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Association between toothbrushing behavior and cardiometabolic multimorbidity among middle aged and older adults in North China: a cross-section study

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Abstract

Objectives To evaluate the association between toothbrushing behavior and cardiometabolic multimorbidity (CMM) among middle-aged and older adults.

Methods Data from the Beijing Health Service Survey were used to estimate the association between toothbrushing behavior and the risk of CMM using multilevel logistic models ($N = 18{,}158$).

Results There were 554 patients with CMM, with a prevalence of 3.05%. We found a higher risk of CMM for those with toothbrushing once or less (OR = 2.16, 95%CI: 1.80, 2.59) compared with those brushed two or more times per day in the crude model. After adjusting for confounding factors, the association between the two remained significant (OR = 1.68, 95%CI: 1.39, 2.04). The effect size was higher in adults with a higher education level (OR = 2.32) compared to those with a lower education level (OR = 1.39, $P_{forinteraction} < 0.01$).

Conclusions Poor toothbrushing practices were associated with CMM among middle-aged and older people. Longitudinal study can be considered to explore the causal association between the two and whether good toothbrushing habits can predict CMM and its progression.

Keywords Toothbrushing behavior, Cardiometabolic multimorbidity, Middle aged and older adults

Introduction

Cardiometabolic multimorbidity (CMM) is one of the most common and consistent multimorbidity patterns in middle-aged and older persons [1, 2]. It is defined as the coexistence of two or more cardiometabolic diseases (CMD), which typically include diabetes, stroke and cardiovascular diseases. The prevalence of CMM is increasing rapidly [3, 4]. In the U.S in 2018, the prevalence of CMM was 14.4% [5], while in Chinese adults it was 11.6% [6]. Individuals with CMM are associated with a variety of adverse outcomes, including an increased risk of depressive symptoms and disability [7, 8]. Morever, their mortality is 4–8 times higher than that of individuals

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without CMM in the elderly [9, 10], resulting in a significant familial and social burden.

Toothbrushing is one of the most widely utilized markers of oral health behavior [11]. In China, 37.7-66.7% of people brush their teeth daily [12, 13]. Oral hygiene behaviors are crucial for both oral health and general health [14, 15]. Studies have demonstrated that good oral health behaviors can prevent oral diseases [16], maintain optimal chewing ability and nutritional status [17], and reduce the risk of diabetes, hypertension, stroke, and cardiovascular disease [18–20]. Conversely, poor oral health behaviors can lead to periodontitis, oral infections, systemic infections and chronic diseases [21, 22]. Moreover, poor oral hygiene has been associated with an increased individual risk of cardiovascular events, diabetes, and heart failure in patients with osteoporosis [23–25]. Regarding pathological mechanisms, periodontal pathogens have been shown to induce endothelial dysfunction and accelerate atherosclerosis in animal models [26, 27]. Additionally, systemic inflammation, often associated with poor oral health, can increase the risk of cardiovascular disease and lead to impaired beta cell function and insulin resistance, which increases the risk of type 2 diabetes [28].

Only three studies have reported the association between oral health and multimorbidity (MM). For example, studies have shown that people with periodontitis are more likely to have MM and chronic illnesses in the Dutch population [29], and there is a higher likelihood of co-occurring cardiovascular and periodontal problems [30, 31]. However, the association between oral health behaviors and CMM has been neglected. The relationship between oral health practices and CMM may differ from that of a single CMD or other pattern of MM, and the intensity of the correlation may vary across different groups. It is crucial to explore the correlation between oral health behavior and CMM. First, identifying risk factors for specific MM patterns, such as CMM, can aid in precise prevention and management. Second, giving the aging population in China, the prevalence and disease burden of CMM are expected to continue to rise, making this research even more relevant.

We hypothesize that poor oral hygiene habits may increase the risk of developing CMM through various pathways, and this association may vary across different populations. Therefore, the purpose of this study is to analyze the association between oral hygiene and CMM, as well as its heterogeneity in different subgroups, using data from the Beijing Health Service Survey. This research aims to provide preliminary evidence for future long-term longitudinal studies and intervention studies.

Methods

Data source and participants

The data used in this study were obtained from the Beijing Health Service Survey, conducted in 2018 by the Beijing Municipal Health Commission. The specific data collection process was described in our previous article [13]. In short, a multistage stratified cluster random sampling method was used to select households from Beijing's 16 districts. Investigator conducted one-on-one interviews with each household member using a tablet computer (PAD). The survey received ethics approval from the institutional review board of the Chinese National Bureau of Statistics (license number 2018-78). Informed consent was obtained from all the respondents prior to the survey. The survey collected a variety of information about each household member, including demographics (age, gender, education level, income, marital status, living arrangement, area), health behavior, self-reported health status, health care needs and utilization, health insurance coverage. Further details of the survey content are accessible on the website http://www.nhc.gov.cn/mohwsbwstjxxzx/dczlxz/201810/ba05fccd129543af912dd0ea447d4d5d.shtml. A total of 12,303 households with 29,202 individuals of all ages participated in the survey. Of those, 18,188 adults aged 45 years or older were selected as the initial study population. After excluding 30 respondents with incomplete data, the final analysis included 18,158 middle-aged and older individuals.

Measurements

Outcome

The dependent variable of interest was the presence or absence of CMM. In this study, CMM was defined as the presence of two or more CMD, including diabetes, heart disease, and stroke. Participants were asked two questions, "Do you suffer from doctor-diagnosed diabetes mellitus (DM)?" (possible options: "Yes" or "No"), "Do you suffer from doctor-diagnosed other chronic diseases?" (respondents could choose up to three other chronic diseases from a list of 132 common chronic diseases from 21 major groups) [32]. In this study, heart disease included rheumatic heart disease, angina pectoris, acute myocardial infarction, other ischemic heart disease, pulmonary heart disease, and other types of heart disease. Based on the type of CMM, participants were categorized into the following groups: having CMM or not, only diabetes + heart disease, only diabetes + stroke, only stroke + heart disease, and all three CMD simultaneously.

Exposure

Self-reported toothbrushing frequency was used as an indicator of oral health behavior. Participants were asked, "How many times do you brush your teeth on average every day?". Possible responses included "two or more",

"once", "less than one", and "never". Toothbrushing frequency were categorized into two groups: two or more per day and once or less per day.

Confounders

Potential confounding variables included age, gender (male, female), education level (junior or less, high school or above), marital status (married, others), area (urban, rural), household per capita income (low, medium, high), smoking status (yes, no), drinking status (yes, no), physical activity (inactive, active), body mass index (BMI, kg/m^2) (underweight, normal, overweight, obesity). Household per capita income was categorized into three groups based on tertiles: low, middle and high. BMI was classified according to the Chinese BMI classification standard: 18.5 was defined as underweight, 18.5≤23.9 as normal, 24.0≤27.9 as overweight, and 28.0 and above as obesity [33].

Table 1 Characteristics of the participants

	All	Frequency of toothbrushing		*P*-value
		Two or more	Once or less	
Age, years	61.34(10.26)	60.28(9.96)	63.10(10.50)	< 0.01
Gender(%)				< 0.01
Male	8778(48.34)	4940(43.67)	3838(56.07)	
Female	9380(51.66)	6373(56.33)	3007(43.93)	
Education(%)				< 0.01
Junior or less	11,240(61.9)	5862(51.82)	5378(78.57)	
High school or above	6918(38.1)	5451(48.18)	1467(21.43)	
Marriage status(%)				< 0.01
Married	16,103(88.68)	10,216(90.30)	5887(86.00)	
Others	2055(11.32)	1097(9.70)	958(14.00)	
Areas(%)				< 0.01
Urban	10,451(57.56)	8004(70.75)	2447(35.75)	
Rural	7707(42.44)	3309(29.25)	4398(64.25)	
Per capita household income(%)				< 0.01
Low	6125(33.73)	2510(22.19)	3615(52.81)	
Medium	6216(34.23)	4136(36.56)	2080(30.39)	
High	5817(32.04)	4667(41.25)	1150(16.80)	
Smoke status(%)				< 0.01
No	13,644(75.14)	8951(79.12)	4693(68.56)	
Yes	4514(24.86)	2362(20.88)	2152(31.44)	
Drink status(%)				< 0.01
No	13,490(74.29)	8855(78.27)	4635(67.71)	
Yes	4668(25.71)	2458(21.73)	2210(32.29)	
Physical activity(%)				< 0.01
Inactive	5935(32.69)	2835(25.06)	3100(45.29)	
Active	12,223(67.31)	8478(74.94)	3745(54.71)	
BMI, kg/m^2(%)				< 0.01
Underweight	518(2.85)	268(2.37)	250(3.65)	
Normal	7364(40.56)	4643(41.04)	2721(39.75)	
Overweight	7570(41.69)	4815(42.56)	2755(40.25)	
Obesity	2706(14.9)	1587(14.03)	1119(16.35)	
All	18,158	11,313	6845	-

Abbreviations BMI, body mass index

Statistical analysis

Participants' characteristics were analyzed descriptively. Means and standard deviations were used for continuous variables, while proportions were used for categorical variables. The t-test was used to compare continuous variables, and the chi-square test was used to compare categorical variables. Multilevel logistic regression models were fitted at the area and individual levels to estimate the association between oral hygiene behavior and the risk of CMM. Models were initially evaluated in a crude model and then adjusted for confounders. Stratified analyses were conducted to examine the association between oral health behaviors and CMM by age, gender and education level. Odds ratio (OR) with corresponding 95% confidence intervals (CI) were reported. P values less than 0.05 were considered statistically significant. All statistical analyses were conducted in Stata 16.0 (StataCorp LP, College Station, Texas).

Results

The average age of the participants was 61.34 years, with 48.34% were male. Of the participants, 11,313 brushed their teeth two or more times per day, while 6845 brushed their tooth once or less per day. Compared to those who toothbrushing two or more, individuals who brushed once or less were older, more likely to be male, had a lower education level, were not married, resided in rural areas, had a lower household per capita income, were more likely to smoke and drink, were inactive, and were more likely to be underweight or obesity (Table 1).

There were 554 patients with CMM, with a prevalence of 3.05%. Among them, 325 had diabetes+heart disease (1.79%), 129 had diabetes+stroke (0.71%), 63 had heart disease+stroke (0.35%), and 37 had all three conditions simultaneously (0.20%). The prevalence of CMM was higher in individuals who brushed their teeth once or less per day (4.12%) compared to those who brushed two or more times per day ($P<0.01$). Similarly, the prevalence of each specific combination of CMM was also higher in those who brushed their teeth once or less per day compared to those who brushed two or more times per day ($P<0.01$) (Table 2).

As shown in Table 3, we found a higher risk of CMM for those who toothbrushing once or less (*OR*=2.16, *95%CI*: 1.80, 2.59) compared to those who brushed two or more times in the crude model. After adjusting for confounding factors, the association between the two remained significant (*OR*=1.68, *95%CI*: 1.39,

Table 2 The prevalence of CMM by brushing frequency

	Frequence of tooth brushing		*P*-value
	two or more	once or less	
CMM			< 0.01
No	11,041(97.60)	6563(95.88)	
Yes	272(2.40)	282(4.12)	
Pattern of CMM			< 0.01
Non-CMM	11,041(97.60)	6563(95.88)	
Diabetes + Heart disease	183(1.62)	142(2.07)	
Diabetes + Stroke	46(0.41)	83(1.21)	
Heart disease + Stroke	26(0.23)	37(0.54)	
Diabetes + Heart disease + Stroke	17(0.15)	20(0.29)	

Abbreviations CMM, cardiometabolic multimorbidity

Table 3 The association between the frequency of toothbrushing and CMM

	Modle[a]	Model[b]
CMM		
No	Ref.	Ref.
Yes	2.16(1.80,2.59)***	1.68(1.39,2.04)***
Pattern of CMM		
Non-CMM	Ref.	Ref.
Diabetes + Heart disease	1.56(1.23,1.98)***	1.23(0.96,1.59)
Diabetes + Stroke	3.99(2.72,5.84)***	3.13(2.10,4.67)***
Heart disease + Stroke	2.39(1.45,3.96)**	2.04(1.17,3.59)*
Diabetes + Heart disease + Stroke	2.70(1.36,5.37)**	1.88(0.91,3.91)

[a] Unadjusted model

[b] Adjusted for age, gender, marital status, education, urban or rural, income, smoke status, drink status, physical activity, BMI

*$P<0.05$, **$P<0.01$, ***$P<0.001$

Abbreviations CMM, cardiometabolic multimorbidity; *BMI*, body mass index

2.04). When examining specific disease combinations, we found that in the unadjusted model, participants who brushed teeth once or less had a higher risk of diabetes + heart disease (*OR* = 1.56, *95%CI*: 1.23, 1.98), diabetes + stroke (*OR* = 3.99, *95%CI*: 2.72, 5.84), heart disease + stroke (*OR* = 2.39, *95%CI*: 1.45,3.96), diabetes + heart disease + stroke (*OR* = 2.70, *95%CI*: 1.36, 5.37). After adjusting for confounding factors, the association between less frequent toothbrushing and CMM persisted for diabetes + stroke (*OR* = 3.13, *95%CI*: 2.10, 4.67) and heart disease + stroke (*OR* = 2.04, *95%CI*: 1.17, 3.59), but was not significantly associated with diabetes + heart disease or diabetes + heart disease + stroke ($P>0.05$).

Stratified by age, gender, and education level, we found that lower toothbrushing frequency was associated with a higher risk of CMM in all groups. The effect size was significantly higher in individuals with a higher education level (OR = 2.32) compared to those with a lower education level (*OR* = 1.39, $P_{forinteraction}<0.01$). In the 45 ~ 59 age group, lower brushing frequency was associated with a higher risk of diabetes + heart disease (*OR* = 2.41, *95%CI*:1.31, 4.46) and diabetes + stroke (*OR* = 3.70, *95%CI*:1.69, 8.09). Among individuals aged 60 years and older, lower brushing frequency was associated with a higher risk of diabetes + stroke (*OR* = 2.86, *95%CI*:1.80, 4.57), heart disease + stroke (*OR* = 2.53, *95%CI*:1.36, 4.72), and diabetes + heart disease + stroke (*OR* = 2.30, *95%CI*:1.00, 5.38). Lower toothbrushing frequency was associated with a high risk for diabetes + stroke among both males (*OR* = 4.23, *95%CI*: 2.47, 7.24) and females (*OR* = 1.89, *95%CI*: 1.01, 3.55). However, the association with heart disease + stroke was only observed among males (OR = 2.91, 95%CI: 1.29, 6.54). Lower frequency of toothbrushing was associated with a higher risk of diabetes + heart disease among individuals with a higher education levels (*OR* = 1.67, *95%CI*:1.08, 2.57), and it was associated with a higher risk of diabetes + stroke among both education levels. The effect size was significantly higher in those with high education level compared to those with a lower education level ($P_{forinteraction}<0.01$), as showed in Table 4.

Discussion

To the best of our knowledge, this is the first study to investigate the association between oral health behaviors and CMM among middle and elderly people. We found that individuals with poor oral health behaviors had a higher risk of CMM compared to those with good oral health behaviors, especially for diabetes + stroke and heart disease + stroke. Furthermore, the association between toothbrushing and CMM was stronger in individuals with a higher education level than in those with a lower education level.

Our study valuable insights into the association of oral health behaviors and CMM among middle-aged and older individuals in China. While previous research has explored the link between oral health and single chronic diseases, our study extends this knowledge by examining the association with a specific multimorbidity pattern, CMM. We found that individuals who brushed their teeth less frequently (less than once a day) had a significantly higher risk of both diabetes + stroke (OR = 3.13) and heart disease + stroke (OR = 2.04) compared to those who brushed their teeth more frequently. This finding is consistent with those from the China Kadoorie Biobank (CKB), which observed a higher risk of major vascular events (OR = 1.12) and major cardiovascular events (OR = 1.18) among individuals (mean age of 51.5 ± 10.6 years) with less frequent toothbrushing [11]. However, our study differs from previous research in several ways. Our study specifically focused on the association between oral health behaviors and CMM, while previous studies often examined single chronic diseases. Our study used a more detailed measurement of toothbrushing frequency (once or less vs. two or more times per day), whereas the CKB study used a simpler categorization

Table 4 The association between the frequency of toothbrushing and CMM by age, gender, education, area

	CMM		Pattern of CMM				
	No	Yes	Non-CMM	Diabetes+Heart disease	Diabetes+Stroke	Heart disease+Stroke	Diabetes+Heart disease+Stroke
Age, years							
45~59	Ref.	2.47(1.62,3.78)***	Ref.	2.41(1.31,4.46)**	3.70(1.69,8.09)**	0.97(0.24,3.86)	1.17(0.29,4.72)
≥60	Ref.	1.57(1.27,1.95)***	Ref.	1.09(0.83,1.43)	2.86(1.80,4.57)***	2.53(1.36,4.72)**	2.30(1.00,5.38)*
$P_{for\ Interaction}$		0.10		0.03	0.12	0.69	0.50
Sex							
Male	Ref.	1.82(1.41,2.38)***	Ref.	1.51(0.80,1.64)	4.23(2.47,7.24)***	2.91(1.29,6.54)*	1.32(0.51,3.51)
Female	Ref.	1.47(1.12,1.94)**	Ref.	1.31(0.93,1.85)	1.89(1.01,3.55)*	1.39(0.61,3.18)	2.65(0.86,8.12)
$P_{for\ Interaction}$		0.30		0.05	0.47	0.24	0.06
Education							
Junior or less	Ref.	1.39(1.11,1.76)**	Ref.	1.07(0.80,1.44)	2.34(1.44,3.78)**	1.86(0.91,3.81)	1.38(0.55,3.46)
High school or above	Ref.	2.32(1.69,3.20)***	Ref.	1.67(1.08,2.57)*	4.95(2.54,9.61)***	2.43(0.99,5.93)	2.44(0.80,7.44)
$P_{for\ Interaction}$		**<0.01**		0.12	**0.01**	0.76	0.48

Note All model adjusted for age, gender, marital status, education, urban or rural, income, smoke status, drink status, physical activity, BMI except for the stratification variables

*$P<0.05$, **$P<0.01$, ***$P<0.001$

Abbreviations CMM, cardiometabolic multimorbidity; *BMI*, body mass index

("regularly" or "occasionally or rarely"). Other studies have found associations between oral health problems (such as oral diseases or tooth loss) and multimorbidity in various populations. For example, a small amount of research has explored the correlation between oral hygiene and multimorbidity, they found that oral health problems such as oral diseases or tooth loss are associated with a higher risk of multimorbidity among different populations. A study based on the U.S. Behavioral Risk Factor Surveillance System (BRFSS) showed that individuals with multimorbidity have a higher risk of tooth loss among those aged 18 and above, with the effect being more pronounced in younger populations than in older ones [34]. Another study based on data from the Longitudinal Ageing Study in India (LASI) found that, those with multimorbidity have a higher risk of oral diseases compared to those without (*OR*=1.60, *95%CI*: 1.48–1.73) among individuals aged 45 and above [35]. A cross-sectional survey of adults aged 60 and above in Mexico found that the prevalence of edentulism is higher among those with multimorbidity compared to those without ($P=0.015$) [36]. A study based on health survey data from Brazil showed that multimorbidity are associated with a 32% and 17% increased risk of severe tooth loss in populations aged 18–59 and 60 and above, respectively [37]. These findings highlight the importance of addressing oral health as part of broader public health strategies to prevent and manage multimorbidity. Overall, our study contributes to the growing body of evidence supporting the association between oral health behaviors and CMM. Further research is warranted to elucidate the underlying mechanisms and inform targeted interventions.

Interestingly, the extent to which oral hygiene was associated with CMM varied across different subgroup participants. We found that the effect size of this association was higher in younger individuals (45–59 years old), men and those with a higher education attainment. Notably, individuals with poor oral hygiene in the high education attainment subgroup had a 2.32-fold higher risk of CMM and a 5-fold higher risk of diabetes+stroke compared to their peers with good oral hygiene. In general, people with a higher education level have better health literacy [38, 39] and are more likely to engage in good oral health behavior [40]. In this study, the proportion of people with a higher education who brush their teeth once or less was significantly lower than that of individuals with a lower education (25% vs. 50%). The strong association between oral hygiene and CMM, even after controlling for other health behaviors and confounding factors, implies that focusing on oral hygiene interventions in individuals with a higher education level may be particularly effective in preventing or delaying the onset of CMM and related conditions. However, further research is needed to elucidate the underlying mechanisms and to confirm the causal relationship between oral hygiene and CMM.

Several possible mechanisms have been proposed to explain the association between oral health behavior and CMM. Firstly, poor oral hygiene can lead to the multiplication of oral bacterial [41, 42] and the development of periodontitis [43].These conditions can cause systemic infection [44] and endothelial dysfunction [45], which are known risk factors for various type of CMD [46]. Second, common risk factors for both oral health and systemic diseases include age, male gender, and smoking [5, 47–50]. This suggests that shared pathophysiological

pathways may underlie the association between oral health and CMM. In our study, we found that oral health behaviors were associated with diabetes+stroke and heart disease+stroke. The mechanisms mentioned above could also explain these associations.

This study has several limitations. First, the cross-sectional design of the study makes it difficult to establish causality between toothbrushing behavior and CMM. Reverse causation, where CMM may influence toothbrushing behavior, cannot be ruled out. Second, the study population was limited to middle-aged and older adults in Beijing, the capital of China. Generalizing the findings to the entire Chinese population may be challenging due to regional variations in health behaviors, access to healthcare, and other factors. Third, while the total sample size was acceptable, the sample sizes within specific CMM subgroups were relatively small. This may have contributed to wider confidence intervals for the effect sizes, indicating larger individual differences and the need for further research to obtain more precise estimates. Fourth, the reliance on self-reported data for CMM prevalence may have led to an underestimation due to recall bias or undiagnosed conditions. Although the National Basic Public Health Project [51] has improved diabetes management and follow-up, undiagnosed heart disease and stroke may still be present in the study population. Self-reported toothbrushing frequency may not accurately reflect actual brushing habits due to social desirability bias, potentially leading to misclassification. Finally, the survey data lacked information on specific oral diseases (periodontitis, dental caries) and dental visits, as well as biological markers, which could have provided additional insights into the mechanisms linking oral health and CMM. We hope that the above limitations can be gradually improved in future research.

Conclusion

Our study found a significant association between poor oral health behavior and CMM among middle-aged and older individuals, Additionally, we observed that educational attainment moderated this association. These findings highlight the importance of addressing oral health behaviors in middle-aged and elderly populations to reduce the risk of CMM. In future studies, longitudinal data can be considered to explore the causal association between the two, whether good toothbrushing habits can predict CMM and its progression, and whether oral treatment is effective in the prognosis of CMM.

Abbreviations

BMI	Body mass index
CKB	China Kadoorie Biobank
CMD	Cardiometabolic diseases
CMM	Cardiometabolic multimorbidity
DM	Diabetes mellitus
OR	Odds ratio
MM	Multimorbidity
95%CI	95% confidence intervals

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Author contributions

Dan Guo, Yanshang Wang: drafting the manuscript, study design, data analysis and interpretation. Yanan Zhao, Ruoxi Ding: drafting the manuscript and critical revision of article for important intellectual content. Ping He: study concept and design, critical revision of article, and supervised the whole process of this work. All authors critically revised successive drafts of the paper and approved the final version.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Human Ethics and Consent to Participate declarations

The survey obtained ethics approval from the institutional review board of the Chinese National Bureau of Statistics (license number 2018-78). Informed consent was obtained from all the respondents prior to the survey. All procedures performed in the study were in accordance with the ethical standards of the Chinese National Bureau of Statistics and with Helsinki declaration (as revised in Tokyo 2004).

Clinical trial number

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Busija L, Lim K, Szoeke C, et al. Do replicable profiles of multimorbidity exist? Systematic review and synthesis [J]. Eur J Epidemiol. 2019;34(11):1025–53.
2. Prados-Torres A, Calderon-Larranaga A, Hancco-Saavedra J, et al. Multimorbidity patterns: a systematic review [J]. J Clin Epidemiol. 2014;67(3):254–66.
3. Glynn LG. Multimorbidity: another key issue for cardiovascular medicine [J]. Lancet. 2009;374(9699):1421–2.
4. Tinetti ME, Fried TR, Boyd CM. Designing health care for the most common chronic condition–multimorbidity [J]. JAMA. 2012;307(23):2493–4.
5. Cheng X, Ma T, Ouyang F et al. Trends in the Prevalence of Cardiometabolic Multimorbidity in the United States, 1999–2018 [J]. Int J Environ Res Public Health, 2022, 19(8).
6. Zhang D, Tang X, Shen P, et al. Multimorbidity of cardiometabolic diseases: prevalence and risk for mortality from one million Chinese adults in a longitudinal cohort study [J]. BMJ Open. 2019;9(3):e024476.
7. Huang ZT, Luo Y, Han L, et al. Patterns of cardiometabolic multimorbidity and the risk of depressive symptoms in a longitudinal cohort of middle-aged and older Chinese [J]. J Affect Disord. 2022;301:1–7.
8. Fishbook BN, Brinton CD, Siever J, et al. Cardiometabolic multimorbidity and activity limitation: a cross-sectional study of adults using the Canadian Longitudinal Study on Aging data [J]. Fam Pract. 2022;39(3):455–63.
9. Canoy D, Tran J, Zottoli M, et al. Association between cardiometabolic disease multimorbidity and all-cause mortality in 2 million women and men registered in UK general practices [J]. BMC Med. 2021;19(1):258.
10. Emerging Risk Factors C, Di Angelantonio E, Kaptoge S, et al. Association of Cardiometabolic Multimorbidity With Mortality [J]. JAMA. 2015;314(1):52–60.

11. Zhuang Z, Gao M, LV J, et al. Associations of toothbrushing behaviour with risks of vascular and nonvascular diseases in Chinese adults [J]. Eur J Clin Invest. 2021;51(12):e13634.
12. Su L, Liu W, Xie B et al. Toothbrushing, Blood Glucose and HbA1c: Findings from a Random Survey in Chinese Population [J]. Sci Rep, 2016, 6(28824).
13. Guo D, Shi Z, Luo Y, et al. Association between oral health behavior and chronic diseases among middle-aged and older adults in Beijing, China [J]. BMC Oral Health. 2023;23(1):97.
14. Sadamori S, Hayashi S, Hamada T. The relationships between oral status, physical and mental health, nutritional status and diet type in elderly Japanese women with dementia [J]. Gerodontology. 2008;25(4):205–9.
15. Carrizales-Sepúlveda EF, Ordaz-Farías A, Vera-Pineda R, et al. Periodontal Disease, Systemic Inflammation and the Risk of Cardiovascular Disease [J]. Heart Lung Circ. 2018;27(11):1327–34.
16. Stefanovska E, Nakova M, Radojkova-Nikolovska V, et al. Tooth-brushing intervention programme among children with mental handicap [J]. Bratisl Lek Listy. 2010;111(5):299–302.
17. Sun L, Wong HM, Mcgrath CPJ. The factors that influence oral health-related quality of life in 15-year-old children [J]. Health Qual Life Outcomes. 2018;16(1):19.
18. Chang Y, Lee JS, Lee KJ, et al. Improved oral hygiene is associated with decreased risk of new-onset diabetes: a nationwide population-based cohort study [J]. Diabetologia. 2020;63(5):924–33.
19. Chang Y, Woo HG, Lee JS, et al. Better oral hygiene is associated with lower risk of stroke [J]. J Periodontol. 2021;92(1):87–94.
20. Isomura ET, Suna S, Kurakami H, et al. Not brushing teeth at night may increase the risk of cardiovascular disease [J]. Sci Rep. 2023;13(1):10467.
21. Scannapieco FA, Cantos A. Oral inflammation and infection, and chronic medical diseases: implications for the elderly [J]. Periodontol. 2000, 2016, 72(1): 153 – 75.
22. De Oliveira C, Watt R, Hamer M. Toothbrushing, inflammation, and risk of cardiovascular disease: results from. Scott Health Surv [J] Bmj, 2010, 340c:2451.
23. Park JH, Park MS, Kim HJ et al. Better oral hygiene is associated with a reduced risk of osteoporotic fracture: a nationwide cohort study [J]. Front Endocrinol (Lausanne), 2023, 14(1253903).
24. Chang Y, Woo HG, Park J, et al. Improved oral hygiene care is associated with decreased risk of occurrence for atrial fibrillation and heart failure: A nationwide population-based cohort study [J]. Eur J Prev Cardiol. 2020;27(17):1835–45.
25. Huh Y, Yoo JE, Park SH, et al. Association of Dental Diseases and Oral Hygiene Care With the Risk of Heart Failure in Patients With Type 2 Diabetes: A Nationwide Cohort Study [J]. J Am Heart Assoc. 2023;12(16):e029207.
26. Parvaneh M, Witting PK, Ku J, et al. Periodontitis induces endothelial dysfunction in mice [J]. Sci Rep. 2021;11(1):14993.
27. Sanz M, Del Marco A, Jepsen S, et al. Periodontitis and cardiovascular diseases: Consensus report [J]. J Clin Periodontol. 2020;47(3):268–88.
28. Polak D, Shapira L. An update on the evidence for pathogenic mechanisms that may link periodontitis and diabetes [J]. J Clin Periodontol. 2018;45(2):150–66.
29. Beukers N, Su N, Van Der Heijden G, et al. Periodontitis is associated with multimorbidity in a large dental school population [J]. J Clin Periodontol. 2023;50(12):1621–32.
30. Larvin H, Kang J, Aggarwal VR, et al. Systemic Multimorbidity Clusters in People with Periodontitis [J]. J Dent Res. 2022;101(11):1335–42.
31. Zhao D, Wu MZ, YU S Y, et al. Periodontitis links to concurrent systemic comorbidities among 'self-perceived health' individuals [J]. J Periodontal Res. 2022;57(3):632–43.
32. The Sixth National Health Services Survey. Classification of Diseases - Code table [M]. Center for Health Statistics and Information, National Health Commussion of the People's Republic China; 2018.
33. Pan XF, Wang L, Pan A. Epidemiology and determinants of obesity in China [J]. Lancet Diabetes Endocrinol. 2021;9(6):373–92.
34. Zhang Y, Leveille SG, Shi L. Multiple Chronic Diseases Associated With Tooth Loss Among the US Adult Population [J]. Front Big Data, 2022, 5(932618).
35. Kanungo S, Ghosal S, Kerketta S et al. Association of Oral Health with Multimorbidity among Older Adults: Findings from the Longitudinal Ageing Study in India, Wave-1, 2017–2019 [J]. Int J Environ Res Public Health, 2021, 18(23).
36. Islas-Granillo H, Borges-Yañez SA, Navarrete-Hernández JJ et al. Indicators of oral health in older adults with and without the presence of multimorbidity: a cross-sectional study [J]. Clin Interv Aging, 2019, 2019(14):219–24.
37. Bomfim RA, Cascaes AM, De Oliveira C. Multimorbidity and tooth loss: the Brazilian National Health Survey, 2019 [J]. BMC Public Health. 2021;21(1):2311.
38. Ahmed S, Kehyayan V, Abdou M et al. Prevalence and determinants of health literacy among the adult population of Qatar [J]. Front Public Health, 2023, 11(1278614).
39. Seeman T, Merkin SS, Crimmins E, et al. Education, income and ethnic differences in cumulative biological risk profiles in a national sample of US adults: NHANES III (1988–1994) [J]. Soc Sci Med. 2008;66(1):72–87.
40. Abu-Gharbieh E, Saddik B, El-Faramawi M et al. Oral Health Knowledge and Behavior among Adults in the United Arab Emirates [J]. Biomed Res Int, 2019, 2019(1):7568679.
41. Seow WK, Cheng E, Wan V. Effects of oral health education and tooth-brushing on mutans streptococci infection in young children [J]. Pediatr Dent. 2003;25(3):223–8.
42. Gregorczyk-Maga I, Pałka A, Fiema M, et al. Impact of tooth brushing on oral bacteriota and health care-associated infections among ventilated COVID-19 patients: an intervention study [J]. Antimicrob Resist Infect Control. 2023;12(1):17.
43. Zimmermann H, Zimmermann N, Hagenfeld D, et al. Is frequency of tooth brushing a risk factor for periodontitis? A systematic review and meta-analysis [J]. Community Dent Oral Epidemiol. 2015;43(2):116–27.
44. El-Shinnawi U, Soory M. Associations between periodontitis and systemic inflammatory diseases: response to treatment [J]. Recent Pat Endocr Metab Immune Drug Discov. 2013;7(3):169–88.
45. Li Q, Ouyang X, Lin J. The impact of periodontitis on vascular endothelial dysfunction [J]. Front Cell Infect Microbiol, 2022, 12:998313.
46. Garcia-Sayan E, Lee M, Stone JR, et al. Endothelial Dysfunction and Cardiometabolic Risk Factors in Mexican American Adults: The Cameron County Hispanic Cohort [J]. Am J Cardiol. 2023;205:75–83.
47. Kiyak HA. Age and culture: influences on oral health behaviour [J]. Int Dent J. 1993;43(1):9–16.
48. Sewpaul R, Mbewu AD, Fagbamigbe AF et al. Prevalence of multimorbidity of cardiometabolic conditions and associated risk factors in a population-based sample of South Africans: A cross-sectional study [J]. Public Health Pract (Oxf), 2021, 2(100193).
49. Al-Omiri MK, Barghout NH, Shaweesh AI, et al. Level of education and gender-specific self-reported oral health behavior among dental students [J]. Oral Health Prev Dent. 2012;10(1):29–35.
50. Jeong K, Cho S, Ryu J et al. Effects of Changes in Smoking Behavior of Older Adults' Oral Health [J]. Healthc (Basel), 2022, 10(11).
51. Commission NH. China health statistics yearbook [J]. Beijing, China: China Union Medical University Publishing House; 2018.

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