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Association between the number of teeth and frailty among Chinese older adults: a nationwide cross-sectional study

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ABSTRACT

Objectives To explore the association between the number of teeth and frailty among older Chinese adults using a nationally representative sample.

Design Cross-sectional analysis was carried out using the 2014 wave data from the Chinese Longitudinal Healthy Longevity Survey, which used a targeted random-sampling design.

Setting This research was conducted in communities from nearly half of the counties and cities in 22 out of 31 provinces throughout China.

Participants Of the 6934 interviewees aged ≥65 years, the final analysis included 3635 older adults who had completed the 2014 wave survey on the variables included in the study.

Primary and secondary outcome measures Outcome variables included frailty, measured by the Frailty Index, and number of teeth. Covariates included demographic characteristics (ie, age, sex, co-residence, marital status, years of education and financial support), body mass index (BMI) and health behaviours (ie, smoking, drinking and exercise). A univariate logistic regression was used to test the factors associated with frailty. A multiple logistic regression model was used, using the frailty score as the dependent variable and the number of teeth together with significant covariates as the independent variables.

Results The prevalence of frailty was 27.68%. The mean number of teeth present was 9.23 (SD=10.03). The multiple logistic regression showed that older adults' demographic variables, health behaviours, BMI, tooth number and chewing pain were significantly associated with frailty. After adjusting for the covariates, older adults with fewer teeth had significantly higher odds of frailty than those with 20 or more teeth (no teeth: OR=2.07, 95% CI 1.53 to 2.80; 1 to 10 teeth: OR=1.77, 95% CI 1.31 to 2.38), except for older adults with 11 to 20 teeth (OR=1.30, 95% CI 0.93 to 1.82).

Conclusions The presence of fewer teeth is significantly associated with frailty status among older Chinese adults. Future studies are needed to explain the specific mechanisms underlying how oral health status is associated with frailty.

Strengths and limitations of this study

- ► This is the first study on frailty and oral health conducted in China.
- ► This study used a large nationally representative sample.
- ► This study measured frailty using the Frailty Index, which included chronic conditions, daily activities, cognitive function and so forth.
- ► The covariates of this study included the measurement of sociodemographic factors, nutritional status and health behaviours, which enabled the assessment of several confounding factors.
- ► This is a cross-sectional study that cannot indicate causal relationships between frailty and oral health.

INTRODUCTION

Populations around the world are rapidly ageing. As an inevitable demographic transition, the ageing population is estimated to become the next global public health challenge.[1] Frailty is one of the most problematic expressions of population ageing.[2] The prevalence of frailty in community-dwelling older adults is 10% to 27% for those older than 65 years and 45% for those older than 85 years.[3] Frailty is a clinical condition that is defined as a reduced ability to cope with acute or external stressors in daily life due to ageing-associated decline in reserve and function.[4] It is associated with a higher risk of falls, hospitalisation, nursing home residence, disability and death,[5] which places a significant burden on the individual, the family and public health systems.

Frailty is believed to develop due to a reduced physiological reserve caused by cumulative molecular and cellular damage during ageing and become evident when physiological decline reaches an aggregate crucial level.[2] Although the pathophysiological changes underlying and preceding frailty

are incompletely understood, multiple causes, inter-relationships and complex pathways have been proposed according to current research findings.[6] Evidence shows that frailty may be modifiable and is considered to have greater reversibility than disability.[7]

It is important to develop interventions targeting risk factors to maintain older adults' quality of life and delay or prevent the development of frailty and its subsequent need for long-term care.[8] Until now, the proposed risk factors for frailty include physiological changes with ageing, inflammation, sarcopenia, polypharmacy, social isolation and malnutrition.[9] Notably, emerging research has shown that frailty is significantly associated with oral health and functions, including tooth number,[10–12] functional dentition,[13] chewing ability,[14 15] periodontitis,[12] utilisation of dental services[11 16 17] and self-perception of oral health.[14 16] More teeth were significantly associated with a lower risk of developing frailty[11–13 17] because tooth loss might be caused by severe periodontal diseases, which can trigger higher levels of inflammatory markers and contribute to the development of frailty.[14] Another line of evidence has proposed that tooth loss can change one's food selection and nutrient intake, resulting in malnutrition and contributing to the development of frailty.[12]

The current evidence on the relationship between the number of teeth and frailty is controversial.[8 10 15 16] The conflicting results might be caused by the confounders of the subjects and the population from which they were recruited. Previous studies have measured frailty using the frailty phenotype, which is based on a predefined set of five criteria exploring the presence/absence of signs or symptoms (ie, involuntary weight loss, exhaustion, slowness, poor handgrip strength and sedentary behaviour).[18] There is a growing tendency to view frailty from a multidimensional perspective consisting of physical, psychological, social and most recently environmental frailty.[19] Although the frailty phenotype is conveniently applied, specific conditions (such as disability or cognitive impairment) can affect the reliability or clinical utility of the frailty phenotype results. Studies using frailty phenotypes cannot rule out confounding factors caused by cognitive impairment, which not only is an important domain of frailty[20] but also is significantly related to tooth number among older adults.[21] In particular, disabling conditions may affect the predictive value of the phenotype for negative health-related events due to a sort of 'ceiling effect'.[18]

The Frailty Index (FI), which assesses a broader spectrum of disorders than the frailty phenotype, might provide more information on exploring the association between tooth loss and frailty. Moreover, the association between tooth number and frailty is poorly understood in developing countries, especially in China, which has the largest population and the most rapidly ageing population in the world. Therefore, the present study is the first study that not only measures FI when exploring the association between tooth loss and frailty but also investigates this relationship among older Chinese adults using a large nationally representative sample.

METHODS

Study design and population

We used data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which is the first national longitudinal project to investigate the determinants of health and longevity of older adults in China from a multidisciplinary perspective.[22] The survey was conducted every 3 years in seven waves, from 1998 to 2014, in randomly selected older adults from nearly half of the counties and cities in 22 out of 31 provinces in China. These data represent approximately 85% of the Chinese population. A targeted random-sampling design was employed to ensure representativeness. Internationally compatible questionnaires were used to collect a comprehensive set of information, including demographic characteristics, family and household characteristics, lifestyle and diet, economic resources, social support, myriad physical, psychological and cognitive health conditions, etc. All the information was obtained through face-to-face interviews as well as some basic physical examinations at the interviewee's home. Interviews were based on voluntary participation and written informed consent was obtained from the participants prior to recruitment.

The data from the CLHLS are of high quality according to its representativeness and randomness of attrition.[23] The response rate of the oldest-old (older than 80 years) participants in the CLHLS was very high (98%) because the Chinese oldest-old adults, in general, may be proud to be a member of such a long-lived group are willing to talk to outside people. However, the response rate decreased among younger older adults aged 65 to 79 (94.9%).[24] The average proportion of incompleteness of an item rated for each respondent in the CLHLS is less than 10%.[25] The details of the sampling design, response rates and systematic assessments of data quality across numerous measures have been described elsewhere.[26] The present study utilised cross-sectional data from the 2014 wave of the CLHLS.

Patient and public involvement

Participants and the public were not involved in the development of the study design or outcome measures. Participation was voluntary and could be terminated at any time. The results will not be distributed to the participants themselves. All data were used strictly confidentially and anonymously.

Outcome variables

Various measurements exist for assessing frailty, with the FI and frailty phenotype being the most common applications.[27] The FI is defined as the proportion of accumulated deficits,[28] and calculated by the proportion of the number of health deficits presented to the total number of possible health deficits for a given individual.[22] For samples of the CLHLS, the FI has been found to be a valid and reliable frailty measure, and an independent and robust predictor of adverse outcomes among the Chinese elderly population.[29 30]

Table 1 Health deficits included in calculating the Frailty Index

Components	Measurement	Deficit	Score
Cognitive impairment	The Chinese version of the mini-mental state examination	≤23	1
Chronic disease conditions	Hypertension, diabetes, tuberculosis, heart disease, stroke/cerebrovascular disease, bronchitis/asthma, cancer, arthritis, bedsores, gastric/duodenal ulcer, Parkinson's disease	Yes	11
Activity of daily living disability	Eating, bathing, dressing, toileting, transferring, continence	Not able to do independently	6
Instrumental activity of daily living disability	Visiting neighbours, cooking meals, shopping, washing clothing, walking continuously for 1 km, lifting a weight of 5 kg, continuously crouching and standing up three times, using public transportation	Not able to do independently	8
Functional limitations	Putting hand behind neck, putting hand behind lower back, raising arm upright, standing up from sitting in a chair, picking up a book from the floor	Not able to do	5
Self-rated health	Self-assessed current global health	Bad	1
Hearing and vision impairment	Hearing and vision loss	Yes	2
Psychological distress	Felt fearful/anxious, lonely/isolated or useless	Often/always	1
Others	Heart rhythm Interviewer-rated health Number of serious illnesses in the past 2 years	Abnormal Bad One/two or more	1 1 1/2
Total			39

As presented in table 1, we used 38 indicators of health deficits encompassing nine major sets of components following the established research[17 22 29 30]: cognitive functioning, chronic disease conditions (self-reports from a list of 11 diseases), activity of daily living disability (needing help in performing the six basic daily activities), instrumental activity of daily living disability (needing help in performing the eight independent living activities), functional limitations (five objective examinations of physical function), self-rated health, hearing and vision impairment, psychological distress and others (eg, abnormal heart rhythm, interviewer-rated health, number of serious illnesses in the past 2 years).

Both face-to-face interviews and basic physical examinations were conducted to obtain the above information of each participant. Cognitive functioning, functional limitations, rhythm of the heart and interviewer-rated health were assessed by the interviewers who were intensively trained according to a nationally standardised procedure before the survey.[25] Other information, such as chronic disease conditions and psychological distress, was recorded according to the response of the participants or the proxy of the participants who were unable to give accurate answers due to impaired hearing, vision or recall problems.[25]

Each item was dichotomised and coded as 1 if a deficit was present (otherwise 0). A score of 2 was assigned for individuals with more than one serious illness in the past 2 years that led to hospital admission or a period of bed confinement. The total score of these 38 items was 39.[29] The FI of each participant was calculated as the total score of an individual divided by the maximum total score of 39. The FI scores ranged from 0 to 1. Cut-off points of FI are needed to identify frail older adults and to estimate the prevalence of frailty at the population level.[31] At present, the universally accepted category of FI scores are as follows: non-frail (0 to 0.10), vulnerable (0.10 to 0.21), frail (0.22 to 0.44) and frailest (≥0.45).[31] In the present study, the FI is categorised as non-frailty (0 to 0.21) and frailty (>0.21).[32]

Independent variable

The self-reported number of teeth was recorded using the following question: 'How many natural teeth do you still have?' In addition, chewing pain was recorded by the question: 'During the past 6 months, did you have a toothache more than once, when biting or chewing?' For older adults who were not able to answer these questions due to cognitive, hearing or linguistic impairments, their closest relative or caregiver was asked to answer for them.[25] The number of teeth of the older adults in this survey is similar to that in the Second National Epidemiological Survey on Oral Health, which confirms that the results of this survey represent the general patterns of tooth loss among elderly adults in China.[33] In accordance with practical and clinical importance, the present study grouped the number of teeth into four categories: 0 tooth, 1 to 10 teeth, 11 to 20 teeth and >20 teeth.[11]

Covariates

Based on well-established literature on the factors influencing frailty, we included covariates for basic

demographic characteristics, body mass index (BMI) and health behaviours. Demographic variables include age (65 to 79 years, 80 to 89 years, 90 to 99 years, ≥100 years), sex, co-residence condition (with household members, alone, in an institution), marital status (currently married and living with spouse, married but not living with spouse, others), years of education (received no education, received more than 1 year of education), financial support (sufficient, insufficient). BMI (kg/m^2) was defined as the ratio between the weight and the square of the height. In the present study, BMI was grouped into four categories:<18.5, 18.5 to 23.9, 24 to 27.9 and ≥28. Health behaviours included smoking (yes vs no), alcohol consumption (yes vs no), regular exercise (yes vs no) and regular physical labour (yes vs no).

Statistical analysis

Baseline characteristics of the subjects were reported as frequency and percentages for categorical variables. We examined the association between frailty and the potential covariates using the X^2 test. A univariate logistic regression was carried out to calculate the crude ORs of the independent variables in association with frailty status. A multiple logistic regression model was used, employing frailty status as the dependent variable, and the dental variables (number of teeth and chewing pain) and covariates as the independent variables. Demographic, nutritional and behavioural covariates identified as statistically significant in the univariate analysis were included in the multiple logistic regression to adjust for the relationship between frailty and the tooth number. P values of less than 0.05 were considered statistically significant. All statistical analyses were performed using SPSS V.22 (SPSS Inc, Chicago, Illinois, USA).

RESULTS

Characteristics of the participants

Of the 7019 interviewees who participated in the 2014 CLHLS, we initially included 6934 participants aged ≥65 years. The final analysis included 3635 older adults who had complete data on frailty and other explanatory factors used in the analyses. The main characteristics of 3635 participants and the frailty status are described in table 2. The average age of the participants was 84.27 years (SD=9.92) and 38.3% (n=1393) of them were aged between 65 years and 79 years. More than half of the participants were female (n=1884, 51.8%), single (n=2051, 56.4%) and living with household members (n=2918, 80.3%). Furthermore, 52.9% of the older adults had not received any education (n=1924), while 83.5% (n=3034) had sufficient financial support. For health behaviours, 66.3% (n=2411) never smoked, 72% (n=2618) never drank alcohol, 82.3% (n=2992) did physical labour regularly, while 68.2% (n=2478) did not exercise. More than half of the subjects (n=2012, 55.4%) had a normal BMI.

Tooth loss and frailty status of the participants

Among all the subjects, the average number of teeth was 9.23 (SD=10.03), 32.4% (n=1179) of the participants had 1 to 10 teeth, and the majority of them reported no chewing pain (n=3066, 84.3%). The average FI score was 0.16 (SD=0.14), and the prevalence of frailty was 27.68%.

Tooth number and other influencing factors of frailty

According to the X^2 tests, frailty status is associated with demographic variables (ie, age category, sex, co-residence condition, marital status, years of schooling and financial support), health behaviours (ie, smoking, drinking, doing physical labour and exercise), BMI and tooth number ($p<0.05$). No significant differences were found in frailty status based on chewing pain (p=0.387) (table 2).

Univariate and multiple logistic regressions were carried out to report both the crude ORs and adjusted ORs of the independent variables as presented in table 3. In the final multiple logistic regression model, the number of teeth is a significant factor in determining frailty after adjusting for covariates, including age category, sex, co-residence, marital status, years of schooling, financial support, smoking, drinking, doing exercise, doing physical labour and BMI.

Participants of older age were at a significantly higher risk of frailty than those participants aged 65 years to 79 years (80 to 89 years old: OR=2.29, 95% CI 1.81 to 2.91; 90 to 99 years old: OR=5.76, 95% CI 4.41 to 7.51; 100 years and older: OR=11.82, 95% CI 8.31 to 16.80). Female participants had a significantly higher risk of being frail (OR=1.40, 95% CI 1.12 to 1.74). For participants who lived alone or in an institution, the risk of frailty was significantly lower (OR=0.58, 95% CI 0.46 to 0.72). Single older adults had a significantly higher risk of frailty than married older adults (OR=1.42, 95% CI 1.15 to 1.76). Participants with insufficient financial support had a significantly higher risk of frailty than those who had sufficient financial support (OR=1.52, 95% CI 1.22 to 1.88).

Smoking and drinking were significantly associated with frailty in the unadjusted analyses, but the association decreased to non-significance in the adjusted analyses. Participants who did not perform physical labour regularly or exercise had a significantly higher risk of frailty than those who did physical labour regularly (OR=1.65, 95% CI 1.32 to 2.06) or exercise (OR=2.65, 95% CI 2.15 to 3.27). Participants with abnormal BMI were at a significantly higher risk of frailty than those within the normal BMI range (<18.5 kg/m^2: OR=1.55, 95% CI 1.25 to 1.93; 24 to 27.9 kg/m^2: OR=1.46, 95% CI 1.17 to 1.82; ≥28 kg/m^2: OR=2.06, 95% CI 1.46 to 2.90).

Participants with fewer teeth were at a significantly higher risk of frailty than those with more than 20 teeth (no teeth: OR=2.07, 95% CI 1.53 to 2.80; 1 to 10 teeth: OR=1.77, 95% CI 1.31 to 2.38), except for participants with 11 to 20 teeth (OR=1.30, 95% CI 0.93 to 1.82). Participants who had chewing pain had a significantly higher risk of frailty than those with no chewing pain (OR=1.64, 95% CI 1.28 to 2.08).

Table 2 Participant characteristics by frailty

Variable	Total (n=3635)	Non-frailty (n=2629)	Frailty (n=1006)	χ^2	P value
Age categories (years), n(%)				628.52	<0.001
65–79	1393 (38.3%)	1248 (47.5%)	145 (14.4%)		
80–89	1201 (33.0%)	906 (34.5%)	295 (29.3%)		
90–99	761 (20.9%)	390 (14.8%)	371 (36.9%)		
≥100+	280 (7.7%)	85 (3.2%)	195 (19.4%)		
Sex, n(%)				95.33	<0.001
Male	1751 (48.2%)	1398 (53.2%)	353 (35.1%)		
Female	1884 (51.8%)	1231 (46.8%)	653 (64.9%)		
Co-residence, n(%)				7.02	0.008
With household members	2918 (80.3%)	2080 (79.2%)	836 (83.1%)		
Alone or in an institution	717 (19.7%)	547 (20.8%)	170 (16.9%)		
Marital status, n(%)				187.98	<0.001
Married	1584 (43.6%)	1329 (50.6%)	255 (25.3%)		
Single	2051 (56.4%)	1300 (49.4%)	751 (74.7%)		
Years of schooling, n(%)				149.47	<0.001
>0	1711 (47.1%)	1399 (53.2%)	312 (31.0%)		
0	1924 (52.9%)	1230 (46.8%)	694 (69.0%)		
Sufficient financial support, n(%)				16.47	<0.001
Yes	3034 (83.5%)	2235 (85.0%)	799 (79.4%)		
No	601 (16.5%)	394 (15.0%)	207 (20.6%)		
Smoking, n(%)				50.78	<0.001
No	2411 (66.3%)	1676 (63.8%)	735 (73.1%)		
Yes	1224 (33.7%)	953 (36.2%)	271 (26.9%)		
Drinking, n(%)				61.6	<0.001
No	2618 (72.0%)	1834 (69.8%)	784 (77.9%)		
Yes	1017 (28.0%)	795 (30.2%)	222 (22.1%)		
Do physical labour regularly, n(%)				6.4	0.011
Yes	2992 (82.3%)	2190 (83.3%)	802 (79.7%)		
No	643 (17.7%)	439 (16.7%)	204 (20.3%)		
Do exercise, n(%)				166.65	<0.001
Yes	1157 (31.8%)	999 (38.0%)	158 (15.7%)		
No	2478 (68.2%)	1630 (62.0%)	848 (84.3%)		
Teeth number, n(%)				182.13	<0.001
>20	672 (18.5%)	594 (22.6%)	78 (7.8%)		
11-20	643 (17.7%)	519 (19.7%)	124 (12.3%)		
1-10	1179 (32.4%)	814 (31.0%)	365 (36.3%)		
0	1141 (31.4%)	702 (26.7%)	439 (43.6%)		
Chewing pain, n(%)				0.75	0.387
No	3066 (84.3%)	2209 (84.0%)	857 (85.2%)		
Yes	569 (15.7%)	420 (16.0%)	149 (14.8%)		

Continued

Table 2 Continued

Variable	Total (n=3635)	Non-frailty (n=2629)	Frailty (n=1006)	χ^2	P value
BMI*, kg/m^2, n(%)				86.32	<0.001
<18.5	633 (17.4%)	364 (13.8%)	269 (26.7%)		
18.5–23.9	2012 (55.4%)	1529 (58.2%)	483 (48.0%)		
24–27.9	748 (20.6%)	563 (21.4%)	185 (18.4%)		
≥28	242 (6.7%)	173 (6.6%)	69 (6.9%)		

*BMI refers to Body Mass Index.

DISCUSSION

We used data from a nationwide longitudinal survey in China to examine the association between frailty and tooth number. To the best of our knowledge, this is the first study exploring the association between frailty and oral health among older Chinese adults. Both univariate and multiple logistic regressions were performed to explore the association between tooth number and frailty. Considering that the relationship between tooth number and frailty might not be purely linear, we transformed the continuous variable FI into a dichotomous variable as non-frail and frail to obtain more practical information about clinical benefit. In addition, age and tooth number were categorised into four groups according to clinical importance to improve the effectiveness of the multiple logistic regression model. The main findings suggested that, after adjusting for sociodemographic, health behavioural and nutritional variables, older adults with fewer teeth had significantly higher odds of frailty than those with more than 20 teeth, except for participants with 11 to 20 teeth.

According to our results, the prevalence of frailty was 27.68%, which is consistent with the previously reported prevalence of frailty among community-dwelling older adults in the Asia-Pacific region.[9] Older adults with fewer than 11 teeth were at higher odds of being frail, while no significant difference in frailty risk was found between older adults with 11 to 20 teeth and those with more than 20 teeth, suggesting a non-linear relationship between tooth number and frailty. Two cross-sectional studies from Brazil and the USA indicated that older adults with more than 20 teeth had a lower chance of being frail than edentulous individuals.[11 17] One cohort study in Japan suggested that older adults who have 20 or more teeth with nine or more occluding pairs of teeth had a significantly lower risk of frailty.[8] By using linear analysis, a cohort study in Mexico suggested that each additional tooth was associated with a lower probability of developing frailty.[12] However, two cross-sectional studies performed in Mexico[16] and Thailand[15] and one cohort study in Denmark[10] did not find a significant association between the number of teeth and frailty. Collectively, current evidence supports that the relationship between frailty and tooth number exists in the older population in Brazil, the USA, Japan, Mexico and China, but does not exist in Danish and Thai older adults. These conflicting findings might be explained by several factors, including the study design, demographic covariates such as age, sex and education level, the ways of defining tooth number and the cultural context from which the participants came from. Our findings confirmed the association among older Chinese adults that fewer teeth are related to being frailer. However, our study observed an absence of a significant difference between older adults with 11 to 20 teeth and those with more than 20 teeth after adjusting for a variety of confounders. This finding might imply that older adults with 11 to 20 teeth might have comparable chances of being frail with older adults having 20 or more teeth. However, previous studies reported 20 teeth as the cut-off point of being frail. The inconsistency might be explained by several reasons. First, the cut-off point of teeth number for being frail among older adults might lie within the range from 11 to 20 teeth, but current studies fail to recognise it. Future studies could explore the specific turning points of the relationship between frailty and tooth number and explain the underlying mechanisms. Second, the distribution of tooth number among the participants in the present study might be different from those of previous studies. Chinese older adults have worse oral health compared with their counterparts in developed countries.[34] Therefore, the characteristics of tooth number among older Chinese adults might lead to a different form of its association with frailty. Third, the important covariates included in the previous studies varied from the present study, such as the number of occluding pairs of teeth, functional teeth and chewing pain. Moreover, our study used FI rather than frailty phenotype to identify the frailty status of the participants. Instead of solely relying on physical markers,[6] FI included a broader combination of health status, such as cognitive impairment, psychosocial status, physical limitations and chronic diseases. Some of these health status variables were viewed as covariates in the analyses of previous studies. However, these hypotheses, as well as the issue of causal order, should be further evaluated in longitudinal studies.

To fully control the potential confounders impacting the association between frailty and tooth number, our study included variables of demographic factors

Table 3 Multiple logistic regression of factors associated with frailty

Independent variables	Unadjusted ORs* (95% CI)	P values	Adjusted ORs (95% CI)	P values
Age category, years (65–79 as reference)				
80–89	2.80 (2.26 to 3.48)	<0.001	2.29 (1.81 to 2.91)	<0.001
90–99	8.19 (6.55 to 10.23)	<0.001	5.76 (4.41 to 7.51)	<0.001
≥100+	19.75 (14.52 to 26.85)	<0.001	11.82 (8.31 to 16.80)	<0.001
Sex (male as reference)				
Female	2.10 (1.81 to 2.44)	<0.001	1.40 (1.12 to 1.74)	0.003
Co-residence (with household members as reference)				
Alone or in an institution	0.77 (0.64 to 0.94)	0.008	0.58 (0.46 to 0.72)	<0.001
Marital status (married as reference)				
Single	3.01 (2.56 to 3.54)	<0.001	1.42 (1.15 to 1.76)	0.001
Years of schooling (>0 as reference)				
0	2.53 (2.17 to 2.95)	<0.001	1.18 (0.96 to 1.44)	0.11
Sufficient financial support (yes as reference)				
No	1.47 (1.22 to 1.77)	<0.001	1.52 (1.22 to 1.89)	<0.001
Smoking (no as reference)				
Yes	0.65 (0.55 to 0.76)	<0.001	1.16 (0.93 to 1.45)	0.187
Drinking (no as reference)				
Yes	0.65 (0.55 to 0.78)	<0.001	0.95 (0.76 to 1.19)	0.66
Do physical labour regularly (yes as reference)				
No	1.27 (1.06 to 1.53)	0.012	1.65 (1.32 to 2.06)	<0.001
Do exercise (yes as reference)				
No	3.29 (2.73 to 3.97)	<0.001	2.65 (2.15 to 3.27)	<0.001
Teeth number (>20 as reference)				
0	4.76 (3.66 to 6.20)	<0.001	2.07 (1.53 to 2.80)	<0.001
1-10	3.42 (2.62 to 4.46)	<0.001	1.77 (1.31 to 2.38)	<0.001
11-20	1.82 (1.34 to 2.47)	<0.001	1.30 (0.93 to 1.82)	0.122
Chewing pain (no as reference)				
Yes	0.91 (0.75 to 1.12)	0.387	1.64 (1.28 to 2.08)	<0.001
BMI*, kg/m^2 (18.5–23.9 as reference)				
<18.5	2.34 (1.94 to 2.82)	<0.001	1.55 (1.25 to 1.923)	<0.001
24–27.9	1.04 (0.86 to 1.26)	0.692	1.46 (1.17 to 1.82)	0.001
≥28	1.26 (0.94 to 1.70)	0.124	2.06 (1.46 to 2.90)	<0.001

*BMI refers to Body Mass Index.

and health behaviours. Congruent with the previous findings, participants who were older, female, single and suffering from insufficient financial support had a significantly higher risk of being frail. Health behaviours, including regular physical labour and exercise, are significantly associated with a lower risk of being frail. In previous studies, physical activities were not considered as a covariate. However, emerging evidence suggests that physical activities could act as a remedy against frailty.[35] A longitudinal survey is needed to confirm the causal relationship. In line with previous studies, our findings also suggest that smoking and drinking are not significantly associated with frailty.[12 17]

BMI was included in our study as a basic indicator of nutritional status. Underweight, overweight and obese older adults were at a significantly higher risk of frailty than those with normal BMI according to our findings as well as a previous study.[17] Identifying the relationship between nutrition and frailty is helpful in understanding the association between frailty and tooth number because some studies proposed that tooth loss could lead to frailty through malnutrition. Tooth loss

could reduce one's chewing ability and alter food selection, thus consuming inadequate nutrients for life and physiological function, and finally contributing to the development of frailty.[36] However, this hypothesis has not been verified in a population study and is opposite to the findings in animal models where dietary restriction could significantly extend lifespan.[37] The role of nutrition in mediating the relationship between frailty and tooth number is still unclear. On the other hand, current findings support that severe periodontitis is associated with the incidence of frailty. Tooth loss as a final consequence of periodontitis could contribute to frailty through inflammation. Inflammatory factors derived from the body's response to periodontal infection may disseminate to other organs and alter their metabolism.[16 21] However, the evidence regarding inflammation and frailty in human beings is still conflicting.[38] There is a lack of studies on understanding the interrelationships among tooth number, inflammation, nutrition and frailty. By including global oral health indicators, inflammatory biomarkers, nutritional biomarkers and behavioural variables, such as daily choice of food or diet, future studies could portray a clearer picture of the mechanisms underlying tooth number and frailty with the goal of identifying aetiological factors that are subject to public health interventions.

Strengths and limitations

This study has some strengths. First, this analysis was performed based on a large nationally representative sample of older Chinese adults, and the response rate of the participants in the CLHLS was high (from 94.9% to 98%), enhancing the generalisability of the results. Second, the multidisciplinary approach of the CLHLS and the large range of data collected allow us to calculate FI and adjust the analyses for demographics, nutrition status and health behaviours to be related to the outcome. Third, the present study measured frailty by calculating the FI, which assesses comprehensive health conditions and is reliable in large sample studies, contributing to a broader and supplementary explanation of previous findings. However, our data must be interpreted with caution. The self-reported tooth number might be subjective, although it has been widely used as a measure of oral health in epidemiological surveys.[13 17] Information on oral health is limited because the CLHLS was not specifically designed for dentate studies. Tooth loss might be inadequate in representing oral functions when understanding the deeper connections between oral health and frailty. Another weakness is the cross-sectional nature of this study. As the time of tooth loss and development of frailty were not determined, a causal relationship could not be established. Previous studies hypothesised that tooth loss could contribute to malnutrition or inflammation, resulting in developing frailty. However, tooth loss could present as one of the consequences or manifestations during the frailty process instead of being the initiator of frailty. For instance, frailty could contribute to losing functional teeth and reducing masseter muscle thickness.[8] Therefore, longitudinal studies are needed to understand the relationship between frailty and tooth number.

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