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Spousal education and frailty levels among Chinese older adults: A national longitudinal study

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ABSTRACT

Background: Prior research has identified one's own education level as a risk factor for frailty. However, the association between spousal education and frailty in later life is uncertain. We aim to examine the longitudinal association between spousal education and frailty levels among Chinese older populations.
Methods: 3856 participants aged 60 and older from the 2011–2018 China Health and Retirement Longitudinal Study were analyzed. A 54-item deficit cumulative frailty index was developed to evaluate frailty levels at each follow-up. Linear mixed-effects models were used to examine the longitudinal association of spousal education with frailty levels, and whether this association varied by sex and own education level.
Results: Higher spouse education was associated with lower frailty levels, and this association decreased with age. Compared with older adults whose spouses had no formal education, older adults whose spouses had less than middle school education had an 8.82 lower level of frailty (95% CI: 15.05 to -2.58, $P < 0.01$); those with spouses with middle school education and above had a 23.44 lower level (95% CI: 31.43 to -15.44, $P < 0.001$). Stratified analysis showed that every additional year of spouse education was also associated with lower frailty levels in non-frail participants at baseline, but stronger among those already frail. The association between high spousal education and lower frailty did not vary by sex or own education.
Conclusion: This study reveals a significant association between having a more educated spouse and lower later-life frailty levels for both older men and women, regardless of one's own educational background. It emphasizes the importance of leveraging educated spouses to prevent and manage frailty.

1. Introduction

Frailty has emerged as a significant public health concern, especially in countries experiencing rapid population aging. Frailty is a geriatric syndrome characterized by the cumulative decline in multiple physiological systems due to decreased physiological reserve and increased vulnerability to stressors (Yang & Lee, 2010). It is estimated that 479 million Chinese people will be aged 60 years or older by 2050 (W. Xu et al., 2019). With the accelerating aging population in China, the number of frail elders is projected to substantially increase. A recent nationally representative study conducted in China (Yin et al., 2018) reported that the prevalence of frailty, measured by the frailty index (FI), was 18.7%, 20.6%, and 28.4% in 2011, 2013, and 2015, respectively, among older adults. Research has demonstrated that frailty elevates the risk for various adverse health outcomes, including a 1.8-2.3-fold increased mortality risk, 1.5-2.6-fold increased risk for restricted physical activity, and 1.2-1.8-fold increased risk for hospitalization (Vermeiren et al., 2016). Moreover, numerous studies have shown that frailty progressively worsens over the later life course, and individuals exhibit some heterogeneity in frailty levels with age (Stolz et al., 2019). Therefore, identifying social factors (e.g., spousal education) associated with frailty levels in late life among older adults is crucial, as this will inform the identification of vulnerable groups at highest risk for rapid frailty deterioration.

A substantial body of research has identified individual-level socioeconomic status indicators, especially education level, as risk factors for frailty level (Hoogendijk et al., 2014; Huibregtse et al., 2021). However, few studies have gone beyond the individual level to examine the association between spousal education and later-life frailty in older adults. Prior research has indicated that family (e.g., children, spouses, siblings,

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etc.) can have a significant impact on late-life health. (Goldman, 2016; Liang et al., 2014; Pinquart & Sörensen, 2011). Marriage can transform individual-level resources like education into family-level resources that promote the well-being of both spouses (Jackson et al., 2015). For example, higher spousal education may provide greater social/emotional support, health knowledge diffusion, chronic disease management, access to care, and positive health behaviors (Liu et al., 2023; Sheehan & Iida, 2021). While prior studies have shown positive effects of higher spousal education for cognitive function (Saenz et al., 2020; M. Xu, 2020), self-reported health (Brown et al., 2014; Lamu et al., 2023), depression (Jang & Kawachi, 2018), and mortality risk (Jaffe et al., 2006; Kravdal, 2008, 2017), no studies have investigated spousal education in relation to frailty among older adults. This is a significant gap given frailty's complex and multifaceted nature. Neglecting spousal education may underestimate the inequalities in frailty in later life associated with educational resources. Attention must also turn to the association between spousal education and frailty levels with age. Age-related declines in functioning and chronic disease accumulation inevitably worsen frailty over time (Stolz et al., 2019). How this key marital resource (spousal education) shapes dynamic frailty can inform interventions to compress morbidity and promote healthy aging across diverse socioeconomic groups.

Additionally, investigating heterogeneity in the association between spousal education and frailty across demographic characteristics (e.g., sex and own education level) is also critical. Such knowledge will facilitate tailored interventions and strategies to reduce frailty disparities in late life across groups. Prior research indicates that sex differences exist in the health impacts of marriage and education. For instance, resource substitution theory posits that women often have lower educational opportunities than men but derive greater health benefits from the education they do obtain (Ross & Mirowsky, 2006, 2010). Additionally, married men appear to primarily gain from non-material spousal resources (e.g., social and emotional support, health behavior norms), while married women benefit more from material resources (e.g., economic resources) (Jaffe et al., 2006; Ross et al., 2012). Thus, exploring interactions between spousal education and sex in shaping frailty levels may help reduce sex disparities in frailty.

Meanwhile, just as one's own education may relatively improve late-life frailty (Hoogendijk et al., 2014; Huibregtse et al., 2021), the association between spousal education and frailty may differ by one's own education level. For example, less educated people may benefit more from the resources of others. As a previous study noted, having highly educated children is more strongly associated with better mental health for less educated parents (Yahirun et al., 2020). However, it has also been suggested that marriages between highly educated spouses can enhance an individual's self-rated health (Brown et al., 2014). Therefore, there might be some interaction between spousal and personal education, implying that one's partner's education could to some extent complement an individual's own educational background. This helps gauge the magnitude of any additional association between spousal education above one's own education and late-life health.

This study utilizes nationally representative longitudinal data from the China Health and Retirement Longitudinal Study (CHARLS) to comprehensively examine the relationship between spousal education and frailty levels and its change with age. It further investigates whether this association differs by sex and own education attainment. The results of the study will improve understanding of the social determinants of frailty and provide new insights into efforts to reduce disparities in later life.

2. Material and methods

2.1. Study participants

Data in this study are derived from the CHARLS for 2011, 2013, 2015, and 2018. CHARLS, a comprehensive social science and health survey of Chinese adults aged 45 or older and their spouses (Zhao et al., 2014). In-depth, one-on-one interviews using a structured questionnaire gathered high-quality, nationally representative data on demographics, lifestyle, health conditions, health service utilization and insurance. The use of multistage stratified probability-proportional-to-size sampling allows CHARLS to be nationally representative of China (see Appendix Methods). The CHARLS baseline survey questioned 17708 individuals from 150 sample counties and 28 provinces in China between June 2011 and March 2012, which response rate was 80.5% (Zhao et al., 2013). The study was followed up in 2013, 2015, and 2018, accordingly. Participants gave their written informed consent and signed it before taking the questionnaire. After the interviewer read the informed consent, illiterate respondents pressed their fingerprints (Zhao et al., 2013). The scientifically constructed sample frame, careful handling of non-response and sampling bias, and frequently evaluated questionnaire and field techniques made CHARLS data high-quality (Zhao et al., 2013, 2014). Furthermore, CHARLS data have been widely utilized to investigate socioeconomic factors that contribute to various health outcomes in older adults (Zhao et al., 2014).

Our final analytical sample consisted of 3856 married participants aged 60 years or older who were interviewed at baseline and at least one follow-up survey (see Appendix Methods), with 12205 observations across baseline and follow-ups (mean follow-up 3.35 times). Appendix Fig. A1 provides a flowchart describing the inclusion and exclusion of study participants.

2.2. Assessment of spousal education

Following previous studies (M. Ma, 2019), spousal education was measured by the number of years of formal schooling completed by the respondent's spouse, ranging from 0 to 19 years based on the typical number of years required to attain a given degree. Specifically, in CHARLS, formal schooling in composed of illiteracy/did not finish elementary school/home school (0 years), elementary school (6 years), middle school (9 years), high school (12 years), vocational school (12 years), two-/three-year college/associate degree (15 years), four-year college/bachelor's degree (16 years), and master's degree or above (19 years).

2.3. Assessment of frailty level

Frailty level was assessed using the FI, which is calculated based on the accumulation of age-related health deficits (Rockwood & Mitnitski, 2007). To construct the FI, we followed the established standard procedures described previously (Searle et al., 2008). The selection of FI-related deficits was based on a recent study utilizing the CHARLS database (Sun et al., 2022). The FI and variables used to construct it have been validated and shown to be of high quality in previous research (Sun et al., 2022). A total of 54 items were collected from CHARLS to calculate the FI, including comorbidities, self-reported health, sensory impairments, physical functioning, disabilities, depression, and cognitive deficits. Each deficit was graded or mapped to the range of 0.00-1.00, with 0.00 indicating no deficit and 1.00 indicating maximum expression of the deficit, as detailed in Appendix Table A1 from Sun et al. (2022). The FI for each respondent was calculated as the number of deficits present divided by the total number of possible deficits answered. The 54-FI is a continuous variable ranging from 0 to 1, with larger values indicating worse frailty status. Based on previous studies (Fan et al., 2020), the FI was categorized using a cut-off of 0.25 to define frail (i.e., non-frail or pre-frail: <0.25; frail: 0.25-1.00). We multiplied the FI by 100 to improve interpretability of the model estimates and treat them as a percentage (Haapanen et al., 2022).

Regarding missing values for FI deficits, to maximize the use of available data and ensure accuracy of the FI, we followed existing literature (Peña et al., 2014; Sun et al., 2022) in excluding participants with $>20\%$ missing deficits. If missing deficits were less than 20%, the

participant's FI score was calculated as the ratio of deficits present to total possible deficits.

In 2011, 2013, 2015, and 2018 during the four surveys, we used the same standard questionnaire and survey criteria to assess frailty level.

2.4. Assessment of covariates

To obtain robust estimates, we have considered multiple issues of confounding based on previous studies (Liu et al., 2023; M. Xu, 2020). The potential confounders included own sex (men or women), own age (continuous), own years of education (continuous), own current residence (rural or urban), and spouse's age (continuous).

We also reference similar studies (Saenz et al., 2020; M. Xu, 2020) to include potential mediating variables to explore potential pathways through which spousal education is associated with frailty, including own public medical insurance coverage (yes or no), own smoking status (current, former, or never smoker), own drinking status (current, former, or non-drinker), own social participation (yes or no), spouse's activities of daily living (ADLs) condition (unimpaired or impaired), and spouse's self-reported health (very good, good, fair, poor, and very poor).

A further description of the covariates is given in Appendix Table A2. All covariates were measured repeatedly during four surveys, consistent with previous research (Mezuk et al., 2022). Variance inflation factor (VIF) values were calculated to measure the degree of multicollinearity among the covariates in our model, and all scores were <10, which is a statistically acceptable indicator against multicollinearity (Appendix Table A3).

2.5. Statistical analysis

The baseline characteristics of the participants were categorized based on spousal education, as means [standard deviation (SD)] for continuous variables or percentages for categorical variables.

Following similar research (M. Xu, 2020), three-level linear mixed-effect models were used to analyze the longitudinal associations of spousal education with frailty. Such models accommodate unbalanced data structures, including differences in the number of tests and intervals between assessments (Atkins, 2005). It has been adopted in previous studies utilizing CHARLS panel data and has been widely proven effective in addressing multiple repeated measures of continuous outcomes (Li et al., 2022). With reference to similar studies (Li et al., 2022; Pigott, 2001), no further interpolation procedures were applied as the linear mixed-model can appropriately handle randomly missing observations of the dependent variable. In our analysis, all available repeated measurements of frailty levels (including baseline frailty level) were included as dependent variables. Observational records of frailty level (level 1) were nested within respondents (level 2) who were nested within couples (level 3). Previous research (Atkins, 2005; M. Xu, 2020) has shown that for longitudinal couple data, there are only two degrees of freedom at level 2, only one random effect can be accurately estimated at the individual level, and a couple can be entered twice, switching between the roles of index participant and spouse. Therefore, consistent with similar research (M. Xu, 2020), a random intercept was specified for the participant at level 2 to account for within-person correlation; a random intercept and a random slope were specified for a couple pair at level 3 to account for their co-dependence. All models were estimated using full-information maximum likelihood estimation with an unstructured covariance matrix for the random effects.

We used the following progressive adjustment strategy in our main analysis. In model 1, the underlying association between spousal education and frailty level was assessed, as was how this association changed with age. Model 2 was further adjusted for confounding variables (own education, own sex, own current residence, and spouse's age). Next, we examined whether the association held after including potential mediators: model 3 added own public medical insurance coverage, model 4 added own smoking and drinking status, model 5 added own social participation, and model 6 added spousal ADL condition and spousal self-reported health. To better present the results, the regression coefficients (β) and 95% confidence intervals (95% CI) were calculated and reported, with β greater than or less than 0 representing a positive or negative correlation between the exposure variables and higher frailty level. The regression coefficients for spousal education indicated the difference in frailty level across spousal education, expressed in percentage. The regression coefficients of interaction terms (spousal education and age) indicated the difference in frailty levels with age across spousal education, expressed in percentage points per year (Haapanen et al., 2022).

Considering potential variations among different demographic groups (Brown et al., 2014; Ross & Mirowsky, 2006), we conducted interaction analyses for sex and respondent's education, respectively. The regression coefficients for the interaction terms (e.g., spousal education and sex) indicate differences in the level of frailty associated with spousal education across sexes. Six sensitivity analyses were also conducted specifically to test the robustness of the results.

All analyses were carried out using STATA 15.0. Two-sided p-values <0.05 were considered statistically significant.

3. Results

3.1. Participant characteristics

Table 1 presents the characteristics of the study population stratified by spouse education categorization. Among the 3856 participants, 1330 (34.5%) had spouses without formal schooling, 1740 (45.1%) had spouses with less than middle school education, and 786 (20.4%) had spouses with middle school education or above. On average, participants were 66 years old and had 3.8 years of education. Over half (51.3%) were characterized as frail. The majority (54.6%) were men. For respondents whose spouses had no formal schooling, those with less than middle school education, and those with middle school education or above, their mean FI (range 0-100) were 28.2 (SD = 12.9), 27.7 (SD = 12.7) and 24.1 (SD = 12.4), respectively. There were some differences across spousal education groups. Participants with spouses having no formal education were more likely to be frail, slightly older, more likely to be men, less educated, more likely to live in rural areas, more likely to be current smokers and drinkers, and less likely to participate in social activities compared to participants with more educated spouses.

3.2. Association between spousal education and frailty levels

Table 2 displays the association between spousal education and frailty levels across 6 models. Model 1 was an unadjusted model, showing higher spousal education was associated with lower frailty levels, and that this association decreased with age. Model 2 adjusted for confounders showed that with 1 year of higher spousal education, the frailty level was 1.64% lower (95% CI: 2.31 to -0.98, $P < 0.001$), and this association decreased with age (β = 0.02, 95% CI: 0.01 to 0.03, $P < 0.001$). After adding public insurance coverage in model 3, the association of spousal education with the frailty level was similar and slightly lower, but still significant. Models 4, 5, and 6 showed similar and slightly increased associations after further introduction of their own health behaviors, own social participation, and spousal health status, respectively.

Multivariate analyses using spousal education as a three-category variable (Table 3) showed that compared to older adults whose spouses had no formal schooling, those whose spouses had below middle school education had lower frailty levels by 8.82% (95% CI: 15.05 to -2.58, $P < 0.01$), but their frailty levels increased by a faster 0.11 percentage points (95% CI: 0.02 to 0.20, $P < 0.05$) per year with age. Compared with older adults whose spouses had no formal schooling, those whose spouses had middle school education or above had lower

Table 1
Baseline characteristics of study participants based on spousal education categorization.

	All (N = 3856)	No formal schooling (n = 1330)	Below middle school (n = 1740)	Middle school or above (n = 786)
Respondents' characteristic				
Frailty index (range 0-100)	27.2 (12.8)	28.2(12.9)	27.7(12.7)	24.1(12.4)
Frail				
Yes	1977 (51.3)	724(54.4)	933(53.6)	320(40.7)
No	1879 (48.7)	606(45.6)	807(46.4)	466(59.3)
Sex				
Men	2105 (54.6)	1014(76.2)	800(46.0)	291(37.0)
Women	1751 (45.4)	316(23.8)	940(54.0)	495(63.0)
Age(years)	66.2 (5.3)	67.2(5.7)	65.8(5.0)	65.5(4.9)
Years of education	3.8(4.3)	3.0(3.8)	3.4(4.0)	6.1(5.0)
Current residence				
Urban	1449 (37.6)	343(25.8)	612(35.2)	494(62.8)
Rural	2407 (62.4)	987(74.2)	1128(64.8)	292(37.2)
Public health insurance coverage				
Covered	3617 (93.8)	1250(94.0)	1636(94.0)	731(93.0)
Not covered	239 (6.2)	80(6.0)	104(6.0)	55(7.0)
Smoking status				
Never smoked	2227 (57.8)	554(41.7)	1108(63.7)	565(71.9)
Former smoker	433 (11.1)	204(15.3)	154(8.9)	75(9.5)
Current smoker	1196 (31.0)	572(43.0)	478(27.5)	146(18.6)
Drinking status				
Never drinking	2154 (55.9)	597(44.9)	1029(59.1)	528(67.2)
Former drinker	450 (11.7)	184(13.8)	203(11.7)	63(8.0)
Current drinker	1252 (32.5)	549(41.3)	508(29.2)	195(24.8)
Social participation				
Yes	1708 (44.3)	529(39.8)	777(44.7)	402(51.1)
No	2148 (55.7)	801(60.2)	963(55.3)	384(48.9)
Spousal characteristic				
Spousal age (years)	65.3 (6.3)	65.5(7.1)	65.2(6.0)	65.2(5.9)
Spousal education (years)	3.6(4.4)	0(0)	3.2(3.0)	10.5(2.1)
Spousal activities of daily living condition				
Impaired	806 (20.9)	341(25.6)	361(20.7)	104(13.2)
Unimpaired	3050 (79.1)	989(74.4)	1379(79.3)	682(86.8)
Spousal self-reported health status				
Very good	182 (4.7)	57(4.3)	71(4.1)	54(6.9)
Good	561 (12.7)	169(12.7)	242(13.9)	150(19.1)
Fair	1864 (48.3)	593(44.6)	865(49.7)	406(51.7)
Poor	1030 (26.7)	419(31.5)	462(26.6)	149(19.0)
Very poor	219 (5.7)	92(6.9)	100(5.7)	27(3.4)

Note. Mean (standard deviation) was used to describe continuous variables and number (constituent ratio [%]) was used to describe categorical variables.

frailty levels by 23.44% (95% CI: 31.43 to -15.44, $P < 0.001$), but their frailty levels increased by a faster 0.32 percentage points (95% CI: 0.20 to 0.43, $P < 0.001$) per year with age.

3.3. Interaction analysis

Further analyses on the interaction between spousal education and sex in Table 4 indicate that the association between years of spouse education and frailty level did not differ by sex ($P > 0.05$) (Model 1), suggesting that higher spouse education is similarly associated with lower frailty level in later life for both males and females. Additionally, the moderating effect of age on the association between spousal education and respondents' frailty did not significantly differ by sex ($P > 0.05$).

We examined whether the association between spousal education and frailty levels varied by own education by estimating the interaction between respondents' own and their spouse's education. Model 2 shows no significant interaction was observed between the couple's education ($P > 0.05$). This indicates that the association between higher spousal education and respondents' lower frailty level is independent of one's own education. Moreover, the association between spousal education and frailty with increasing age was also not varied by one's own educational background ($P > 0.05$).

These results remained similar when both interaction terms with sex and own education were included in Model 3 at the same time.

3.4. Stratified analysis

Table 5 shows the association between years of spouse education and frailty levels among the frail and non-frail participants at baseline. Among those not frail at baseline, every additional year of spouse education was associated with a 0.90% lower frailty level (95% CI: 1.56 to -0.23, $P < 0.01$). This negative association was stronger among those already frail, with a 1.64% lower frailty level (95% CI: 2.64 to -0.64, $P < 0.01$). For non-frail and frail participants at baseline, the negative association between spousal education and frailty diminished with older age to 0.01 percentage points (95% CI: 0.004 to 0.02, $P < 0.01$) and 0.02 percentage points (95% CI: 0.01 to 0.04, $P < 0.01$), respectively.

3.5. Sensitivity analysis

As shown in Appendix Table A4, we further included current marital duration with reference to previous studies (Liu et al., 2023), to reduce confounding related to a spouse's marital duration. After adjusting for current marital duration, the negative association between years of spousal education and respondents' frailty persisted, with frailty level decreasing by 1.71% (95% CI: 2.39 to -1.03, $P < 0.001$) for each additional year of spouse education. With increasing age, the negative association between each year of spouse education and respondents' frailty weakened by 0.02 percentage points (95% CI: 0.01 to 0.03, $P < 0.001$).

Moreover, with reference to prior research (Lee et al., 2023), repeating the analysis using a mixed-effects model with personal-level random intercepts and standard errors clustering at the spouse-pair

Table 2
Association of spousal education with frailty.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Spousal education	-1.65 (-2.33, -0. 97) ***	-1.64 (-2.31, -0.98) ***	-1.63 (-2.30, -0. 97) ***	-1.74 (-2.40, -1.08) ***	-1.74 (-2.41, -1.09) ***	-1.75 (-2.41, -1.10) ***
Spousal education × Age	0.02 (0.01, 0. 03) ***	0.02 (0.01, 0.03) ***	0.02 (0.01, 0.03) ***	0.02 (0.01, 0.03) ***	0.02 (0.01, 0.03) ***	0.02 (0.01, 0.03) ***
Public health insurance coverage (ref: not covered)						
Covered			0.39 (-0.30, 1.09)	0.41 (-0.29, 1.10)	0.45 (-0.24, 1.14)	0.40 (-0.24, 1.14)
Smoking status (ref: never smoked)						
Former smoker				1.96 (1.21, 2.70) ***	1.99 (1.25, 2.73) ***	1.98 (1.24, 2.72) ***
Current smoker				-0.21 (-0.99, 0.57)	-0.16 (-0.93, 0.62)	-0.18 (-0.96, 0.61)
Drinking status (ref: never drinking)						
Former drinker				2.57 (1.97, 3.17) ***	2.59 (1.25, 2.73) ***	2.54 (1.94, 3.14) ***
Current drinker				0.24 (-0.30, 0.78)	0.29 (-0.25, 0.83)	0.22 (-0.31, 0.76)
Social participation (ref: no)						
Yes					-1.26(-2.50-0.83) ***	-1.25(-1.61, -0.90) ***
Spousal activities of daily living condition (ref: unimpaired)						
Impaired						2.27(1.85, 2.70)
Spousal self-reported health status (ref: very good)						
Good						0.24(-0.54, 0.10)
Fair						1.08(0.38, 1.78) ***
Poor						2.01(1.24, 2.78) ***
Very poor						2.19(1.22, 3.16) ***
Number of observations	12205	12205	12205	12205	12205	12205
Log likelihood	10499.7	10754.7	10755.3	10824.7	10848.8	10923.1

Note. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.
Model 1 was unadjusted, model 2 further adjusted for confounding variables (own education, own sex, own current residence, and spouse's age), model 3 added own public medical insurance coverage, model 4 added own smoking and drinking status, model 5 added own social participation, and model 6 added spousal activities of daily living condition and spousal self-reported health.

Table 3
Association of spousal education categories with frailty.

Spousal education categories	Unadjusted model	Adjusted model
Spousal education		
No formal schooling	Reference	Reference
Below middle school	-6.60 (-13.03, -0.17) *	-8.82 (-15.05, -2.58) **
Middle school or above	-22.65 (-30.89, -14.40) ***	-23.44 (-31.43, -15.44 ***
Spousal education × Age		
No formal schooling × Age	Reference	Reference
Below middle school × Age	0.10 (0.01, 0.19) *	0.11 (0.02, 0.20) *
Middle school or above × Age	0.32 (0.20, 0.44) ***	0.32 (0.20, 0.43) ***
Number of observations	12205	12205
Log likelihood	10505.4	10919.7

Note. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.
Multivariate linear mixed-effect models were adjusted for own sex, own education, current residence, spouse's age, own public medical insurance coverage, own smoking status, own drinking status, own social participation, spousal activities of daily living condition, and spousal self-reported health.

Table 4
Interaction analysis of the association between spousal education and frailty.

Variables	Model 1	Model 2	Model 3
Spousal education	-1.64 (-2.60, -0.69) **	-1.98(-2.92, -1.04) ***	-1.78(-2.87, -0.68) **
Spousal education × Age	0.02 (0.01, 0.04) **	0.02 (0.01, 0.04) ***	0.02 (0.01, 0.04) **
Spousal education × Sex	-0.32 (-1.68, 1.03)		-0.49 (-1.91, 0.93)
Spousal education × Own education		0.07 (-0.06, 0.21)	0.08 (-0.05, 0.23)
Spousal education × Age × Sex	0.004 (-0.01, 0.02)		0.01 (-0.01, 0.03)
Spousal education × Age × Own education		-0.00 (-0.00, 0.00)	-0.00 (-0.00, 0.00)
Number of observations	12205	12205	12205
Log likelihood	10923.3	10925.2	10925.4

Note. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.
Models 1–3 were adjusted for own sex, own education, current residence, spouse's age, own public medical insurance coverage, own smoking status, own drinking status, own social participation, spousal activities of daily living condition, and spousal self-reported health.

level. Each additional year of spousal education was associated with a 1.78% (95% CI: 2.45 to -1.12, $P < 0.001$) lower frailty level, and their frailty level increased a faster 0.12 percentage points per year with age (95% CI: 0.01 to 0.03, $P < 0.001$).

Additionally, four other sensitivity analyses were conducted to minimize potential bias. These analyses included: employing more stringent cutoffs (10% or less) for missing FI items, selecting older adults with at least 3 or 4 completed surveys, and adjusting for follow-up status, respectively. Follow-up status was a categorical variable constructed with reference to previous research (Avila et al., 2021), and included: completed follow-up, death, and loss to follow-up for reasons other than death. The results were consistent with the primary analyses.

4. Discussion

Utilizing a nationally representative longitudinal survey, this study examined the association between spousal education and frailty levels among Chinese older adults for the first time. Overall, higher spousal

Table 5
Association of spousal education with frailty stratified by participants' baseline frailty status.

	Unadjusted model	Adjusted model
Non-frail at baseline (n = 1879)		
Spousal education	-0.81 (-1.50, -0.13) *	-0.90 (-1.56, -0.23) **
Spousal education × Age	0.01 (0.002, 0.02) *	0.01 (0.004, 0.02) **
Number of observations	5953	5953
Log likelihood	6633.7	6795.4
Frail at baseline (n = 1977)		
Spousal education	-1.48 (-2.51, -0.45) **	-1.64 (-2.64, -0.64) **
Spousal education × Age	0.02 (0.01, 0.03) **	0.02 (0.01, 0.04) **
Number of observations	6252	6252
Log likelihood	5306.1	5433.9

Note. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.
Multivariate linear mixed-effect models were adjusted for own sex, own education, current residence, spouse's age, own public medical insurance coverage, own smoking status, own drinking status, own social participation, spousal activities of daily living condition, and spousal self-reported health.

education is associated with lower frailty levels in later life, especially among older adults who are already frail. However, this negative association attenuates with increasing age. Notably, although frailty level is lower for male versus female older adults, the effect of higher spousal education is similarly associated with lower frailty level in later life for both husbands and wives. Additionally, an older adult's own education level is negatively associated with frailty, while the effect of spousal education on frailty was independent of the older adult's own level of education. These findings provide valuable insights on how spousal education shapes frailty in later life.

Higher spousal education is associated with lower frailty levels among older adults, even after adjusting for one's own education. This finding was consistent with previous studies on spousal education and other health outcomes (Brown et al., 2014; Liu et al., 2023; Saenz et al., 2020; Sheehan & Iida, 2021; M. Xu, 2020), suggesting that spousal education promotes health behaviors and improves health outcomes. Our study identifies improvements in late-life frailty that have not been reported in previous research. Importantly, analyses using spousal education as a three-categorical variable showed that compared to older adults whose spouses had no formal education, older adults whose spouses had less than middle school education, and those with middle school education and above had the FI by as much as 8.82% and 23.44% lower, respectively, which had reached the minimal clinically important differences in the FI (0.03) (Eendebak et al., 2018). Marriage allows spouses to share and/or exchange material and non-material resources obtained through their education (Jackson et al., 2015). More educated spouses can provide protective resources within the marriage that are conducive to reducing frailty, such as social and emotional support, health knowledge, positive health behaviors, and economic stability (Liu et al., 2023; Sheehan & Iida, 2021). Moreover, previous research has shown that more educated spouses are more likely to be alive and living with respondents (Kravdal, 2008, 2017), and living with a partner has been shown to have a beneficial factor for frailty (Kojima et al., 2020). Notably, there is a greater protective association between high spousal education and late-life frailty among Chinese older adults who were already frail. This may be due to the fact that more educated spouses likely have the ability to navigate complex healthcare systems, enabling better care coordination and access for their partner (Sheehan & Iida, 2021).

Although older men are less frail than older women (Yin et al., 2018), the negative association between spousal education and frailty did not differ by sex, consistent with two previous studies on spousal education and cognitive function (Saenz et al., 2020; M. Xu, 2020). However, this sex pattern differs from some recent work on the association between spousal education and other health outcomes. For example, husbands' education has a greater impact on wives' self-reported health (Brown et al., 2014), depression (Jang & Kawachi, 2018), and sleep duration (Sheehan & Iida, 2021). In contrast, other research indicates a wife's education has a greater protective effect for husband's mortality risk (Skalická & Kunst, 2008), and the EQ-5D-5L index (Lamu et al., 2023). The similar protective association between spousal education and frailty across sexes may arise from certain factors. On the one hand, sex norms around decision-making and resource allocation within marriage may shape pathways. For instance, a husband's education may operate more through economic mechanisms, while a wife's education works through health behaviors, jointly influencing frailty (Jaffe et al., 2006). On the other hand, late-life frailty captures multidimensional health problems accumulating across the life course (Yang & Lee, 2010). The broader risks assessed by frailty measures may explain the lack of sex differences, in contrast to the studies mentioned above that focused on specific health outcomes. Additional research is needed to elucidate these complex biological, social, and behavioral pathways. Disentangling the relative contribution of various mechanisms linking spousal education to frailty reduction can inform tailored interventions.

Although older adults with higher spousal education had relatively lower frailty levels, frailty levels still increased with age. This diverges from cognition patterns observed in previous research, where more years of spousal education may decelerate cognitive decline in late life (Saenz et al., 2020; M. Xu, 2020). In contrast, we found frailty differences by spousal education narrowed with increasing age among older Chinese adults, a novel finding. Our results are somewhat consistent with the "age as leveler" theory (X. Xu et al., 2015), which posits that differences in own frailty across spousal education groups diminish with age as the morbidity advantages conferred by high socioeconomic position are caught up by universal physiological frailty and/or compensated for by welfare policies (House et al., 2005; Stolz et al., 2017). Inevitable age-related declines in functioning and the accumulation of chronic diseases may not be completely altered or delayed by spousal education (L. Ma et al., 2018). This physiological erosion may outweigh the protective effects of spousal education, reducing frailty differences. Moreover, improved healthcare access and elderly welfare programs in China likely benefited older adults across spousal education levels. Expansion of pensions, health insurance, and other social security programs provides relatively equitable economic resources (Bairoliya et al., 2018), weakening internal socioeconomic disparities. Thus, external socioeconomic compensation policies may mitigate the association between spousal education and frailty level. In sum, despite beneficial associations earlier, spousal education could not overcome the increasing level of frailty with age. This highlights the importance of multifaceted interventions to prevent late-life frailty.

By estimating the interaction between one's own and spousal education, we found the association between spousal education and one's own frailty did not differ by level of one's own education. This lack of significant interaction suggests the benefits of spousal education may operate in parallel to the benefits of one's own education. This is consistent with the results of a previous study examining the effect of spousal education on sleep duration in older Americans (Sheehan & Iida, 2021). The mechanisms linking one's own versus spousal education to health likely differ. One's own education acts through enhancing health knowledge and self-management skills (Hoogendijk et al., 2014), whereas spousal education works more via emotional support and promoting healthy behaviors (Jackson et al., 2015). Since multiple factors shape older adult health, one's own and spousal education are only two such influences, with non-overlapping roles. Thus, a strong multiplicative interaction may not exist. Moreover, it is possible that the interactions may be obscured by other sociocultural factors that are difficult to measure. Therefore, although no strong interaction was observed between own education and spousal education, this does not mean that they are independent, and further research is needed to explore the potential relationship between them. These insights could inform targeted information for health education policies. Nonetheless, both own and spousal education remain important targets for

interventions aiming to reduce late-life frailty levels.

In many countries and cultures, family and kinship networks play critical roles in older adult health and wellbeing (Goldman, 2016). Spouses in particular, as core family members, can significantly impact health through their education and involvement (Jackson et al., 2015). To systematize efforts preventing and slowing frailty deterioration, our findings suggest considering familial factors and spousal education's health promotion role when making policies. For instance, programs could be designed to engage spousal participation or provide spouse training (Liu et al., 2023). For highly educated older couples, leveraging spousal health knowledge and management skills through family-based education and interventions may help decelerate late-life frailty worsening. For less educated couples or already frail older adults, strengthening health literacy training for spouses could improve caregiving capacities to delay further frailty increases (Sheehan & Iida, 2021). Given the enormous and heterogeneous global older population, policies must also address differing needs by education level through tailored approaches. For example, health education content and formats should be designed specifically for older adults and spouses of varying educational backgrounds. Overall, our study highlights that late-life frailty prevention efforts should take into account spousal education factors in the marital setting and focus on preventing the deterioration of late-life frailty among vulnerable older adults who have low-education spouses. Policies and programs involving spouse education-based interventions show promise for reducing frailty disparities in aging populations worldwide.

We acknowledge some potential limitations. First, we cannot rule out the possibility of unmeasured variables and residual confounding influencing the associations observed. Mating a partner with high education is likely to be related to a vast amount of unobserved individual characteristics that would predict low frailty (Saenz et al., 2020). Future studies should make such an attempt to control for unobserved characteristics. Second, even though the survey is nationally representative (Zhao et al., 2014), the analytic sample may represent a healthier selective group than the general older population because married participants with at least one follow-up were included in the analysis. To minimize potential attrition bias, we repeated analyses by selecting older adults with 2 or more and 3 follow-ups, and incorporating a follow-up status variable (with categories of completed follow-up, death, and loss to follow-up for reasons other than death) into the model, and the findings persisted. Additionally, the CHARLS survey sampled only community-dwelling older adults and did not include those residing in nursing homes. Thus, the CHARLS sample may not fully represent the entire older Chinese population and could potentially be biased. However, previous research indicates that only 1.5% of Chinese older adults live in nursing homes (Zhao et al., 2014). Nonetheless, we recommend judicious interpretation of the generalizability of our results to the broader older population in China. Third, although we excluded those missing 20% items to maximize data use and ensure FI accuracy as in prior research (Peña et al., 2014; Sun et al., 2022), there may still be selection bias in missing values. We repeated analyses on participants with $\leq$10% missing FI items (He et al., 2023) and showed consistent results which may reduce the potential impact of such a possible bias on the results.

5. Conclusion

This study provides evidence that having a more educated spouse is associated with lower frailty levels for both older men and women in China, independent of one's own educational background. As the global population ages, these findings may help identify older adults at high risk for frailty based on low spousal education. The results highlight the importance of the marital environment, specifically leveraging a partner's knowledge and resources to potentially prevent frailty progression. Broad family-based health efforts that promote education and shared health knowledge between spouses could help reduce disparities in frailty.

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Ethical statement

I certify that this manuscript is original and has not been published and will not be submitted elsewhere for publication while being considered by *SSM-Population Health*. And the study is not split up into several parts to increase the quantity of submissions and submitted to various journals or to one journal over time. No data have been fabricated or manipulated to support our conclusions. No data, text, or theories by others are presented as if they were our own.

The submission has been explicitly derived from all co-authors. And authors whose names appear on the submission have contributed sufficiently to the scientific work and therefore share collective responsibility and accountability for the results. YG had full access to all the data in the study and takes responsibility for the integrity of data and the accuracy of the data analysis. FY and YG conceptualized the analysis, developed the analysis plan, and conducted data analysis. YG wrote the first draft of the report. FY interpreted findings, critically reviewed the report for important intellectual content, contributed to manuscript writing, and approved the final version. The authors declare that they have no conflict of interest.

This article does not contain any studies with human participants or animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

CRediT authorship contribution statement

Yujia Guo: Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Fan Yang:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors have no conflicts of interest to report related to this article.

Data availability

The data used in this study were obtained from the publicly available database \"China Health and Retirement Longitudinal Study (CHARLS)\".

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2024.101607.

References

Atkins, D. C. (2005). Using multilevel models to analyze couple and family treatment data: Basic and advanced issues. *Journal of Family Psychology, 19*(1), 98–110. https://doi.org/10.1037/0893-3200.19.1.98

Avila, J. C., Mejia-Arangom, S., Jupiter, D., Downer, B., & Wong, R. (2021). The effect of diabetes on the cognitive trajectory of older adults in Mexico and the United States. *The Journals of Gerontology: Serie Bibliographique, 76*(4), e153–e164. https://doi.org/10.1093/geronb/gbaa094

Bairoliya, N., Canning, D., Miller, R., & Saxena, A. (2018). The macroeconomic and welfare implications of rural health insurance and pension reforms in China. *Journal of the Economics of Ageing, 11*, 71–92. https://doi.org/10.1016/j.jeoa.2017.01.004

Brown, D. C., Hummer, R. A., & Hayward, M. D. (2014). The importance of spousal education for the self-rated health of married adults in the United States. *Population Research and Policy Review, 33*(1), 127–151. https://doi.org/10.1007/s11113-013-9305-6

Eendebak, R., Theou, O., Van Der Valk, A., Godin, J., Andrew, M., McNeil, S., & Rockwood, K. (2018). Defining minimal important differences and establishing categories for the frailty index. *Innovation in Aging, 2*(suppl_1), 715–716. https://doi.org/10.1093/geroni/igy023.2649

Fan, J., Yu, C., Guo, Y., Bian, Z., Sun, Z., Yang, L., Chen, Y., Du, H., Li, Z., Lei, Y., Sun, D., Clarke, R., Chen, J., Chen, Z., Lv, J., & Li, L. (2020). Frailty index and all-cause and cause-specific mortality in Chinese adults: A prospective cohort study. *The Lancet Public Health, 5*(12), e650–e660. https://doi.org/10.1016/S2468-2667(20)30113-4

Goldman, A. (2016). All in the family: The link between kin network bridging and cardiovascular risk among older adults. *Social Science & Medicine, 166*, 137–149. https://doi.org/10.1016/j.socscimed.2016.07.035

Haapanen, M. J., Jylhävä, J., Kortelainen, L., Mikkola, T. M., Salonen, M., Wasenius, N. S., Kajantie, E., Eriksson, J. G., & Von Bonsdorff, M. B. (2022). Early-life factors as predictors of age-associated deficit accumulation across 17 Years from midlife into old age. *The Journals of Gerontology: Series A, 77*(11), 2281–2287. https://doi.org/10.1093/gerona/glac007

He, D., Qiu, Y., Yan, M., Zhou, T., Cheng, Z., Li, J., Wu, Q., Liu, Z., & Zhu, Y. (2023). Associations of metabolic heterogeneity of obesity with frailty progression: Results from two prospective cohorts. *Journal of Cachexia, Sarcopenia and Muscle, 14*(1), 632–641. https://doi.org/10.1002/jcsm.13169

Hoogendijk, E. O., Van Hout, H. P. J., Heymans, M. W., Van Der Horst, H. E., Frijters, D. H. M., Broese Van Groenou, M. I., Deeg, D. J. H., & Huisman, M. (2014). Explaining the association between educational level and frailty in older adults: Results from a 13-year longitudinal study in The Netherlands. *Annals of Epidemiology, 24*(7), 538–544.e2. https://doi.org/10.1016/j.annepidem.2014.05.002

House, J. S., Lantz, P. M., & Herd, P. (2005). Continuity and change in the social stratification of aging and health over the life course: Evidence from a nationally representative longitudinal study from 1986 to 2001/2002 (Americans' changing lives study). *The Journals of Gerontology: Serie Bibliographique, 60*(2), S15–S26. https://doi.org/10.1093/geronb/60.Special_Issue_2.S15

Huibregtse, B. M., Newell-Stamper, B. L., Domingue, B. W., & Boardman, J. D. (2021). Genes related to education predict frailty among older adults in the United States. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 76*(1), 173. https://doi.org/10.1093/geronb/gbz092

Jackson, S. E., Steptoe, A., & Wardle, J. (2015). The influence of partner's behavior on health behavior change: The English longitudinal study of ageing. *JAMA Internal Medicine, 175*(3), 385. https://doi.org/10.1001/jamainternmed.2014.7554

Jaffe, D. H., Eisenbach, Z., Neumark, Y. D., & Manor, O. (2006). Effects of husbands' and wives' education on each other's mortality. *Social Science & Medicine, 62*(8), 2014–2023. https://doi.org/10.1016/j.socscimed.2005.08.030

Jang, S.-N., & Kawachi, I. (2018). Contrasting effects of spousal education on depressive symptoms among Korean middle-aged and older adults. *Annals of Geriatric Medicine and Research, 22*(1), 33–39. https://doi.org/10.4235/agmr.2018.22.1.33

Kojima, G., Walters, K., Iliffe, S., Taniguchi, Y., & Tamiya, N. (2020). Marital status and risk of physical frailty: A systematic review and meta-analysis. *Journal of the American Medical Directors Association, 21*(3), 322–330. https://doi.org/10.1016/j.jamda.2019.09.017

Kravdal, Ø. (2008). A broader perspective on education and mortality: Are we influenced by other people's education? *Social Science & Medicine, 66*(3), 620–636. https://doi.org/10.1016/j.socscimed.2007.10.009

Kravdal, Ø. (2017). Large and growing social inequality in mortality in Norway: The combined importance of marital status and own and spouse's education. *Population and Development Review, 43*(4), 645–665. https://www.jstor.org/stable/26622772.

Lamu, A. N., Chen, G., & Olsen, J. A. (2023). Amplified disparities: The association between spousal education and own health. *Social Science & Medicine, 323*, Article 115832. https://doi.org/10.1016/j.socscimed.2023.115832

Lee, M., Demmer, R. T., Kucharska-Newton, A., Windham, B. G., Palta, P., Shippee, T., & Lutsey, P. L. (2023). Spousal cognitive status and risk for declining cognitive function and dementia: The Atherosclerosis Risk in Communities Study. *Journal of Aging and Health, 35*(9), 688–698. https://doi.org/10.1177/08982643231155997

Li, C., Ma, Y., Yang, C., Hua, R., Xie, W., & Zhang, L. (2022). Association of cystatin C kidney function measures with long-term deficit-accumulation frailty trajectories and physical function decline. *JAMA Network Open, 5*(9), Article e2234208. https://doi.org/10.1001/jamanetworkopen.2022.34208

Liang, J., Zhang, P., Zhu, X., Qiao, Y., Zhao, L., He, Q., Zhang, L., & Liang, Y. (2014). Effect of intergenerational and intragenerational support on perceived health of older adults: A population-based analysis in rural China. *Family Practice, 31*(2), 164–171. https://doi.org/10.1093/fampra/cmt073

Liu, M., Yang, Y., Lyu, X., Zhang, J., Liu, Y., Xu, D., Wu, H., Lei, J., Deng, Y., Zhao, C., Hu, X., Xie, W., Huang, J., Wu, S., Zhang, Y., Zhang, H., He, Y., Peng, Z., Wang, Y., … Ma, X. (2023). Declined prevalence, improved awareness and control of hypertension are associated with spousal educational attainment: A mega-data study. *Social Science & Medicine, 336*, Article 116256. https://doi.org/10.1016/j.socscimed.2023.116256

Ma, M. (2019). Does children's education matter for parents' health and cognition? Evidence from China. *Journal of Health Economics, 66*, 222–240. https://doi.org/10.1016/j.jhealeco.2019.06.004

Ma, L., Tang, Z., Zhang, L., Sun, F., Li, Y., & Chan, P. (2018). Prevalence of frailty and associated factors in the community-dwelling population of China. *Journal of the American Geriatrics Society, 66*(3), 559–564. https://doi.org/10.1111/jgs.15214

Mezuk, B., Dang, L., Jurgens, D., & Smith, J. (2022). Work expectations, depressive symptoms, and passive suicidal ideation among older adults: Evidence from the health and retirement study. *The Gerontologist, 62*(10), 1454–1465. https://doi.org/10.1093/geront/gnac110

Peña, F. G., Theou, O., Wallace, L., Brothers, T. D., Gill, T. M., Gahbauer, E. A., Kirkland, S., Mitnitski, A., & Rockwood, K. (2014). Comparison of alternate scoring of variables on the performance of the frailty index. *BMC Geriatrics, 14*(1), 25. https://doi.org/10.1186/1471-2318-14-25

Pigott, T. D. (2001). A review of methods for missing data. *Educational Research and Evaluation, 7*(4), 353–383. https://doi.org/10.1076/edre.7.4.353.8937

Pinquart, M., & Sörensen, S. (2011). Spouses, adult children, and children-in-law as caregivers of older adults: A meta-analytic comparison. *Psychology and Aging, 26*(1), 1–14. https://doi.org/10.1037/a0021863

Rockwood, K., & Mitnitski, A. (2007). Frailty in relation to the accumulation of deficits. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 62*(7), 722–727.

Ross, C. E., Masters, R. K., & Hummer, R. A. (2012). Education and the gender gaps in health and mortality. *Demography, 49*(4), 1157–1183. https://doi.org/10.1007/s13524-012-0130-z

Ross, C. E., & Mirowsky, J. (2006). Sex differences in the effect of education on depression: Resource multiplication or resource substitution? *Social Science & Medicine, 63*(5), 1400–1413. https://doi.org/10.1016/j.socscimed.2006.03.013

Ross, C. E., & Mirowsky, J. (2010). Gender and the health benefits of education. *The Sociological Quarterly, 51*(1). https://doi.org/10.1111/j.1533-8525.2009.01164.x

Saenz, J. L., Beam, C. R., & Zelinski, E. M. (2020). The association between spousal education and cognitive ability among older Mexican adults. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 75*(7), e129–e140. https://doi.org/10.1093/geronb/gbaa002

Searle, S. D., Mitnitski, A., Gahbauer, E. A., Gill, T. M., & Rockwood, K. (2008). A standard procedure for creating a frailty index. *BMC Geriatrics, 8*(1), 1–10.

Sheehan, C., & Iida, M. (2021). Spousal educational attainment and sleep duration among American older adults. *The Journals of Gerontology: Serie Bibliographique, 76*(5), 1015–1026. https://doi.org/10.1093/geronb/gbaa206

Skalická, V., & Kunst, A. E. (2008). Effects of spouses' socioeconomic characteristics on mortality among men and women in a Norwegian longitudinal study. *Social Science & Medicine, 66*(9), 2035–2047. https://doi.org/10.1016/j.socscimed.2008.01.020

Stolz, E., Mayerl, H., & Freidl, W. (2019). Fluctuations in frailty among older adults. *Age and Ageing, 48*(4), 547–552. https://doi.org/10.1093/ageing/afz040

Stolz, E., Mayerl, H., Waxenegger, A., Rásky, É., & Freidl, W. (2017). Impact of socioeconomic position on frailty trajectories in 10 European countries: Evidence from the survey of health, ageing and retirement in europe (2004–2013). *Journal of Epidemiology & Community Health, 71*(1), 73–80. https://doi.org/10.1136/jech-2016-207712

Sun, J., Kong, X., Li, H., Chen, J., Yao, Q., Li, H., Zhou, F., & Hu, H. (2022). Does social participation decrease the risk of frailty? Impacts of diversity in frequency and types of social participation on frailty in middle-aged and older populations. *BMC Geriatrics, 22*(1), 553. https://doi.org/10.1186/s12877-022-03219-9

Vermeiren, S., Vella-Azzopardi, R., Beckwée, D., Habbig, A.-K., Scafoglieri, A., Jansen, B., Bautmans, I., Bautmans, I., Verté, D., Beyer, I., Petrovic, M., De Donder, L., Kardol, T., Rossi, G., Clarys, P., Scafoglieri, A., Cattrysse, E., de Hert, P., & Jansen, B. (2016). Frailty and the prediction of negative health outcomes: A meta-analysis. *Journal of the American Medical Directors Association, 17*(12), 1163.e1–1163.e17. https://doi.org/10.1016/j.jamda.2016.09.010

Xu, M. (2020). Spousal education and cognitive functioning in later life. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 75*(7), e141–e150. https://doi.org/10.1093/geronb/gbz014

Xu, W., Li, Y.-X., & Wu, C. (2019). Incidence of frailty among community-dwelling older adults: A nationally representative profile in China. *BMC Geriatrics, 19*(1), 378. https://doi.org/10.1186/s12877-019-1393-7

Xu, X., Liang, J., Bennett, J. M., Botoseneanu, A., & Allore, H. G. (2015). Socioeconomic stratification and multidimensional health trajectories: Evidence of convergence in later old age. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 70*(4), 661–671. https://doi.org/10.1093/geronb/gbu095

Yahirun, J. J., Sheehan, C. M., & Mossakowski, K. N. (2020). Depression in later life: The role of adult children's college education for older parents' mental health in the United States. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 75*(2), 389–402. https://doi.org/10.1093/geronb/gby135

Yang, Y., & Lee, L. C. (2010). Dynamics and heterogeneity in the process of human frailty and aging: Evidence from the U.S. Older adult population. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 65B*(2), 246–255. https://doi.org/10.1093/geronb/gbp102

Yin, J. H., Zeng, Y. B., Zhou, Z., & Fang, Y. (2018). Study on the status of frailty and related determinants among the elderly in China. *Zhonghua liu xing bing xue za zhi* =

Zhonghua liuxingbingxue zazhi, 39(9), 1244–1248. https://doi.org/10.3760/cma.j.issn.0254-6450.2018.09.019

Zhao, Y., Hu, Y., Smith, J. P., Strauss, J., & Yang, G. (2014). Cohort profile: The China health and retirement longitudinal study (CHARLS). *International Journal of Epidemiology, 43*(1), 61–68.

Zhao, Y., Strauss, J., Yang, G., Giles, J., Hu, P., Hu, Y., Lei, X., Park, A., Smith, J. P., & Wang, Y. (2013). *China health and retirement longitudinal study–2011–2012 national baseline users' guide, 2*. Beijing: National School of Development, Peking University.