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Oral health and nutrition: addressing disparities in socioeconomically disadvantaged older adults in rural China

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Abstract

Background Inequalities in oral health and nutrition present substantial challenges for vulnerable older adults. Although poor oral health is known to increase the risk of inadequate dietary quality and compromised nutritional status, limited evidence exists on this relationship among socioeconomically disadvantaged older adults in rural areas—a particularly vulnerable population. This study investigates the association between oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural China.

Methods A cross-sectional study was conducted among 310 socioeconomically disadvantaged older adults aged 60 or above in rural Shaanxi province, northwest China. Oral health was assessed using indicators of oral problems measured by the 5-item Oral Health Impact Profile (OHIP-5) and the number of missing teeth. Dietary quality was evaluated through the Simplified Healthy Eating Index (SHEI) and dietary patterns, while nutritional status was assessed using the Short-Form Mini Nutritional Assessment (MNA-SF). Multiple linear regression examined associations between oral health, adherence to a healthy diet and nutritional status, while quantile regression analyzed its relationship with dietary patterns.

Results Among participants, an average of 14.08 teeth were missing, increasing to 17.30 when considering number of missing teeth not replaced with dentures. The mean OHIP-5 score was 5.78. The average SHEI score was 14.70, and the mean MNA-SF score was 11.57. Regression analyses consistently showed a negative association between poor oral health and both adherence to a healthy diet—including reduced intake of the "vegetable and meat" dietary pattern—and nutritional status. Heterogeneity analysis found no significant variations across care arrangements and family poverty status.

Conclusions This study highlights the critical relationship between oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural China. The findings underscore the need for targeted interventions to improve oral health, dietary intake and nutritional well-being in aging populations with disadvantaged and rural settings.

Keywords Socioeconomically disadvantaged, Older adults, Oral health, Dietary quality, Nutritional status

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Introduction

The rapid aging of the global population poses significant challenges for oral health, particularly among socioeconomically disadvantaged older adults in rural areas. By 2050, the global population aged 60 and older is projected to surpass 2.1 billion, more than doubling from 1.0 billion recorded in 2020 [1]. Aging is closely linked to declining oral health, which affects over 57% of older adults worldwide [2]. This issue is especially severe in developing countries, where the prevalence of oral disorders continues to rise. Within these nations, socioeconomically disadvantaged groups, particularly those in rural areas, experience disproportionate barriers due to unequal access to oral health services and limited health literacy [3]. In China, where the population aged 60 and older is expected to reach 487 million by 2050, oral health concerns are especially pressing [4]. Between 1990 and 2019, China has recorded the largest global increase in the prevalence of oral disorders and related disability-adjusted life years [5]. Over 210 million individuals aged 55 and older suffer from oral disorders, with a prevalence exceeding 54.3% [6]. Rural older adults face even greater challenges, exhibiting higher rates of missing teeth, unrepaired missing teeth, and untreated caries [7]. These issues are further exacerbated for socioeconomically disadvantaged older adults in rural areas, who often struggle with financial constraints, lower education levels, and limited access to dental services [8], mirroring trends seen in other developing countries [9]. In 2022, low-income rural households have a per capita disposable income of only 10.9% of that of wealthier counterparts, and many socioeconomically disadvantaged older adults lack a junior high school diploma and live in remote areas, limiting their access to both care and information [10, 11]. Poor oral health not only impairs essential functions, but also exacerbates systemic conditions, leads to pain and psychosocial distress, and increases mortality rates [12].

The relationship between oral health and nutrition is intricately interconnected. Poor oral health limits food choices and elevates the risk of nutrition deficiencies, while inadequate nutrition, in turn, worsens oral health, creating a detrimental cycle. Aging and illness often accelerate oral health deterioration, leading to difficulties in chewing and processing food, which profoundly affect dietary preferences and nutritional intake [13]. Older adults, in particular, tend to favor soft, easily chewable foods over harder, fiber-rich alternatives, resulting in higher consumption of fats, carbohydrates, and processed foods, while reducing their intake of fruits, vegetables, nuts, and meat [14]. These dietary shifts contribute to nutrient deficiencies, lower dietary quality, and negatively impact overall health and quality of life [15].

Consequently, malnutrition risk, like poor oral health, has emerged as a significant public health concern among older adults, particularly in rural areas of developing countries, including China. Studies indicate that malnutrition risk is 1.5 to 2 times higher in these populations compared to urban areas, with rates reaching up to 64.9% among the most socioeconomically disadvantaged groups [16]. In China, a cohort study finds that 48.6% of adults aged 60 and older have moderate or high nutritional risk, with rural areas showing higher rates (50.9%) compared to urban areas (38.5%) [17]. Older adults in rural areas, especially those with low income, low education, disabilities, or living alone, are at greater risk of poor diets, often characterized by high grain consumption and low intake of fruits, vegetables, and protein sources [16, 18]. In rural China, reliance on self-sufficient food production, driven by a "survival-dependent-on-nature" mindset [19], causes dietary patterns highly dependent on seasonal fluctuations, leading to periods of inadequate nutrition. Furthermore, social support systems, such as community canteens and nutritional aid programs, remain in the pilot phase [20]. A 2019 study reports that over 74.9% of older adults in impoverished rural areas fail to meet the recommended intake levels of critical micronutrients, increasing the risk of malnutrition and poor health outcomes [21].

The relationship between oral health, dietary quality and nutritional status in older adults is well-documented, including studies on Chinese populations, but gaps remain regarding socioeconomically disadvantaged groups, particularly those in rural areas. Research shows that the association between oral health and nutrition varies across demographic and socioeconomic groups, with pronounced disparities observed among individuals with lower socioeconomic status [22]. In China, urban-rural disparities are evident, with rural older adults consistently showing poorer oral health, lower dietary quality, and higher malnutrition rates [17, 23]. Among socioeconomically disadvantaged individuals in rural areas, financial constraints and limited healthcare access exacerbate both oral health and nutritional challenges. While some studies have involved this group, they often lack depth or fail to include detailed subgroup analyses. For instance, rural socioeconomically disadvantaged older adults, particularly those who are living alone, experience significantly worse oral health and nutritional outcomes [24]. However, most existing research centers on the general elderly population, overlooking the specific vulnerabilities of lower socioeconomic subgroups, underscoring the need for more targeted research.

This study aims to examine the association between oral health, dietary quality, and nutritional status among socioeconomically disadvantaged older adults in rural China, a population identified as particularly vulnerable.

Oral health, dietary quality, and nutritional status will be assessed using validated tools, including the 5-item Oral Health Impact Profile (OHIP-5), the number of missing teeth, the Simplified Healthy Eating Index (SHEI) and dietary patterns, and the Short-Form Mini Nutritional Assessment (MNA-SF). The analysis will explore the associations between oral health and dietary quality using both a priori and a posteriori dietary assessment approaches, with robustness checks performed through index transformation methods. Similarly, the association between oral health and nutritional status will be examined using the same analytic strategy. Heterogeneity analyses will be conducted to identify potential variations in these associations based on care arrangements and family poverty status.

Materials and methods

Data collection and samples

This study utilized data from a cross-sectional survey conducted in one of China's 832 former national-level impoverished counties, located in Shaanxi province. As of 2023, individuals aged 60 and older accounted for 21.6% of the province's population, slightly higher than the national average of 21.1%, while the per capita GDP in Shaanxi was $12125.9, below the national average of $12680.8 [25, 26]. In the surveyed county, vulnerable rural groups constituted 12.6% of the rural population, significantly exceeding the national average of 8.0% [26]. The per capita disposable income of rural residents in the sampled county was $1,979.7, lower than the national average of $2,326.8 for previously designated poor counties [26]. These demographic and economic indicators suggested that the sampled population representatively reflected the conditions of rural older adults in less developed regions of China.

This study targeted rural older adults in the selected county, either receiving government-supported care for the extremely impoverished or belonging to households eligible for minimum living allowances, who were all welfare recipients. The extremely impoverished were classified under the "Three No's" category: individuals unable to work, without income, and lacking a legal obligor capable of providing support, meeting all three criteria [27]. Since 2006, China has implemented a bottom-up assistance program to ensure a basic standard of living for this vulnerable group [28]. For households receiving minimum living allowances, the rural subsistence allowance system, introduced in 2007, provides financial support to low-income families [29]. Eligible criteria for these allowances in the sampled county were based on the per capita net income of family members below the local threshold ($762.1 per person per year) and assets meeting regulatory standards in the sampled county. Older adults meeting either of these criteria qualified for admission to public nursing homes (i.e., social welfare facilities) at reduced or no cost, while others who did not meet these conditions were ineligible for such services.

The study comprised older adults residing in both home-based and public nursing home settings, with participant lists provided by local authorities. Of 675 individuals from all public nursing homes, 112 were included after excluding those with severe disabilities or communication impairments. For the home-based group, villages with fewer than five extremely impoverished individuals and towns with fewer than three eligible villages were excluded. All individuals in villages with more than five extremely impoverished older adults were surveyed, resulting in 208 completed surveys from 282 identified participants. If fewer eligible participants were available on the survey day, additional low-income individuals were randomly selected to ensure at least five participants per village. Trained investigators conducted face-to-face, one-on-one interviews with each older adult, with caregivers present to assist when needed. After excluding cases with missing data on key variables, the final analysis retained 310 older adults, with a response rate of 96.88%.

Measurements

Independent variables

Oral health was assessed in three key dimensions: oral problems, total number of missing teeth, and number of missing teeth not replaced with dentures. Oral problems were measured using the Chinese version of OHIP-5 scale, which evaluates Oral Health-Related Quality of Life [30]. The OHIP-5 includes five concerns: difficulty chewing, painful aching, uncomfortable to eat, worsened sense of taste, and difficulty doing jobs (because of oral problems). Responses were recorded on a 5-point Likert scale (0 = never, 4 = very often) (Table A1). Each item was analyzed as both a score (0–4) and a count (0 = no symptoms, 1 = any symptoms), indicating whether the problem had occurred in the past month. A composite total OHIP-5 score (0–20) was created by summing the Likert responses across all five items, with higher scores indicating poorer oral health. Similarly, a total OHIP-5 count (0–5) was calculated, reflecting the number of distinct oral problems reported. Both the average score and dichotomized prevalence are presented for a more comprehensive understanding.

Since oral problems were calculated based on subjective responses from the OHIP-5, objective measures of the number of missing teeth were assessed in two dimensions: total number of missing teeth and number of missing teeth not replaced with dentures. To fully understand the impact of the number of missing teeth on oral health and aging, it is essential to consider both types of missing teeth to ensure a balanced focus on dental prosthetics as

well as on the biological and preventive preservation of natural teeth [31, 32]. The number of missing teeth and the presence of dentures were self-reported, with trained investigators verifying counts when interviewed. For both, two measures were used: the number of missing teeth (continuous) and categorical tooth loss, classified as severe tooth loss (12–32 missing teeth) or non-severe tooth loss (fewer than 12 missing teeth). These classifications were applied separately to both tooth loss with and without denture replacement. Retaining at least 20 natural teeth is considered essential for maintaining functional dentition and oral health [33].

Dependent variables

The dependent variables included dietary quality and nutritional status. Dietary quality was assessed through a priori method, which involved predefined measures of adherence to a healthy diet, and a posteriori method, which identified dietary patterns using data-driven approaches.

Adherence to a healthy diet assessment. SHEI score, a Chinese adaptation of the Healthy Eating Index, was designed to assess adherence to a healthy diet within the Chinese population [34]. The framework, a simple food frequency questionnaire, was derived from the Chinese Longitudinal Healthy Life Survey, a nationally representative longitudinal study [35]. This study collected data on the frequency of consumption for 13 food items (Figure A1). The reproducibility and validity of the questionnaire have been confirmed in the Chinese population [36, 37]. Responses were categorized as: "always or almost every day", "sometimes or occasionally", or "rarely or never". For salt-preserved vegetable and sugar, responses were scored of 0, 1, and 2, respectively. For the remaining 11 items, the scoring was reversed: 2, 1, and 0, respectively. The total score, ranging from 0 to 26, represented overall dietary quality, with higher scores reflecting more adherence to a healthy diet.

Dietary patterns assessment. To provide a nuanced understanding of dietary quality among the sample population, Principal Component Analysis (PCA) —a widely used approach within the posteriori dietary pattern methodology—was employed [38]. Intake frequencies of 13 food items were standardized to account for unit differences before conducting factor analysis, as recommended by existing research [39]. The number of factors was determined using the scree plot, selecting those with eigenvalues greater than 1. To enhance the interpretability of factor loadings, varimax orthogonal rotation was applied. Dietary patterns were named based on factor loadings, professional judgement and practical considerations [39]. Factor scores were calculated by weighting food intake frequencies with their respective loading, with higher scores indicating stronger adherence to specific dietary patterns. Participants were then categorized into four quartiles (Q1, Q2, Q3, Q4), ranging from lowest to highest adherence to the patterns.

Nutritional status assessment. Nutritional status was evaluated using the MNA-SF, a widely adopted six-item tool for malnutrition screening, particularly in older adults [40]. The MNA-SF assessed the loss of appetite, weight loss, mobility, stress or illness, dementia or depression, and body mass index. Scores ranged from 0 to 14, with higher scores indicating better nutritional status. The MNA-SF was extensively validated, showing high sensitivity and specificity for detecting malnutrition and malnutrition risk, making it a reliable tool in both clinical and community settings [41].

Control variables

Control variables included demographic characteristics, socioeconomic status, health conditions, and health behaviors. Demographic characteristics covered gender, age, prior stable partnership status (defined as 1 = having ever had a long-term partner, 0 = bachelor), as well as educational attainment, categorized as either illiterate (= 0) or literate (= 1). Socioeconomic status was measured by care arrangements, family poverty status, and pension coverage. Care arrangements were classified as either home-based (= 0) or public nursing home care (= 1). Family poverty status was divided into extreme poverty (= 1) (recipients of government-supported care for extremely impoverished individuals) and non-extreme poverty (= 0) (families receiving minimum living allowances). Pension coverage was categorized as either having purchased a pension (= 1) or not (= 0). Health conditions included the presence of chronic disease and disability, while health behaviors focused on current smoking and drinking status to directly reflect the immediate impact, with both health conditions and behaviors coded as binary variables.

Statistical analysis

All statistical analyses were performed using Stata 18.0, with graphs generated in GraphPad Prism 9.50. First, descriptive statistics summarized the sample, with continuous variables reported as means and standard deviations, and categorical variables as frequencies and percentages. Second, to examine the relationship between oral health (clustered at the village level) and both dietary quality and nutritional status, multiple linear regression was used, adjusting for all control variables. For analyzing dietary patterns, quantile regression was employed, as it effectively addresses skewness and offers insights into how determinants influence various quantiles of the dependent variable [42]. Given the small sample size, a bootstrap procedure was applied (repeated 100 times) to enhance the robustness of the results. This

method minimizes the weighted sum of absolute residuals, making it more resilient to outliers and deviations from normality [43]. Robustness tests were additionally conducted using categorical independent variables in each analysis. Third, the inter-group difference test—used by bootstrap methods (repeated 500 times)—examined whether the average marginal effects differed significantly by care arrangements and family poverty status. A significance level of 0.05 was set for all statistical tests.

Results

Descriptive statistics

Table 1 described the descriptive characteristics of the 310 rural older adults in the study. The majority were male (83.23%), with a mean age of 71.48 years (SD = 6.96). Nearly half (41.94%) of the welfare recipients were bachelors, and an equal proportion (41.94%) were illiterate. A total of 34.19% of participants utilized public nursing home services, and 61.29% were living in extreme poverty. Despite 92.90% having pension coverage, the monthly pension amount was only $17.03 per person, markedly lower than the rural per capita consumption expenditure of $214.94 per month [26], highlighting significant financial constraints. In terms of health, 68.71% reported having at least one chronic disease, and 19.68% had a disability. Regarding health behaviors, 46.13% were current smokers, and 34.52% were current drinkers.

Table 1 Summary statistics (*N* = 310)

Variables	Mean ± SD	*N* (%)
Independent variables		
OHIP-5 score	5.78 ± 5.59	
Difficulty chewing (frequent)	1.40 ± 1.47	
Painful aching (frequent)	1.07 ± 1.41	
Uncomfortable to eat (frequent)	1.36 ± 1.51	
Taste worse (frequent)	1.15 ± 1.42	
Difficulty doing jobs (frequent)	0.81 ± 1.30	
Total number of missing teeth	14.08 ± 9.78	
Number of missing teeth not replaced with dentures	17.30 ± 10.45	
Dependent variables		
SHEI score	14.70 ± 3.10	
MNA-SF score	11.57 ± 1.82	
Control variables		
Gender (1 = male)		258 (83.23)
Age	71.48 ± 6.96	
Prior stable partnership status (1 = having had a long-term partner)		180 (58.06)
Literate (1 = yes)		180 (58.06)
Care arrangements (1 = nursing home care)		106 (34.19)
Family poverty status (1 = extreme poverty)		190 (61.29)
Pension coverage (1 = yes)		288 (92.90)
Chronic disease (1 = yes)		213 (68.71)
Disability (1 = yes)		61 (19.68)
Smoking (1 = yes)		143 (46.13)
Drinking (1 = yes)		107 (34.52)

Notes: OHIP-5: 5-item Oral Health Impact Profile; SHEI: Simplified Healthy Eating Index; MNA-SF: Short-Form Mini Nutritional Assessment. Continuous variables report Mean and standard deviation (SD), and discrete variables report number (N) and percentages (%)

The average OHIP-5 score was 5.78 out of 20 (SD = 5.59), indicating a moderate level of oral problems. Among the five dimensions, the most common issues were difficulty chewing (Mean = 1.40, SD = 1.47) and uncomfortable to eat (Mean = 1.36, SD = 1.51), and the lowest impact was observed in difficulty doing jobs, with a mean score of 0.81 (SD = 1.30). On average, participants had 14.08 missing teeth (SD = 9.78), which increased to 17.30 (SD = 10.45) when considering number of missing teeth not replaced with dentures. The average SHEI score was 14.70 out of 26 (SD = 3.10), reflecting high consumption of fresh vegetable, garlic, eggs, and bean products, and lower intake of fresh fruit, mushrooms or algae, nut products, and fish (Figure A1). MNA-SF score averaged 11.57 out of 14 (SD = 1.82) and 43.55% were at risk or experiencing malnutrition.

The association between oral health and adherence to a healthy diet

Table 2 presented the association between oral health and adherence to a healthy diet among rural older adults. The results indicated that OHIP-5 score and the number of missing teeth were negatively associated with the SHEI score. However, these associations were not statistically significant, except for difficulty chewing (Column 1). Specifically, difficulty chewing showed a significant negative association with SHEI score (β=-0.236, $p < 0.05$), while OHIP-5 score and the other four dimensions (painful aching, uncomfortable to eat, worsened sense of taste, difficulty doing jobs) had non-significant negative associations with the SHEI score ($p > 0.05$). Likewise, total number of missing teeth and number of missing teeth not replaced with dentures exhibited non-significant negative associations with SHEI score ($p > 0.05$).

To ensure robustness, adjustment was made by including variables such as OHIP-5 count and whether participants experienced severe tooth loss, including tooth loss not replaced with dentures (variables description in Table A2). The adjusted results remained consistent, with non-significant negative associations observed for OHIP-5 count, severe tooth loss, and severe tooth loss not replaced with dentures ($p > 0.05$, Column 2).

Table 2 Multiple regression analysis between oral health and adherence to a healthy diet

Variables	SHEI score	
	(1)	(2)
OHIP-5 score	-0.060	
	(0.033)	
OHIP-5 count		-0.078
		(0.100)
Difficulty chewing (frequent)	**-0.236***	
	(0.117)	
Difficulty chewing (1 = any symptoms)		-0.397
		(0.356)
Painful aching (frequent)	-0.137	
	(0.122)	
Painful aching (1 = any symptoms)		-0.118
		(0.343)
Uncomfortable to eat (frequent)	-0.191	
	(0.118)	
Uncomfortable to eat (1 = any symptoms)		-0.278
		(0.361)
Taste worse (frequent)	-0.210	
	(0.127)	
Taste worse (1 = any symptoms)		-0.361
		(0.350)
Difficulty doing jobs (frequent)	-0.130	
	(0.134)	
Difficulty doing jobs (1 = any symptoms)		0.113
		(0.374)
Total number of missing teeth	-0.012	
	(0.018)	
Tooth loss (1 = severe)		-0.239
		(0.337)
Number of missing teeth not replaced with dentures	-0.005	
	(0.017)	
Tooth loss not replaced with dentures (1 = severe)		-0.170
		(0.361)

Notes: OHIP-5: 5-item Oral Health Impact Profile; SHEI: Simplified Healthy Eating Index. In Column (1), the independent variables used continuous variables. In Column (2), the independent variables used categorical variables for robust check. Gender, age, prior stable partnership status, literate, care arrangements, family poverty status, pension coverage, chronic disease, disability, smoking, and drinking were controlled in the analysis. Cluster effect at the village level. Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

The association between oral health and dietary patterns

In addition to examining dietary quality, an exploratory analysis was conducted to assess the relationship between oral health and dietary patterns. The Kaiser-Meyer-Olkin measure for sampling adequacy of 13 food groups was 0.680 and Bartlett's test of sphericity (χ^2=336.235, $p<0.001$) confirmed the appropriateness of PCA (Table A3). Based on Kaiser's criterion, four factors were extracted, with a cumulative explained variance of 47.26% (Table A4). These factors were labeled according to their dominant food group loading as: "eggs-bean products pattern", "fresh fruit-dairy products-nut products pattern", "fresh vegetable-meat pattern", and "garlic-mushroom or algae pattern" (Table A5). These four patterns had similar existence and application in different countries and regions.

Table 3 displayed the quantile regression results examining the association between oral health and these dietary patterns. Oral problems—especially difficulty chewing, painful aching, uncomfortable to eat and worsened sense of taste—were significantly negatively associated with "fresh vegetable-meat pattern" (the coefficient of the fourth quantiles: β=-0.124, $p<0.01$; β=-0.162, $p<0.01$; β=-0.102, $p<0.05$; β=-0.088, $p<0.05$). Tooth loss with or without denture replacement, was not significantly associated with this pattern. For example, OHIP-5 score was significantly negatively associated with the "fresh vegetable and meat" pattern across the fourth, third, and second quantiles of this pattern (β=-0.041, $p<0.001$; β=-0.033, $p<0.001$; β=-0.035, $p<0.01$). These findings suggested that older adults with more severe oral health challenges may be less inclined to consume foods that require significant chewing, such as fresh vegetable and meat.

In contrast, OHIP-5 score and tooth loss with or without denture replacement, showed minimal and statistically insignificant associations with other dietary patterns, such as the "eggs-bean products pattern" and the "fresh fruit-dairy products-nut products pattern" ($p>0.05$). This suggested that oral health may not significantly affect preferences for these dietary patterns.

Sensitivity analyses, using alternative specifications of the independent variables, confirmed the robustness of these associations. No significant deviations were observed when using OHIP-5 count and indicators of severe tooth loss, reinforcing the consistency of these findings (Table A6).

The association between oral health and nutritional status

Table 4 reported the association between oral health and nutritional status of older adults. The results showed that both oral problems and the number of missing teeth were significantly negatively associated with nutritional status. Specifically, OHIP-5 score was significantly negatively linked with a lower MNA-SF score (β=-0.046, $p<0.05$), particularly in the dimension of uncomfortable to eat (β=-0.204, $p<0.05$). Additionally, both tooth loss with and without denture replacement were significantly associated with a lower MNA-SF score (β=-0.041, $p<0.001$; β=-0.026, $p<0.05$).

Similarly, when applying alternative specifications of the independent variables—such as OHIP-5 count and severe tooth loss—similar patterns emerged, confirming the robustness of the results, with significant negative associations observed for both oral problems and tooth loss ($p<0.05$).

Table 3 Quantile regression analysis between oral health and dietary patterns

Dietary patterns	Quantile			
	Q1	Q2	Q3	Q4
Panel A. OHIP-5 score				
Eggs-bean products pattern	Ref.	0.001	0.009	-0.003
		[-0.029,0.031]	[-0.013,0.030]	[-0.022,0.017]
Fresh fruit-dairy products-nut products pattern	Ref.	0.016	0.014	-0.003
		[-0.011,0.043]	[-0.011,0.039]	[-0.032,0.026]
Fresh vegetable-meat pattern	Ref.	**-0.035****	**-0.033*****	**-0.041*****
		[-0.059,-0.010]	[-0.049,-0.016]	[-0.063,-0.018]
Garlic-mushroom or algae pattern	Ref.	-0.002	0.016	0.019
		[-0.027,0.024]	[-0.011,0.042]	[-0.013,0.050]
Panel B. Difficulty chewing (frequent)				
Eggs-bean products pattern	Ref.	-0.012	0.020	-0.043
		[-0.152,0.128]	[-0.063,0.103]	[-0.125,0.039]
Fresh fruit-dairy products-nut products pattern	Ref.	0.030	0.002	-0.044
		[-0.059,0.118]	[-0.097,0.102]	[-0.164,0.076]
Fresh vegetable-meat pattern	Ref.	**-0.106****	**-0.103*****	**-0.124****
		[-0.181,-0.031]	[-0.162,-0.043]	[-0.197,-0.050]
Garlic-mushroom or algae pattern	Ref.	-0.017	0.036	0.033
		[-0.114,0.080]	[-0.085,0.158]	[-0.110,0.175]
Panel C. Painful aching (frequent)				
Eggs-bean products pattern	Ref.	-0.022	0.020	0.009
		[-0.147,0.103]	[-0.074,0.114]	[-0.076,0.094]
Fresh fruit-dairy products-nut products pattern	Ref.	0.071	0.083	0.094
		[-0.054,0.196]	[-0.014,0.181]	[-0.021,0.209]
Fresh vegetable-meat pattern	Ref.	-0.077	**-0.133*****	**-0.162****
		[-0.175,0.021]	[-0.197,-0.069]	[-0.261,-0.063]
Garlic-mushroom or algae pattern	Ref.	-0.005	0.088	0.019
		[-0.126,0.115]	[-0.010,0.187]	[-0.098,0.136]
Panel D. Uncomfortable to eat (frequent)				
Eggs-bean products pattern	Ref.	0.035	0.024	-0.008
		[-0.103,0.174]	[-0.060,0.109]	[-0.096,0.080]
Fresh fruit-dairy products-nut products pattern	Ref.	0.069	0.059	0.007
		[-0.021,0.159]	[-0.028,0.146]	[-0.092,0.106]
Fresh vegetable-meat pattern	Ref.	**-0.120****	**-0.140*****	**-0.102***
		[-0.193,-0.046]	[-0.204,-0.076]	[-0.180,-0.024]
Garlic-mushroom or algae pattern	Ref.	-0.006	0.094	0.076
		[-0.108,0.097]	[-0.011,0.198]	[-0.003,0.155]
Panel E. Taste worse (frequent)				
Eggs-bean products pattern	Ref.	-0.007	-0.020	0.028
		[-0.169,0.155]	[-0.155,0.115]	[-0.084,0.141]
Fresh fruit-dairy products-nut products pattern	Ref.	0.006	0.033	-0.089
		[-0.108,0.119]	[-0.077,0.144]	[-0.201,0.023]
Fresh vegetable-meat pattern	Ref.	**-0.078***	-0.049	**-0.088***
		[-0.145,-0.011]	[-0.128,0.030]	[-0.169,-0.008]
Garlic-mushroom or algae pattern	Ref.	0.021	0.030	0.087
		[-0.098,0.139]	[-0.091,0.152]	[-0.018,0.193]
Panel F. Difficulty doing jobs (frequent)				
Eggs-bean products pattern	Ref.	0.037	0.023	-0.010
		[-0.102,0.176]	[-0.076,0.122]	[-0.098,0.078]
Fresh fruit-dairy products-nut products pattern	Ref.	0.032	0.039	-0.009
		[-0.115,0.179]	[-0.088,0.166]	[-0.141,0.123]
Fresh vegetable-meat pattern	Ref.	**-0.107***	-0.045	-0.076
		[-0.201,-0.012]	[-0.142,0.051]	[-0.194,0.041]

Table 3 (continued)

Dietary patterns	Quantile			
	Q1	Q2	Q3	Q4
Garlic-mushroom or algae pattern	Ref.	-0.010	0.005	-0.043
		[-0.109,0.089]	[-0.112,0.121]	[-0.154,0.068]
Panel G. Total number of missing teeth				
Eggs-bean products pattern	Ref.	0.015	0.013	0.008
		[-0.001,0.031]	[-0.002,0.028]	[-0.007,0.023]
Fresh fruit-dairy products-nut products pattern	Ref.	-0.011	-0.002	-0.006
		[-0.029,0.007]	[-0.018,0.014]	[-0.027,0.015]
Fresh vegetable-meat pattern	Ref.	-0.008	-0.005	-0.002
		[-0.021,0.005]	[-0.019,0.009]	[-0.014,0.011]
Garlic-mushroom or algae pattern	Ref.	-0.007	0.001	0.011
		[-0.023,0.010]	[-0.019,0.021]	[-0.008,0.029]
Panel H. Number of missing teeth not replaced with dentures				
Eggs-bean products pattern	Ref.	0.012	0.009	0.003
		[-0.001,0.026]	[-0.004,0.021]	[-0.010,0.017]
Fresh fruit-dairy products-nut products pattern	Ref.	-0.005	0.006	-0.002
		[-0.022,0.011]	[-0.009,0.020]	[-0.023,0.020]
Fresh vegetable-meat pattern	Ref.	-0.007	-0.003	-0.008
		[-0.021,0.006]	[-0.014,0.008]	[-0.019,0.004]
Garlic-mushroom or algae pattern	Ref.	-0.005	-0.002	0.007
		[-0.019,0.009]	[-0.019,0.015]	[-0.010,0.024]

Notes: OHIP-5: 5-item Oral Health Impact Profile. The bootstrap process was applied for 100 times. The independent variables used continuous variables. Gender, age, prior stable partnership status, literate, care arrangements, family poverty status, pension coverage, chronic disease, disability, smoking, and drinking were controlled in the analysis. Cluster effect at the village level. Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Heterogeneity analysis

Table 5 presented subgroup analyses examining the associations between oral health, adherence to a healthy diet, and nutritional status. In Panel A, no significant interactions were observed between oral problems and either SHEI score or MNA-SF score, suggesting consistent results across public nursing home and home-based care settings (inter-group difference test, $p>0.05$). Panel B also showed no significant differences in oral problems and SHEI score or MNA-SF score by family poverty status (inter-group difference test, $p>0.05$).

Discussion

This study investigates the relationship between oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural western China—a population representing some of the nation's most vulnerable individuals. To our knowledge, this represents the first comprehensive analysis of how poor oral health is linked to dietary quality and nutritional challenges in this underserved, resource-limited setting. The findings reveal a high prevalence of both poor oral health and inadequate nutrition in this population. Specifically, impaired oral health, characterized by oral problems and the number of missing teeth, is associated with unhealthy dietary patterns, including reduced intake of essential food groups such as fresh vegetable and meat. Moreover, poor oral health directly correlates with compromised nutritional status, highlighting its critical role in shaping nutritional well-being in this vulnerable population.

Firstly, this study underscores significant oral health disparities and poor nutritional status among socioeconomically disadvantaged older adults in rural China. The surveyed welfare recipients, heavily reliant on public support, exhibited low educational attainment and lack of family support, with 41.94% illiterate and 41.94% unmarried, nearly half of the participants experienced oral problems and had malnutrition risk or malnutrition. The findings align with previous research, revealing pronounced rural-urban disparities in oral health, worsened by low socioeconomic status [21]. With an average OHIP-5 score of 5.78 and 14.08 missing teeth—both higher than those of the general rural population [44, 45]—this underscores the greater oral health burden faced by this group. Similar trends are observed in other developing countries, such as Rwanda and Afghanistan, where low education, limited income, and disabilities restrict access to dental care [3]. For state-designated vulnerable individuals, including those living in extreme poverty or receiving subsistence allowances, the lack of stable income and residence in under-developed areas further compound their ability to manage unexpected costs, such as healthcare expenses and high transportation costs to access distant dental services [46]. Despite high rates of missing teeth and oral problems, rural older

Table 4 Multiple regression analysis between oral health and nutritional status

Variables	MNA-SF score	
Panel A	**(1)**	**(2)**
OHIP-5 score	**-0.046***	
	(0.023)	
OHIP-5 count		**-0.117***
		(0.059)
Difficulty chewing (frequent)	-0.099	
	(0.067)	
Difficulty chewing (1 = any symptoms)		-0.177
		(0.171)
Painful aching (frequent)	-0.111	
	(0.084)	
Painful aching (1 = any symptoms)		-0.332
		(0.223)
Uncomfortable to eat (frequent)	**-0.204***	
	(0.078)	
Uncomfortable to eat (1 = any symptoms)		**-0.480***
		(0.201)
Taste worse (frequent)	-0.139	
	(0.100)	
Taste worse (1 = any symptoms)		-0.236
		(0.272)
Difficulty doing jobs (frequent)	-0.155	
	(0.098)	
Difficulty doing jobs (1 = any symptoms)		-0.385
		(0.252)
Total number of missing teeth	**-0.041*****	
	(0.011)	
Tooth loss (1 = severe)		**-0.567****
		(0.208)
Number of missing teeth not replaced with dentures	**-0.026***	
	(0.011)	
Tooth loss not replaced with dentures (1 = severe)		-0.394
		(0.216)

Notes: OHIP-5: 5-item Oral Health Impact Profile; MNA-SF: Short-Form Mini Nutritional Assessment. In Column (1), the independent variables used continuous variables. In Column (2), the independent variables used categorical variables for robust check. Gender, age, prior stable partnership status, literate, care arrangements, family poverty status, pension coverage, chronic disease, disability, smoking, and drinking were controlled in the analysis. Cluster effect at the village level. Standard errors in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

socioeconomically disadvantaged adults report low self-perceived severity, as reflected in the average OHIP-5 score, which aligns with findings from previous studies [47]. This may be due to psychological adaptation to chronic symptoms, normalization of tooth loss with aging, resistance caused by historical economic hardships, or prioritization of immediate health and financial needs over dental care, particularly among low socioeconomically disadvantaged older adults [11, 47]. The lack of focused research on this vulnerable population highlights the urgent need for targeted investigations to address oral health inequities.

Furthermore, dietary assessments highlight a high rate of malnutrition risk within this population, with the average SHEI score of 14.70 (out of 26) and MNA-SF score of 11.57 (out of 14). These findings align with previous studies in rural China [48, 49], indicating significant dietary deficiencies among older adults in these regions. Resource limitations and age-related challenges drive dependence on refined grains and preserved staples, rather than nutrient-dense options like meat, eggs, dairy, and mushrooms or algae [50]. Additionally, dietary preferences in this socioeconomically disadvantaged group show a clear polarization: higher consumption of fresh vegetables, garlic, and eggs, but lower intake of fresh fruits and fish compared to the general older adults [51, 52]. This reflects both economic constraints—restricting access to more expensive foods— and cultural factors, such as the belief in garlic's health benefits and eggs' cost-effectiveness as a protein source. These habits contribute to nutrient imbalances, with excesses in garlic and eggs and deficiencies in essential vitamins, minerals, and fatty acids, increasing the risk of health issues. Alarming, the risk of malnutrition and malnutrition rates in rural areas exceed 40.6% [53], much higher than the rates observed in urban areas [54]. These disparities are likely driven by urban populations' better access to affordable food, healthcare, and social support systems [55]. Socioeconomic factors, including income and education, further influence dietary patterns, with socioeconomically disadvantaged older adults facing limited access to nutrient-rich foods, exacerbating poorer dietary intake and deterioration in nutrition.

Secondly, regression analysis demonstrates a significant negative association between certain oral problems, dietary quality, and nutritional status among socioeconomically disadvantaged older adults in rural areas. Consistent with previous findings, the priori dietary quality reveals difficulty chewing restricting healthy food choices, as reducing the intake of harder foods like nuts, meat, and legumes [56]. Additionally, taste alterations linked to oral problems shift dietary preferences toward processed and sugary foods, further diminishing dietary quality [57]. For posteriori dietary quality, oral problems also hinder adherence to diets rich in fresh vegetable and meat, essential for cognitive health and preventing age-related chronic diseases [12, 58]. Furthermore, poor oral health increases the risk of malnutrition. The cumulative impact of conditions like caries and periodontitis impairs masticatory function and leads to tooth loss, increasing susceptibility to malnutrition and related health complications [59]. Meta-analyses confirm that individuals with inadequate dentition are 21% more likely to be at risk of

Table 5 Heterogeneity analysis

Variables	SHEI score			MNA-SF score		
Panel A	**Nursing home care**	**Home-based care**	***P*-value**	**Nursing home care**	**Home-based care**	***P*-value**
OHIP-5 score	-0.034	-0.066	0.662	-0.020	**-0.057***	0.338
	(0.047)	(0.042)		(0.030)	(0.026)	
Total number of missing teeth	-0.002	-0.017	0.673	-0.027	**-0.052****	0.234
	(0.024)	(0.027)		(0.015)	(0.016)	
Panel B	**Extreme poverty**	**Non-extreme poverty**	***P*-value**	**Extreme poverty**	**Non-extreme poverty**	***P*-value**
OHIP-5 score	-0.054	-0.046	0.896	-0.040	-0.050	0.826
	(0.039)	(0.056)		(0.023)	(0.036)	
Total number of missing teeth	0.000	-0.027	0.509	**-0.035****	**-0.046***	0.631
	(0.023)	(0.034)		(0.013)	(0.022)	

Notes: OHIP-5: 5-item Oral Health Impact Profile; SHEI: Simplified Healthy Eating Index; MNA-SF: Short-Form Mini Nutritional Assessment. The inter-group difference test used the bootstrap process, applied 500 times. Both in Panel A and Panel B, the independent variables used continuous variables. Gender, age, prior stable partnership status, literate, care arrangements, family poverty status, pension coverage, chronic disease, disability, smoking, and drinking were controlled in the analysis. Cluster effect at the village level. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

malnutrition or being malnourished than those with adequate dentition [60].

WHO highlights significant disparities in oral health, dietary quality and nutritional status, particularly pronounced among socioeconomically disadvantaged populations, where poor oral health is closely linked to nutritional deficiencies and multimorbidity [61, 62]. For example, studies in marginalized communities, such as those in Karachi, show a strong association between oral health and increased comorbidity linked to nutritional deficiencies [9]. Our findings emphasize the complex interplay between oral health, dietary quality, and nutritional status among socioeconomically disadvantaged older adults in rural China, an area with relatively limited research. Specifically, tooth loss, difficulty chewing, and uncomfortable to eat are key contributors to dietary quality and nutritional status, while uncomfortable to eat is less recognized in general populations [63]. These individuals are more likely to suffer from untreated dental issues, which impair their ability to consume nutrient-rich foods like fruits, vegetables, and protein-rich items. Socioeconomic barriers, including low income and social isolation, limited health literacy, and financial constraints, exacerbate these issues by restricting access to dental care and nutritious food [11, 64]. Research shows that individuals facing severe socioeconomic challenges are 7 to 9 times more likely to avoid necessary dental treatment, further worsening oral health [65]. This convergence of poor oral health, inadequate nutrition, and socioeconomic challenges severely impacts the overall health and quality of life of these at-risk populations.

Thirdly, heterogeneity analysis finds no significant differences in the impact of oral health on adherence to a healthy diet and nutritional status across care arrangements or family poverty status. While public nursing homes may offer a broader variety of foods, severe oral problems drive both home-based and public nursing home residents to prioritize softer, easier-to-chew foods [66], nullifying any notable difference in the oral health-nutrition relationship between these groups. Similarly, poverty status does not significantly modify this relationship in this context. Regardless of whether they reside in rural communities or public nursing homes, socioeconomically disadvantaged older adults exhibit comparable levels of poor oral health and nutritional status [59]. Shared poverty-related barriers, such as limited access to dental care and nutrient-rich foods, constrain nutritional improvements across these groups, obscuring any distinct effects of poverty alone.

This study has several limitations. First, the cross-sectional design restricts causal inference; future research employing longitudinal data or experimental designs could provide stronger causal evidence. Second, the focus on older adults in western rural China may limit the generalizability of findings; cross-regional comparisons could enhance external validity. Cross-regional comparisons, including studies in other regions of China or internationally, could enhance external validity and provide a broader understanding of the associations between oral health, dietary quality, and nutritional status. Third, reliance on self-reported measures of oral health and nutritional status, particularly regarding missing teeth and denture presence, may introduce biases. While self-reports are common in large-scale surveys, they can be affected by recall bias and may not accurately reflect true health status. This study only assessed denture presence, without examining type or usage habits. Future studies could incorporate objective assessments, such as oral exams or clinical evaluations to improve measurement accuracy. Lastly, the relatively small sample size limits the statistical power of our analyses and may impact the generalizability of our results. Although our sample is representative of socioeconomically disadvantaged older adults in rural China, a larger sample size would allow for more robust conclusions and a deeper understanding of the nuances within this population. Future studies with

larger and more diverse samples could strengthen the findings and provide more reliable evidence on the relationship between oral health, dietary quality and nutritional status.

Despite its limitations, this study makes important contributions to the literature. It sheds light on the significant disparities in oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural areas. Additionally, by adopting a multidimensional perspective, it provides a deeper understanding of how poor oral health affects both dietary quality and nutritional status, particularly in vulnerable populations.

Conclusions

In summary, this study suggests a significant association between oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural western China. Poor oral health appears to be associated with reduced adherence to a healthy diet, particularly lower consumption of fresh vegetables and meat, which may negatively impact nutritional status. Given the findings, targeted interventions to improve oral health may help enhance dietary intake and nutritional status for older adults in resource-limited settings.

Abbreviations

OHIP-5	5-item Oral Health Impact Profile
SHEI	Simplified Healthy Eating Index
PCA	Principal Component Analysis
MNA-SF	Short-Form Mini Nutritional Assessment

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

QFG, XTW, and YJS designed the study, analyzed the data, and drafted the manuscript. QFG, XTW, YXJ, WHC, and YJS conducted the literature review, performed the data analysis and contributed to manuscript preparation. QFG and YJS offered valuable feedback and ensured quality control. QFG, XTW, YXJ, WHC, KXG, and YJS reviewed the results and revised the manuscript. All authors critically reviewed the article for significant intellectual content and approved the final manuscript.

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Data availability

Public availability of data would compromise the privacy of participants. Data will be made available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by Xi'an Gaoxin Hospital in China (2019-KY005). As permitted by the ethics committee, verbal informed consent was obtained from all participants before their involvement. We certified that the study was performed in accordance with the 1964 Declaration of Helsinki and later amendments.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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References

1. Ageing and health [Internet]. Geneva, World Health Organization.: 2024 [cited 2024 Nov 13]. Available from: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health
2. Ferrari AJ, Santomauro DF, Aali A, Abate YH, Abbafati C, Abbastabar H, et al. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the global burden of disease study 2021. Lancet. 2024;403(10440):2133–61.
3. Luan Y, Sardana D, Jivraj A, Liu D, Abeyweera N, Zhao Y, et al. Universal coverage for oral health care in 27 low-income countries: a scoping review. Global Health Res Policy. 2024;9(1):34. https://doi.org/10.1186/s41256-024-00376-9
4. Xinhua News Agency. By 2050, the elderly will account for about one-third of China's total population [Internet]. Beijing: State Council of China; 2018 [cited 2024 Nov 13]. Available from: https://www.gov.cn/xinwen/2018-07/19/content_5307839.htm
5. Tu C, Wang G, Hu Z, Wang S, Yan Q, Liu X. Burden of oral disorders, 1990–2019: estimates from the global burden of disease study 2019. Archives Med Sci. 2023;19(4):930–40. https://doi.org/10.5114/aoms/165962
6. Global burden of disease study 2021. (GBD 2021) [Internet]. Seattle: Institute for Health Metrics and Evaluation; 2024 [cited 2024 Nov 13]. Available from: https://vizhub.healthdata.org/gbd-results
7. Liu H, Wang Z. Oral health status report of the elderly in China [Internet]. Beijing: Expert Group; 2023. China Oral Health Development Report (2022). Available from: https://www.pishu.com.cn/skwx_ps/initDatabaseDetail?siteId=14%26contentId=14300487
8. Yan S, Yingjuan Y. Study on the fairness of oral health among middle-aged and elderly people in China from the perspective of National health. Electron J Gen Stomatology. 2019;6(17):26–7. https://doi.org/10.16269/j.cnki.cn11-9337/r.2019.17.014
9. Sharif H, Hammash M, Anwer W, Hassan N, Seemi T, Sheikh SS. Evaluation of oral health among people with Multimorbidity in the marginalized population of Karachi, Pakistan: a multicenter cross-sectional study. J Taibah Univ Med Sci. 2024;19(3):500–15. https://doi.org/10.1016/j.jtumed.2024.03.008
10. Gao M, Jiang F, Wang J, et al. Population ageing and income inequality in rural China: an 18-year analysis. Humanit Social Sci Commun. 2024;11:1605. https://doi.org/10.1057/s41599-024-04110-1.
11. An R, Jiang G, Wu Z, et al. Perceptions and experience of rural older people in oral health management in China: a qualitative study. BMC Oral Health. 2024;24:644. https://doi.org/10.1186/s12903-024-04401-8.
12. Peres MA, Macpherson LMD, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. Oral diseases: a global public health challenge. Lancet. 2019;394(10194):249–60.
13. Poudel P, Paudel G, Acharya R, et al. Oral health and healthy ageing: a scoping review. BMC Geriatr. 2024;24(1):33. https://doi.org/10.1186/s12877-023-04613-7
14. Shen J, Qian S, Huang L, Tao Y, Chen H, Deng K, et al. Association of the number of natural teeth with dietary diversity and nutritional status in older adults: A cross-sectional study in China. J Clin Periodontol. 2023;50(2):242–51. https://doi.org/10.1111/jcpe.13728

15. Santos L. The impact of nutrition and lifestyle modification on health. Eur J Intern Med. 2022;97:18–25. https://doi.org/10.1016/j.ejim.2021.09.020
16. Nazri NS, Vanoh D, Leng SK. Malnutrition, low diet quality and its risk factors among older adults with low socio-economic status: a scoping review. Nutr Res Rev. 2021;34(1):107–16. https://doi.org/10.1017/S0954422420000189
17. Wei K, Wang H, Yang J, Lin S, Li C. Nutritional risk and adverse health outcomes in Chinese community-dwelling older adults: a study based on the elderly nutritional indicators for geriatric malnutrition assessment (ENIGMA). Nutrition. 2024;126:112489. https://doi.org/10.1016/j.nut.2024.112489
18. Deng C, Vicerra PMM. Household structure and dietary diversity among older adults in rural and urban China: a cross-sectional study. BMC Public Health. 2024;24(1):3004. https://doi.org/10.1186/s12889-024-20434-8
19. Liu Z. Survival dependent on nature: the relationship of famine and commodity market in late Ming dynasty. J Cent South Univ (Social Sciences). 2011;17(04):108–13.
20. Ministry of Civil Affairs of the People's Republic of China. Circular on printing and issuing the action plan for actively developing elderly meal-assistance services [Internet]. 2023. Available from: https://www.gov.cn/zhengce/zhengceku/202310/content_6911233.htm
21. Liu Z, Zhao L, Man Q, Wang J, Zhao W, Zhang J. Dietary micronutrients intake status among Chinese elderly people living at home: data from CNNHS 2010–2012. Nutrients. 2019;11(8):1787. https://doi.org/10.3390/nu11081787
22. Shahar S, Vanoh D, Mat Ludin AF, Singh DKA, Hamid TA. Factors associated with poor socioeconomic status among Malaysian older adults: an analysis according to urban and rural settings. BMC Public Health. 2019;19(S4):549. https://doi.org/10.1186/s12889-019-6866-2
23. Jiang L, Li J, Luo M, Yang Z, Wu L, Liu B, et al. Analysis of factors associated with tooth loss in older adults from 1995 to 2015: a population-based cross-sectional survey in Guangdong, China. Clin Oral Invest. 2024;28(11):601. https://doi.org/10.1007/s00784-024-06001-w
24. Wang D, Zhang R, Wang Z, Yang J, Wang Z, Li X. Oral health-related quality of life and its influencing factors among the elderly in rural areas of Xinjiang Uygur autonomous region. Chin Prev Med. 2022;23(9):664–8. https://doi.org/10.16506/j.1009-6639.2022.09.005
25. Shaanxi Provincial Bureau of Statistics. Statistical Bulletin of National Economic and Social Development of Shaanxi Province in 2023 [Internet]. 2024. Available from: http://snzd.stats.gov.cn/tjgb/2024/45709.shtml
26. State Statistical Bureau. 2023 Statistical Bulletin of the People's Republic of China on National Economic and Social Development [Internet]. 2024. Available from: http://tjj.shaanxi.gov.cn/tjsj/ndsj/tjgb/qg_443/202403/t20240327_2324311.html
27. Department of Civil Affairs. Notice of the Ministry of Civil Affairs on issuing the. Measures for the Identification of Especially Poor Persons [Internet]. 2021. Available from: https://www.gov.cn/zhengce/zhengceku/2021-05/09/content_5605472.htm
28. Lei X, Chen Z. Towards common prosperity: the logic of change and the way forward for extreme poverty aid system in China. J Shandong Univ (Philosophy Social Science). 2023;0329–40. https://doi.org/10.19836/j.cnki.37-1100/c.2023.03.004.
29. The State Council. Notice of the State Council on establishing the rural minimum living security system in China [Internet]. 2007. Available from: https://www.gov.cn/zhuanti/2015-06/13/content_2878972.htm
30. Lü H, He F. Reliability and validity of the Chinese version of the 5-item oral health impact profile. West China J Stomatology. 2020;38(2):145–8.
31. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global burden of severe tooth loss: A systematic review and Meta-analysis. J Dent Res. 2014;93(Suppl 7):S20–8. https://doi.org/10.1177/0022034514537828.
32. Müller F, Shimazaki Y, Kahabuka F, Schimmel M. Oral health for an ageing population: the importance of a natural dentition in older adults. Int Dent J. 2017;67(Suppl 2):7–13. https://doi.org/10.1111/idj.12329.
33. Xu X, Zhao Y, Wu B, Pei Y, Gu D. Association between tooth loss and frailty among Chinese older adults: the mediating role of dietary diversity. BMC Geriatr. 2023;23(1):668. https://doi.org/10.1186/s12877-023-04355-6
34. Jiang Z, Xu Z, Zhou M, et al. The influence of healthy eating index on cognitive function in older adults: chain mediation by psychological balance and depressive symptoms. BMC Geriatr. 2024;24:904. https://doi.org/10.1186/s12877-024-05497-x.
35. The Chinese Longitudinal Healthy Longevity Survey (CLHLS)-Longitudinal Data. (1998–2018). Peking University Open Data. Available from: https://opendata.pku.edu.cn/dataset.xhtml?persistentId=doi:10.18170/DVN/WBO7LK%26version=2.0
36. Liu D, Ju H, Yang ZY, et al. Food frequency questionnaire for Chinese children aged 12–17 years: validity and reliability. Biomed Environ Science: BES. 2019;32(7):486–95. https://doi.org/10.3967/bes2019.066.
37. Zhao W, Hasegawa K, Chen J. The use of food-frequency questionnaires for various purposes in China. Public Health Nutr. 2002;5(6a):829–33. https://doi.org/10.1079/phn2002374.
38. Schwedhelm C, Iqbal K, Knüppel S, Schwingshackl L, Boeing H. Contribution to the Understanding of how principal component analysis-derived dietary patterns emerge from habitual data on food consumption. Am J Clin Nutr. 2018;107(2):227–35. https://doi.org/10.1093/ajcn/nqx027.
39. Pei Z, Zhang J, Qin W, Hu F, Zhao Y, Zhang X, Cong X, Liu C, Xu L. Association between dietary patterns and depression in Chinese older adults: a longitudinal study based on CLHLS. Nutrients. 2022;14(24):5230. https://doi.org/10.3390/nu14245230.
40. Rubenstein LZ, Harker JO, Salva A, Guigoz Y, Vellas B. Screening for undernutrition in geriatric practice: developing the short-form mini-nutritional assessment (MNA-SF). J Gerontol A Biol Sci Med Sci. 2001;56(6):M366–73. https://doi.org/10.1093/gerona/56.6.m366
41. Kaiser MJ, Bauer JM, Uter W, Donini LM, Stange I, Volkert D, et al. Prospective validation of the modified mini nutritional assessment short-forms in the community, nursing home, and rehabilitation setting. J Am Geriatr Soc. 2011;59(11):2124–8. https://doi.org/10.1111/j.1532-5415.2011.03659.x
42. Koenker R, Hallock KF. Quantile regression. J Economic Perspect. 2001;15(4):143–56. https://doi.org/10.1257/jep.15.4.143.
43. Shawtari FA, Saiti B, Mohamad MHS, Rashid HMA. Does intense monitoring matter? A quantile regression approach. Borsa Istanbul Rev. 2017;17(2):75–85. https://doi.org/10.1016/j.bir.2017.02.004.
44. Reyes Garita P, Tran VT, Chatzopoulou E, Toko-Kamga L, Bouchard P, Carra MC. Oral hygiene behaviors and periodontitis among patients with chronic diseases and its impact on tooth loss and oral health-related quality of life: a cross-sectional study of data from the compare e-cohort. Clin Oral Invest. 2024;28(10):518. https://doi.org/10.1007/s00784-024-05903-z
45. An R, Li S, Li Q, Luo Y, Wu Z, Liu M, et al. Oral health behaviors and oral health-related quality of life among dental patients in China: a cross-sectional study. Patient Prefer Adherence. 2022;16:3045–58. https://doi.org/10.2147/PPA.S385386
46. Perpiña Castillo C, Ribeiro Barranco R, Curtale R, Kompil M, Jacobs-Crisioni C, Vallecillo Rodriguez S, Aurambout JP, Batista e Silva F, Sulis P, Auteri D. Are remote rural areas in Europe remarkable? Challenges and opportunities. J Rural Stud. 2024;105:103180. https://doi.org/10.1016/j.jrurstud.2023.103180.
47. Slade GD, Sanders AE. The paradox of better subjective oral health in older age. J Dent Res. 2011;90(11):1279–85. https://doi.org/10.1177/0022034511421931.
48. Park S, Kim HJ, Kim K. Do where the elderly live matter? Factors associated with diet quality among Korean elderly population living in urban versus rural areas. Nutrients. 2020;12(5):1314. https://doi.org/10.3390/nu12051314
49. Chen H, Wang X, Ji JS, Huang L, Qi Y, Wu Y, et al. Plant-based and planetary-health diets, environmental burden, and risk of mortality: a prospective cohort study of middle-aged and older adults in China. Lancet Planet Health. 2024;8(8):e545–53.
50. Byker Shanks C, Haack S, Tarabochia D, Bates K, Christenson L. Factors influencing food choices among older adults in the rural Western USA. J Community Health. 2017;42(3):511–21. https://doi.org/10.1007/s10900-016-0283-6
51. Zhao D, Ning J, Zhao Y, et al. Associations of dietary and drinking water habits with number of natural teeth: a longitudinal study in the Chinese elderly population. BMC Geriatr. 2021;21:525. https://doi.org/10.1186/s12877-021-02473-7.
52. Yan LL, Li C, Zou S, et al. Healthy eating and all-cause mortality among Chinese aged 80 years or older. Int J Behav Nutr Phys Activity. 2022;19:60. https://doi.org/10.1186/s12966-022-01280-6.
53. Wu X, Xu Y, Liu Y, Ma A, Zhong F, Gao T, et al. Relationships between oral function, dietary intake and nutritional status in older adults aged 75 years and above: a cross-sectional study. BMC Public Health. 2024;24(1):1465. https://doi.org/10.1186/s12889-024-18906-y
54. Lin W, Xiao T, Fang Y, Sun M, Yang Y, Chen J, et al. The association of malnutrition and health-related factors among 474,467 older community-dwellers: a population-based data mining study in Guangzhou, China. Nutrients. 2024;16(9):1338. https://doi.org/10.3390/nu16091338
55. Yang D, Acharya Y, Liu X. Social health insurance consolidation and urban-rural inequality in utilization and financial risk protection in China. Soc Sci Med. 2022;308:115200. https://doi.org/10.1016/j.socscimed.2022.115200

56. Uy SNMR, Deng K, Fok CTC, Fok MR, Pelekos G, Tonetti MS. Food intake, masticatory function, tooth mobility, loss of posterior support, and diminished quality of life are associated with more advanced periodontitis stage diagnosis. J Clin Periodontol. 2022;49(3):240–50. https://doi.org/10.1111/jcpe.13588
57. Sergi G, Bano G, Pizzato S, Veronese N, Manzato E. Taste loss in the elderly: possible implications for dietary habits. Crit Rev Food Sci Nutr. 2017;57(17):3684–9. https://doi.org/10.1080/10408398.2016.1160208
58. Deng Y, Deng J, Jiang K, Shi Y, Feng Z, Wu R, et al. Correlation between vegetable and fruit intake and cognitive function in older adults: a cross-sectional study in Chongqing, China. Nutrients. 2024;16(18):3193. https://doi.org/10.3390/nu16183193
59. Toniazzo MP, Amorim P, de Muniz S, Weidlich FWMG. Relationship of nutritional status and oral health in elderly: systematic review with meta-analysis. Clin Nutr. 2018;37(3):824–30. https://doi.org/10.1016/j.clnu.2017.03.014
60. Zelig R, Goldstein S, Touger-Decker R, Firestone E, Golden A, Johnson Z, et al. Tooth loss and nutritional status in older adults: a systematic review and meta-analysis. JDR Clin Translational Res. 2022;7(1):4–15. https://doi.org/10.1177/2380084420981016
61. Oral health [Internet]. Geneva: World Health Organization; 2024 [cited 2024 Nov 13]. Available from: https://www.who.int/news-room/fact-sheets/detail/oral-health
62. The inequality epidemic: low-income teens face higher risks of obesity, inactivity, and poor diet [Internet]. Geneva: World Health Organization. 2024. Available from: https://www.who.int/europe/news/item/23-05-2024-the-inequality-epidemic--low-income-teens-face-higher-risks-of-obesity--inactivity-and-poor-diet
63. Vandenberghe-Descamps M, Labouré H, Septier C, Feron G, Sulmont-Rossé C. Oral comfort: a new concept to understand elderly People's expectations in terms of food sensory characteristics. Food Qual Prefer. 2018;70:57–67. https://doi.org/10.1016/j.foodqual.2017.08.009.
64. Hussein S, Kantawalla RF, Dickie S, Suarez-Durall P, Enciso R, Mulligan R. Association of oral health and mini nutritional assessment in older adults: a systematic review with meta-analyses. J Prosthodontic Res. 2022;66(2):208–20. https://doi.org/10.2186/jpr.JPR_D_20_00207
65. Wamala S, Merlo J, Boström G. Inequity in access to dental care services explains current socioeconomic disparities in oral health: the Swedish National surveys of public health 2004–2005. J Epidemiol Commun Health. 2006;60(12):1027–33. https://doi.org/10.1136/jech.2006.046896.
66. Czwikla J, Herzberg A, Kapp S, Kloep S, Schmidt A, Rothgang H, et al. Home care recipients have poorer oral health than nursing home residents: results from two German studies. J Dent. 2021;107:103607. https://doi.org/10.1016/j.jdent.2021.103607

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