(1.00,1.00)	0.8788		1.00 (1.00, 1.00)	0.5692	

Discussion

This cross-sectional study investigated the predictive value of TyG, TyG-WHtR, TyG-BMI, TyG-WC, and HOMA-IR score as alternative IR indices for periodontitis in the general population. According to the results of our study (n = 1,588), HOMA-IR score and TyG-WHtR were positively associated with the risk of periodontitis, and TyG-WHtR exhibited the strongest association (OR = 1.14, 95% CI: 1.02–1.27, P = 0.0244), indicating a 14% increased risk per unit increase. HOMA-IR score (OR = 1.00, 95% CI: 1.00–1.00, P = 0.0028) was positively associated with the risk of developing periodontitis. Conversely, there was no statistically significant association between TyG (OR = 1.15, 95% CI: 0.97–1.35, P = 0.1066), TyG-WC (OR = 1.00, 95% CI: 1.00–1.00, P = 0.1599), and TyG-BMI (OR = 1.00, 95% CI: 1.00–1.01, P = 0.1449) and periodontitis. The AUC of HOMA-IR (0.551) and TyG-WHtR (0.539) was slightly higher than that of TyG-WC (0.532), TyG (0.528), and TyG-BMI (0.517). As the AUCs for HOMA-IR and TyG-WHtR were slightly higher, then they can be promising markers for periodontitis. TyG-BMI (OR = 1.00, 95% CI: 1.00–1.01, P = 0.1449).

Periodontitis and diabetes have a two-way association, and these two diseases affect each other [8]. Our study revealed a positive association between periodontitis and IR. Both diseases have several causes. However, both are affected by inflammation, and they require early diagnosis and treatment [4, 9, 11]. High triglyceride levels are a manifestation of hyperlipidemia, and serum lipid metabolism can be adversely affected by the upregulation of proinflammatory factors induced by periodontitis [18]. Periodontal bacteria may promote reactive oxygen species (ROS) overproduction by downregulating enzymatic antioxidant defense systems, leading to oxidative stress. The interaction between inflammation and oxidative stress disrupts insulin signaling pathways and promotes IR [47].

In addition, some studies have revealed a causal association between periodontitis and obesity [20, 42]. A previous epidemiological study assessed the effect of obesity on the onset and progression of periodontitis. Results showed that elevated body mass index, WC, percentage of subcutaneous fat, and blood lipid levels are associated with an increased risk of developing periodontitis [1]. In terms of the underlying biological mechanism for this association, adipose tissue-derived cytokines, such as tumor necrosis factor-alpha and interleukin-6, can affect systemic metabolism and contribute to the development of low-grade systemic inflammation [24]. However, the currently available evidence varies, and it is inconclusive [27]. Therefore, the combined use of TyG index and obesity-related data is clinically important for assessing the association between IR and periodontitis.

Compared with the previous use of hypersinsulinemic-euglycemic clamp (HEMC) as a method for evaluating IR, TyG is more convenient and easier to obtain and calculate [46]. A previous study used different screening metrics to predict the association between metabolic-associated fatty liver disease (MAFLD) and nonalcoholic fatty liver disease (NAFLD). In women, TyG-WHtR had the best performance in identifying MAFLD/NAFLD. In men, TyG-WC had the best performance in identifying MAFLD/NAFLD [38]. A recent study showed that TyG-BMI is more effective in predicting prediabetes [25]. Further, TyG-related indicators have a practical value in clinical practice. Our study results were comparable to those of prior investigations conducted by Lee et al. [30], which explored the association between modified triglyceride index and periodontitis among Korean adults. This study emphasized that the TyG-WHtR index emerged as a superior predictor of the association between periodontitis and IR. However, different results were obtained for the association between TyG-BMI and TyG-WC and periodontitis, which can be possibly attributed to the various characteristics of the populations. BMI, WC, and WHtR are three common anthropometric measures. BMI is the most widely used method for assessing adiposity. Nevertheless, it cannot differentiate the other components of body weight, such as bones, muscles, and internal organs and does not reflect fat distribution. Further, it is affected by region and disease [29]. WC is an indicator of abdominal obesity. Nevertheless, height affects accuracy [6]. In contrast, WHtR, which is another indicator of abdominal obesity, has earned support from systematic evaluations and meta-analyses due to its efficacy in predicting cardiovascular and metabolic risks [2]. Further, the analysis was extended by conducting a comparative assessment of HOMA-IR and TyG-related indices, thereby providing a more comprehensive view of the underlying metabolic associations.

Our study revealed that HOMA-IR score and TyG-WHtR were superior than the other indices in predicting periodontitis. However, it is important to note that HOMA-IR requires the measurement of endogenous insulin, which is not typically included in basic and routine blood tests. Although HOMA-IR is widely used as a surrogate marker of insulin resistance, it has inherent limitations. Unlike direct measures such as the HEMC (the gold standard), HOMA-IR lacks precision due to its reliance on static fasting glucose and insulin levels, which do not account for dynamic glucose metabolism or β-cell function [50]. Additionally, there is no universally accepted diagnostic cutoff for HOMA-IR, leading to variability in defining insulin resistance across studies [33]. Furthermore, HOMA-IR assumes a linear relationship between fasting insulin and glucose, which may not

hold true in populations with impaired pancreatic β-cell function (e.g., advanced diabetes) [43]. These limitations highlight the need for cautious interpretation of our findings and underscore the value of complementary markers such as TyG-WHtR, which may better reflect adipose tissue-driven insulin resistance. WHtR is an easily usable marker of generalized and abdominal obesity. Another study shows that WHtR is a more accurate indicator of cardiometabolic risk factors, particularly when detecting abdominal fat accumulation, than WC and BMI [22].

Another notable finding in our study was the mean age of participants with periodontitis (51.9 years), which aligns with previous reports suggesting a potential decline in periodontitis prevalence among older populations [7, 16, 49]. This observation may reflect age-related factors influencing disease diagnosis. For instance, tooth loss, which is more prevalent in the elderly due to advanced periodontal destruction or other comorbidities [26], could lead to exclusion of edentulous individuals from periodontitis assessments. Future studies including edentulous populations or longitudinal designs are needed to clarify the relationship between aging and periodontitis prevalence.

Our study provides novel information showing that HOMA-IR score and TyG-WHtR index can be early biomonitoring markers of periodontitis in susceptible populations. This study had several limitations: First, the results of the current study might have been influenced by selection bias, and cohort studies could provide more robust evidence. Second, this study had a relatively small sample size as some individuals had missing data. Therefore, the generalizability of the TyG-related indicators in larger populations should be cautiously evaluated. Third, as a cross-sectional investigation, a causal relationship between insulin resistance (IR) markers (e.g., HOMA-IR, TyG-WHtR) and periodontitis cannot be established. While we observed significant associations, the design precludes causal inference—it remains unclear whether IR precedes periodontitis or vice versa. For example, chronic inflammation from periodontitis may exacerbate systemic insulin resistance [40]. Longitudinal or interventional studies are necessary to disentangle this bidirectional relationship.

Conclusion

Our study identifies HOMA-IR and TyG-WHtR as the most robust indicators of insulin resistance (IR) associated with periodontitis in a nationally representative population. These findings suggest that incorporating these markers into clinical practice may enhance early identification of individuals at risk for periodontitis, particularly in populations with metabolic dysregulation. However, the cross-sectional design and sample size limitations preclude causal inferences and generalizability to edentulous or specific high-risk subgroups. Future large-scale longitudinal studies are required to validate these findings, establish causality, and explore the utility of HOMA-IR and TyG-WHtR in primary prevention strategies for periodontitis.

Acknowledgements
The authors sincerely thank the National Health and Nutrition Examination Survey (NHANES) database for providing data. We would also like to thank Haifeng Lang for helpful discussions.

Authors' contributions
Yiyuan Lang designed the study, conducted data analysis, and drafted the manuscript. Xin Song conducted data analysis and drafted the manuscript. Yan Chen, Han Mei and Chengyu Wu have contributed to the production of charts and data processing. Changao Xue and Rui Zhang reviewed the article. All authors read and approved the final manuscript.

Funding
This study was supported by a grant from the Science and Technology Department of Jiangsu Province (Grant.BE2020707).

Data availability
Publicly available datasets were analyzed in this study. This data can be accessed at: The National Health and Nutrition Examination Survey https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethics approval and consent to participate
The study was conducted by the Declaration of Helsinki and was approved by the Institutional Review Board of the National Centre for Health Statistics. All participants provided informed consent before enrollment.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Stomatology, Nanjing First Hospital, Nanjing Medical University, Nanjing, Jiangsu, China. [2]The Third Clinical Medical College, Nanjing Medical University, Nanjing, Jiangsu, China.

Received: 7 November 2024 Accepted: 4 March 2025
Published online: 19 March 2025

References

1. Arboleda S, Vargas M, Losada S, Pinto A. Review of obesity and periodontitis: an epidemiological view. Br Dent J. 2019;227(3):235–9. https://doi.org/10.1038/s41415-019-0611-1.
2. Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. Obes Rev. 2012;13(3):275–86. https://doi.org/10.1111/j.1467-789X.2011.00952.x.
3. Batista TM, Haider N, Kahn CR. Defining the underlying defect in insulin action in type 2 diabetes. Diabetologia. 2021;64(5):994–1006. https://doi.org/10.1007/s00125-021-05415-5.
4. Blasco-Baque V, Garidou L, Pomié C, Escoula Q, Loubieres P, Le Gall-David S, Lemaitre M, Nicolas S, Klopp P, Waget A, Azalbert V, Colom A, Bonnaure-Mallet M, Kemoun P, Serino M, Burcelin R. Periodontitis induced by Porphyromonas gingivalis drives periodontal microbiota dysbiosis and insulin resistance via an impaired adaptive immune response. Gut. 2017;66(5):872–85. https://doi.org/10.1136/gutjnl-2015-309897.

5. Borgnakke, W. S., Genco, R. J., Eke, P. I., & Taylor, G. W. (2018). Oral Health and Diabetes. In C. C. Cowie et al. (Eds.), Diabetes in America (3rd ed., pp. 24-1–24-20). National Institute of Diabetes and Digestive and Kidney Diseases (US). https://www.ncbi.nlm.nih.gov/books/NBK567979/.
6. Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. Nutr Res Rev. 2010;23(2):247–69. https://doi.org/10.1017/s0954422410000144.
7. Caton JG, Armitage G, Berglundh T, Chapple ILC, Jepsen S, Kornman KS, Mealey BL, Papapanou PN, Sanz M, Tonetti MS. A new classification scheme for periodontal and peri-implant diseases and conditions - Introduction and key changes from the 1999 classification. J Clin Periodontol. 2018;45(Suppl 20):S1-s8. https://doi.org/10.1111/jcpe.12935.
8. Chee B, Park B, Bartold PM. Periodontitis and type II diabetes: a two-way relationship. Int J Evid Based Healthc. 2013;11(4):317–29. https://doi.org/10.1111/1744-1609.12038.
9. Cutler CW, Shinedling EA, Nunn M, Jotwani R, Kim BO, Nares S, Iacopino AM. Association between periodontitis and hyperlipidemia: cause or effect? J Periodontol. 1999;70(12):1429–34. https://doi.org/10.1902/jop.1999.70.12.1429.
10. Dang K, Wang X, Hu J, Zhang Y, Cheng L, Qi X, Liu L, Ming Z, Tao X, Li Y. The association between triglyceride-glucose index and its combination with obesity indicators and cardiovascular disease: NHANES 2003–2018. Cardiovasc Diabetol. 2024;23(1):8. https://doi.org/10.1186/s12933-023-02115-9.
11. Darby, I. (2022). Risk factors for periodontitis & peri-implantitis. Periodontol .2000, 90(1), 9–12. https://doi.org/10.1111/prd.12447
12. Defronzo RA. Banting Lecture. From the triumvirate to the ominous octet: a new paradigm for the treatment of type 2 diabetes mellitus. Diabetes. 2009;58(4):773–95. https://doi.org/10.2337/db09-9028.
13. Du J, Liu Y, Luo Z, Wang M, Liu Y. Identification of periodontal disease diagnostic markers via data cross-validation. Int Dent J. 2025. https://doi.org/10.1016/j.identj.2025.01.011.
14. Eke PI, Borgnakke WS, Genco RJ. Recent epidemiologic trends in periodontitis in the USA. Periodontol 2000. 2020;82(1):257–67. https://doi.org/10.1111/prd.12323.
15. Eke PI, Page RC, Wei L, Thornton-Evans G, Genco RJ. Update of the case definitions for population-based surveillance of periodontitis. J Periodontol. 2012;83(12):1449–54. https://doi.org/10.1902/jop.2012.110664.
16. Eke PI, Wei L, Borgnakke WS, Thornton-Evans G, Zhang X, Lu H, McGuire LC, Genco RJ. Periodontitis prevalence in adults ≥ 65 years of age, in the USA. Periodontol 2000. 2016;72(1):76–95. https://doi.org/10.1111/prd.12145.
17. Er LK, Wu S, Chou HH, Hsu LA, Teng MS, Sun YC, Ko YL. Triglyceride glucose-body mass index is a simple and clinically useful surrogate marker for insulin resistance in nondiabetic individuals. PLoS ONE. 2016;11(3):e0149731. https://doi.org/10.1371/journal.pone.0149731.
18. Fentoğlu Ö, Köroğlu BK, Hiçyılmaz H, Sert T, Özdem M, Sütçü R, Tamer MN, Orhan H, Ay ZY, Öztürk Tonguç M, Kırzıoğlu FY. Pro-inflammatory cytokine levels in association between periodontal disease and hyperlipidaemia. J Clin Periodontol. 2011;38(1):8–16. https://doi.org/10.1111/j.1600-051X.2010.01644.x.
19. Gay IC, Tran DT, Paquette DW. Alcohol intake and periodontitis in adults aged ≥30 years: NHANES 2009–2012. J Periodontol. 2018;89(6):625–34. https://doi.org/10.1002/jper.17-0276.
20. Gorman A, Kaye EK, Apovian C, Fung TT, Nunn M, Garcia RI. Overweight and obesity predict time to periodontal disease progression in men. J Clin Periodontol. 2012;39(2):107–14. https://doi.org/10.1111/j.1600-051X.2011.01824.x.
21. Guerrero-Romero F, Simental-Mendía LE, González-Ortiz M, Martínez-Abundis E, Ramos-Zavala MG, Hernández-González SO, Jacques-Camarena O, Rodríguez-Morán M. The product of triglycerides and glucose, a simple measure of insulin sensitivity. Comparison with the euglycemic-hyperinsulinemic clamp. J Clin Endocrinol Metab. 2010;95(7):3347–51. https://doi.org/10.1210/jc.2010-0288.
22. Iliodromiti S, Celis-Morales CA, Lyall DM, Anderson J, Gray SR, Mackay DF, Nelson SM, Welsh P, Pell JP, Gill JMR, Sattar N. The impact of confounding on the associations of different adiposity measures with the incidence of cardiovascular disease: a cohort study of 296 535 adults of white European descent. Eur Heart J. 2018;39(17):1514–20. https://doi.org/10.1093/eurheartj/ehy057.
23. Janakiram, C., Dye, B. A. (2020). A public health approach for prevention of periodontal disease. Periodontol. 2000, 84(1), 202–214. https://doi.org/10.1111/prd.12337
24. Jepsen, S., Suvan, J., & Deschner, J. (2020). The association of periodontal diseases with metabolic syndrome and obesity. Periodontol. 2000, 83(1), 125–153. https://doi.org/10.1111/prd.12326
25. Jiang C, Yang R, Kuang M, Yu M, Zhong M, Zou Y. Triglyceride glucose-body mass index in identifying high-risk groups of pre-diabetes. Lipids Health Dis. 2021;20(1):161. https://doi.org/10.1186/s12944-021-01594-7.
26. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global Burden of severe tooth loss: a systematic review and meta-analysis. J Dent Res. 2014;93(7 Suppl):20s–8s. https://doi.org/10.1177/0022034514537828.
27. Keller A, Rohde JF, Raymond K, Heitmann BL. Association between periodontal disease and overweight and obesity: a systematic review. J Periodontol. 2015;86(6):766–76. https://doi.org/10.1902/jop.2015.140589.
28. Khamseh ME, Malek M, Abbasi R, Taheri H, Lahouti M, Alaei-Shahmiri F. Triglyceride Glucose Index and Related Parameters (Triglyceride Glucose-Body Mass Index and Triglyceride Glucose-Waist Circumference) Identify Nonalcoholic Fatty Liver and Liver Fibrosis in Individuals with Overweight/Obesity. Metab Syndr Relat Disord. 2021;19(3):167–73. https://doi.org/10.1089/met.2020.0109.
29. Kleine CE, Moradi H, Streja E, Kalantar-Zadeh K. Racial and ethnic disparities in the obesity paradox. Am J Kidney Dis. 2018;72(5 Suppl 1):S26-s32. https://doi.org/10.1053/j.ajkd.2018.06.024.
30. Lee HJ, Lee JW, Kim S, Kwon YJ. Comparison of the triglyceride glucose index and modified triglyceride glucose indices in assessing periodontitis in Korean adults. J Periodontal Res. 2023;58(3):503–10. https://doi.org/10.1111/jre.13108.
31. Li L, Li L, Zhou Y, Chen X, Xu Y. Association between triglyceride-glucose index and risk of periodontitis: a cross-sectional study. Int J Gen Med. 2021;14:9807–16. https://doi.org/10.2147/ijgm.S339863.
32. Li W, Song J, Chen Z. The association between dietary vitamin C intake and periodontitis: result from the NHANES (2009–2014). BMC Oral Health. 2022;22(1):390. https://doi.org/10.1186/s12903-022-02416-7.
33. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 1985;28(7):412–9. https://doi.org/10.1007/bf00280883.
34. Mealey BL, Oates TW. Diabetes mellitus and periodontal diseases. J Periodontol. 2006;77(8):1289–303. https://doi.org/10.1902/jop.2006.050459.
35. Meusel DR, Ramacciato JC, Motta RH, Brito Júnior RB, Flório FM. Impact of the severity of chronic periodontal disease on quality of life. J Oral Sci. 2015;57(2):87–94. https://doi.org/10.2334/josnusd.57.87.
36. Muniyappa R, Lee S, Chen H, Quon MJ. Current approaches for assessing insulin sensitivity and resistance in vivo: advantages, limitations, and appropriate usage. Am J Physiol Endocrinol Metab. 2008;294(1):E15-26. https://doi.org/10.1152/ajpendo.00645.2007.
37. Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, Flemmig TF, Garcia R, Giannobile WV, Graziani F, Greenwell H, Herrera D, Kao RT, Kebschull M, Kinane DF, Kirkwood KL, Kocher T, Kornman KS, Kumar P, S., et al. Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Clin Periodontol. 2018;45(Suppl 20,):S162-s170. 10.1111/jcpe.12946
38. Peng H, Pan L, Ran S, Wang M, Huang S, Zhao M, Cao Z, Yao Z, Xu L, Yang Q, Lv W. Prediction of MAFLD and NAFLD using different screening indexes: A cross-sectional study in U.S. adults. Front Endocrinol (Lausanne). 2023;14: 1083032. https://doi.org/10.3389/fendo.2023.1083032.
39. Richards D. Review finds that severe periodontitis affects 11% of the world population. Evid Based Dent. 2014;15(3):70–1. https://doi.org/10.1038/sj.ebd.6401037.
40. Ryder MI. Porphyromonas gingivalis and Alzheimer disease: Recent findings and potential therapies. J Periodontol. 2020;91 Suppl 1(Suppl 1):S45-s49. https://doi.org/10.1002/jper.20-0104.
41. Sanz M, Herrera D, Kebschull M, Chapple I, Jepsen S, Beglundh T, Sculean A, Tonetti MS, et al. Treatment of stage I-III periodontitis-The EFP S3 level clinical practice guideline. J Clin Periodontol. 2020;47 Suppl 22(Suppl 22):4–60. https://doi.org/10.1111/jcpe.13290.
42. Saxlin T, Suominen-Taipale L, Leiviskä J, Jula A, Knuuttila M, Ylöstalo P. Role of serum cytokines tumour necrosis factor-alpha and interleukin-6 in

the association between body weight and periodontal infection. J Clin Periodontol. 2009;36(2):100–5. https://doi.org/10.1111/j.1600-051X.2008.01350.x.
43. Singh B, Saxena A. Surrogate markers of insulin resistance: A review. World J Diabetes. 2010;1(2):36–47. https://doi.org/10.4239/wjd.v1.i2.36.
44. Song IS, Han K, Park YM, Ji S, Jun SH, Ryu JJ, Park JB. Severe Periodontitis Is Associated with Insulin Resistance in Non-abdominal Obese Adults. J Clin Endocrinol Metab. 2016;101(11):4251–9. https://doi.org/10.1210/jc.2016-2061.
45. Tam CS, Xie W, Johnson WD, Cefalu WT, Redman LM, Ravussin E. Defining insulin resistance from hyperinsulinemic-euglycemic clamps. Diabetes Care. 2012;35(7):1605–10. https://doi.org/10.2337/dc11-2339.
46. Tao LC, Xu JN, Wang TT, Hua F, Li JJ. Triglyceride-glucose index as a marker in cardiovascular diseases: landscape and limitations. Cardiovasc Diabetol. 2022;21(1):68. https://doi.org/10.1186/s12933-022-01511-x.
47. Thouvenot K, Turpin T, Taïlé J, Clément K, Meilhac O, Gonthier MP. Links between Insulin Resistance and Periodontal Bacteria: Insights on Molecular Players and Therapeutic Potential of Polyphenols. Biomolecules. 2022;12(3): 378. https://doi.org/10.3390/biom12030378.
48. Tian N, Chen S, Han H, Jin J, Li Z. Association between triglyceride glucose index and total bone mineral density: a cross-sectional study from NHANES 2011–2018. Sci Rep. 2024;14(1):4208. https://doi.org/10.1038/s41598-024-54192-9.
49. Tonetti MS, Jepsen S, Jin L, Otomo-Corgel J. Impact of the global burden of periodontal diseases on health, nutrition and wellbeing of mankind: A call for global action. J Clin Periodontol. 2017;44(5):456–62. https://doi.org/10.1111/jcpe.12732.
50. Wallace TM, Levy JC, Matthews DR. Use and abuse of HOMA modeling. Diabetes Care. 2004;27(6):1487–95. https://doi.org/10.2337/diacare.27.6.1487.
51. Zeze T, Shinjo T, Sato K, Nishimura Y, Imagawa M, Chen S, Ahmed AK, Iwashita M, Yamashita A, Fukuda T, Sanui T, Park K, King GL, Nishimura F. Endothelial Insulin Resistance Exacerbates Experimental Periodontitis. J Dent Res. 2023;102(10):1152–61. https://doi.org/10.1177/00220345231181539.

Publisher's Note