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Association between oral health and physio-cognitive decline syndrome of older adults in China and its sex differences: a cross-sectional study

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Abstract

Background Physio-Cognitive Decline Syndrome (PCDs) is characterized by the coexistence of MIND (mobility impairment, no disability) and CIND (cognitive impairment, no dementia), which predicts dementia risk. Deteriorating oral health can contribute to malnutrition, cognitive decline, and physical frailty, all of which may exacerbate PCDs symptoms. This study investigates the association between oral health and PCDs, exploring sex differences in this relationship.

Method A cross-sectional analysis of the baseline data from the Nanjing Brain Health Cohort included 252 participants aged 60 and older, assessing physical mobility (6-meter walk test, grip strength), cognitive function (MoCA), and oral health (natural teeth count, denture use, tongue and lip motor function, masticatory and swallowing ability, Oral Frailty Index). Logistic regression models were used to examine associations between oral health and PCDs.

Results Among participants, 15.5% were classified as having PCDs. The odds of having PCDs were lower with a higher number of teeth (OR = 0.939, 95% CI: 0.890–0.991, $p = 0.021$), while impaired tongue and lip motor function increased the odds of PCDs (OR = 3.811, 95% CI: 1.059–13.717, $p = 0.041$). In females, the odds of MIND and CIND were lower with a greater number of teeth and denture use. For males, the odds of PCDs were higher with oral frailty (OR = 5.202, 95% CI: 1.429–18.940, $p = 0.012$).

Conclusions Findings underscore the significant association between oral health and the odds of PCDs among older adults, with sex-specific effects. For women, maintaining natural teeth and proper denture use are associated with

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lower odds of MIND and CIND, while for men, oral frailty is linked to higher odds of PCDs. Healthcare providers should consider oral health and incorporate sex-specific strategies.

Keywords Physio-cognitive decline syndrome, Oral frailty, Oral function, Sex differences

Introduction

Dementia is a growing global concern, with a reported prevalence of 5.30% among Chinese people aged 60 years and older [1]. It impacts overall health, increases mortality risks, and places a considerable burden on public health systems [2]. In response to this challenge, studies have focused on modifiable factors that influence health outcomes, indicating that dual impairments in cognitive function and mobility are linked to an elevated risk of dementia [3]. One clinical phenotype that has emerged to identify at-risk community-dwelling older adults is Physio-Cognitive Decline Syndrome (PCDs), which reflects simultaneous declines in physical mobility and cognitive function [4].

PCDs have been shown to increase the risk of falls, disability, mortality, and incident dementia [5]. PCDs integrate clinical features of both physical and cognitive impairments, allowing for the screening of older adults at high risk for adverse outcomes. This enables early interventions that promote healthy aging. Recognizing the implications of PCDs highlights the urgent need for effective screening of prevalent and early-stage reversible conditions among at-risk community-dwelling older adults. The operational definition of PCDs proposed by the Asian Working Group for Sarcopenia 2019 (AWGS 2019) identifies a significant group of at-risk older adults, establishing a phenotype with a clearly defined, potentially reversible pathological etiology [6]. An individual is classified as having PCDs when there is both mobility impairment no disability (MIND: slow gait or/and weak handgrip) and cognitive impairment no dementia (CIND: ≥1.5 SD below the mean for age-, sex-, and education-matched norms in any cognitive domain but without dementia) [7]. This classification into four phenotypes—Robust, CIND, MIND, and PCDs—enhances our understanding of varying risk levels among older adults. PCDs successfully comprises a considerable population of at-risk older people and potentially serves as a treatment target at an early preclinical stage of unhealthy aging [8]. This underscores the importance of focusing on PCDs, as they may provide more timely predictions of adverse outcomes. Identifying individuals with PCDs allows healthcare providers to implement targeted interventions earlier, potentially reducing the risk of falls, disability, mortality, and incident dementia [9, 10]. Early identification of risk factors associated with PCDs can enhance prevention and management. However, current research primarily focuses on imaging analysis and adverse outcomes, while factors influencing PCDs remain under-examined.

A randomized controlled trial involving older adults with comorbidities highlights that factors such as physical exercise, cognitive training, dietary education, and chronic condition management are effective multimodal interventions for the prevention and treatment of PCDs [11]. Despite this, the role of oral health remains unexamined. Oral health is recognized as "a standard of health of the oral and related tissues that enables an individual to eat, speak, and socialize without active disease, discomfort, or embarrassment, and which contributes to general well-being." [12]. Maintaining good oral health is essential for ensuring a high quality of life, particularly in older adults. As individuals age, notable changes in oral structures and functions can lead to various oral health problems, such as tooth loss and difficulties with chewing. Studies have demonstrated that poor oral health is associated with malnutrition [13], sarcopenia [14], cognitive impairment [15], physical frailty [16], and accumulating multi-morbidity [17]. Poor oral health can exacerbate cognitive decline [18] and mobility issues [19], both of which are core aspects of PCDs. The biological mechanisms linking oral health and cognitive function involve several key factors. Oral microbiome dysbiosis and inflammation from periodontal bacteria can impair brain function and promote systemic inflammation [20]. Additionally, research indicates that tooth loss is associated with atrophy in the medial temporal lobe, accounting for approximately 9% of cognitive decline [21]. Furthermore, chewing plays an important role in regulating the hypothalamic-pituitary-adrenal (HPA) axis and protecting hippocampus-dependent cognitive functions [22]. Nevertheless, the association between oral health and PCDs in older adults has not been clarified.

Oral health status is supported by a variety of factors related to dental and oral function. Existing studies use the number of teeth [23], periodontal disease [24], self-rated oral health [25], oral diadochokinesis [26], and masticatory function [27] as indicators of oral health. Dibello et al.'s systematic review [28] emphasizes the significance of oral health indicators in predicting adverse health outcomes in older adults and highlights that these indicators are currently underutilized in health surveys and clinical practices. The impact of single oral health indicators on PCDs warrants further exploration. Furthermore, the term "oral frailty" was coined to recognize the multidimensional nature of poor oral health. Suzuki et al. [29] believe that oral frailty represents a cumulative state of slightly poor oral condition and function, which can serve as an effective predictor of physical frailty. Studies have shown that oral frailty, characterized by the loss or decline of various oral functions such as the number of teeth, periodontal status, swallowing ability, biting force, and tongue pressure, is an important risk factor for physical frailty and mortality in community-dwelling elderly individuals [16]. Oral frailty is an emerging concept that offers a comprehensive perspective on the interactions between various factors. However, it raises important questions about how these interactions collectively impact PCDs and other phenotypes. Some studies focus on single of oral health indicators, whereas others emphasize oral frailty, with each approach offering its advantages: single indicators can provide specific insights into particular aspects of oral health, whereas oral frailty captures the cumulative effects of multiple factors, offering a broader understanding of oral health's impact on overall health decline. To thoroughly investigate the relationship between oral health and PCDs, it is essential to explore how both single of oral health indicators and oral frailty relate to PCDs. This comprehensive approach allows for a more nuanced understanding of the implications of each factor for PCDs and other phenotypes.

Studies indicate that the incidence of PCDs differs between males and females, with males exhibiting a higher prevalence [4]. Understanding the factors contributing to this disparity is crucial for informing targeted interventions and improving health outcomes. The study conducted by Su et al. identified notable differences in oral health and hygiene behaviors between the two sexes, demonstrating higher levels of oral health awareness [30]. These disparities can lead to variations in clinical indicators of disease, health behaviors, and perceptions of oral health, resulting in a disproportionate burden of oral diseases between sexes. Moreover, studies suggest that cognitive decline differs with age based on sex, often attributed to physiological differences [31, 32]. Consequently, males and females experience oral health issues differently, and distinct physiological mechanisms influence the outcomes. Recognizing these sex differences is vital when examining the relationship between oral health and PCDs, as they may highlight specific factors through which these conditions interact.

As mentioned above, this study aimed to investigate the association of single indicators of oral health and oral frailty with PCDs and other phenotypes among older adults, as well as the sex differences in these associations.

Methods

To provide a comprehensive understanding of how various indicators of oral health relate to PCDs, we developed a conceptual framework illustrated in Fig. 1. Drawing on the model proposed by Castrejón-Pérez et al. [33], which highlights the impact of oral health on frailty in community-dwelling elderly, and the mechanisms linking dual decline and dementia outlined by Tian et al. [3], we aimed to provide a comprehensive understanding of how these indicators relate to PCDs.

Study design and population

This was a cross-sectional study conducted in accordance with the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [34]. The data were derived from the Nanjing Brain Health Cohort, a prospective study designed to assess and identify risk factors associated with aging, frailty, and cognitive function, specifically using the baseline data collected from participants at the start of the cohort. Participants were recruited from six communities in Jiangning District, Nanjing, China, between June 2023 and August 2023. The inclusion criteria for this study were individuals aged 60 years or older who have lived in the community for over 6 months. Participants were excluded based on the following criteria: severe psychiatric or neurodegenerative disorders, major brain injuries, cerebrovascular diseases, epilepsy, encephalitis, significant hearing or visual impairments, serious physical disabilities, and inability to provide informed consent. The Ethical Committee of the Nanjing Medical University, China, approved this study (NMU2023-562).

Sample size

The study utilized the PASS (Power Analysis and Sample Size) 2023 statistical software (NCSS LLC., Kaysville, U.T., USA) [35] to calculate the required sample size for a cross-sectional study. Based on previous research indicating a 13.3% prevalence of PCDs among community-dwelling elderly individuals [4, 11], a 95% confidence interval was established with a permissible error of 0.05. This calculation determined that a minimum sample size of 196 elderly participants is necessary. Considering a 20% dropout rate during the survey, the total number of participants required is at least 245.

Variables and measurements

Physical and cognitive examination

Participants were asked to walk 6 m at their usual pace, with walking speed measured through two timed trials. To ensure consistency, participants were instructed by the researcher to begin walking from a standing position, and the time was measured with a stopwatch from the moment their toes crossed the starting line until they crossed the finish line. The maximum speed from these trials was recorded for gait speed analysis (meters per second, m/s). Handgrip strength was measured using a Jamar hand dynamometer. Participants were instructed to stand with their elbows extended and to grip the

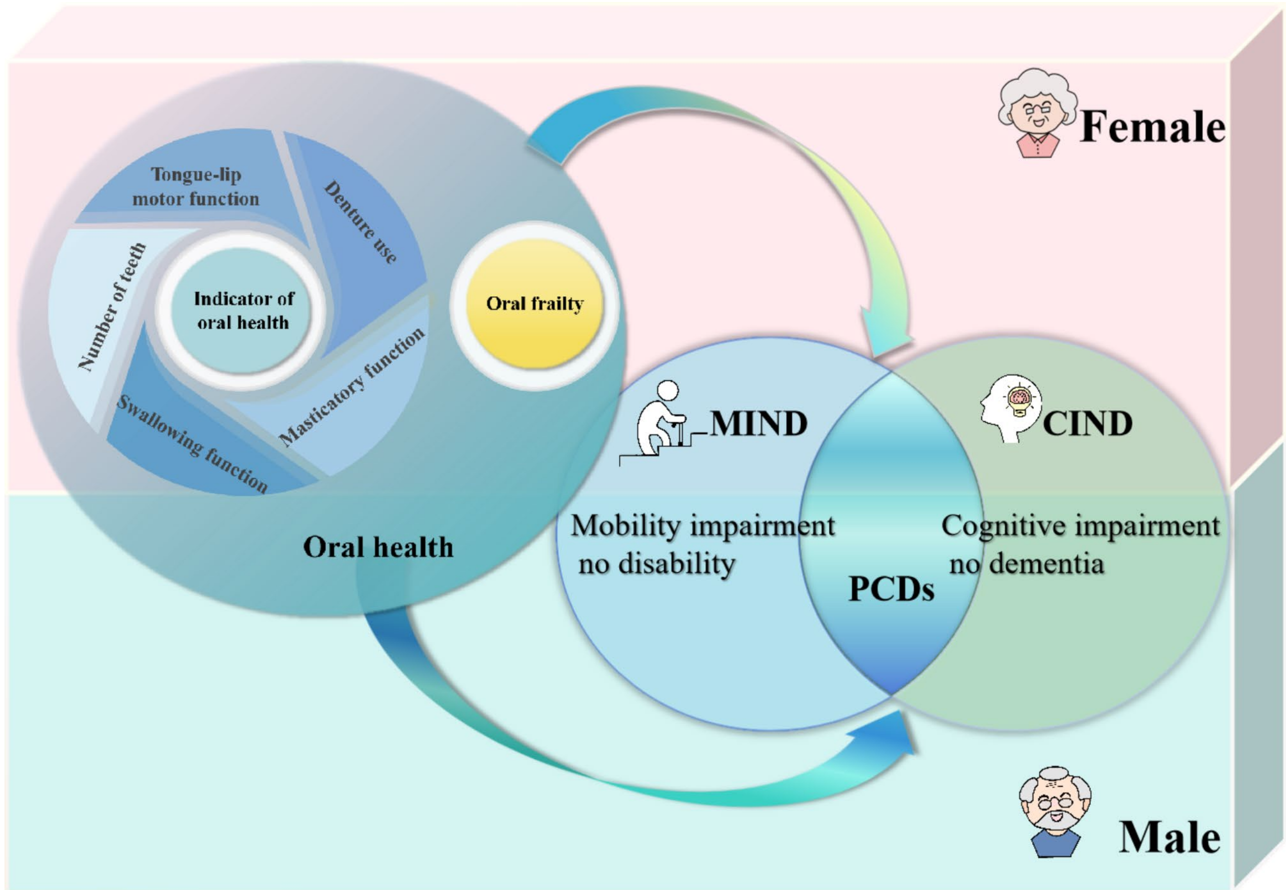

Fig. 1 The conceptual framework for the association between oral health and physio-cognitive decline syndrome (PCDs)
Notes: The arrows illustrate that oral health impacts PCDs and other phenotypes in varied ways across different populations

dynamometer with their dominant hand as hard as possible for a few seconds. Two measurements were taken from the dominant hand, separated by a 15–20 s rest interval to prevent fatigue, and the maximal value was used as the final measurement result.

Cognitive function was evaluated using the Chinese versions of the MoCA in a quiet room to minimize distractions [36]. The assessment included subdomains such as visuospatial executive function, naming, attention, language, abstraction, delayed recall, and orientation. Participants received clear instructions for each section, and the entire assessment typically lasted about 10–15 min. The specific items of the MoCA were detailed by Nasreddine and his associates [37]. To ensure the validity of the assessment, all investigators involved were trained in standardized procedures for administering the MoCA.

Definition and measurement of MIND, CIND, PCDs

MIND is characterized by weakness, indicated by grip strength < 28 kg for men and < 18 kg for women, or slowness, defined as a usual gait speed < 1 m/s, based on the cutoff values recommended by AWGS 2019 [38]. CIND is identified when any cognitive domain score on the MoCA is 1.5 standard deviations below age-, sex-, and education-matched norms, excluding dementia. PCDs are defined as the concurrent presence of MIND and CIND.

Oral health-related variables

Number of teeth The total count of natural teeth present in the participant's mouth (0–32), was assessed by professionally trained investigators.

Denture use Indicates whether the participant is utilizing dental prosthetics. Participants were asked about their use of dentures, and trained investigators visually examined their oral cavity to confirm the presence of any complete or partial dentures.

Tongue and lip motor function The Oral diadochokinesis (ODK) was used to evaluate tongue-lip motor function by measuring the articulation of the syllables "pa", "ta", and "ka" [39]. Participants articulated each syllable 20 times as quickly as possible, with the total time recorded using a phone's digital counter. To ensure consistency and minimize variability, participants were instructed to practice articulating each syllable 2 to 3 times before the actual measurement. The articulation rate was calculated by dividing 20 by the total time for each syllable, reflecting the motor speed and function of the lips and tongue. This calculation was objectively measured by the investigator to ensure accuracy and reliability. Poor ODK status was defined as: for men, "pa" and "ta" <5.2 times/s and "ka" <4.4 times/s; for women, "pa" <5.6 times/s, "ta" <5.4 times/s, and "ka" <5.0 times/s [16]. Reduced motor function of the tongue and lips was indicated by poor ODK status.

Swallowing function The Repetitive Saliva Swallowing Test (RSST) assessed swallowing function decline [40]. Participants performed voluntary swallowing as quickly as possible for 30 s, with the total swallows serving as the RSST score. Prior to testing, participants were instructed to remain relaxed and to swallow saliva without any external aids. The number of swallows during this period was objectively measured by the investigator to ensure accuracy. A score of fewer than 3 swallows in 30 s indicated abnormal swallowing performance.

Decreased masticatory function Assessed through a question about difficulties in eating tough foods compared to six months ago. A response of "yes" classifies a participant as having decreased masticatory function.

Oral frailty In this study, oral frailty was assessed using three indicators: having fewer than 20 natural teeth, an 8-item Oral Frailty Index (OFI-8) score of 4 or higher, and poor ODK status. The OFI-8 was self-reported by participants, while the number of teeth and poor ODK status were measured objectively by the investigators. Previous research has demonstrated the scientific validity of this assessment method [41]. The OFI-8 serves as a screening tool for evaluating oral frailty in the elderly, encompassing five dimensions: denture use, swallowing function, chewing ability, oral health-related behaviors, and social participation. It scores from 0 to 11, with higher scores indicating worse oral health, and a score of ≥4 signifies oral frailty. The Chinese version of OFI-8 demonstrates acceptable reliability, with a Cronbach's α of 0.949 and a re-test reliability coefficient of 0.786 [42].

Covariates

In our study, we identified covariates associated with PCDs based on existing literature [43–45]. The covariates included sociodemographic factors (age, sex, education level, marital status, monthly income, and status of living alone), lifestyle (smoking, alcohol drinking, and sedentary behavior), and health conditions. They were collected using a self-designed questionnaire. Additionally, the Instrumental Activities of Daily Living (IADL) scale was employed to assess participants' performance in daily activities [46].

Statistical analysis

All statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized using mean and standard deviation (SD) or median and interquartile range (IQR) (e.g., gait speed, cognitive performance, number of teeth), while categorical variables were represented as percentages and frequencies (e.g., sex, age group, education level, etc.). Logistic regression models (multinomial and binary) were conducted to evaluate the associations between single indicators of oral health, oral frailty, and PCDs. A binary logistic regression model was developed when PCDs were considered as a dichotomous variable (PCDs and non-PCDs); a multinomial logistic regression model was built when PCDs were considered as a multicategorical variable (PCDs, MIND, CIND, and Robust).

In the overall population analysis, age, sex, education level, marital status, monthly income, living alone status, smoking, alcohol consumption, sedentary behavior, IADL, and multimorbidity were included as covariates. To assess whether associations varied between males and females, separate analyses were conducted with sex treated as a stratification factor, while adjusting for all covariates except sex. A significant level of $p < 0.05$ was considered statistically significant for all tests. Estimated effects were presented as odds ratios (OR) with 95% confidence intervals (95% CI). The Hosmer-Lemeshow test was utilized to assess model fit, with all regression equations yielding p-values greater than 0.05, indicating satisfactory model fit. Furthermore, all VIF estimates were below 1.338, and collinearity tolerance values exceeded 0.748, suggesting no multicollinearity issues.

Results

In this study, a total of 252 participants were involved in the final analysis (Fig. 2). The participants' characteristics are described in Table 1. Among the 252 participants (134 females and 118 males, median age 71 years), there were 39 (15.5%), 55 (21.8%), 46 (18.3%), and 112 (44.4%) individuals in the PCDs, MIND, CIND, and robust groups, respectively. Compared to the other three groups, the PCDs group had a higher proportion of males (approximately 56.4%), lower handgrip strength, slower gait speed, poorer performance on IADL and cognitive assessments, and relatively longer sedentary time. Furthermore, a higher proportion of individuals in the PCDs group were classified as having oral frailty compared to the other categories. Figure 3 presents a Sankey Diagram illustrating the associations between various oral health exposure factors—such as denture use, a number of

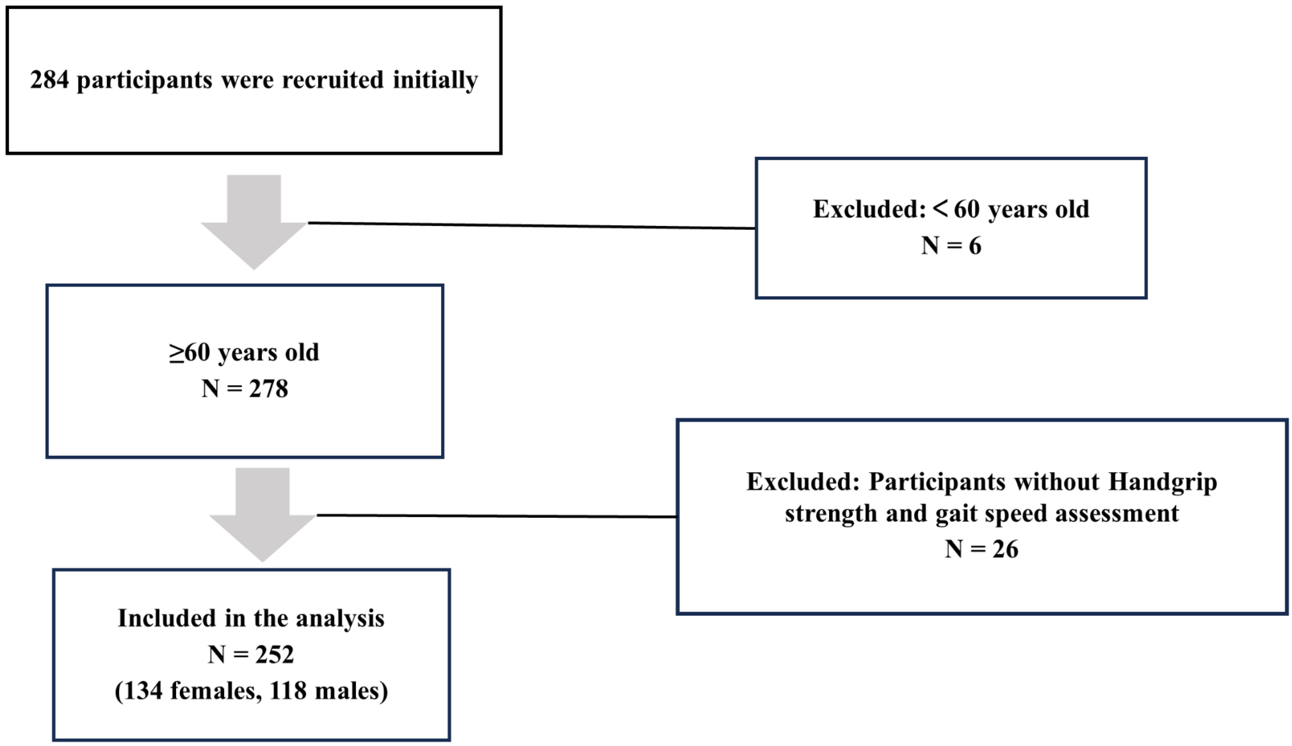

Fig. 2 Flowchart showing how the analyzed participants were selected

teeth < 20, reduced motor function of the tongue and lips, decreased swallowing and masticatory functions, and oral frailty—and phenotypes including PCDs, MIND, CIND, and Robust. The flow lines, color-coded to distinguish between males and females, visually depict the distribution of subjects across these factors and health outcomes.

The association between single indicators of oral health and PCDs, along with the sex differences in this association, is presented in Tables 2 and 3. Binary logistic regression showed that decreased masticatory function was associated with a lower likelihood of PCDs in females (OR = 0.180, 95% CI: 0.038–0.858, $p = 0.031$), indicating it acted as a protective factor. Conversely, a higher number of teeth was also identified as a protective factor in males (OR = 0.892, 95% CI: 0.824–0.966, $p = 0.005$). Multinomial logistic regression revealed that, compared to the robust group, a higher number of teeth (OR = 0.939, 95% CI: 0.890–0.991, $p = 0.021$) was associated with lower odds of PCDs, while impaired tongue and lip motor function (OR = 3.811, 95% CI: 1.059–13.717, $p = 0.041$) was identified as a significant factor associated with higher odds of PCDs. Stratified by sex, a higher number of teeth was associated with reduced odds of PCDs in males (OR = 0.903, 95% CI: 0.831–0.981, $p = 0.016$). In females, a higher number of teeth (OR = 0.886, 95% CI: 0.815–0.963, $p = 0.004$) and denture use (OR = 0.098, 95% CI: 0.022–0.432, $p = 0.002$) were significantly associated with lower odds of MIND; a higher number of teeth (OR = 0.922, 95% CI: 0.854–0.995, $p = 0.037$) and denture use (OR = 0.168, 95% CI: 0.041–0.679, $p = 0.012$) were significantly associated with lower odds of CIND.

The association of oral frailty with PCDs and other phenotypes, as well as the sex differences in this association, is shown in Table 4. Binary logistic regression indicated that oral frailty was a significant factor associated with higher odds of PCDs in males (OR = 5.202, 95% CI: 1.429–18.940, $p = 0.012$), but it was not statistically significant in females (OR = 0.133, 95% CI: 0.017–1.041, $p = 0.055$). Multinomial logistic regression showed that the odds for elderly males with oral frailty of having PCDs were 4.929 times higher (OR = 4.929, 95% CI: 1.229–19.768, $p = 0.024$).

Discussion

The present study provides empirical evidence for the association between oral health and PCDs in older adults. The three most critical findings are: (1) the number of teeth and the tongue and lip motor function are associated with PCDs; (2) among females, there are connections between the number of teeth and the use of dentures with the MIND and CIND phenotypes; and (3) in males, oral frailty is significantly linked to PCDs.

This study concludes that specific oral health indicators—namely, the number of teeth and the motor function of the tongue and lips—are associated with PCDs in

Table 1 Sociodemographic characteristics of participants by PCD status

	Overall participants	PCDs	MIND	CIND	Robust
n(%)	252	39 (15.5)	55 (21.8)	46 (18.3)	112 (44.4)
Sex, n (%)					
Female	134 (42.9)	17 (43.6)	31 (56.4)	27 (58.7)	59 (52.7)
male	118 (46.8)	22 (56.4)	24 (43.6)	19 (41.3)	53 (47.3)
Age group, n (%)					
60–69	108 (42.9)	13 (33.3)	19 (34.5)	21 (45.7)	55 (49.1)
≥ 70	144 (57.1)	26 (66.7)	36 (65.5)	25 (54.3)	57 (50.9)
Education level, n (%)					
No education or pre-school	46 (18.3)	10 (25.6)	12 (21.8)	8 (17.4)	16 (14.3)
Primary school or below	115 (45.6)	15 (38.5)	30 (54.5)	17 (37.0)	53 (47.3))
Middle school or above	91 (36.1)	14 (35.9)	13 (23.6)	21 (45.7)	43 (38.4)
Marital status, n (%)					
married	212 (84.1)	32 (82.1)	43 (78.2)	37 (80.4)	100 (89.3)
widowed/unmarried	40 (15.9)	7 (17.9)	12 (21.8)	9 (19.6)	12 (10.7)
Monthly incomes, n (%)					
< 2000	188 (74.6)	33 (84.6)	47 (85.5)	33 (71.7)	75 (67.0)
2000–4000	41 (16.3)	1 (2.6)	3 (5.5)	7 (15.2)	30 (26.8)
>4000	23 (9.1)	5 (12.8)	5 (9.1)	6 (13.0)	7 (6.3)
Living alone, n (%)					
No	25 (64.1)	37 (67.3)	30 (65.2)	70 (62.5)	25 (64.1)
Yes	14 (35.9)	18 (32.7)	16 (34.8)	42 (37.5)	14 (35.9)
Lifestyle					
Smoking, n (%)					
No	208 (82.5)	32 (82.1)	48 (87.3)	37 (80.4)	91 (81.3)
Yes	44 (17.5)	7 (17.9)	7 (12.7)	9 (19.6)	21 (18.8)
Alcohol drinking, n (%)					
No	53 (21.0)	7 (17.9)	15 (27.3)	14 (30.4)	17 (15.2)
Yes	199 (79.0)	32 (82.1)	40 (72.7)	32 (82.1)	95 (84.8)
Sedentary time, n (%)					
<5 h/d	183 (72.6)	21 (53.8)	45 (81.8)	30 (65.2)	87 (77.7)
≥ 5 h/d	69 (27.4)	18 (46.2)	10 (18.2)	16 (34.8)	25 (22.3)
IADL, n (%)					
Normal	202 (80.2)	25 (64.1)	45 (81.8)	39 (84.8)	93 (83.0)
Impaired	50 (19.8)	14 (35.9)	10 (18.2)	7 (15.2)	19 (17.0)
Multi-morbidity, n (%)					
No	168 (66.7)	25 (64.1)	42 (76.4)	29 (63.0)	72 (64.3)
Yes	84 (33.3)	14 (35.9)	13 (23.6)	17 (37.0)	40 (35.7)
Physical examination					
Gait speed, (mean ± SD, m/s)	1.24 ± 0.27	1 ± 0.25	1.02 ± 0.29	1.25 ± 0.16	1.37 ± 0.23
Handgrip, n (%)					
Maintained	196 (77.8)	15 (38.5)	23 (41.8)	48 (100.0)	112 (100.0)
Reduced	56 (22.2)	24 (61.5)	32 (58.2)	/	/
Cognitive performance					
Moca (mean ± SD, scores)	19.70 ± 4.04	16.36 ± 3.16	20.35 ± 3.31	17.63 ± 4.44	21.24 ± 3.56
Oral health					
Number of teeth, Median (IQR)	23 (16,27)	22 (7,28)	22 (13,27)	23 (16.5,26)	24 (18,27)
Denture use					
NO	144 (57.1)	23 (59.0)	35 (63.6)	28 (60.9)	58 (51.8)
Yes	108 (42.9)	16 (41.0)	20 (36.4)	18 (39.1)	54 (48.2)
Tongue and lip motor function, n (%)					
Maintained	45 (17.9)	5 (12.8)	8 (14.5)	5 (10.9)	27 (24.1)
Reduced	207 (82.1)	34 (87.2)	47 (85.5)	41 (89.1)	85 (75.9)
Swallowing function, n (%)					

Table 1 (continued)

	Overall participants	PCDs	MIND	CIND	Robust
Maintained	244 (96.8)	38 (97.4)	54 (98.2)	45 (97.8)	107 (95.5)
Reduced	8 (3.2)	1 (2.6)	1 (1.8)	1 (2.2)	5 (4.5)
Decreased masticatory function					
No	144 (57.1)	26 (66.7)	26 (47.3)	25 (54.3)	67 (59.8)
Yes	108 (42.9)	13 (33.3)	29 (52.7)	21 (45.7)	45 (40.2)
Oral frailty					
No	194 (77.0)	27 (69.2)	42 (76.4)	35 (76.1)	90 (80.4)
Yes	58 (23.0)	12 (30.8)	13 (23.6)	11 (23.9)	22 (19.6)

Notes: SD: Standard deviation; IQR: Interquartile range; IADL: Instrumental activities of daily living

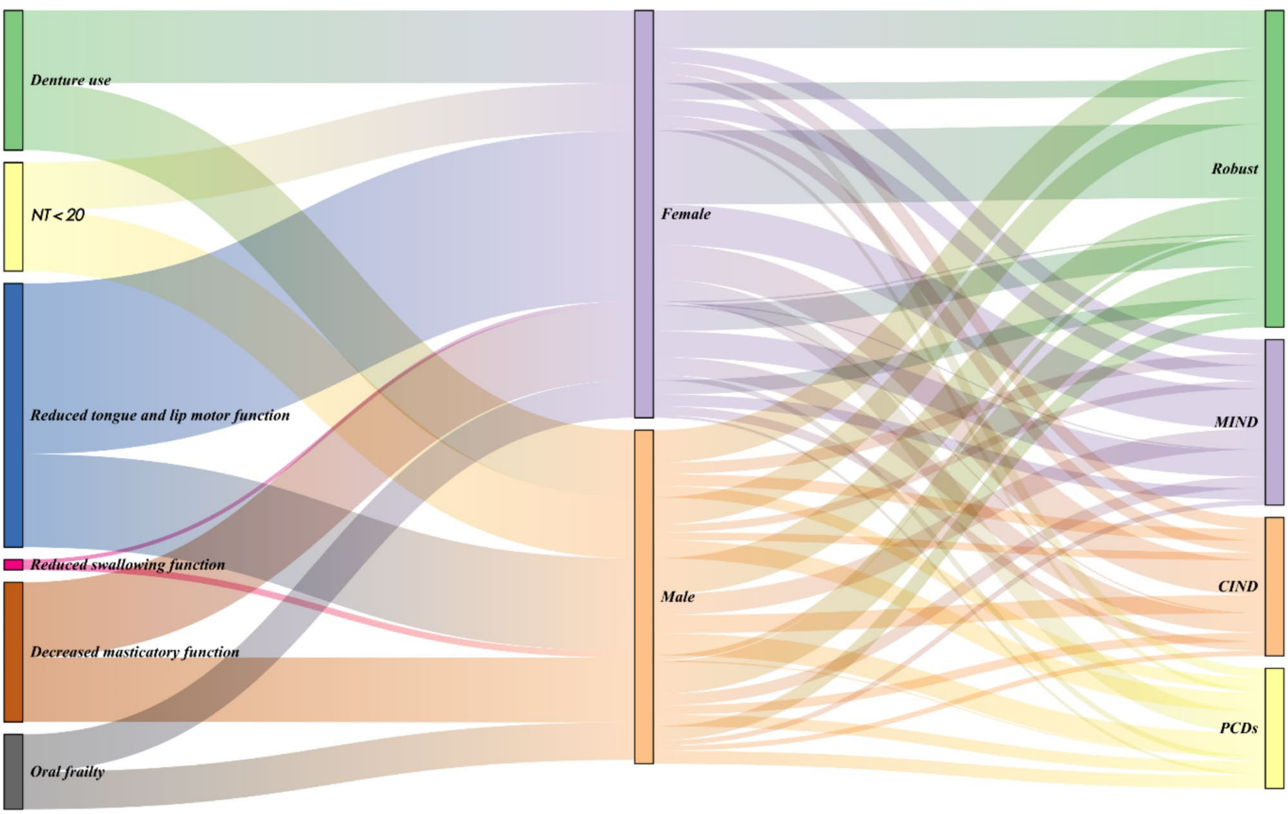

Fig. 3 Associations of sex-stratified oral health with PCDs and other phenotypes: a Sankey diagram
Notes: NT: Number of teeth, MIND: Mobility Impairment No Disability, CIND: Cognitive Impairment No Dementia, PCDs: Physio-Cognitive Decline Syndrome

Table 2 Association of various single indicators of oral health with PCDs and other phenotypes

	PCDs vs. non-PCDs†		PCDs vs. Robust‡		MIND vs. Robust‡		CIND vs. Robust‡	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Overall participants								
Number of teeth	0.956 (0.911,1.003)	0.069	0.939 (0.890,0.991)	0.021	0.969 (0.921,1.018)	0.209	0.964 (0.917,1.014)	0.153
Denture use	0.656 (0.258,1.666)	0.375	0.447(0.164,1.223)	0.117	0.459 (0.202,1.043)	0.603	0.502 (0.217,1.158)	0.106
Tongue and lip motor function	2.438 (0.742,8.006)	0.142	3.811 (1.059,13.717)	0.041	2.000 (0.678,5.904)	0.209	3.028 (0.904,10.137)	0.072
Swallowing function	0.396 (0.004,3.920)	0.428	0.225 (0.021,2.462)	0.222	0.247 (0.022,2.767)	0.257	0.307 (0.029,3.200)	0.323
Decreased masticatory function	0.464 (0.199,1.081)	0.075	0.531 (0.213,1.329)	0.176	1.440 (0.672,3.083)	0.348	1.098 (0.500,2.409)	0.816

Notes: OR: Odds Ratio, 95% CI: 95% confidence interval

†Binary Logistic Regression, ‡Multinomial Logistic Regression

Odds Ratio adjusted for “Sex”, “Age”, “Education level”, “Monthly incomes”, “Marital status”, “Living alone”, “Smoking”, “Alcohol drinking”, “Sedentary time”, “IADL”, “Multi-morbidity”

Table 3 Association of various single indicators of oral health with PCDs and other phenotypes

	PCDs vs. non-PCDs†		PCDs vs. Robust‡		MIND vs. Robust‡		CIND vs. Robust‡	
	OR (95% CI)	***p***	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***
Females								
Number of teeth	1.037 (0.956,1.125)	0.380	1.001 (0.913,1.097)	0.984	0.886 (0.815,0.963)	0.004	0.922 (0.854,0.995)	0.037
Denture use	1.003 (0.237,4.233)	0.997	0.460 (0.099,2.127)	0.320	0.098 (0.022,0.432)	0.002	0.168 (0.041,0.679)	0.012
Tongue and lip motor function	/	/	/	/	/	/	/	/
Swallowing function	/	/	/	/	/	/	/	/
Decreased masticatory function	0.180 (0.038,0.858)	0.031	0.289 (0.054,1.541)	0.146	3.219 (0.885,11.706)	0.076	2.686 (0.772,9.344)	0. 120
Males								
Number of teeth	0.892 (0.824,0.966)	0.005	0.903 (0.831,0.981)	0.016	1.017 (0.937,1.104)	0.689	0.971 (0.887,1.062)	0.519
Denture use	0.523 (0.124,2.207)	0.378	0.508 (0.113,2.284)	0.377	0.639 (0.181,2.262)	0.488	0.937 (0.216,4.073)	0.931
Tongue and lip motor function	3.067 (0.774,12.161)	0.111	3.411 (0.841,13.841)	0.086	1.625 (0.507,5.208)	0.414	2.596 (0.651,10.349)	0.176
Swallowing function	0.179 (0.012,2.207)	0.216	/	/	/	/	/	/
Decreased masticatory function	0.576 (0.152,2.285)	0.418	0.570 (0.143,2.276)	0.570	0.613 (0.179,2.094)	0.435	0.621 (0.154,2.502)	0.503

Notes: OR: Odds Ratio, 95% CI: 95% confidence interval

†Binary Logistic Regression, ‡Multinomial Logistic Regression

Odds Ratio adjusted for “Age”, “Education level”, “Monthly incomes”, “Marital status”, “Living alone”, “Smoking”, “Alcohol drinking”, “Sedentary time”, “IADL”, “Multi-morbidity”

/After stratifying by sex, the Swallowing function variable was normal in the female PCDs group, while the Tongue and lip motor function variable declined in the same group; therefore, they were not included in the binary and multiple regression analyses for females. The Swallowing function variable was normal in the male CIND and MIND groups, so it was excluded from the multiple regression analysis for males

Table 4 Association of oral frailty with PCDs and other phenotypes as well as sex differences in this association

		PCDs vs. non-PCDs†		PCDs vs. Robust‡		MIND vs. Robust‡		CIND vs. Robust‡	
		OR (95% CI)	***p***	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***	**OR (95% CI)**	***p***
Overall participants									
Oral frailty	NO	1 (Reference)	NA	1 (Reference)	NA	1 (Reference)	NA	1 (Reference)	NA
	Yes	1.287 (0.549,3.018)	0.561	1.434 (0.560,3.670)	0.452	1.111 (0.474,2.604)	0.808	1.348 (0.553,3.286)	0.512
Females									
Oral frailty	NO	1 (Reference)	NA	1 (Reference)	NA	1 (Reference)	NA	1 (Reference)	NA
	Yes	0.133 (0.017,1.041)	0.055	0.145 (0.016,1.334)	0.088	1.719 (0.495,5.972)	0.394	1.958 (0.507,7.561)	0.329
Males									
Oral frailty	NO	1 (Reference)	NA	1 (Reference)	NA	1 (Reference)	NA	1 (Reference)	NA
	Yes	5.202 (1.429,18.940)	0.012	4.929 (1.229,19.768)	0.024	0.844 (0.209,3.406)	0.812	1.006 (0.218,4.646)	0.994

Notes: OR: Odds Ratio, 95% CI: 95% confidence interval

†Binary Logistic Regression, ‡Multinomial Logistic Regression

Odds Ratio adjusted for “Sex” (“Sex” did not serve as an adjustment variable in female or male group), “Age”, “Education level”, “Monthly incomes”, “Marital status”, “Living alone”, “Smoking”, “Alcohol drinking”, “Sedentary time”, “IADL”, “Multi-morbidity”

the overall population, with the robust group serving as the reference. This suggests that a higher number of teeth and better motor function of the tongue and lips are associated with lower odds of PCDs. Therefore, maintaining good oral health may be considered a potential strategy to help address such conditions. Previous studies have underscored the importance of maintaining natural teeth for overall health and well-being. Tooth loss can reduce interocclusal contacts, leading to diminished somatosensory feedback to the central nervous system [47]. Moreover, Shin’s study [48] indicates a positive correlation between the number of teeth and handgrip strength, suggesting that having more teeth is linked to better physical function. Additionally, preserving natural teeth is equally important for cognitive health. A dose-response meta-analysis conducted by Qi et al. [49] reveals that tooth loss increases the risk of cognitive impairment by 1.48 times and dementia by 1.28 times. These findings collectively emphasize the vital role of natural teeth in preserving both physical and cognitive well-being, thereby supporting our observation of the connection between the number of natural teeth and PCDs. In addition to tooth count, the motor function of the tongue and lips plays a pivotal role in these health outcomes. Suzuki et al. [50] found an association between oral function and cognitive decline in patients with mild cognitive impairment (MCI), who exhibited decreased motor function of the tongue and lips. Older adults with reduced tongue-lip motor function demonstrate a significantly slower chewing rate compared to those without this symptom [51].

This impairment can lead to incomplete bolus formation and inefficient mastication, ultimately compromising nutritional intake, which is essential for maintaining both mobility and cognitive function. Moreover, difficulties in articulation due to decreased motor function may result in social withdrawal, further impacting overall health and contributing to the progression of PCDs. Thus, considering the issues related to the two primary oral health indicators—the number of teeth and the motor function of the tongue and lips—contribute to a broader strategy for addressing the problems associated with PCDs.

Our findings reveal that the number of teeth and denture use are associated with single functional decline phenotypes, specifically MIND and CIND, in females, while these associations do not extend to PCDs. Research indicates that tooth loss and denture use are associated with cognitive impairment in older adults [52]. For seniors, maintaining sufficient natural teeth is crucial for cognitive health, as it helps preserve oral function and nutrition. Dentures can help mitigate the adverse effects of tooth loss; however, a complete absence of teeth is associated with increased frailty and other health complications [53]. This association may be influenced by notable differences in health-seeking behaviors between sexes. Females often prioritize their health and oral hygiene, routinely seeking dental care, which can lead to fewer oral health issues [54, 55]. This proactive approach means that when problems do arise, they tend to manifest more as isolated symptoms rather than compounded health issues. In contrast, males may neglect dental health, resulting in a more complex interplay between oral health and overall physical or cognitive decline. Interestingly, our results support this notion, as in males, the number of teeth is associated with the dual functional decline phenotype, namely PCDs. Consequently, the observed associations in females suggest that maintaining dental health may play a significant role in safeguarding against MIND or CIND, whereas neglecting oral health in males could contribute to the development of PCDs.

We identify sex differences in the association between oral frailty and PCDs among older adults. In males, oral frailty is identified as a risk factor for PCDs, while there is no such association observed in females. Although aging males generally maintain better muscle mass and strength compared to females [56], they are often exposed to higher risk factors for frailty, such as smoking, lower physical activity, and smaller social networks [57]. These factors exacerbate the relationship between oral frailty and PCDs in males. Studies consistently show that men have a higher predisposition to periodontal disease, despite women being more susceptible to tooth loss and edentulism. This male bias can be attributed to systemic factors such as diabetes and obesity, which further confirm their vulnerability to periodontal conditions [58]. Moreover, oral health behaviors exhibit notable sex differences; males frequently report poorer oral health and demonstrate less effective oral hygiene practices, leading to fewer dental visits compared to females [30]. In contrast, females tend to be more proactive in seeking dental care, resulting in fewer complications and a lower risk of PCDs. This divergence in health-seeking behaviors exacerbates frailty and overall decline in males, who frequently neglect their oral health. Nutritional implications are also critical, as oral frailty can impair nutritional intake, further aggravating health outcomes in males. Many men prioritize convenience in their diets, which can lead to inadequate nutrition and worsen their health status. Overall, these findings emphasize the necessity of a comprehensive approach to oral health, particularly for males, to mitigate the risks associated with PCDs. Addressing these disparities could significantly enhance health outcomes and quality of life for older adults.

Interestingly, our findings suggest that decreased masticatory function is associated with a lower likelihood of PCDs in females. Similarly, oral frailty in females shows a trend toward being protective, although this association did not reach statistical significance. Both findings appear counterintuitive. One possible explanation is that unrecognized variables may mediate the relationship between oral health and PCDs. For example, adaptations in dietary habits due to reduced masticatory function might lead to a preference for softer, nutrient-rich foods, thereby improving overall health [59]. Additionally, the reliance on subjective evaluations of masticatory function may not fully capture the actual physiological capabilities of the participants, which could complicate the interpretation of these results [60]. Further research is needed to explore the multifactorial influences contributing to these associations and to better understand the underlying mechanisms.

This study explores the association between oral health and PCDs through various indicators, revealing sex differences that inform tailored preventive strategies. However, this study has some limitations. First, its cross-sectional design limits the ability to infer causal relationships between oral health and PCDs. Future longitudinal studies are needed to better understand the temporality and progression of these associations. Second, while we explored several oral health indicators, other factors such as diet, socioeconomic status, and mental health were not assessed, which may also influence PCDs. Third, the study's sample was drawn from a limited geographical area in China, which could affect the generalizability of the results to other populations.

Conclusions

The study suggests an association between good oral health and lower odds of PCDs in older adults, with notable sex differences. For women, maintaining natural teeth and the proper use of dentures are associated with lower odds of MIND and CIND. In contrast, men exhibiting signs of oral frailty appear to have higher odds of experiencing PCDs. These findings highlight the association between oral health and the odds of PCDs, underscoring the prevention potential; however, further research is needed to establish causality and inform recommendations for preventive measures.

Abbreviations

CI	Confidence Interval
CIND	Cognitive Impairment No Dementia
IADL	Instrumental Activities of Daily Living
IQR	Interquartile Range
MIND	Mobility Impairment No Disability
MoCA	The Montreal Cognitive Assessment
ODK	Oral Diadochokinesis
OFI-8	Oral Frailty Index-8
OR	Odds Ratio
PCDs	Physio-Cognitive Decline Syndrome
RSST	Repetitive Saliva Swallowing Test
SD	Standard Deviation

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Author contributions
YXL, MG, YF, YL, AA, SC, YY, SN, ES, YC and XL conceived and designed the study. YXL, YF, YL, AA and SC contributed to data collection. YXL, MG and YF analyzed and interpreted the data. YXL drafted the manuscript, while MG and XL provided valuable comments and revisions. YC and XL supervised the entire study process. All authors read and approved the final manuscript.

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Data availability
The materials and data used in this study are available from the corresponding author upon reasonable request for non-commercial purposes, with strict adherence to patient privacy protection when providing such data.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of the Nanjing Medical University (NMU2023-562). All participants provided written informed consent.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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