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Risk correlates of cardiovascular diseases, diabetes, and periodontal diseases: a cross-sectional study in India

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Abstract

Background Quantifying shared risk factors among periodontal disease (PD), cardiovascular disease (CVD), type 2 diabetes (DM2) can bolster Common Risk Factor Approach (CRFA), enabling integration of PD prevention into non-communicable disease (NCD) prevention strategies. The objective of the study is to assess extent of overlap of shared risk factors between CVD, DM2, PD.

Materials and methods This is an analytical cross-sectional study conducted at a tertiary care medical and dental teaching hospital in South India, from July 2022 to April 2024. Study included 600 participants (ages 18–75) divided into three groups: Group A: DM2, CVD, or both and PD; Group B: DM2 or CVD; and Group C: PD alone. Various demographic, metabolic, habit related, dietary and periodontal disease severity related risk factors were evaluated in the study.

Results Among 600 participants, 55.5% were male, 58.8% were under 50 years. Statistically significant odds ratios (ORs) for shared risk factors between Group A and Group B were observed for age > 50 (0.58), sedentary lifestyle (0.43), fat intake > 41 g/d (1.87), HbA1C ≥ 6.5% (0.56), FBS > 126 mg/dL (2.35) and family history of NCDs (9.8). For Group A versus Group C, statistically significant ORs were seen for age > 50 (0.55), HbA1c 5.7%-6.4% (0.34), triglycerides > 150 mg/dL (0.04), education (0.52), alcohol use (1.53) and poor oral hygiene (3.01). Severity of periodontal disease assessed using PSR, HbA1c, triglycerides, fat intake, age, education, obesity were identified as vital shared risk factors.

Conclusion and relevance Age, education, obesity, PSR, HbA1c, triglycerides emerged as significant shared risk factors. Integrating these factors into surveillance tools may enhance NCD and PD risk identification, supporting CRFA-based healthcare approach.

Trial registration CTRI/ 2022/06/043279 registered on 15th of June 2022.

Keywords Disease prevention, Health Equity, Integrated Health Care Systems, Risk adjustment, Risk Factor, Risk reduction behaviour

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Background

Non-communicable diseases (NCDs), such as cardiovascular diseases (CVDs), diabetes mellitus (DM), carry significant health consequences. NCDs account for 74% of global deaths. [1] In India, NCDs have a major socio-economic impact. [2] Approximately 5.8 million people die from NCDs annually in India. To address this situation, India established the National NCD Monitoring Framework to help reduce premature NCD-related deaths by one-third by 2030. [3].

Periodontal disease (PD) is a chronic inflammatory disease which imposes significant burden on both individual quality of life and healthcare systems. Globally, PD stands 11th in terms of prevalence [4], with 51% occurrence rate in India [5]. In the U.S. alone, PD led to an estimated economic loss of $154.06 billion in 2018, while Europe incurred €158.64 billion in oral health related costs [6]. Out-of-pocket expenses for dental care account for about 14% of healthcare spending in Organisation for Economic Co-operation and Development (OECD) countries [7], and in India, per capita dental expenditure is compromised due to inequity in care availability, resulting in a high productivity loss [8].

It is of substantial import to understand that PD, and NCDs are linked through several elements. [9] Immune-inflammatory responses contribute to the link between NCDs and PD. Invasion by periodontal pathogens result in release of pro-inflammatory cytokines like interleukin (IL) 1α and β, IL-6, lipopolysaccharides, prostaglandin E2, thromboxane. This affects intracellular pathways controlling insulin resistance, affect thrombogenesis, cause thromboembolic events and generate autoantibodies. [10] This immune-inflammatory response results in the development and exacerbation of various chronic diseases like diabetes, cardiovascular diseases, chronic obstructive pulmonary disease and other NCDs. [10] Another important element connecting NCD and PD are the risk factors implicated in PD and NCD initiation and progression. PD and NCDs share many risk factors [11] and prevalence of NCD and PD risk factors in the Indian population have been estimated. [12, 13] Tobacco use, physical inactivity, alcohol abuse, stress, age, gender, socioeconomic factors, education are some of the risk factors that have been implicated as risk factors associated with both NCDs and PD. [12, 13].

These links between NCDs and PD provide avenues for integrating NCD and PD care delivery to reduce the socioeconomic burden imposed by these diseases on the population. Traditional health promotion efforts tend to adopt a siloed approach targeting individual diseases. In contrast, the Common Risk Factor Approach (CRFA) addresses multiple diseases by managing shared risk factors. CRFA proposes a horizontal, integrated strategy that considers shared determinants of health to improve overall population health. [11] CRFA supports merging oral health promotion with broader health policies, aiming to reduce social disparities in health and enhance the population's general well-being.

Supporting CRFA is challenging due to lack of adequate numerical data on the impact of different risk factors on PD and NCDs. By measuring the risk variables that PD and NCDs share, our study intends to close this gap. This study is based on the premise that there are several risk factors and indicators that are shared by PD and major NCDs including diabetes and cardiovascular disease. The study aims to quantify the overlap of shared risk factors between cardiovascular disease (CVD), type 2 diabetes (DM2), and periodontal disease (PD). By assessing the degree of this overlap, the study underscores CRFA's potential to incorporate periodontal disease prevention into broader public health efforts, thereby aiding in reduction of NCD burden and associated complications.

Materials and Methods

Study design and setting

This analytical cross-sectional study, conducted at a tertiary medical teaching college and dental hospital in South India from July 2022 to April 2024, adheres to the STROBE guidelines [14] (supplementary Table 1). The study protocol received scientific and ethical approval from the Institutional Review Board (IRB) in accordance with the Declaration of Helsinki and guidelines set by the Indian Council of Medical Research 2017.

Eligibility criteria

The study included participants aged 18–75, divided into three groups based on presence or absence of type 2 diabetes (DM), cardiovascular disease (CVD), or periodontal disease (PD):

- *Group A*: DM2, CVD, or both plus PD
- *Group B*: DM2 or CVD without PD
- *Group C*: PD without DM2 or CVD

Exclusions included those without DM2, CVD, or PD, unwilling participants, or individuals in critical condition. The definitions of DM2, CVD, and periodontal disease were based on previously published protocol. [15] The decision tree for participant recruitment is given in Fig. 1.

The explanatory factors assessed are age, gender, occupation, access to care, affordability of care, familial pattern, family size, insurance, socioeconomic status assessed using modified Kuppuswamy criteria [16], body mass index (BMI) [17],tobacco usage, physical activity measurement [18], alcohol consumption assessed using

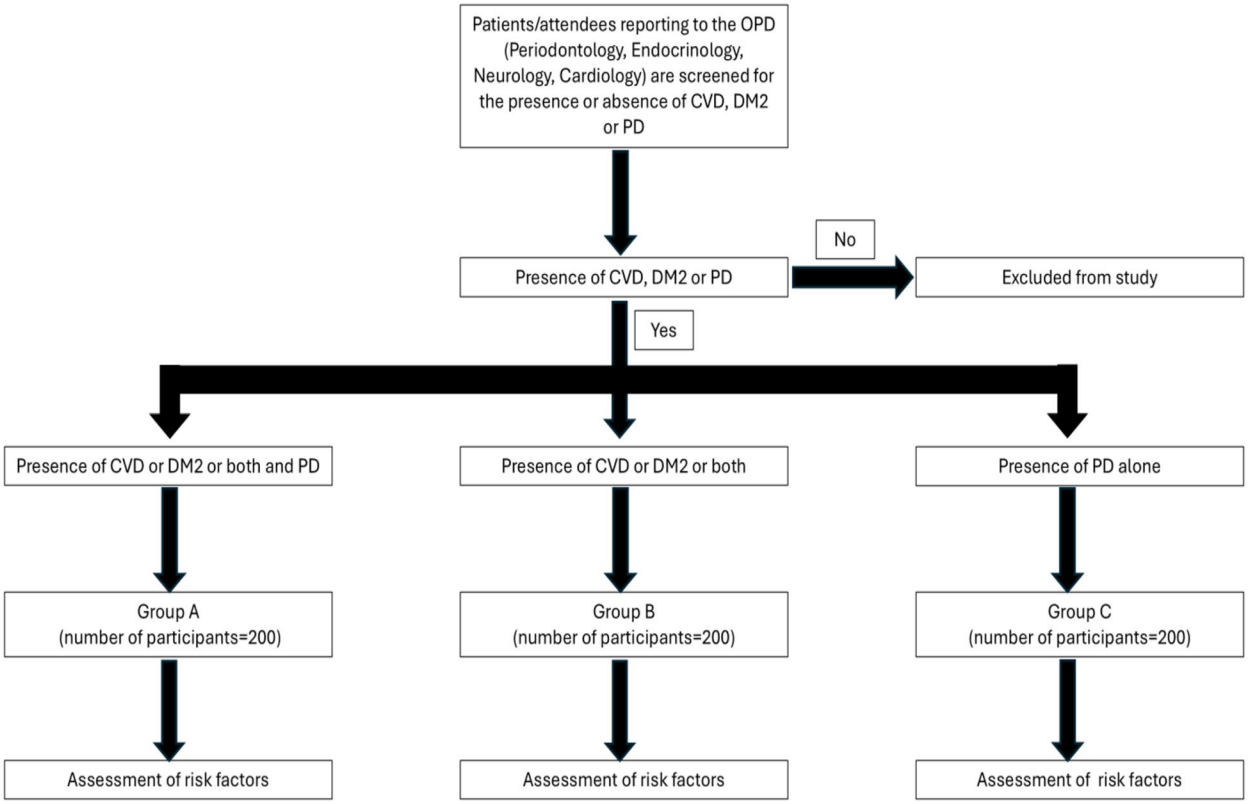

Fig. 1 Decision tree for participant recruitment and participant grouping

Alcohol Use Disorders Identification Test (AUDIT) [19], carbohydrate, fat and protein intake assessed using food frequency questionnaire [20],stress assessed using stress assessment tool [21],Oral hygiene assessed using Simplified Oral Hygiene Index (OHI-S) [22],plaque index [23] and gingival Index [24], severity of periodontal tissue destruction assessed using periodontal screening and recording index(PSR) [25], level of glycemic control assessed using HbA1c, fasting blood sugar(FBS), lipid profile.

Data sources

After obtaining informed consent, data was recorded using forms for clinical and laboratory investigations, alongside questionnaires on risk factors. Each participant was assigned unique ID for anonymity across documents and databases. Data collection methods included patient interviews, review of medical records, pathological reports, and oral examinations. Interviews, lasting 15–20 min, were conducted by Investigator LP or Investigator MK, both trained in interview techniques. The data collection process and the tools were standardized. The examiners were trained, and calibration sessions were conducted pre-study and during the study to ensure consistency. The calibration session involved data collection followed by review of the data collected and retraining, if necessary, until satisfactory consistency in data collection was demonstrated by the examiners.

Study size

Based on the results obtained in a previous study assessing the shared risk factors of NCDs and PD and taking into consideration the risk factor with the highest degree of agreement as a common risk factor [26], an estimated 40% prevalence of shared risk factors between NCD and PD has been anticipated. The necessary minimum sample size for each group was determined to be 164 based on anticipated 40% prevalence of shared risk factors between PD and any NCD, a power of 80%, and a 5% margin of error. The study's planned sample size was raised to 200 participants each group to account for any missing data, resulting in a total of 600 participants.

Statistical methods

Data analyses is done using the R Package and SPSS Version 29.0.2.0. The data obtained is tabulated and analyzed using descriptive statistics. The risk factors are expressed as percentages. Bivariate analysis using Pearson's chi-square test has been used to assess association of each risk factor with Periodontal disease, CVD and

Diabetes. Multinomial logistic regression is utilized to distinguish the occurrence of risk factors between groups and to identify significant risk factors for having both types of disease These factors have been ranked by how strongly they predict the common risk for Non communicable diseases and periodontal disease and how well they can discriminate between the two types of diseases by the deviance in the multinomial logistic regression model(partial chi-squared statistics). In this statistical analysis the discrimination model and the common risk model compares how different factors (like age, education, cholesterol levels, etc.) influence a certain outcome (like the likelihood of developing a disease condition). The Discrimination model is more focused on factors that help distinguish between different groups or outcomes, while the Common Risk model looks at factors contributing to overall risk.

Results

This study, conducted from July 2022 to April 2024 at a South Indian tertiary care hospital, screened patients and attendees reporting to the out-patient section of the departments involved in the study. 600 eligible participants were recruited and grouped into Groups A, B and C, each group having 200 participants (Fig. 1). 55.5% of the participants were males and 58.8% under 50 years. The percentage distribution of demographic characteristics and risk factors is given in Supplementary Table 1a-e along with the assessment of the association of these factors amongst the different groups. A significant association was found in terms of 20 of the risk factors assessed (Supplementary Table 1a, b, c, d, e).

Following this, multinomial logistic regression identified significant risk factors across the study groups: Group A (NCD + PD), Group B (NCD only), and Group C (PD only). (Table 1) Comparison 1 refers to Groups A vs. B, while Comparison 2 is for Groups A vs. C. Odds ratios (OR) less than 1 indicate associations with both groups in a comparison, whereas OR greater than 1 suggests an association with only one group. A confidence interval excluding 1 indicates a significant association and the findings are detailed in Table 1.

Age significantly influenced both comparisons, with ORs of 0.58 and 0.55 for Comparisons 1 and 2, respectively, indicating that individuals over 50 years are less likely to be in Groups B and C compared to Group A. Fat consumption exceeding 41 g/day was also significant, being 87% more likely in Group B and 3.29 times more likely in Group C compared to Group A. A sedentary lifestyle was significantly less prevalent in Group B compared to Group A (OR: 0.43, CI: 1.64 to −0.06). Elevated HbA1c levels (≥6.5%) had 44% reduced risk for NCD alone as compared to NCD and PD while HbA1c between 5.7–6.4% indicated 34% reduced risk for PD alone as compared to NCD and PD. Triglycerides (≥150 mg/dL) has 4% increased risk of NCD and PD compared to PD alone. Sedentary lifestyle can increase the likelihood of a combination of NCD and PD by 57% as compared to NCD alone. Education can reduce the risk for PD alone by 48% when compared to the risk for NCD and PD. A PSR value of 3 (indicating moderate levels of periodontal disease) indicates a 69% more risk of NCD and PD as compared to PD alone while PSR value of 4 (suggestive of severe periodontal destruction) indicates 11% greater risk of PD alone as compared to NCD and PD. Poor oral hygiene assessed using Oral Hygiene Index-Simplified (OHI-S) showed a three times greater risk of PD in patients with poor oral hygiene as compared to risk for NCD and PD combined. FBS > 126 mg/dl showed a 2.35 times increased risk for NCD as compared NCD and PD and a family history of the diseases increased the risk for NCD alone by 9.8 times as compared to NCD and PD.

Logistic regression analysis was performed to rank the risk factors by their predictive strength for shared risks associated with non-communicable diseases (NCDs) and periodontal diseases (PD), as well as their ability to discriminate between the two disease types (Table 2).

This analysis differentiated between the Discrimination model, which focuses on factors that distinguish between outcomes, and the Common Risk model, which looks at factors contributing to overall risk. Key discriminators included PSR, HbA1c, triglycerides, fat consumption, age, education, cholesterol, family history, LDL, OHI-S, alcohol consumption, access to care, and FBS. In the Common Risk model, severity of periodontal tissue destruction assessed using PSR, HbA1c, triglycerides, fat consumption, age, education, and obesity were highly significant, highlighting their critical role in assessing common risks (Fig. 2).

Discussion

Quantifying shared risk factors between PD and major NCDs is vital for tracking trends, shaping policy, and assessing interventions. The common risk factor model proposed by Sheiham and Watt [11] had diet, stress, smoking, alcohol, exercise, hygiene as common risk factors. Whereas Janakiram et al. [26] had identified smoking, family history, obesity, hypercholesterolemia, high blood pressure and alcoholism as the shared risk factors. In this research, periodontal disease severity assessed using PSR, HbA1c, age, education, obesity, triglycerides, and fat intake were identified as shared risk factors for diabetes, cardiovascular disease (CVD), or both, alongside periodontal disease.

Periodontal disease can result in systemic inflammatory response through the release of various

Table 1 Multinomial logistic regression analysis to distinguish risk factors significant amongst the groups

Variable		Odds Ratio -OR	CI- lower limit	CI-Upper limit
Age	Age > 50 years:1	0.58	−0.95	−0.15
	Age > 50 years:2	0.55	−1	−0.2
	Age < 50 years(Ref)	1	-	-
Sex	Female:1	1.18	−0.23	0.56
	Female:2	1.02	−0.38	0.42
	Male (Ref)	1	-	-
Obesity	Overweight:1	1.14	−0.3	0.56
	Overweight:2	1.41	−0.08	0.78
	Obese:1	0.67	−0.98	0.17
	Obese:2	0.58	−1.15	0.07
	Underweight and Normal (Ref)	1	-	-
Socioeconomic status assessed using the modified Kuppuswamy criteria	Lower middle class:1	0.91	−0.58	0.4
	Lower middle class:2	1.05	−0.44	0.54
	Upper lower class and lower class:1	1.24	−0.36	0.8
	Upper lower class and lower class:2	0.97	−0.63	0.58
	Upper and middle class (Ref)	1	-	-
Tobacco Use	Current Smoker & Current use of Chewing Tobacco:1	1.25	−0.17	0.61
	Current Smoker & Current use of Chewing Tobacco:2	1.2	−0.21	0.57
	Non-user/past user of tobacco (Ref)	1	-	-
Physical activity	Low activity:1	0.75	−0.72	0.15
	Low activity:2	0.89	−0.56	0.33
	Sedentary:1	0.43	−1.64	−0.06
	Sedentary:2	0.83	−0.89	0.53
	High and medium activity (Ref)	1	-	-
Alcohol use	AUDIT zone 2, 3 and 4:1	0.93	−0.49	0.35
	AUDIT zone 2, 3 and 4:2	1.53	0.02	0.83
	AUDIT zone 1 (Ref)	1	-	-
Macronutrients consumption in g/day Carbohydrates	Carbohydrates > 272:1	1.15	−0.25	0.53
	Carbohydrates > 272:2	1.04	−0.35	0.43
	Carbohydrates ≤ 272 (Ref)	1	-	-
Macronutrients consumption in g/day Fats	Fats > 41:1	1.87	0.23	1.02
	Fats > 41:2	3.29	0.78	1.6
	Fats ≤ 41 (Ref)	1	-	-
Macronutrients consumption in g/day Proteins	Proteins ≤ 52:1	0.9	−0.5	0.3
	Proteins ≤ 52:2	1.04	−0.36	0.44
	Proteins > 52 (Ref)	1	-	-
Stress	Moderate stress:1	0.72	−0.88	0.24
	Moderate stress:2	0.77	−0.82	0.3
	Severe stress:1	0.77	−0.92	0.4
	Severe stress:2	0.74	−0.98	0.36
	Low stress (Ref)	1	-	-
Oral hygiene assessed using Oral hygiene index-simplified (OHI-S)	Poor:1	0.72	−0.77	0.11
	Poor:2	3.01	0.53	1.67
	Good and fair (Ref)	1	-	-

Table 1 (continued)

Variable		Odds Ratio -OR	CI- lower limit	CI-Upper limit
Level of glycemic control assessed using glycated haemoglobin levels in percentage (HbA1c%)	HbA1c(5.7–6.4):1	0.64	−1.06	0.16
	HbA1c(5.7–6.4):2	0.34	−1.62	−0.52
	HbA1c > = 6.5:1	0.56	−1.07	−0.1
	HbA1c > = 6.5:2	0	−1296.22	1255.98
	HbA1c < 5.7 (Ref)	1	-	-
Fasting blood sugar (FBS) levels in mg/dl	FBS > 126 mg/dl:1	2.35	0.4	1.31
	FBS > 126 mg/dl:2	0	−1177.42	1142.19
	FBS ≤ 126 mg/dl (Ref)	1	-	-
Total Cholesterol in mg/dl	Borderline high 200–240 mg/dl:1	1.22	−0.47	0.86
	Borderline high 200–240 mg/dl:2	0	−1872.16	1836.63
	High > 240 mg/dl:1	1.36	−0.44	1.06
	High > 240 mg/dl:2	0	−2145.61	2110.19
	Normal < 200 mg/dl (Ref)	1	-	-
High Density Lipoprotein (HDL) in mg/dl	Low < 40 mg/dl:1	0.94	−0.54	0.42
	Low < 40 mg/dl:2	0.88	−0.61	0.36
	Normal 40–60 mg/dl and high > 60 mg/dl (Ref)	1	-	-
Low Density Lipoprotein (LDL) in mg/dl	Borderline high 130–159 mg/dl:1	1.48	−0.1	0.89
	Borderline high 130–159 mg/dl:2	0.93	−0.59	0.44
	High and very high ≥ 160 mg/dl:1	1.53	−0.25	1.09
	High and very high ≥ 160 mg/dl:2	0	−1137.18	1103.92
	Normal and near optimal ≤ 129 mg/dl(Ref)	1	-	-
Triglycerides in mg/dl	High > 150 mg/dl:1	0.63	−0.93	0
	High > 150 mg/dl:2	0.04	−4.45	−2.08
	Normal 60–150 mg/dl(Ref)	1	-	-
Periodontal disease severity assessed using Periodontal screening and recording index (PSR)	PSR3:1	0	−7902.25	7816.19
	PSR3:2	0.69	−7677.46	7676.71
	PSR4:1	0	−6208.54	6123
	PSR4:2	1.11	−7676.98	7677.19
	PSR 1 and 2 (Ref)	1	-	-
Access to care	No:1	0.81	−0.69	0.27
	No:2	1.43	−0.09	0.81
	Yes (Ref)	1	-	-
Education	Post high school to professional degree:1	0.71	−0.75	0.06
	Post high school to professional degree:2	0.52	−1.08	−0.23
	Uneducated to high school (Ref)	1	-	-
Occupation	Semi-skilled:1	1.35	−0.45	1.05
	Semi-skilled:2	1.68	−0.26	1.3
	Skilled/Professional:1	1.76	−0.28	1.41
	Skilled/Professional:2	1.79	−0.31	1.47
	Unskilled (Ref)	1	-	-
Family history of occurrence of CVD, DM or PD	Family history of occurrence of CVD, DM or PD:1	9.8	0.81	3.76
	Family history of occurrence of CVD, DM or PD:2	0.99	−0.71	0.68
	No family history of occurrence of CVD, DM or PD (Ref)	1	-	-
Number of members in the family	5–6 members:1	1.82	−0.09	1.29
	5–6 members:2	0.85	−0.75	0.42
	7–10 members:1	1.68	−0.37	1.41
	7–10 members:2	0.59	−1.39	0.32
	1–4 members (Ref)	1	-	-

Table 1 (continued)

Variable		Odds Ratio -OR	CI- lower limit	CI-Upper limit
Health Insurance	No:1	1.18	−0.23	0.56
	No:2	1.47	−0.01	0.78
	Yes (Ref)	1	-	-

Dependent variable: Group 1-NCD and PD; Group 2- NCD only; Group 3-PD only

1 indicates comparison between Groups A and B

2 indicates comparison between Groups A and C

Table 2 Discrimination and common risk model to rank the risk factor

Risk Factor	df	Discrimination		Common risk	
		Deviance	Pr (> Chi)	Deviance	Pr (> Chi)
Periodontal disease severity assessed using Periodontal Screening and Recording Index (PSR)	4	767.6	0.00	213.1	0.00
Level of glycemic control assessed Glycated hemoglobin levels (HbA1c) in percentage	4	267.2	0.00	80.8	0.00
Triglycerides in mg/dl	2	70.3	0.00	28.6	0.00
Macronutrients consumption in g/day-Fats	2	33.5	0.00	26.2	0.00
Age	2	10.8	0.00	10.7	0.00
Education	2	9.5	0.01	7.5	0.01
Obesity	4	8.9	0.06	7.2	0.03
Total Cholesterol in mg/dl	4	61.3	0.00	4.6	0.10
Family history of occurrence of CVD, DM or PD	2	18.8	0.00	3.6	0.06
Physical activity	4	5.3	0.26	2.5	0.29
Health Insurance	2	3.7	0.16	2.5	0.11
Occupation	4	3.2	0.53	2.3	0.32
Low Density Lipoprotein (LDL) in mg/dl	4	38.9	0.00	2.1	0.35
Stress	4	1.6	0.80	1.4	0.49
Tobacco Use	2	1.4	0.50	1.3	0.25
Oral hygiene assessed using Oral hygiene Index-Simplified (OHI-S)	2	30.0	0.00	1.3	0.26
Alcohol use assessed using AUDIT	2	6.7	0.04	1.0	0.31
High Density Lipoprotein (HDL) in mg/dl	4	3.6	0.47	0.7	0.71
Number of members in the family	4	7.2	0.12	0.6	0.75
Socioeconomic status assessed using modified Kuppuswamy criteria	4	2.7	0.61	0.3	0.85
Sex	2	0.8	0.68	0.3	0.60
Macronutrients consumption in g/day- Carbohydrates	2	0.5	0.77	0.3	0.60
Access to care	2	6.2	0.05	0.2	0.64
Fasting Blood Sugar (FBS) in mg/dl	2	114.0	0.00	0.1	0.71
Macronutrients consumption in g/day -Proteins	2	0.5	0.76	0.0	0.86

df-Degree of freedom

Pr (> Chi)- Partial chi-squared statistics

pro-inflammatory cytokines. This in-turn can affect various intracellular pathways that can affect the homoeostatic mechanisms in the body resulting in various systemic diseases [10]. Periodontal probing pocket depth (PPPD), a measure of severity of periodontal tissue destruction, assessed using PSR, was observed to be linked with combined NCD and periodontal disease when it ranged between 3.5–5.5 mm. Periodontal pocket is defined as a pathologically deepened gingival sulcus and is one of the clinical features of periodontal disease. As mentioned previously, inflammation, [27] as well as periodontal pathogens have been implicated in the interlink between systemic diseases and periodontal disease [28] and our study has given a numerical visualization of the extent of the interlink.

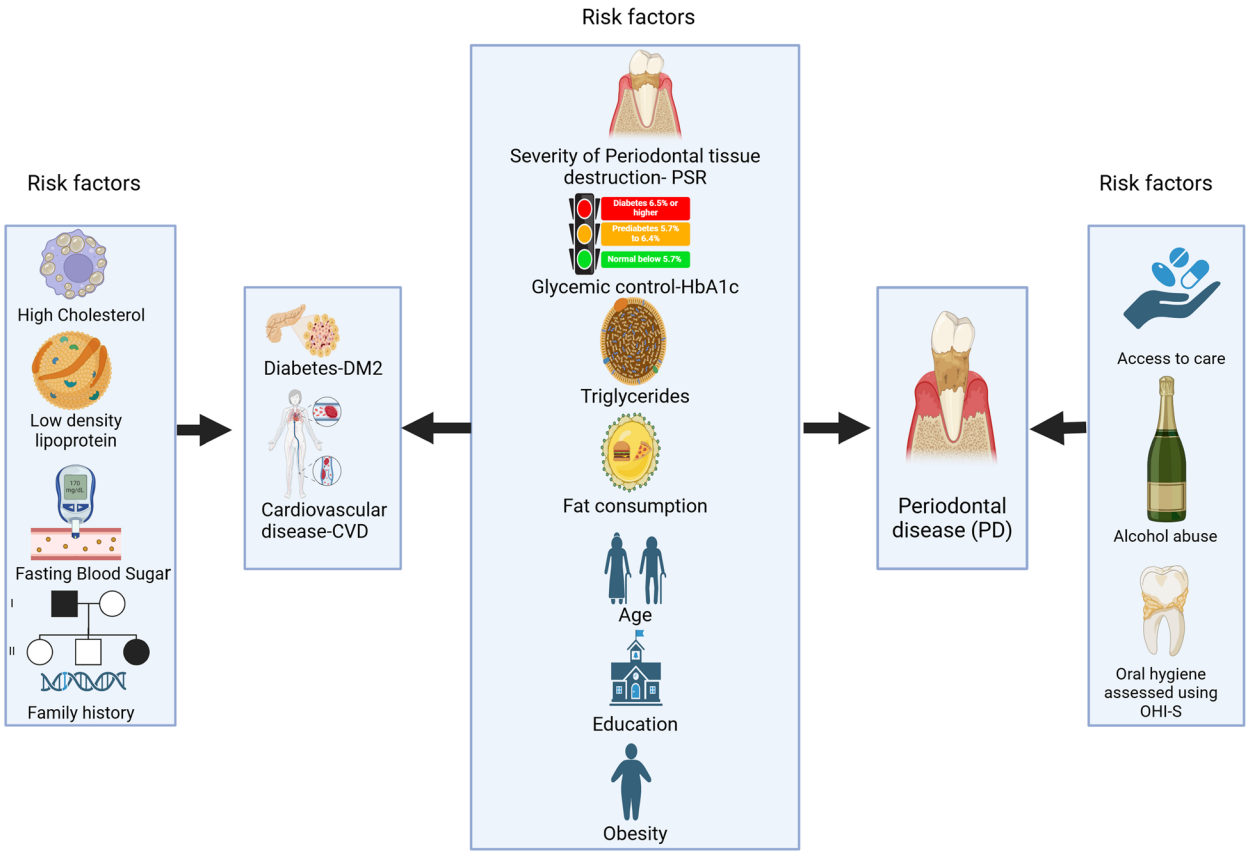

Fig. 2 Shared risk factors and discriminators of NCD and PD

HbA1c represents the glycated haemoglobin levels and represents diabetic state. Literature has shown that the HbA1c levels were more significantly associated with patients diagnosed with stage III/IV periodontitis [29]. In our study, participants with HbA1c between 5.7%–6.4% and HbA1c > 6.5% were identified to more likely have both NCD and periodontal disease rather than either NCD or periodontal disease alone. HbA1c levels have been noted to be higher in non-diabetic periodontitis patients [30]. Diabetes can increase the inflammation in the periodontal tissues. In addition, they can alter the immune response of the host to the periodontal pathogen resulting in hyper-inflammatory response with resultant destruction of the supporting structures of the teeth. Moreover, the advanced glycation end products can adversely affect the bone metabolism and impair healing of tissues. [31] Diabetes, with its pro-inflammatory effect, can result endothelial dysfunction with an increase the risk for atherosclerosis and various cardiovascular events [32]. Thus, the findings from our study agree with the existing literature.

A significant association between age and disease incidence was also observed, with individuals over 50 having an elevated risk of combined NCD and periodontal conditions. It has been observed in previous research that aging is associated with elevations in systemic markers of inflammation [33] and has been identified as a common predictor of CVD in men and women. Moreover, the free-radical theory of aging states that aging results in accumulation of free radicals with resultant development of pathologies and disorders associated with aging [34].

Education levels affected disease outcomes, with higher education correlating to a lower risk of either NCD or PD alone. Oshio et al. have observed a reduction in risk for NCDs with education [35]. Another study showed that in non-educated women, there were low odds of occurrence of NCDs, but the odds increased in women with less than five years of schooling and again reduced for women with five to nine years of schooling. In men, the odds for occurrence of NCDs increased with the level of education [36].

Obesity was found to be a significant shared risk factor, especially in overweight participants in our study. Obesity has been shown to increase the odds of periodontal disease [37]. In the English Longitudinal Study of Ageing (ELSA), and the Health and Retirement Study

(HRS), obesity was associated with an elevated risk of NCDs [38]. Obesity has been associated with an increase in the levels of TNFα and its receptors; this can cause a hyper-inflammatory state, resulting in changes in insulin resistance and endothelial function, increasing the risk for DM and NCDs. This altered immune response also results in destruction of the periodontal tissue [39].

High-fat diets correlated with increased risk. Research has shown that consumption of diet high in saturated fat and cholesterol resulted in more bone loss on exposure to lipopolysaccharides of periodontal pathogens [40]. Animal meat sources of Saturated Fatty Acids and dairy fat can increase atherosclerotic lipoproteins and increase the risk for CVDs [41]. However, unsaturated fatty acids have been seen to have protective effect and aid in prevention of development of metabolic diseases and reduce cardiovascular events [37].

Triglycerides above 150 mg/dl were associated with a higher likelihood of combined disease, mirroring trends seen in systemic disease research. Research has shown that the occurrence of periodontal disease in people with elevated triglyceride level was 1.499-times higher than in those who had normal levels of triglycerides [42]. Evidence from existing literature also proves an association between triglycerides and the development of CVD [43].

Gender, occupation, and insurance can affect the risk for systemic and oral diseases. Women and individuals from lower socioeconomic backgrounds showed differing disease trends. Systemic health may be impacted by the immune-boosting effects of estrogens and the immunosuppressive effects of progesterone and testosterone [44]. Males are more likely than females to acquire severe periodontal disease due to a clustering of factors such as smoking and tobacco chewing, poor dental hygiene, and socioeconomic position [44]. A gradient related to the risk of developing periodontal disease with change in occupation has been seen. Professionals have been observed to have less risk of developing the disease [45]. In terms of insurance, the percentage of people who received therapy and were able to control these risk factors was lower among the uninsured, even though the prevalence of hypertension and increased LDL cholesterol was comparable for the insured and uninsured. Chronically ill patients without insurance were more likely to not have a standard site for care or access to care [46]. Majority of the participants in our study belonged to the lower middle-class group with a uniform distribution in terms of gender. This might have contributed to the variation observed in our study regarding the effects of gender and socioeconomic status on NCDs and Periodontal disease.

Low activity and sedentary lifestyle are risk factors for with NCD and PD rather than NCD or PD alone and the effect is statistically significant for sedentary lifestyle. This is analogous to the results obtained from existing literature [47]. Sedentary behaviour is seen to have a dose–response relationship to NCD [48]. This may be attributed to the increased risk of metabolic syndrome in these individuals which will lead to a chronic inflammatory state with the ensuing propensity for enabling the progression of NCDs and PD.

Carbohydrate and protein consumption have not been shown to have a statistically significant role as shared risk factors of NCD and PD. However, literature shows that both high saturated fats and less-diversified foods in the diet have significant positive associations with the prevalence of NCDs and PD. Therefore, optimum and moderate diet diversity is recommended to prevent these NCDs and PD [49].

In our study, although smoking was seen to be associated with NCD or PD alone as compared to a combination of both NCD and PD, the association was not statistically significant. 60%,58% and 54% of the participants in groups A, B and C were non-users or past users of tobacco. This distribution of tobacco users in the groups might have been one of the factors that has affected the outcome of our research. Moreover, self-reported assessment of tobacco use may also contribute to the variation of our results from the existing literature. However, similar results have been obtained in the study in which the Summary Exposure Value (SEV) of smoking was negatively associated with periodontitis prevalence [50].

In our study, stress has not been identified as statistically significant shared risk factor for NCD and PD. Self-reported and subjective nature of stress assessment might have contributed to the variation seen in our study. However, the analysis has shown that stress is 23 to 28% more likely to be a risk factor for a combination of NCD and PD rather than NCD or PD alone suggesting that stress reduction strategies can aid in holistic management of diseases.

Borderline high and high levels of cholesterol, high LDL, high FBS, family history of NCD were indicative of an increased likelihood of NCD alone rather than PD alone or a combination of NCD and PD. Dyslipidaemia is a crucial risk factor for NCDs [51] similar to a high level of FBS [52]. and this is proven in our study also. However, in contrast to the findings from our study, dyslipidaemia was also seen to be associated with periodontitis through a direct pathway and indirectly through HbA1c and obesity in the US population [53]. Similar discrepancy is seen between the results from our study and literature in the familial pattern of occurrence of NCD and PD as genetics has been identified as risk factor for both NCDs and PD in literature [54].

Alcohol use, access to care and OHI-S were factors that are indicative of risk for PD alone as compared to NCD alone or combination of NCD and PD. OHI-S is a definite indicator of the risk for periodontal disease as poor oral hygiene is one of the most important factors for initiation of PD. In our study, it was observed that alcohol use is more likely to be associated with PD alone or a combination of NCD and PD rather than NCD alone. NCD-related burden of deaths can be significantly attributed to alcohol consumption, especially for cancer and liver cirrhosis [55]. This is not reflected in our study probably due to the focus on NCDs other than cancer or liver cirrhosis. Literature has shown that alcohol use has been associated with increased alveolar bone loss [56]. Lack of access to care has been associated periodontal disease. A compromised access to care affects oral health care delivery and affects oral health of the patient [57].

Our study demonstrates that certain risk factors can predisposing to occurrence of both NCDs and PD acting as common risk factors or help to discriminate between the occurrence of either NCDs or PD. Factors like HbA1c, triglycerides, increased consumption of fat, PSR, age, and total cholesterol are crucial in discriminating between different outcomes or risk levels. Obesity, family history of the disease, and physical activity are important though not critical discriminating factors. Similar to the discrimination model, HbA1c, triglycerides, increased consumption of fat and PSR, are critical in assessing common risks. Obesity, total cholesterol, family history of disease, education, and age demonstrate minimal significance as a shared risk factor. Factors like tobacco use, OHIS, Alcohol, number of members in the family, stress, and insurance are not relevant as common or shared risk factors of NCDs and PD.

Although external validity of the study is compromised as it is a hospital-based study, the study provides a numerical identity to an exhaustive array of risk factors shared between NCDs and PD. The Community Based Assessment Checklist (CBAC) is in use for NCD risk factor surveillance [58]. Several risk factors in CBAC are the same as the shared risk factors identified through our study. Severity of periodontal tissue destruction assessed using PSR as well as oral hygiene assessment may be added to the checklist to incorporate PD as well as oral disease risk factor assessment into the NCD risk assessment checklist. This can bring about the initiation of the integrated health care delivery through the common risk factor approach. Future research, using a modified risk surveillance tool, may help understand the effectiveness of the integration of NCD and PD care through common risk factor surveillance.

Conclusion

The study identified age, education, obesity, severity of periodontal disease assessed using PSR, HbA1c, triglycerides, and increased consumption of fats as shared risk factors for type 2 diabetes, cardiovascular disease, and periodontal disease. Including these in disease surveillance tools may help detect NCD and periodontal disease risks, supporting integrated healthcare through a Common Risk Factor Approach to enhance prevention and management.

Existing literature has shown that due to the two-way relationship between diabetes and periodontal disease and the role of immune and inflammatory pathways that link periodontal disease with the NCDs, management of the periodontal disease, may help in reducing the risk for NCDs. Our study, which shows that the severity of periodontal tissue destruction is a shared risk factor of periodontal disease and NCDs, also highlights the importance of identifying the presence of periodontal disease and facilitating its management. Thus, integrated care delivery through the CRFA may help mitigate the risk for NCDs and PD and reduce the socio-economic burden imposed by these conditions on the society.

Abbreviations

AUDIT	Alcohol Use Disorders Identification Test
BMI	Body Mass Index
CRFA	Common Risk Factor Approach
CBAC	Community Based Assessment Checklist
CVD	Cardiovascular diseases
DM	Diabetes Mellitus
ELSA	English Longitudinal Study of Ageing
FBS	Fasting Blood Sugar
GI	Gingival Index
HbA1c	Glycated Haemoglobin level
HDL	High Density Lipoprotein
HRS	Health and Retirement Study
IRB	Institutional Review Board
LDL	Low Density Lipoprotein
NCDs	Non-communicable diseases
OECD	Organisation for Economic Co-operation and Development (OECD)
OHI-S	Oral Hygiene Index-Simplified
OR	Odds Ratio
PD	Periodontal disease
PI	Plaque Index
PPPD	Periodontal Probing Pocket Depth
PSR	Periodontal Screening and Recording Index
SEV	Summary Exposure Value
STROBE	Strengthening the Reporting of Observational studies in Epidemiology

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions
LP and CJ: Contributed to conception, design, data acquisition and interpretation, drafted and critically revised the manuscript GG and SCB: Contributed to data interpretation, performed all statistical analyses and critically revised the manuscript RV, MK, SS, ARP, SR: Contributed to design, data acquisition and interpretation and critically revised the manuscript SS and AF: Contributed to conception, design and critically revised the manuscript All authors reviewed the manuscript.

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Data availability
"The datasets analysed during the current study are available from the corresponding author on reasonable request."

Declarations

Ethics approval and consent to participate
This epidemiological study was designed in compliance with the principles of the Helsinki Declaration and the study was approved by the institutional scientific review committee and the institutional ethics committee. The study received ethical approvals from the Institutional Review Board and the Kasturba Medical College and Kasturba Hospital Institutional Ethics Committee, under the reference IEC-834/2021 and informed consent was obtained from the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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