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Can Social Mobility Impact Frailty Trajectories of Chinese Adults in Later Life? A Nationwide Longitudinal Study

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Abstract

Background and Objectives: Evidence remains unclear on the impact of life-course socioeconomic position (SEP) mobility on frailty trajectories in later life. We aim to examine the longitudinal effects of social mobility on frailty trajectories among Chinese middle-aged and older populations.

Research Design and Methods: A total of 13 239 participants aged 45 and older from the 2011–2018 China Health and Retirement Longitudinal Study were analyzed. Based on changes in SEP from childhood to adulthood, 5 patterns of social mobility were established. A 32-item deficit cumulative frailty index (FI) was developed to evaluate frailty trajectories at each follow-up. Linear mixed-effects models were used to examine the longitudinal association of the 5 social mobility patterns with the frailty trajectory.

Results: The trajectory of late-life FI increased across all 5 social mobility groups during the follow-up. The FI trajectory had the largest disparity between stable high SEP and stable low SEP, with a faster increase in FI of 0.489 (95% confidence interval [CI]: 0.327–0.650, $p < .001$) in the stable low versus stable high SEP group. The FI trajectories of individuals in the upward and downward mobility groups fall between those in the stable high SEP and low SEP groups. Specifically, compared to the stable high SEP group, the increase in FI was 0.229 (95% CI: 0.098–0.360, $p = .001$) faster in the downward mobility group, and 0.145 (95% CI: 0.017–0.273, $p = .03$) faster in the upward mobility group. The impact of social mobility on frailty trajectories was more pronounced among middle-aged adults and women.

Discussion and Implications: These findings emphasize that policies to identify vulnerable populations and reduce frailty inequalities should focus on the socioeconomic environment across the life course, with particular attention paid to those with consistently low SEP and downward mobility.

Translational significance: The impact of socioeconomic position mobility over the life course on the frailty trajectories of middle-aged and older Chinese adults is unclear. The findings highlight that advantageous/disadvantageous socioeconomic factors accumulate over the life course, resulting in increasing disparities in frailty trajectories in later life. Downward mobility is associated with higher frailty trajectories, whereas transitioning from an early disadvantage to a more advantageous socioeconomic position can mitigate frailty progression. The study emphasizes the significance of employing a life-course perspective in policy-making to mitigate frailty inequalities in later life, with a focus on women and middle-aged adults experiencing social mobility.

Keywords: China, Health inequalities, Life course, Frailty index, Social mobility

Background and Objectives

Frailty has emerged as a significant public health concern, particularly in countries facing rapid population aging. Frailty is a syndrome of old age characterized by the cumulative decline of multiple biological systems due to reduced physiological reserves and increased vulnerability to stressors (Yang & Lee, 2010). Extensive research has demonstrated that frailty follows a dynamic trajectory that worsens over time in later life, although there is substantial heterogeneity in individual frailty trajectories, with some individuals experiencing a more rapid progression of frailty than others (Stolz et al., 2019). Consequently, it is critical to identify risk factors that influence frailty trajectories, such as socioeconomic factors, as this will inform the identification of vulnerable populations prone to rapid frailty progression.

A large body of literature identifies socioeconomic risk factors of frailty among older individuals, although most studies have examined socioeconomic position (SEP) during a single period of the life course. These studies have identified education, occupation, and income as the primary socioeconomic factors that influence the incidence frailty in older population (Ma et al., 2018; Stolz et al., 2017). However, existing studies have primarily examined childhood or adult socioeconomic factors in isolation (Faul et al., 2021; Y. Li et al., 2020; Ye et al.,

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2021), the changes and cumulative effects of socioeconomic circumstances throughout the life course may be neglected. The life-course approach acknowledges that health outcomes in later life are influenced by a combination of childhood and adulthood socioeconomic experiences (Faul et al., 2021; Payne & Xu, 2022; Van Der Linden, Sieber, et al., 2020; Zhu et al., 2023). If either of these stages is neglected, an incomplete understanding of the health effects may result. An important conceptual model in the life-course framework is the "social mobility model," which proposes that continuity and change in an individual's socioeconomic advantages/disadvantages from childhood to adulthood may affect health later in life, and that health differences between individuals widen as advantages and disadvantages accumulate (Boyle et al., 2009).

More importantly, attention should not only be paid to the impact of health at a single point in time, but also to how such health's dynamic trajectory is affected in later years. This approach enables us to move beyond examining isolated snapshots of socioeconomic status and instead highlight the interactions between childhood and adult socioeconomic factors, providing insights into how they collectively shape frailty trajectory differences in later life. By comparing the effects of different mobility pathways (such as upward, downward, and no mobility) on frailty trajectory in later life, we can more comprehensively explore how socioeconomic status changes and accumulates over the life course and reveal the underlying mechanisms of frailty trajectory disparities in later life.

Most of the current research on the impact of social mobility on health outcomes in later life has focused on developed countries (Faul et al., 2021; Iveson & Deary, 2017; McLoughlin et al., 2023; Melchior et al., 2018). Certain studies (Q. Wang & Kang, 2019; Wen & Gu, 2011; Zhu et al., 2023) in China have examined the impact of social mobility on cognitive functioning, depression, self-reported health, activities of daily living, and mortality risk in later life. These studies have investigated the changes and cumulative effects of socioeconomic circumstances/factors throughout the life course, and also examined the accumulative effect of early experiences on health in later life. However, to date, longitudinal research examining the effects of life-course SEP mobility on frailty trajectories, especially among Chinese populations, is lacking. Four population-based studies (Alvarado et al., 2008; Herr et al., 2015; Shiau et al., 2023; Van Der Linden, Cheval, et al., 2020) conducted in developed countries or regions have examined the relationship between SEP and frailty from a life-course perspective, but can social mobility affect frailty trajectories in later life? This question cannot be answered yet. First, the majority of these studies were cross-sectional in design, assessing frailty at a single point in time, which fails to capture the dynamic character and trajectory of frailty over time. Second, these studies have primarily examined SEP in children or adults separately; however, the effect of changes in SEP from childhood to adulthood, also known as social mobility, on frailty outcomes has not been well examined. Third, most of these studies were conducted in developed countries or regions, which may limit the generalizability of their findings to middle-aged and elderly populations in developing countries such as China, which have distinct social and economic contexts. When investigating the effect of social mobility on frailty trajectories among middle-aged and older adults in China, it is essential to address the above question.

Moreover, further examination of the heterogeneity of the effects of social mobility on frailty trajectories across demographic characteristics (such as age and gender) is critical, and this knowledge will facilitate the development of targeted interventions and strategies to reduce health inequalities in frailty trajectories across populations in their later life. First, studying the middle-aged and older populations separately enables us to capture the distinct life experiences, health challenges, and socioeconomic conditions that individuals face during different stages of adulthood. Middle-aged individuals may still be in prime working age, experiencing career advancements or setbacks, whereas the elderly population may be retired and facing age-related health issues (Kim & Durden, 2007; Zacher et al., 2014). By understanding how social mobility influences frailty trajectories across these different age groups, we can develop targeted interventions and policies to promote healthy aging and improve overall well-being in the course of one's later life. Also, previous studies have been mainly limited to older adults (Alvarado et al., 2008; Herr et al., 2015). The incorporation of younger (middle-aged) participants may shed more light on the cumulative nature of frailty. Second, examining the impact of social mobility on frailty trajectories in relation to gender is crucial. Previous research has shown that gender differences exist in socioeconomic opportunities and health outcomes (Walters et al., 2002). Women often face unique challenges, such as gender-based discrimination, caregiving responsibilities, and lower labor force participation rates (Walters et al., 2002). Therefore, exploring how social mobility interacts with gender in shaping frailty trajectories will provide insights into the specific vulnerabilities and resilience factors experienced by men and women, and assist in reducing gender disparities in frailty trajectories.

At the same time, the association between social mobility and frailty trajectory may vary across social–economic–historical contexts. China has experienced tremendous political, social, and economic change in recent decades, resulting in a high level of social mobility. When the People's Republic of China was established in 1949, its economy was devastated by decades of warfare, resulting in a fragile economic system and dire living conditions for the population (Payne & Xu, 2022). The centrally planned economy implemented in 1949 showed a mixed picture of outcomes. Not until the reform and opening up starting in 1978, when China transitioned from a planned economy to a market economy, did China's economy embark on the path of modernization and improvement of its people's living standards (Zhu et al., 2023). After decades of development, China has sustained rapid economic growth, which is believed to be unprecedented in scale and pace in mankind's history (Q. Wang & Kang, 2019). Meanwhile, the rising disparities between rural and urban areas, across socioeconomic strata in wealth and health have also intensified. The middle-aged and older population in this study experienced the socioeconomic reforms described above during their life course. Most of them had experienced planned economies in their early lives, where socioeconomic resources were generally scarce, whereas changes in the socioeconomic context in adulthood led to the differentiation of social resources (Wen & Gu, 2011). This unique context of dramatic social change offers an excellent opportunity to investigate deeper into the effects of socioeconomic mobility over the life course on frailty trajectories in later life. The present study utilizes data from the China Health and Retirement Longitudinal Study

(CHARLS), a nationally representative longitudinal study of Chinese adults aged 45 and older. It seeks to investigate in depth the effect of social mobility, specifically changes in SEP from childhood to adulthood, on the progression of frailty in later life. Additionally, the study explores whether this effect varies by age and gender, considering potential differences between demographic categories.

Research Design and Methods

Study Participants

Data in this study are derived from the CHARLS, which is a comprehensive social science and health survey of Chinese adults aged 45 or older and their spouses (Zhao et al., 2014). The use of multistage stratified probability-proportional-to-size sampling allows CHARLS to be nationally representative of China (see Supplementary Methods). The CHARLS baseline survey questioned 17,708 individuals from 28 provinces in China between June 2011 and March 2012, where the response rate was 80.5% (Zhao et al., 2013). The study was followed by three surveys in 2013, 2015, and 2018. Additionally, all alive respondents in the 2011 survey were invited to participate in the 2014 Life History Survey, which included questions about important childhood and family events. The weighted value variable in the CHARLS database adjusts for nonresponse and sampling-frame problems in each phase.

The current study included data from participants aged 45 years and older who were interviewed at baseline (2011), for a total of 16,931 participants. We further excluded 3,061 participants who lacked information on social mobility at baseline, 403 participants who lacked a valid assessment of FI at baseline, and 228 participants who lacked a reassessment of FI during follow-up. The final analytic sample included 13,239 participants who were interviewed at baseline and followed up at least once. Supplementary Figure 1 depicts participant inclusion and exclusion. Additional analysis revealed that the characteristics of the final analysis sample were not significantly different from those of the original sample, except that they were more likely to be slightly younger (mean [standard deviation {*SD*}]: 58.65 [9.15] vs 59.11 [9.77], $p = .02$), currently live in a rural area, and have a partner (Supplementary Table 1).

Assessment of Social Mobility

Following the previous studies (Luo & Waite, 2005; Q. Wang & Kang, 2019; Wen & Gu, 2011), the concept of social mobility was operationalized based on changes in individual socioeconomic conditions from childhood to adulthood. Based on previous studies (Luo & Waite, 2005), we created composite indices of childhood and adult socioeconomic conditions, respectively, by calculating the average of standardized of their respective measures. The indices were further categorized into three equal groups: low, middle, and high. A social mobility variable was subsequently created with five categories measuring socioeconomic changes from childhood to adulthood: stable low, downward, stable middle, upward, and stable high. More detailed descriptions and classifications of the variables are provided in Supplementary Methods and Supplementary Table 2.

Assessment of Frailty and Frailty Progression

Frailty was evaluated by the frailty index (FI), which was calculated as the accumulation of age-related health deficits (Rockwood & Mitnitski, 2007). To construct the FI, we followed established standard procedures that were previously described (Searle et al., 2008). The selection of FI-related defects was based on a recent study that utilized the CHARLS database (He et al., 2023). This FI and the variables used to construct it have been validated in previous studies and have demonstrated reliable quality. A total of 32 items were collected from CHARLS to calculate FI in this study, including comorbidity, self-reported health, sensory impairment, physical function, disability, depression, and cognition deficits. Except for cognition, each deficit was categorized or mapped into the 0.00–1.00 interval, with 0.00 indicating the absence of a deficit and 1.00 indicating the maximal expression of the deficit, as details are shown in Supplementary Table 3, which is derived from the CHARLS section of the He et al., (2023) literature. The FI was calculated for each respondent as the number of deficits present in a person divided by the total number of answered possible deficits. The 32-FI is a continuous variable that ranges from 0.00 to 1.00, with a higher value indicating a worse, frailer status. According to previous studies (Fan et al., 2020; He et al., 2023), the FI was categorized using a defined cutoff point of 0.25 (i.e., nonfrail or prefrail: <0.25; frail: 0.25–1.00).

Regarding the missing values of FI items, respondents in all four waves with no missing items were 71.2%, 68.0%, 62.5%, and 55.2%, respectively. Therefore, to make the maximum use of available data and ensure the accuracy of the FI, we regarded missing 10% of the total number of deficits (i.e., three) as the threshold for exclusion with reference to previous studies (He et al., 2023; Herr et al., 2015). If respondents had more than three missing values on these items, their FI would be considered missing. In addition, we conducted sensitivity analyses using different thresholds (e.g., 5%) by referring to previous studies, and the results were robust (Fan et al., 2020).

Frailty progression was evaluated by repeated measurements of FI in 2011, 2013, 2015, and 2018, using the same standard questionnaire and survey criteria for all four surveys.

Statistical Analysis

The data were weighted using the individual weights provided by CHARLS before any statistical analysis to restore the representativeness of the data and get a reliable estimate. The baseline characteristics of the participants were categorized based on their social mobility groups by using weighted data.

Following similar studies (Faul et al., 2021; He et al., 2023), linear mixed-effect models (equation described in Supplementary Methods) with a random intercept and slope were used to analyze the associations of social mobility with the baseline level of frailty and its annual rate of change, with "stable high" as the reference. Such models accommodate unbalanced data structures, including differences in the number of tests and intervals between assessments. 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 (C. Li et al., 2022; Faul et al., 2021). In the linear mixed-effect models, all available repeated measurements of FI (including baseline FI) were included as outcome variables. Consistent with previous studies (Faul et al., 2021; He et al., 2023), social mobility, time (follow-up years since baseline), interaction of social mobility and time, and covariates were included as exposure variables for fixed effects. Supplementary Methods and Supplementary Tables 4 and 5 describe covariates. The regression coefficients of social mobility indicated the differences in baseline FI as compared with the reference. The regression coefficient of time indicated the overall FI change rate during follow-up (annual FI change). The regression coefficients of interaction terms (social mobility and time) indicated the differences in the annual rate of change in FI associated with social mobility. Two different models were introduced: one without adjustment; the other adjusted for covariates. All models were estimated using full-information maximum-likelihood estimation with an unstructured covariance matrix for the random effects. To better present the results, the regression coefficients (β) and 95% confidence intervals (95% CI) were calculated and reported multiplied by 100, with β greater than or less than 0 representing a positive or negative correlation between the exposure variable and the increase in FI. Marginal effects were used to graph linear adjusted predictions of FI over the follow-up while holding covariates constant (Olaya et al., 2019). With reference to similar studies (C. 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. Nevertheless, we also performed a sensitivity analysis with multiple imputations of missing data for FI and covariates, and the results proved to be robust.

Considering potential variations among different demographic groups (Walters et al., 2002; Zacher et al., 2014), we stratified the analysis by age group and gender. In particular, given that there may be a notable discrepancy in current SEP and frailty prevalence among adults of different ages (Supplementary Table 6; Van der Linden, Cheval, et al., 2020), we stratified the analysis into three groups by age (45–59, 60–74, and 75 and older).

More details of statistical methods, including seven sensitivity analyses, are shown in Supplementary Methods. All analyses were carried out using STATA 15.0. Two-sided *p*-values <.05 were considered statistically significant.

Results

Participant Characteristics

A total of 13,239 participants were included in the study, with the majority having experienced mobile socioeconomic conditions from childhood to adulthood. Specifically, 24.5% (3236) of the participants were downwardly mobile and 36.6% (4851) were upwardly mobile, whereas 8.5% (1125), 17.3% (2290), and 13.1% (1737) of the participants had a consistently low, medium, and high SEP, respectively, throughout their lifetime. Table 1 presents the characteristics of the weighted study population stratified by social mobility group. Based on the total weighted sample, the mean age was 58.86 years ($SD = 0.11$) and women made up 52.1%. The mean scores of the FI for each wave were 0.17 ($SD = 0.001$), 0.19 ($SD = 0.001$), 0.21 ($SD = 0.002$), and 0.23 ($SD = 0.002$), respectively (range, 0–1). Middle-aged and older adults with stable low SEP were more likely to have a higher FI, to be older, women, live in rural areas, be single, have never smoked, not currently use alcohol, and not participate in social activities compared to middle-aged and older adults with other social mobility patterns.

Association Between Social Mobility and Level of Frailty at Baseline

The top half of Table 2 shows unadjusted and adjusted mean effects on baseline FI levels for the five socioeconomic conditional mobility patterns from childhood to adulthood. In the unadjusted model, a clear and graded pattern emerges in the relationship between social mobility and baseline FI. The stable low group, characterized by a low socioeconomic status throughout childhood and adulthood, exhibits the highest baseline FI, whereas the stable high group displays the lowest FI. This graded relationship persists even after accounting for covariates in the adjusted model. Compared to the stable high group, individuals in the upward mobility group had a baseline FI that was 2.001 higher (95% CI: 1.211–2.792, $p < .001$), individuals in the stable medium SEP had a baseline FI that was 2.556 higher (95% CI: 1.639–3.473, $p < .001$), individuals experiencing downward mobility had a baseline FI that was 3.004 higher (95% CI: 2.169–3.838, $p < .001$), and individuals in the stable low SEP showed a significantly highest baseline FI of 5.349 (95% CI: 4.264–6.434, $p < .001$).

Association Between Social Mobility and the Progression of Frailty Over Time

As listed at the bottom of Table 2, there was a significant increase in FI during the observation period, and all social mobility patterns were found to have a significant acceleration effect on the FI increase over time, except for the stable high SEP group. In the multivariable linear mixed-effect model, participants exhibited a significant increase in FI of 0.749 units per year during the follow-up period ($p < .001$). When compared to the stable high group, the increase in FI was 0.489 (95% CI: 0.327–0.650, $p < .001$) faster in the stable low group, 0.229 (95% CI: 0.098–0.360, $p = .001$) faster in the downward mobility group, 0.172 (95% CI: 0.018–0.326, $p = .03$) faster in the stable middle SEP group, and 0.145 (95% CI: 0.017–0.273, $p = .03$) faster in the upward mobility group. Figure 1 shows the trajectories of predicted means of FI over time for each social mobility group, and adjusted for covariates.

Heterogeneity and Sensitivity Analysis

Table 3 shows that social mobility significantly affected baseline FI and FI progression in middle-aged adults (45–59 years). Among older adults aged 60–74 years, social mobility significantly affected their baseline FI and had no significant effect on FI progression. However, for older adults aged 75 and over, social mobility had no significant effect on either their baseline FI or FI progression. Supplementary Figure 2 shows the frailty trajectory for the social mobility group among each age group.

The effect of social mobility on baseline FI was significant across genders, with a similar graded pattern to that found in the main analysis. Among women, all other patterns of social mobility significantly accelerated the progression of FI compared to the stable high group. However, among men, only individuals with stable low SEP show a significant difference in the rate of FI progression compared to the stable high group (Table 4).

The results of seven sensitivity analyses were all reasonably consistent with our primary models (Supplementary Tables 7–13).

Discussion and Implications

Using a nationally representative longitudinal survey, this study identified five patterns of social mobility based on

Table 1. Baseline Characteristics of Weighted Study Participants[a]

Characteristics	Total	Social mobility group					*p* Value
		Stable low SEP	Downward mobility	Stable middle SEP	Upward mobility	Stable high SEP	
Total observations (*N*)	13,239	1,125 (8.5%)	3,236 (24.5%)	2,290 (17.3%)	4,851 (36.6%)	1,737 (13.1%)	
Age	58.86 ± 0.11	62.58 ± 0.32	60.00 ± 0.23	59.38 ± 0.23	58.69 ± 0.20	55.15 ± 0.29	<.001
Gender							<.001
Men	6,381 (47.9%)	384 (34.3%)	1,133 (33.6%)	1,027 (44.3%)	2,859 (58.0%)	978 (55.2%)	
Women	6,858 (52.1%)	741 (65.7%)	2,103 (66.4%)	1,263 (55.7%)	1,992 (42.0%)	759 (44.8%)	
Current residence							<.001
Rural	8,428 (56.3%)	894 (76.5%)	2,446 (71.6%)	1,669 (68.9%)	2,804 (49.3%)	615 (27.4%)	
Urban	4,811 (43.7%)	231 (23.5%)	790 (28.4%)	621 (31.1%)	2047 (50.7%)	1,122 (72.6%)	
Marital status							<.001
Partnered	11,700 (86.8%)	907 (77.2%)	2,790 (84.2%)	2,018 (86.7%)	4,380 (89.3%)	1,605 (89.6%)	
Single	1,539 (13.2%)	218 (22.8%)	446 (15.8%)	272 (13.3%)	471 (10.7%)	132 (10.4%)	
Smoking status							<.001
Current smoker	3,916 (29.0%)	289 (25.3%)	780 (23.3%)	668 (29.6%)	1652 (32.7%)	527 (29.8%)	
Former smoker	1,073 (8.9%)	79 (6.5%)	198 (5.7%)	187 (8.3%)	461 (11.3%)	148 (9.6%)	
Never smoked	7,933 (62.2%)	747 (68.2%)	2,225 (71.0%)	1,390 (62.1%)	2,574 (56.0%)	997 (60.6%)	
Current alcohol use							<.001
Yes	4,465 (33.8%)	262 (24.0%)	879 (26.4%)	726 (31.3%)	1,906 (39.3%)	692 (39.3%)	
No	8,773 (66.2%)	863 (76.0%)	2,357 (73.6%)	1,564 (68.7%)	2,944 (60.7%)	1,045 (60.7%)	
Social participation							<.001
Yes	5,872 (47.4%)	442 (38.4%)	1,341 (43.3%)	944 (43.7%)	2,236 (48.9%)	909 (58.5%)	
No	6,752 (52.6%)	656 (61.6%)	1,782 (56.7%)	1,261 (56.3%)	2,331 (51.1%)	722 (41.5%)	
FI (range: 0–1)							
FI 2011	0.17 ± 0.001	0.23 ± 0.006	0.19 ± 0.003	0.19 ± 0.003	0.17 ± 0.002	0.13 ± 0.004	<.001
FI 2013	0.19 ± 0.001	0.24 ± 0.005	0.20 ± 0.003	0.20 ± 0.003	0.19 ± 0.002	0.14 ± 0.004	<.001
FI 2015	0.21 ± 0.002	0.28 ± 0.005	0.23 ± 0.003	0.23 ± 0.003	0.21 ± 0.003	0.16 ± 0.004	<.001
FI 2018	0.23 ± 0.002	0.30 ± 0.006	0.25 ± 0.003	0.25 ± 0.004	0.23 ± 0.003	0.17 ± 0.006	<.001

Notes: FI = frailty index; SEP = socioeconomic position.
[a]Mean ± standard deviation (*SD*) was used to describe continuous variables and number (constituent ratio [%]) was used to describe categorical variables. All measures were assessed at baseline unless otherwise indicated. Estimates are weighted using individual sampling weights with household and individual nonresponse adjusted.

Table 2. Association of Life-Course Social Mobility With Level and Progression of Frailty

Social mobility group	Unadjusted		Adjusted[b]	
	β (95% CI)[a]	*p* Value	β (95% CI)[a]	*p* Value
Frailty level				
Stable high	Reference		Reference	
Upward	3.047 (2.229, 3.865)	<.001	2.001 (1.211, 2.792)	<.001
Stable middle	4.452 (3.524, 5.379)	<.001	2.556 (1.639, 3.473)	<.001
Downward	6.569 (5.754, 7.384)	<.001	3.004 (2.169, 3.838)	<.001
Stable low	9.686 (8.614, 10.759)	<.001	5.349 (4.264, 6.434)	<.001
Frailty progression				
Time, years	0.752 (0.646, 0.858)	<.001	0.749 (0.638, 0.859)	<.001
Stable high × Time	Reference		Reference	
Upward × Time	0.167 (0.044, 0.290)	.008	0.145 (0.017, 0.273)	.03
Stable middle × Time	0.201 (0.051, 0.351)	.008	0.172 (0.018, 0.326)	.03
Downward × Time	0.246 (0.119, 0.372)	<.001	0.229 (0.098, 0.360)	.001
Stable low × Time	0.529 (0.362, 0.696)	<.001	0.489 (0.327, 0.650)	<.001

Notes: β = regression coefficients; CI = confidence interval.
[a]β (95% CI) was calculated by linear mixed-effect models and presented as multiplied by 100.
[b]Multivariate linear mixed-effect models were adjusted for gender, age, residence, marital status, smoking status, current alcohol use, and social participation.

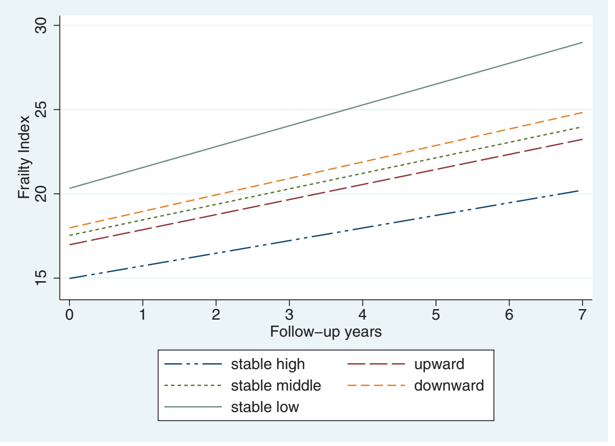

Figure 1. Trajectories of predicted mean of frailty index over time for each social mobility group.

changes in participants' SEP from childhood to adulthood, and it investigated the effects of social mobility on the progression of frailty as measured by FI in middle-aged and older Chinese populations for the first time. Overall, frailty trajectories increased over time for all socially mobile groups. Notably, the frailty trajectories of individuals with upward and downward mobility patterns were situated between those of the stable high and stable SEP groups. Specifically, individuals with upward social mobility had higher frailty trajectories than those with a stable high SEP, whereas individuals with downward social mobility had lower frailty trajectories than those with a stable low SEP. Furthermore, the study identified heterogeneity in the effect of social mobility on frailty trajectories across different sociodemographic characteristics. Significant differences in social mobility patterns were observed in the rate of frailty progression among middle-aged adults (aged 45–59 years), but no such differences were found among older adults (aged 60 years and older). Among male middle-aged and older adults, the rate of frailty progression was faster in only the stable low SEP group compared to the stable high SEP group. However, in women, all other patterns of social mobility, except for stable high SEP, were associated with accelerated frailty progression. These findings provide valuable insights into how social mobility throughout the life course may affect the progression of frailty in later life.

We observed that low SEP at any period of the life course was associated with adverse manifestations of frailty in later life. Particularly, the most striking disparities in the level of frailty were observed between individuals with persistently high SEP and those with persistently low SEP from early life to adulthood. The disparity in frailty levels widened over time, implying the cumulative impact of socioeconomic advantage or disadvantage on long-term health outcomes (Dannefer, 2003). Previous research suggests that individuals with higher SEP tend to have better access to resources that promote health, which can lead to healthier behaviors, preventive healthcare utilization, and overall healthier lifestyles, reducing the risk of frailty (Van der Linden, Cheval, et al., 2020). Conversely, individuals who are persistently socioeconomically disadvantaged may face barriers to healthcare access, limited resources for maintaining good health, and heightened exposure to stressors that accelerate the progression of frailty (Y. Li et al., 2020). Over time, these factors accumulate and contribute to higher levels of frailty. This finding underscores the compounding influence of socioeconomic circumstances throughout the life course, leading to widening disparities in frailty outcomes during later life.

A previous European longitudinal study from a life-course perspective found that the association between socioeconomic status in childhood and frailty in old age disappears when adult socioeconomic status is taken into account (Van der Linden, Cheval, et al., 2020). This Chinese longitudinal study, however, reveals that the effect of childhood SEP on frailty at older ages is persistent and does not disappear with adult socioeconomic status mobility. The trajectories of individuals in the upward and downward mobility groups fall between those in the stable high SEP and low SEP groups. Participants who experienced socioeconomic disadvantage during childhood but achieved higher SEPs in adulthood exhibited better frailty outcomes compared to those with similar childhood backgrounds who remained in the lower SEP group throughout their lives. This suggests that upward mobility (such as from low SEP to high SEP) can partially compensate for disadvantages early in life. However, those who experienced downward socioeconomic mobility from childhood to adulthood had worse performance in frailty than the group with lifetime advantaged SEP, suggesting that the benefits of higher SEP in childhood can be diluted by subsequent downward mobility over the life course. These findings support the notion of a "gradient constraint" on social inequality in frailty, where social mobility moderates rather than creates or widens the magnitude of social class differences (Boyle et al., 2009). Similar patterns have been observed in other health-related studies (Faul et al., 2021; Salmela et al., 2021). Therefore, social mobility is considered to have the potential to reduce health inequalities in terms of frailty (Iveson & Deary, 2017; Kendig & Nazroo, 2016).

For adulthood, the current SEP and frailty prevalence would vary across age groups (Van Der Linden, Cheval, et al., 2020). Therefore, further stratified analyses by age would be more informative. More importantly, the age patterns of social gradients in frailty trajectory in China differ substantially from the observed patterns in high-income societies. A study (Stolz et al., 2017) conducted among older adults in continental Europe has shown that SEP-based frailty trajectory disparities increase with age, which only considers a single period in the life course as well as a single indicator measure of SEP, such as education, occupational class, and wealth. In contrast, in China, differences in the progression of frailty due to mobility in SEP over the life course emerge strongly in midlife and converge in old age, which is a very novel finding in our study. These conflicting results may be attributed to the use of SEP predictors for one period of the life course in the previous study, which may confound health disparities due to socioeconomic status across the life course. Our findings are somewhat consistent with the "age-as-leveller" theory (Xu et al., 2015), which means that socioeconomic gaps between individuals diminish or disappear in later life due to morbidity compression in high SEP individuals being caught up by universal biological frailty and/or compensating welfare state policies (House et al., 2005; Stolz et al., 2017). Especially, older participants had a higher FI compared to the middle aged, to the extent that there was less space for FI to rise (Ma et al., 2018). A previous study (Cheng et al., 2022) reported similar findings, with an association between

Table 3. Association of Life-Course Social Mobility With Level and Progression of Frailty Stratified by Age

Social mobility group	Unadjusted		Adjusted[b]	
	β (95% CI)[a]	*p* Value	β (95% CI)[a]	*p* Value
45–59 years (*n* = 7,665)				
Frailty level				
Stable high	Reference		Reference	
Upward	2.941 (2.281, 3.602)	<.001	2.500 (1.763, 3.238)	<.001
Stable middle	4.499 (3.663, 5.335)	<.001	3.693 (2.729, 4.657)	<.001
Downward	5.819 (5.134, 6.504)	<.001	3.801 (2.975, 4.627)	<.001
Stable low	8.992 (8.123, 9.861)	<.001	6.087 (4.694, 7.480)	<.001
Frailty progression				
Time, years	0.628 (0.538, 0.717)	<.001	0.592 (0.506, 0.679)	<.001
Stable high × Time	Reference		Reference	
Upward × Time	0.150 (0.040, 0.260)	.008	0.128 (0.017, 0.239)	.03
Stable middle × Time	0.180 (0.041, 0.319)	.01	0.157 (0.001, 0.313)	.05
Downward × Time	0.160 (0.046, 0.274)	.006	0.187 (0.069, 0.305)	.002
Stable low × Time	0.428 (0.284, 0.572)	<.001	0.467 (0.280, 0.653)	<.001
60–74 years (*n* = 4,758)				
Frailty level				
Stable high	Reference		Reference	
Upward	1.939 (0.094, 3.783)	.04	2.242 (0.416, 4.068)	.02
Stable middle	2.742 (0.743, 4.741)	.007	2.047 (0.074, 4.020)	.04
Downward	4.854 (3.057, 6.650)	<.001	2.929 (1.087, 4.771)	.002
Stable low	7.397 (5.509, 9.284)	<.001	5.608 (3.699, 7.517)	<.001
Frailty progression				
Time, years	1.115 (0.742, 1.487)	<.001	1.123 (0.743, 1.502)	<.001
Stable high × Time	Reference		Reference	
Upward × Time	−0.006 (−0.398, 0.387)	1.0	−0.034 (−0.434, 0.366)	.9
Stable middle × Time	0.103 (−0.312, 0.518)	.6	0.076 (−0.348, 0.499)	.7
Downward × Time	0.046 (−0.345, 0.437)	.3	0.027 (−0.371, 0.425)	.9
Stable low × Time	0.192 (−0.218, 0.601)	.4	0.155 (−0.261, 0.571)	.5
≥ 75 years (*n* = 816)				
Frailty level				
Stable high	Reference		Reference	
Upward	−2.564 (−9.378, 4.250)	.5	−2.646 (−8.869, 3.577)	.4
Stable middle	−1.591 (−8.714, 5.533)	.7	−3.845 (−10.296, 2.607)	.2
Downward	1.269 (−5.105, 7.642)	.7	−1.086 (−6.740, 4.568)	.7
Stable low	4.264 (−2.274, 10.801)	.2	1.005 (−5.220, 7.230)	.8
Frailty progression				
Time, years	1.646 (1.010, 2.281)	<.001	1.630 (0.997, 2.263)	<.001
Stable high × Time	Reference		Reference	
Upward × Time	0.223 (−0.586, 1.032)	.6	0.209 (−0.597, 1.016)	.6
Stable middle × Time	−0.504 (−1.452, 0.444)	.3	−0.405 (−1.360, 0.550)	.4
Downward × Time	−0.116 (−0.855, 0.623)	.8	−0.222 (−0.946, 0.503)	.5
Stable low × Time	0.135 (−0.661, 0.931)	.7	0.200 (−0.598, 0.999)	.6

Notes: β = regression coefficients; CI = confidence interval.
[a]β (95% CI) was calculated by linear mixed-effect models and presented as multiplied by 100.
[b]Multivariate linear mixed-effect models were adjusted for gender, age, residence, marital status, smoking status, current alcohol use, and social participation.

higher systemic inflammatory markers and frailty progression observed among middle-aged adults, but no significant relationship was found among older adults aged 60 years and older. In addition, individuals in their middle years often experience significant life changes and increased responsibilities, such as career development, establishing families, and raising children, which make them more sensitive to fluctuations in their economic circumstances (Kim & Durden, 2007; Zacher et al., 2014). In contrast, during old age, individuals tend to live relatively stable lives, and the development of China's social security system, including pensions and health insurance, provides relatively equalized financial support and

Table 4. Association of Life-Course Social Mobility With Level and Progression of Frailty Stratified by Gender

Social mobility group	Unadjusted		Adjusted[b]	
	β (95% CI)[a]	*p* Value	β (95% CI)[a]	*p* Value
Men (*n* = 6,381)				
Frailty level				
Stable high	Reference		Reference	
Upward	2.388 (1.378, 3.399)	<.001	1.409 (0.458, 2.361)	.004
Stable middle	3.753 (2.580, 4.926)	<.001	2.462 (1.334, 3.591)	<.001
Downward	5.157 (4.048, 6.267)	<.001	2.639 (1.530, 3.747)	<.001
Stable low	8.694 (7.235, 10.152)	<.001	5.143 (3.662, 6.624)	<.001
Frailty progression				
Time, years	0.844 (0.680, 1.008)	<.001	0.838 (0.663, 1.012)	<.001
Stable high × Time	Reference		Reference	
Upward × Time	0.059 (−0.122, 0.240)	.5	0.039 (−0.153, 0.231)	.7
Stable middle × Time	0.063 (−0.152, 0.278)	.6	0.052 (−0.174, 0.278)	.7
Downward × Time	0.087 (−0.117, 0.290)	.4	0.061 (−0.148, 0.270)	.6
Stable low × Time	0.336 (0.083, 0.590)	.009	0.328 (0.065, 0.592)	.02
Women (*n* = 6,858)				
Frailty level				
Stable high	Reference		Reference	
Upward	4.380 (3.017, 5.744)	<.001	2.860 (1.576, 4.144)	<.001
Stable middle	5.074 (3.607, 6.541)	<.001	2.817 (1.386, 4.249)	<.001
Downward	6.828 (5.596, 8.059)	<.001	3.479 (2.251, 4.707)	<.001
Stable low	9.801 (8.226, 11.377)	<.001	5.728 (4.177, 7.279)	<.001
Frailty progression				
Time, years	0.678 (0.525, 0.770)	<.001	0.653 (0.528, 0.778)	<.001
Stable high × Time	Reference		Reference	
Upward × Time	0.298 (0.133, 0.462)	<.001	0.268 (0.101, 0.435)	.002
Stable middle × Time	0.352 (0.150, 0.554)	.001	0.299 (0.096, 0.502)	.004
Downward × Time	0.381 (0.231, 0.531)	<.001	0.363 (0.210, 0.515)	<.001
Stable low × Time	0.684 (0.478, 0.891)	<.001	0.621 (0.429, 0.813)	<.001

Notes: β = regression coefficients; CI = confidence interval.
[a]β (95% CI) was calculated by linear mixed-effect models and presented as multiplied by 100.
[b]Multivariate linear mixed-effect models were adjusted for age, residence, marital status, smoking status, current alcohol use, and social participation.

resources for older adults (Bairoliya et al., 2018). These external socioeconomic compensation policy developments have helped to weaken internal socioeconomic disparities among the elderly, thus mitigating the impact of social mobility on their frailty progression.

Frailty trajectories based on social mobility also exhibit gender heterogeneity. For male middle-aged and older adults, only experiencing persistent low SEP throughout life significantly contributes to the accelerated progression of frailty in later life. Conversely, women who experience socioeconomic disadvantage at any stage of life, even if they move to a higher SEP in adulthood, still exhibit an accelerated progression of frailty over time. This suggests that the effects of socioeconomic disadvantage on women's frailty trajectories are persistent and cumulative in the course of their later life, and that the adverse consequence of prior disadvantage persists despite upward social mobility. Research has shown that socioeconomic factors over the life course have different exposures and vulnerabilities across genders (Walters et al., 2002). The association between experiencing socioeconomic deprivation in early life and the risk of health problems in later life is stronger and more consistent for women compared to men, despite women attaining higher SEP in adulthood. Low childhood socioeconomic status (SES), for example, is associated with accelerated trajectories of high blood pressure from young adulthood to early midlife for women, but not men (Janicki-Deverts et al., 2012). Similarly, the adverse impacts of childhood SES on adult body mass index are stronger among women than men (Giskes et al., 2008).

This study highlights the necessity of considering the disparities in frailty trajectory in later life based on SEP mobility throughout the life course, informing the identification of vulnerable populations who are rapidly frail and policies to mitigate frailty inequalities. Research (Chen, 2016) has pointed out that social mobility in China has the potential and risk of progressive entrenchment, which poses a challenge to achieving health equity in frailty among older adults. Due to limited social mobility, disparities in health outcomes such as frailty and their progression are persistent, reinforcing cycles of disadvantage and accelerating the frailty progression in later life, with an enduring impact on older individuals and society. To mitigate these risks, it is essential for policies to prioritize the promotion of social mobility while placing greater emphasis on addressing the underlying structural barriers that impede social mobility and exacerbate health inequalities in frailty for older adults (T. Wang, 2019). Studies have indicated that despite the existence of numerous policies for geriatric health, there are still significant disparities in the distribution and utilization of health service resources for older adults in China, as well as in the early life stages (J. Li et al., 2018). Therefore, it is crucial to account for the accumulation and changes of socioeconomic risk factors throughout the entire life course, including early life stages, when formulating public health policies aimed at reducing inequalities in frailty (Kendig & Nazroo, 2016). It is important to identify and provide targeted support to vulnerable populations who have experienced disadvantageous SEP throughout their lives or who are mobile to unfavorable SEP in adulthood. The findings of this study suggest that adopting a social mobility perspective may be a new avenue for preventing the worsening of frailty in older adults, and that health intervention policies should be implemented from the early stages of life to mitigate health inequalities in later life, such as frailty (Zhu et al., 2023). Considering the greater impact of social mobility on the worsening trajectory of frailty among women in this study, the aforementioned measures should prioritize and strengthen early intervention and support for women.

This study had numerous significant methodological and substantive merits. First, the large size and national representativeness of the CHARLS sample provide us with the opportunity to examine for the first time the impact of life-course mobility in socioeconomic status on the level and progression of frailty in middle-aged and older Chinese adults, and the results are generalizable to the broader Chinese population (Zhao et al., 2014). Second, this study has a prospective design with repeated measures of FI, which provides a unique opportunity to consider the dynamic nature of frailty by examining longitudinal trajectories. Third, the application of a linear mixed-effects model is appropriate for the complex longitudinal character of the data in this study and takes full advantage of the available data (C. Li et al., 2022). Fourth, the diverse sensitivity analysis ensures the robustness of our results. We also acknowledge that there are some potential limitations. First, information on childhood and adulthood SEP was measured retrospectively and self-reported, and thus recall bias may be present. However, previous research has reported that recall information is a reliable measure (Baldwin et al., 2019). Furthermore, to mitigate the potential impact of this bias, we adopted the variables and methods utilized in previous studies to construct composite indicators of childhood and adult SEP, with different socioeconomic measures to better capture the socioeconomic conditions in Chinese settings (Q. Wang & Kang, 2019; Wen & Gu, 2011). Second, there is a possibility of selection bias due to the exclusion of 4,469 individuals who either did not attend their first follow-up visit or had missing information. However, to address this potential bias, we employed the inverse probability weighting approach (C. Li et al., 2022). Notably, applying this method did not alter our conclusions based on the results obtained. Additionally, further analyses indicated that the characteristics of the final analysis sample were not significantly different from those of the original sample, except for a slightly younger age, a greater likelihood of residing in rural areas, and having a partner. Third, we cannot rule out the potential that unmeasured variables and residual confounding may have influenced the correlations observed in this study. For example, respondents having more than one job experience or holding more than one job may potentially bias the measurement of adult SEP, whereas we mitigated the potential bias to some extent through sensitivity analyses (excluding occupational variables or restricting the sample to those only holding a primary job). Finally, it is important to note that the measures of social mobility used in this study do not encompass information from all stages of life due to data limitations, and there may be discrepancies in current SEP among adults of different ages. However, we have included the most relevant indicators of an individual's socioeconomic status based on available data and in accordance with similar studies (Payne & Xu, 2022; Q. Wang & Kang, 2019). Future studies should take into account a wider range of socioeconomic indicators and investigate the influence of socioeconomic status at critical life stages, such as childhood, adulthood, and late adulthood, on health outcomes in later life.

Conclusion

This study examines frailty trajectories based on socioeconomic mobility over the life course among the Chinese middle-aged and older population. We find the most disparity in frailty trajectories between individuals with the most and least advantageous SEPs throughout their lives, and this disparity tends to widen over time. Downward social mobility is associated with higher frailty trajectories compared to stable high SEP. However, moving from an early disadvantage to a more favorable SEP has the potential to mitigate the escalation of the frailty burden, particularly among males. Furthermore, the study reveals that the effect of social mobility on frailty trajectories is more pronounced in middle-aged adults and less so in older adults. These findings highlight the significance of employing a life-course perspective to health interventions in policy-making, particularly in earlier life stages, to reduce disparities in the level and progression of frailty. Implementing preventive actions that specifically target vulnerable populations, such as women and middle-aged adults experiencing social mobility, with a focus on those with persistently low SEP and downward mobility, could be advantageous.

Supplementary Material

Supplementary data are available at *Innovation in Aging* online.

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Conflict of Interest

None.

Data Availability

The data used in this study were obtained from the publicly available database "China Health and Retirement Longitudinal Study (CHARLS)," which is published at https://charls.charlsdata.com/pages/data/111/zh-cn.html

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