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Changes in handgrip strength and incident edentulism among middle-aged and older adults in China: a longitudinal analysis of CHARLS

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Research Article

Keywords: Handgrip strength, Muscle strength decline, Edentulism, Tooth loss, Ageing, China Health and Retirement Longitudinal Study

Posted Date: November 1st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11059795/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Evidence on whether changes in muscle strength precede complete tooth loss remains limited. We examined the association between handgrip strength changes during 2011–2015 and incident edentulism during 2015–2018 in Chinese middle-aged and older adults.

Methods

This longitudinal analysis used the 2011, 2015 and 2018 waves of the China Health and Retirement Longitudinal Study. Participants were aged ≥ 45 years in 2011, reported retaining natural teeth in both 2011 and 2015, and had oral outcome data in 2018. Grip strength decline was calculated as the 2011 value minus the 2015 value. Changes in low grip strength status were classified as persistently non-low, recovered, incident low, or persistently low. Multivariable logistic regression estimated odds ratios (ORs) and 95% confidence intervals (CIs), adjusting for baseline grip strength and sociodemographic, lifestyle and health characteristics. Supplementary analyses used natural cubic splines, change quartiles, multiple imputation and modified Poisson regression.

Results

Among 7005 participants in the complete-case analysis, 439 (6.3%) reported incident edentulism in 2018. Each standard deviation (7.36 kg) greater decline in grip strength was associated with an adjusted OR of 1.26 (95% CI 1.12–1.42). Compared with persistently non-low grip strength, the ORs were 1.54 (1.14–2.09) for incident low grip strength, 1.75 (1.08–2.85) for persistently low grip strength, and 1.10 (0.67–1.81) for recovered grip strength. There was no statistical evidence of nonlinearity (P = 0.794). Estimates were consistent after multiple imputation (OR 1.26, 1.11–1.42) and in modified Poisson regression (risk ratio 1.23, 1.10–1.38).

Conclusions

Greater grip strength decline over four years was associated with subsequent self-reported edentulism among adults who retained natural teeth in 2015. Incident and persistently low grip strength were also associated with edentulism. These findings extend longitudinal evidence linking changes in muscle strength to oral health and support further investigation of their shared determinants.

Background

Edentulism, the loss of all natural teeth, represents an important cumulative outcome of dental caries, periodontal disease and inadequate access to oral healthcare. Tooth loss can affect chewing, speech

and appearance, with consequences for food choice, social participation and quality of life. Global burden studies and policy reviews have highlighted severe tooth loss as a persistent public health concern in ageing populations, closely related to socioeconomic circumstances and access to dental services [1, 2, 3]. Identifying health changes that precede complete tooth loss may help clarify how oral health deteriorates among middle-aged and older adults who still retain natural teeth.

Handgrip strength is widely used in clinical and population research because it is inexpensive, simple to measure and suitable for repeated assessment. The Prospective Urban Rural Epidemiology study and UK Biobank have linked lower grip strength to a range of adverse health outcomes [4, 5]. Muscle weakness is also central to sarcopenia, although grip strength alone does not capture muscle mass, physical performance or the multidimensional features of frailty [6]. Muscle function and oral health may share nutritional, inflammatory and social determinants as people age, making their longitudinal relationship clinically relevant.

Most earlier studies examined oral health as an exposure in relation to subsequent declines in muscle strength or physical function [7, 8]. More recently, analyses of the China Health and Retirement Longitudinal Study (CHARLS) have examined the reverse direction. Jian et al. reported that higher standardised grip strength was associated with a lower likelihood of subsequent complete tooth loss, while Li et al. investigated bidirectional longitudinal associations between edentulism and sarcopenia [9, 10]. However, a single grip strength measurement cannot distinguish longstanding weakness from a recent decline or describe how an individual's strength changes over time.

Continuous changes in grip strength and transitions in low grip strength status provide complementary information. The former retain the magnitude of change, whereas the latter distinguish persistent weakness, newly developed weakness and recovery from low grip strength. We therefore used three CHARLS waves to examine grip strength changes during 2011–2015 in relation to self-reported incident edentulism in 2018, restricting follow-up to participants who still retained natural teeth at the end of the change assessment period.

Methods

Study design and participants

This was a longitudinal secondary analysis of CHARLS, a study using multistage sampling to collect sociodemographic, health, household and economic information from Chinese residents aged 45 years or older and their spouses. The cohort design has been described previously [11]. We used data from the 2011, 2015 and 2018 waves and organised reporting with reference to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [12].

Participants were eligible if they were aged ≥ 45 years in 2011, reported that they had not lost all their natural teeth in both 2011 and 2015, and had edentulism status recorded in 2018. Grip strength change was assessed between 2011 and 2015; outcome follow-up began in 2015 and ended at the 2018

assessment. The primary analysis required complete grip strength measurements and model covariates. Participants with observed grip strength and outcome data but missing covariates were included in the multiple imputation analysis. This design separated the assessment of grip strength change from the subsequent observation of edentulism. The sample size was determined by the availability of eligible participants in these survey waves.

Handgrip strength and definitions of change

Grip strength was measured in kilograms using a dynamometer, with repeated measurements of each hand. We used the maximum recorded value across the left and right hands at each wave. Values below 0 kg or above 100 kg were treated as missing. Grip strength change was defined as the 2015 value minus the 2011 value, so that negative values indicated a decline. For the continuous regression analysis, we reversed this difference to obtain grip strength decline, calculated as the 2011 value minus the 2015 value, and divided it by the standard deviation of the change. This standard deviation was 7.36 kg in eligible participants with both grip measurements. Estimates therefore refer to a 7.36 kg greater decline over the four-year assessment period.

Low grip strength was defined as < 28 kg in men and < 18 kg in women, using the thresholds in the Asian Working Group for Sarcopenia 2019 consensus [13]. Participants were classified into four groups: persistently non-low grip strength (non-low at both assessments); recovered grip strength (low in 2011 and non-low in 2015); incident low grip strength (non-low in 2011 and low in 2015); and persistently low grip strength (low at both assessments). These categories were defined directly from the two measurements and the sex-specific thresholds. Variable definitions and coding are provided in Additional file 1, Table S1.

Incident edentulism

Edentulism was ascertained from participants' self-reports of having lost all their natural teeth. Among participants who did not report edentulism in either 2011 or 2015, a positive report in 2018 was classified as incident edentulism. Because the exact date of complete tooth loss was unavailable, the outcome was analysed as a binary event during 2015–2018. Edentulism in this study refers specifically to self-reported loss of all natural teeth.

Covariates

Covariates were obtained from the 2011 survey and included age, sex, urban or rural residence, educational attainment, marital status, current smoking, current alcohol use, hypertension, diabetes, health insurance and baseline grip strength. Education was classified as less than primary school, primary school, junior high school, or senior high school and above. Marital status was classified as married or other. Smoking, alcohol use, hypertension, diabetes and insurance were coded from the

corresponding survey variables. Age and baseline grip strength were entered as continuous variables; the remaining covariates were categorical. These variables covered major demographic, socioeconomic, behavioural and health characteristics relevant to both muscle strength and oral health.

Statistical analysis

Participant characteristics were summarised according to incident edentulism status in 2018. Continuous variables are presented as medians and interquartile ranges, and categorical variables as counts and percentages. Logistic regression estimated odds ratios (ORs) and 95% confidence intervals (CIs). The primary model for continuous grip strength decline adjusted for all covariates. Changes in low grip strength status were analysed using four models, with persistently non-low grip strength as the reference: model 1 was unadjusted; model 2 adjusted for age, sex and baseline grip strength; model 3 additionally adjusted for residence, education, marital status, smoking and alcohol use; and model 4 further adjusted for hypertension, diabetes and health insurance. All four models used the same complete-case sample.

A natural cubic spline with three degrees of freedom was used to describe the association between continuous grip strength decline and incident edentulism. Nonlinearity was assessed using a likelihood ratio test comparing the spline model with the linear model. The plotted association was referenced to the prediction grid value closest to zero change and displayed over the 1st to 99th percentiles of grip strength decline. We also divided grip strength change, calculated as the 2015 value minus the 2011 value, into ascending quartiles. The lowest quartile (Q1), representing greater decline, was the reference; adjustment was identical to that in the primary continuous model.

Missing covariates were addressed using multiple imputation by chained equations among participants with observed grip strength and outcome data. Twenty datasets were generated with five iterations per dataset. The imputation model included the outcome, grip strength change, baseline grip strength and analysis covariates. Outcome, grip strength and age were not imputed; categorical covariates were imputed using methods appropriate to their measurement scales. Fully adjusted models were fitted in each dataset and combined using Rubin's rules [14, 15]. This analysis addressed missing covariates rather than missing grip strength or outcome measurements. We also fitted modified Poisson regression with a log link and robust variance to estimate risk ratios (RRs) [16].

Exploratory subgroup analyses were conducted by age (45–64 or ≥ 65 years), sex, residence, education (less than primary school or primary school and above) and diabetes. Each model omitted the corresponding stratifying covariate from the main adjustment set. Age-stratified models therefore did not retain continuous age, and education-stratified models did not retain four-category education. Interaction was assessed using a Wald test of the product term between continuous grip strength decline and each subgroup variable. Benjamini–Hochberg-adjusted interaction P values were also reported (Additional file 1, Table S4).

Analyses were performed in R. All tests were two-sided, with $P < 0.05$ used to indicate statistical significance; interpretation emphasised effect estimates and their CIs. Models were unweighted individual-level analyses and did not incorporate survey weights, strata or clustering.

Results

Participant characteristics

The 2011 survey included 17708 participants, of whom 16932 were aged ≥ 45 years and had oral status data; 15446 reported retaining natural teeth. Among 11591 participants who also retained natural teeth in 2015, 10302 had oral outcome data in 2018. Both grip strength measurements were available for 7128 participants, and 7005 had complete covariate data and entered the primary analysis (Fig. 1). In 2018, 439 participants (6.3%) reported incident edentulism and 6566 did not. Availability of oral status and grip measurements across the relevant waves is summarised in Additional file 1, Table S2. Missingness of each grip measurement by outcome status before the grip-data exclusion is shown in Table S3.

Participants with incident edentulism were older at baseline than those without edentulism (median 62.0 versus 57.0 years), more often lived in rural areas (73.8% versus 65.8%), and were less often married (80.9% versus 91.1%). Their median grip strength was 30.0 kg in 2011 and 26.5 kg in 2015, compared with 32.5 kg and 30.1 kg, respectively, among participants without incident edentulism. Median changes in grip strength were − 3.2 kg and − 2.5 kg, respectively (Table 1).

Table 1
Participant characteristics by incident edentulism status

Characteristic	No incident edentulism (n = 6566)	Incident edentulism (n = 439)
Age, years	57.0 (50.0, 62.0)	62.0 (56.0, 67.0)
Male	3046 (46.4)	192 (43.7)
Rural residence	4322 (65.8)	324 (73.8)
Less than primary school	2869 (43.7)	255 (58.1)
Primary school or above	3697 (56.3)	184 (41.9)
Married	5982 (91.1)	355 (80.9)
Current smoking	1972 (30.0)	138 (31.4)
Current alcohol use	2197 (33.5)	127 (28.9)
Hypertension	1586 (24.2)	116 (26.4)
Diabetes	373 (5.7)	23 (5.2)
Health insurance	6221 (94.7)	416 (94.8)
Grip strength in 2011, kg	32.5 (26.0, 40.0)	30.0 (24.0, 38.1)
Grip strength in 2015, kg	30.1 (24.1, 38.0)	26.5 (21.5, 33.5)
Grip strength change, kg	−2.5 (− 7.0, 2.1)	−3.2 (− 8.0, 1.5)

Values are medians (25th, 75th percentiles) or n (%). All characteristics were measured in 2011 except grip strength in 2015 and grip strength change. Change was calculated as the 2015 value minus the 2011 value. Education is shown in two categories for descriptive purposes; regression models retained four categories (less than primary school, primary school, junior high school, and senior high school or above).

Continuous grip strength decline and incident edentulism

After adjustment for baseline grip strength, age, sex, residence, education, marital status, smoking, alcohol use, hypertension, diabetes and health insurance, each standard deviation greater decline in grip strength was associated with an OR of 1.26 for incident edentulism (95% CI 1.12–1.42; P < 0.001; Table 2). The spline curve showed increasing odds of edentulism with greater grip strength decline, without statistical evidence of departure from linearity (P for nonlinearity = 0.794; Fig. 2).

Table 2
Continuous grip strength decline and incident edentulism

Analysis	N	Events	Effect	Estimate (95% CI)	P value
Complete-case logistic regression	7005	439	OR	1.26 (1.12–1.42)	< 0.001
Multiple imputation logistic regression	7128	449	OR	1.26 (1.11–1.42)	< 0.001
Modified Poisson regression	7005	439	RR	1.23 (1.10–1.38)	< 0.001

Estimates are per standard deviation (7.36 kg) greater grip strength decline during 2011–2015. All models adjusted for age, sex, residence, education, marital status, current smoking, current alcohol use, hypertension, diabetes, health insurance and grip strength, measured in 2011. Multiple imputation used 20 datasets and addressed missing covariates; grip strength and outcomes were not imputed. Modified Poisson regression used robust variance. OR, odds ratio; RR, risk ratio; CI, confidence interval.

Changes in low grip strength status and incident edentulism

The persistently non-low, recovered, incident low and persistently low grip strength groups comprised 5922, 315, 561 and 207 participants, respectively. Corresponding numbers of edentulism events were 316, 25, 66 and 32, with observed proportions of 5.3%, 7.9%, 11.8% and 15.5% (Table 3; Fig. 3). Compared with persistently non-low grip strength, the unadjusted OR was 2.37 (95% CI 1.79–3.13) for incident low grip strength and 3.24 (2.19–4.81) for persistently low grip strength. After full adjustment, these estimates were 1.54 (1.14–2.09; P = 0.005) and 1.75 (1.08–2.85; P = 0.023), respectively. The fully adjusted OR for recovered grip strength was 1.10 (0.67–1.81; P = 0.710). Descriptive group means at the two assessments are shown in Additional file 1, Table S5 and Fig. S1.

Table 3
Changes in low grip strength status and incident edentulism

Grip strength status	N / events (proportion)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Persistently non-low	5922 / 316 (5.3%)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
Recovered	315 / 25 (7.9%)	1.53 (1.00–2.34)	1.09 (0.66–1.79)	1.09 (0.66–1.80)	1.10 (0.67–1.81)
Incident low	561 / 66 (11.8%)	2.37 (1.79–3.13)	1.61 (1.19–2.18)	1.54 (1.14–2.09)	1.54 (1.14–2.09)
Persistently low	207 / 32 (15.5%)	3.24 (2.19–4.81)	1.84 (1.13–2.98)	1.75 (1.08–2.84)	1.75 (1.08–2.85)

Low grip strength was defined as < 28 kg in men and < 18 kg in women. Groups indicate non-low at both assessments, low to non-low, non-low to low, and low at both assessments, respectively. Model 1: unadjusted. Model 2: age, sex and 2011 grip strength. Model 3: model 2 plus residence, education, marital status, smoking and alcohol use. Model 4: model 3 plus hypertension, diabetes and health insurance. All models included 7005 participants and 439 events. Model 4 P values were 0.710, 0.005 and 0.023 for recovered, incident low and persistently low grip strength, respectively. OR, odds ratio; CI, confidence interval.

Quartile and sensitivity analyses

Across ascending quartiles of grip strength change (2015 minus 2011), the proportions of participants reporting incident edentulism were 7.5%, 6.4%, 5.6% and 5.5%. Compared with Q1, adjusted ORs were 0.77 (95% CI 0.58–1.01) for Q2, 0.66 (0.49–0.89) for Q3 and 0.61 (0.44–0.84) for Q4 (Table 4), consistent with the direction of the continuous association.

Table 4
Quartiles of grip strength change and incident edentulism

Change quartile	N	Events	Proportion, %	Adjusted OR (95% CI)	P value
Q1 (lowest change)	1819	136	7.5	1.00 (reference)	—
Q2	1723	110	6.4	0.77 (0.58–1.01)	0.055
Q3	1720	97	5.6	0.66 (0.49–0.89)	0.006
Q4 (highest change)	1743	96	5.5	0.61 (0.44–0.84)	0.002

Change was calculated as grip strength in 2015 minus grip strength in 2011 and divided into ascending quartiles; Q1 represents greater decline. Adjustment was identical to that in the complete-case model in Table 2. Quartiles describe the sample distribution and do not represent clinical thresholds. OR, odds ratio; CI, confidence interval.

The multiple imputation analysis included 7128 participants and 449 events. The pooled OR per standard deviation greater decline was 1.26 (95% CI 1.11–1.42; P < 0.001). Modified Poisson regression in the 7005 complete cases yielded an RR of 1.23 (1.10–1.38; P < 0.001; Table 2).

Subgroup analyses

Point estimates for grip strength decline were above 1 in all examined strata. There was no clear evidence of interaction by age, sex, residence, education or diabetes (interaction P values 0.546–0.988; all Benjamini–Hochberg-adjusted interaction P values 0.988). Estimates were less precise in some smaller strata, including participants with diabetes. These exploratory results are presented in Additional file 1, Table S4 and Fig. S2.

Discussion

Principal findings

In this longitudinal CHARLS analysis, declining grip strength during 2011–2015 was associated with self-reported incident edentulism during 2015–2018. Each 7.36 kg greater decline was associated with 26% higher odds of edentulism after adjustment for baseline grip strength and sociodemographic, lifestyle and health characteristics. The corresponding estimate from modified Poisson regression indicated a 23% higher relative risk. Incident and persistently low grip strength were also associated with subsequent edentulism. The continuous, quartile and status-change analyses together suggest that changes in muscle strength are relevant to understanding later oral health.

By considering change alongside initial grip strength, this study extends evidence based on single measurements. The association describes a greater decline among participants with the same measured baseline grip strength and model covariates. It suggests that preceding changes in muscle strength deserve attention when studying later oral health. The clinical value of repeated measurements for risk assessment remains to be established.

Comparison with previous research

The relationship between oral health and muscle function has been investigated for several decades. Hämäläinen et al. examined oral status in relation to five-year changes in grip strength in older people, and Tsakos et al. subsequently studied tooth loss and declines in physical and cognitive function [7, 17]. In prospective cohorts from the UK and USA, Kimble et al. assessed several oral health markers against subsequent muscle strength and physical performance; associations varied by both oral marker and functional outcome [8]. Albani et al., using cross-sectional data from the Newcastle 85 + and TOOTH

studies, likewise found that oral symptoms and tooth loss were associated with different aspects of frailty and physical functioning [18]. Together, these studies support distinguishing structural tooth loss from oral symptoms and chewing difficulties when interpreting links with physical function.

Related longitudinal evidence includes an association between poor oral health and physical frailty in older British men, and a Japanese community study linking a composite oral frailty measure to physical frailty and mortality [19, 20]. CHARLS analyses have also related edentulism to subsequent sarcopenia [21]. Although definitions and outcomes differ, these studies place oral health within the broader context of functional ageing. A systematic review showed substantial variation in how oral frailty is defined and measured, encompassing dentition, chewing, swallowing and other functions [22]. The outcome in our analysis was narrower: self-reported complete loss of natural teeth.

The CHARLS analysis by Jian et al. is particularly relevant. Using 2015–2018 data, that study observed 488 complete tooth loss events among 8360 participants and found an inverse association with standardised grip strength [9]. Our analysis focused instead on grip strength change during 2011–2015 and required participants to remain dentate at the end of that period. The studies therefore address related but distinct aspects of muscle strength: its level at one assessment and its change over preceding years. Because both used CHARLS and overlapping outcome periods, agreement between their findings should not be interpreted as replication in an independent population.

Li et al. subsequently constructed two CHARLS samples to investigate edentulism in relation to subsequent sarcopenia and sarcopenia in relation to subsequent edentulism. Confirmed and severe sarcopenia were associated with later edentulism [10]. Their classification combined muscle mass, strength and physical performance, whereas our exposure was confined to grip strength. Our results therefore concern changes in muscle strength rather than the onset, remission or progression of sarcopenia. They may capture one component of a broader functional process linking muscle health and tooth loss.

Longitudinal associations of sarcopenia with cardiovascular disease and mild cognitive impairment have also been reported in CHARLS [23, 24]. These findings suggest that impaired muscle function often accompanies changes across several health domains. Extending this perspective to complete tooth loss may help explain how declining general function is expressed in oral health. Direct comparisons of effect sizes across these studies are nevertheless limited by differences in exposure definitions, follow-up periods and outcomes.

Interpretation of grip strength changes

Incident and persistently low grip strength represent different patterns. The incident group crossed a sex-specific threshold during follow-up, while the persistent group had low strength at both assessments. A person with persistently low strength may have limited muscle strength reserve even without a large absolute decline. Accordingly, the magnitude of decline and low grip strength status

convey complementary information; persistent weakness does not necessarily indicate the fastest decline.

Associations for incident and persistently low grip strength attenuated substantially after adjustment for age, sex and baseline strength. This attenuation indicates that differences in initial characteristics contributed to the unadjusted associations and underscores the importance of considering starting levels in studies of change. Reference data across the life course show marked age and sex differences in grip strength [25]. Although we used sex-specific thresholds and adjusted for age, categorisation loses continuous information, and small measurement fluctuations near a threshold may change group assignment. Agreement with the continuous analysis improves interpretability but does not remove this measurement concern.

The recovered group did not differ statistically from the persistently non-low group, but it contained only 315 participants and 25 events. Its CI of 0.67–1.81 includes potentially meaningful associations in either direction. Thus, the data do not establish that the likelihood of edentulism returns to that of participants with persistently non-low strength after recovery. Similarly, the higher point estimate for persistently low than incident low grip strength does not establish a difference between these groups, which were not directly compared.

The spline and quartile analyses were compatible with a graded association without an evident change point. A nonsignificant test for nonlinearity does not establish strict linearity, particularly where observations are sparse at the distribution tails. The 7.36 kg standard deviation is the unit used to express the association in this sample; it does not identify a clinical threshold or a target for improving grip strength.

Potential explanations

Nutrition provides one plausible link between muscle strength and oral health. Adequate energy and protein intake support muscle function, and nutritional deficits may contribute to declining strength [26]. Conversely, tooth loss and chewing discomfort may alter food choices and discourage consumption of foods that are difficult to chew. The relation between dentition and nutrition also depends on denture function, food preparation, eating habits and household support. A systematic review of denture use found that better chewing and eating do not invariably translate into consistent improvements in dietary intake; longitudinal work on incident malnutrition also suggests that oral indicators capture different aspects of nutritional vulnerability [27, 28].

This potentially bidirectional process is relevant to the timing of our measurements. Excluding participants who were edentulous in 2015 established that complete tooth loss followed the change assessment period, but did not establish that oral health was intact during that period. Participants may already have had extensive partial tooth loss, dental pain or chewing difficulties during 2011–2015. Such problems could accompany restricted intake and grip strength decline while also preceding loss of the

remaining teeth. Grip strength decline may therefore reflect concurrent deterioration in general and oral health, including effects of oral disease that were present before complete tooth loss.

Inflammation offers another plausible explanation. Periodontitis involves microbial dysbiosis, host immune responses and destruction of the tooth-supporting tissues, with complex interactions between local disease and systemic inflammation [29, 30]. Chronic low-grade inflammation is implicated in multiple age-related diseases and functional decline [31]. Longitudinal studies and systematic reviews have also associated inflammatory markers with lower muscle strength or its decline [32, 33]. A sustained inflammatory burden could contribute to both muscle impairment and periodontal tissue damage, producing an association between declining grip strength and later edentulism.

Edentulism, however, is the cumulative endpoint of oral disease, treatment decisions and access to care, rather than a measure of current periodontal inflammation. Complete tooth loss also changes the tissues and potential sources of periodontal inflammation [1, 34]. The present findings therefore cannot establish inflammatory mediation. Clarifying this pathway requires repeated assessments of periodontal health, inflammatory markers and muscle function before teeth are lost.

Daily self-care and social circumstances may also contribute. Declining strength can accompany fatigue, restricted mobility and wider functional limitations, potentially making oral cleaning, attendance at dental appointments and completion of treatment more difficult. Grip strength is not itself a direct measure of the manual dexterity required for oral hygiene. Education, economic resources, residence and family support may influence nutrition, health behaviour and access to dental services simultaneously; these conditions are central to oral health inequalities [2]. Adjustment for education, residence, marital status and insurance only partly captures this context, as income, dental attendance, oral hygiene practices and treatment history were not included.

Finally, handgrip strength and oral muscle function should be distinguished. Maximal hand force, bite force, tongue pressure and swallowing performance describe different functions. Our study did not measure the latter indicators. Joint assessment of general muscle strength and oral function would help distinguish shared functional ageing from local impairment in future work.

Clinical and public health implications

These findings support considering oral health alongside muscle function in comprehensive assessments of middle-aged and older adults. In an individual with declining strength, concurrent eating difficulties, nutritional change or oral symptoms may warrant further assessment of tooth retention, chewing and oral care needs. This integrated perspective is consistent with the broader emphasis on muscle health in the Asian Working Group for Sarcopenia 2025 consensus and with multidimensional approaches to oral frailty [35, 36]. Its translation into a grip-strength-based screening or referral strategy would require evaluation of thresholds, predictive performance and clinical benefit.

Prevention should continue to address dental caries and periodontal disease while recognising the nutritional and functional needs of older adults. A useful next step would be to evaluate coordinated

muscle health management, oral examination, nutritional support and assistance with self-care [2, 26]. Intervention studies should assess tooth retention, periodontal disease progression, chewing and quality of life alongside changes in strength. The present observational association alone does not establish that resistance exercise or improved grip strength prevents tooth loss.

Strengths and limitations

The principal strengths are the repeated grip strength measurements and separation of the change assessment period from outcome follow-up. Assessing both continuous change and changes in low grip strength status extended the analysis beyond a single measurement. Excluding participants already edentulous in 2015 ensured that those entering follow-up remained at risk of complete tooth loss. Adjustment for baseline strength and consistent findings from multiple imputation and modified Poisson regression further supported interpretation of the association.

Several limitations should be considered. First, edentulism was self-reported without clinical confirmation, and causes of tooth loss could not be distinguished. The absence of information on remaining tooth number, periodontal severity, dental pain, dentures and chewing function during the change assessment period limited control for pre-existing oral disease. Second, change was derived from only two grip strength assessments, which cannot distinguish sustained decline from transient illness or measurement variation. Random error and regression to the mean may influence both change scores and threshold-based groups, and baseline adjustment does not necessarily eliminate these effects [37].

Third, covariates were mainly measured in 2011 and did not capture subsequent changes in health, lifestyle or social circumstances. Body mass index, dietary intake, physical activity, depression, cognition and daily functioning were not included in the models, leaving scope for residual confounding. Some of these factors may also lie on a causal pathway, so their interpretation requires attention to timing and the assumed causal structure.

Fourth, inclusion depended on participation across several waves and availability of oral and grip strength measurements. Included participants may therefore differ in health or follow-up circumstances from those excluded. Multiple imputation addressed missing covariates among participants with observed grip strength and outcomes, but could not correct selection associated with missing exposure measurements, missing outcomes, death or loss to follow-up. Death was not analysed separately. The findings consequently apply most directly to participants meeting the eligibility criteria with observed outcome data.

Fifth, although CHARLS used national sampling, our analyses did not incorporate sampling weights, strata or clustering. The observed proportions should not be interpreted as national incidence estimates, and within-sample correlation may affect conventional standard errors. Sixth, the exact timing of complete tooth loss was unavailable and the outcome observation period was relatively short. Finally, low grip strength thresholds derived from sarcopenia guidance were applied to a sample that also

included adults aged 45–59 years; their clinical meaning may differ across age groups. These considerations, together with the observational design, limit causal interpretation and support validation in independent populations.

Conclusions

Among Chinese middle-aged and older adults who retained natural teeth in 2015, greater grip strength decline during 2011–2015 was associated with self-reported incident edentulism in 2018. Incident and persistently low grip strength showed associations in the same direction. Repeated muscle strength assessment adds information about functional changes that precede adverse oral outcomes. Further studies incorporating repeated oral examinations, nutritional assessment and muscle function measurements are needed to clarify the direction of these associations and identify modifiable determinants.

Abbreviations

CHARLS, China Health and Retirement Longitudinal Study; CI, confidence interval; OR, odds ratio; RR, risk ratio; SD, standard deviation; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology.

Declarations

Ethics approval and consent to participate

This study was a secondary analysis of publicly available, de-identified data from the China Health and Retirement Longitudinal Study (CHARLS). The original CHARLS study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Peking University (IRB00001052-11015). The CHARLS research team obtained written informed consent from all participants. No additional ethics approval from the authors' institution was required because this analysis used only publicly available, de-identified secondary data and involved no new participant recruitment, direct contact with participants or collection of biological samples.

Consent for publication

Not applicable. This article reports only aggregate results and contains no personally identifiable information.

Availability of data and materials

The CHARLS data used in this study are available through the project website (https://charls.pku.edu.cn/), subject to registration and the project's data access and use requirements [38]. Additional aggregate results are provided in Additional file 1.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no specific funding.

Authors' contributions

YTL and JSL designed the study. YMH acquired and analysed the data. YTL drafted the manuscript. LYX and PPD revised the manuscript. All authors read and approved the final manuscript.

Clinical trial number

Not applicable.

Acknowledgements

We thank the CHARLS research team, field staff and participants.

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Figures

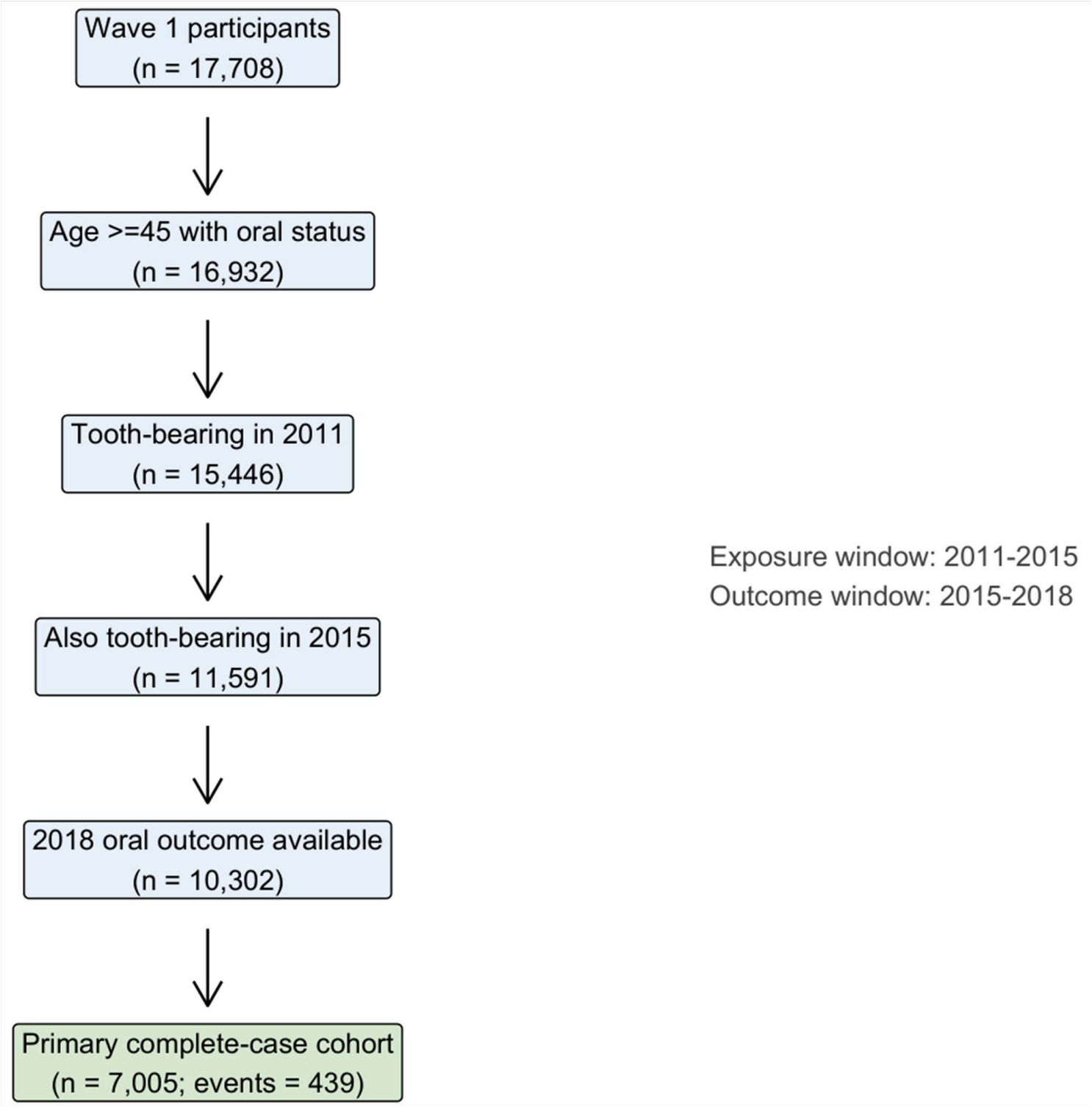


Figure 1

Participant selection and study timing. Grip strength change was assessed during 2011–2015, followed by outcome assessment during 2015–2018. Among participants with oral outcome data in 2018, 7128 had both grip strength measurements and 7005 also had complete covariates; 439 reported incident edentulism. Multiple imputation included 7128 participants.

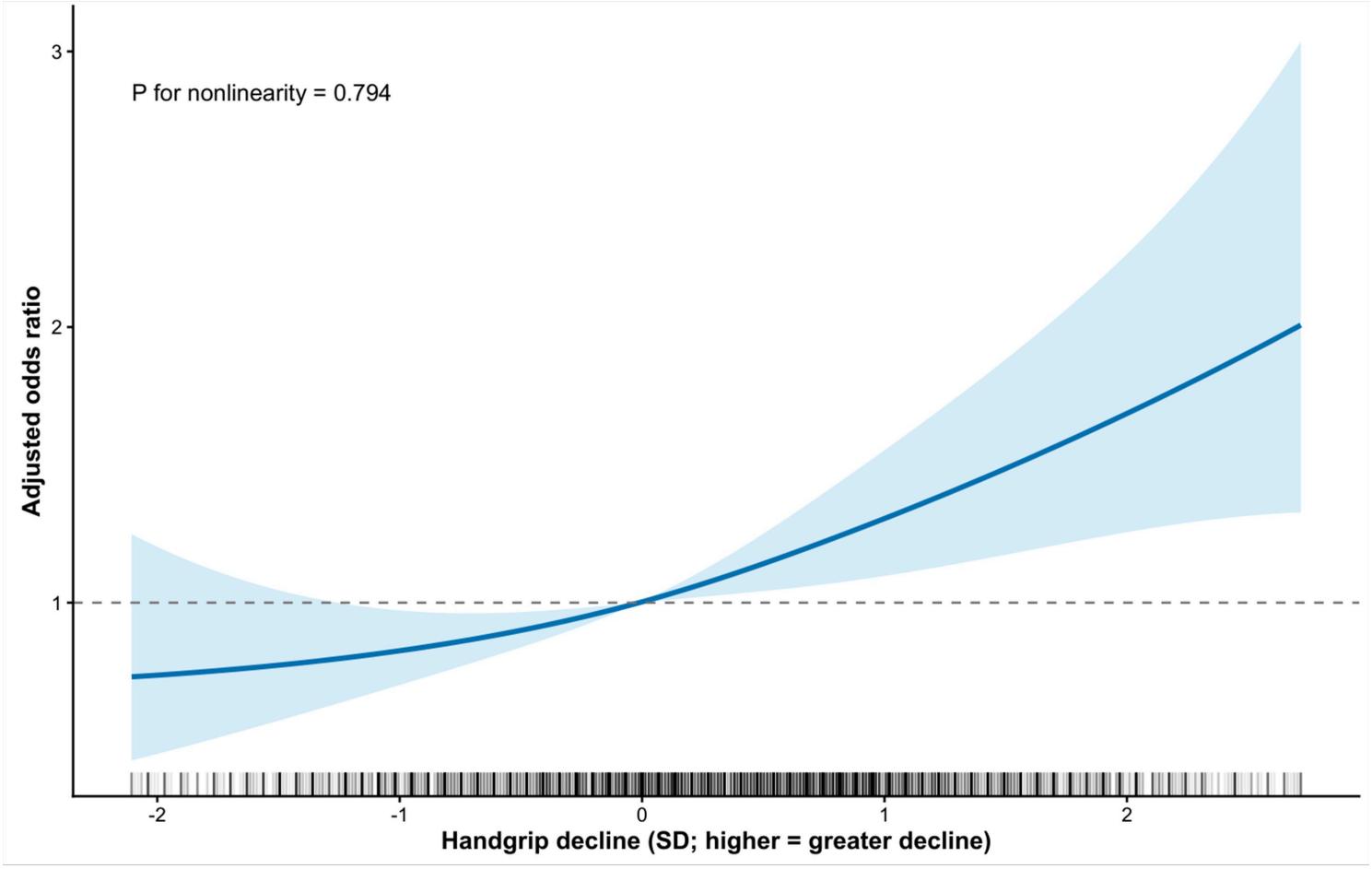


Figure 2

Adjusted association between grip strength decline and incident edentulism. The natural cubic spline used three degrees of freedom. The solid line indicates the OR and shading the 95% CI; the rug shows the distribution of grip strength decline. Each horizontal-axis unit represents a 7.36 kg greater decline; negative values indicate increases. The reference was the prediction grid value closest to zero change. The plot spans the 1st to 99th percentiles. Adjustment was identical to Table 2. P for nonlinearity = 0.794.

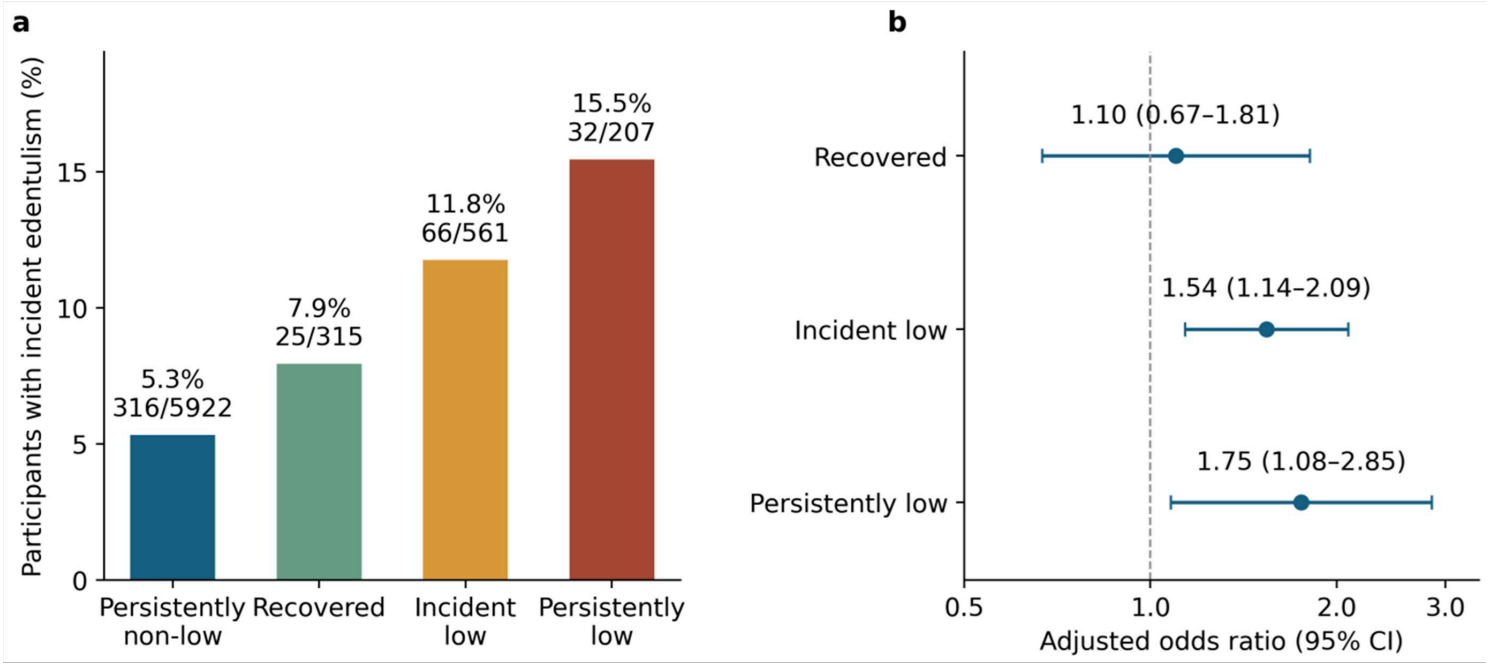


Figure 3

Incident edentulism by changes in low grip strength status. Panel a shows observed proportions reporting incident edentulism in 2018, with events and group totals above the bars. These are unadjusted sample proportions. Panel b shows fully adjusted odds ratios and 95% confidence intervals, with persistently non-low grip strength as the reference. Low grip strength was defined as <28 kg in men and <18 kg in women. Adjustment followed model 4 in Table 3. Group membership was based on the 2011 and 2015 measurements.

Supplementary Files

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