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Original Report

Adult Socioeconomic Position Mediates the Association Between Childhood Socioeconomic Position and Later-Life Frailty Trajectory: A Nationally Representative Cohort Study

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Abstract

Background and Objectives: Early-life risk factors influence the aging process in the short term and shape its trajectory in the long term. We aim to (1) explore the association between childhood socioeconomic position (cSEP) and frailty trajectories and (2) test whether adult socioeconomic position (aSEP) mediates the association between cSEP and frailty trajectories.

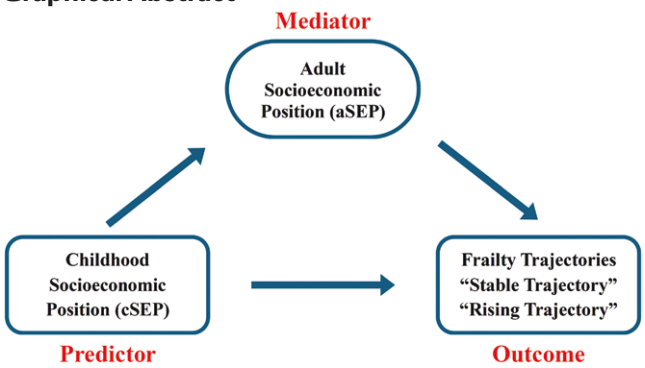
Research Design and Methods: We analyzed 4 waves of the China Health and Retirement Longitudinal Study data. The frailty index was estimated based on the number of individual deficits across 40 indicator variables. Principal component analysis was used to generate cSEP and aSEP. Group-based trajectory models were used to identify the patterns of frailty trajectories over time. Causal mediation analysis was conducted to determine whether the aSEP mediated the association between cSEP and frailty trajectories.

Results: We identified 3 distinct trajectories of frailty progression. Low cSEP was significantly associated with "High and increasing frailty trajectory" (odds ratio [OR] = 1.76, 95% confidence intervals [95% CI]: 1.38–2.23; adjusted OR = 1.55, 95% CI: 1.22–1.97). About 30% of the cSEP effect on rising frailty trajectory was mediated through the aSEP, and there is a significant gender disparity in the mediating effect of aSEP (18% among men and 51% among women, respectively).

Discussion and Implications: Our findings suggest that policies that initially benefit children will yield well-being benefits as they reach adulthood. Promoting ongoing cSEP advantages increases the likelihood of delaying frailty progression in later life. This study underscores the critical importance of addressing social determinants of health throughout one's life course to foster healthy aging and diminish health disparities in later stages of life.

Keywords: Frailty trajectories, Life course approach, Socioeconomic position

Graphical Abstract



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Translational Significance: Early-life risk factors influence the aging process in the short term and shape its trajectory in the long term. Our study shows adult socioeconomic position partially mediates the association between childhood socioeconomic position (cSEP) and later-life frailty trajectory and there is a significant gender disparity in the mediating effect. Our findings suggest that policies that initially benefit children will yield well-being benefits as they reach adulthood. Promoting ongoing cSEP advantages increases the likelihood of delaying frailty progression in later life. These findings underscore the importance of addressing social determinants over the life course to promote healthy aging.

Frailty, a reflection of the biological aging processes, significantly affects numerous older adults. It's marked by a decline in both physical and cognitive functions and an increased vulnerability to stressors like illness or injury (Clegg et al., 2013). Prior research emphasizes the significance of individual heterogeneity in the development of frailty (Rogers et al., 2017; Verghese et al., 2021). A pivotal theory that delineates health disparities across the lifespan is the Cumulative Disadvantage Theory, defining it as the "systemic tendency for interindividual divergence in a given characteristic over time" (Dannefer, 2003). The theory posits that aging begins early in life, driven by the accumulation of molecular and cellular damage. A wealth of evidence from life course studies suggests that the decline in cognitive and physical functioning with age stems from early-life experiences and shares common risk factors and causative mechanisms (Haapanen et al., 2018; Plassman et al., 2010).

Early-life risk factors influence the aging process in the short term and shape its trajectory in the long term. Epidemiological studies have extensively examined the role of socioeconomic factors in early-life affecting aging in adulthood and older ages. Nonetheless, certain studies have only validated the association between childhood socioeconomic position (cSEP) and frailty during specific periods in adulthood, failing to elucidate the dynamic nature of frailty, which leads to biased estimates (Dimitriadis et al., 2023; Shiau et al., 2023). Others have employed mixed-effects models to appraise the connection between cSEP and average frailty trajectories, overlooking trajectory heterogeneity across population groups. For instance, an analysis of Survey of Health, Ageing, and Retirement in Europe (SHARE) data via mixed-effects models indicated childhood socioeconomic conditions are linked to old-age frailty, mediated by adult socioeconomic conditions (Van der Linden et al., 2020).

Existing evidence on the association between cSEP and frailty primarily originates from European populations using data from SHARE (Stolz, Mayerl, Waxenegger, Rasky, et al., 2017), the English Longitudinal Study on Ageing (ELSA), and panel data in Sweden (Agahi et al., 2014; Tampubolon, 2016). Post-war European socioeconomic transitions markedly differ from those in China during the same period. The majority of older Chinese individuals born between the 1930s and 1960s experienced childhood poverty and even starvation, albeit with minimal inequalities. However, owing to China's rapid economic growth in recent decades, adulthood among these generations exhibits substantial socioeconomic heterogeneity. This presents an opportunity to explore the impact of early-life socioeconomic position on the progression of later-life frailty.

Employing nationally collected longitudinal data, this study aims to: (1) investigate the association between cSEP and frailty trajectories in later life; and (2) examine the potential mediating effect of adult socioeconomic position (aSEP) on the association between cSEP and later-life frailty trajectories.

Method

Study Population

We utilized four waves of data from the China Health and Retirement Longitudinal Study (CHARLS), gathered biannually from 2011 to 2018. Additionally, the analysis incorporated data from the 2014 CHARLS life history survey. CHARLS provides a comprehensive array of information covering demographics, family structure and transfers, health status, functional abilities, biomarkers, healthcare access, insurance, employment, retirement, pensions, income, consumption, individual and household assets, as well as community-level details encompassing history, migration, infrastructure, and public facilities (Zhao et al., 2014). The CHARLS baseline survey, employing multistage cluster sampling, was conducted in 28 provinces, 150 counties/districts, and 450 villages/urban communities throughout the nation, encompassing approximately 10,000 households and 17,500 individuals.

Measures

Frailty Index

In this study, frailty was operationalized as the accumulation of deficits, a construct previously defined in research (Rockwood & Mitnitski, 2007). The Frailty Index (FI) was calculated by tabulating the number of deficits an individual presented across 40 indicator variables spanning the four CHARLS waves. These variables encompassed various medical symptoms, diagnosed conditions, and assessments of functional activities and activities of daily living. For a comprehensive list of variables and their respective coding, please refer to Supplementary Table S1. The FI score ranged from 0 (indicating no deficits) to 1 (representing the highest level of deficits).

Childhood and adulthood socioeconomic position

We derived cSEP through a principal component analysis (PCA) involving six socioeconomic indicators before age 17. These indicators encompassed: (1) the father's or stepfather's highest education, (2) the mother's or stepmother's highest education, (3) the father's occupation, (4) the mother's occupation, and two additional questions: (5) "When you were a child before age 17 was there ever a time when your family did not have enough food to eat?," and (6) "When you were a child before age 17, compared to the average family in the same community/village at that time, how was your family's financial situation?." The PCA process yielded a socioeconomic score, subsequently categorized into three socioeconomic positions: low, moderate, and high.

The aSEP was determined based on various factors, including household ownership of durable goods such as

automobiles, electric bicycles, refrigerators, and air conditioners, among others, dwelling characteristics (such as the type of flooring, walls, and cooking stoves), and access to essential services like improved water, sanitation, and cooking fuel. We ensured the distribution of categories for each variable, excluding those with more than 90% or less than 10% representation. After this screening process, a total of 15 variables were ultimately included in the PCA (refer to Supplementary Table S2). The analysis resulted in a score, which was subsequently categorized into three aSEP categories: low, moderate, and high.

Covariates

Demographic and behavioral factors were evaluated at baseline, encompassing age, gender, place of residence (rural/urban), tobacco use, alcohol consumption, and physical activity. The 28 provinces were classified into four regions: Eastern, Middle, Western, and Northeast China, as per the National Bureau of Statistics regional classification. Household wealth per capita was segmented into quintiles. Tobacco use was assessed through self-reported questions, categorizing individuals as never smokers, noncurrent smokers, or current smokers. Alcohol consumption behaviors were delineated using drinking habit inquiries, grouping respondents as lifetime abstainers, former drinkers, current moderate drinkers, or current at-risk drinkers. The level of physical activity (low, moderate, or high) was determined based on a composite assessment of frequency, duration, and intensity.

Statistical Analyses

We performed the analyses using STATA v17.0 (Stata Corp., 2015. College Station, TX, USA) and SAS, version 9.4 (SAS Institute, Inc., Cary, NC, USA). Cohort characteristics at baseline were presented as numbers and percentages. To

Table 1. Baseline Characteristics of the Older Adults Aged 50+ by Childhood Socioeconomic Position (cSEP)

Variable	Low cSEP (n = 3,197)	Moderate cSEP (n = 1,591)	High cSEP (n = 2,412)	Total	N
	% (Weighted)	% (Weighted)	% (Weighted)	% (Weighted)	
Baseline age groups (N = 7,200)					
50–59	48.1	43.0	53.9	48.9	3,537
60–69	38.5	32.7	31.5	34.9	2,627
70+	13.3	24.3	14.5	16.2	1,036
Sex (N = 7,200)					
Men	50.5	50.4	45.9	48.9	3,582
Women	49.5	49.6	54.1	51.1	3,618
Regions (N = 7,200)					
Eastern China	30.8	34.8	38.1	34.1	2,244
Middle China	31.7	28.6	29.5	30.3	2,320
Western China	31.5	29.2	24.1	28.5	2,174
Northeast China	6.0	7.4	8.4	7.1	462
Residence (N = 7,200)					
Rural	68.4	63.4	46.0	59.8	4,810
Urban	31.6	36.6	54.0	40.2	2,390
Wealth quantiles (n = 7,031)					
Q1 (Lowest)	22.3	17.7	14.1	18.6	1,393
Q2	21.7	19.2	14.9	18.9	1,448
Q3	20.5	21.1	17.0	19.5	1,455
Q4	19.5	19.8	21.0	20.0	1,418
Q5 (Highest)	16.0	22.1	33.1	23.0	1,317
Tobacco use (n = 6,581)					
Current smokers	34.1	32.5	29.4	32.2	2,201
Noncurrent smokers	3.5	2.8	2.5	3.0	199
Never smokers	62.4	64.6	68.1	64.8	4,181
Alcohol consumption (n = 7,113)					
Lifetime abstainers	57.9	58.0	58.7	58.2	4,106
Former drinkers	8.8	9.8	8.0	8.8	658
Moderate drinkers	26.4	25.7	27.5	26.6	1,849
At-risk drinkers	6.9	6.6	5.8	6.4	500
Physical activity (n = 6,913)					
Low level	73.4	76.9	80.1	76.4	5,162
Moderate level	11.2	10.2	9.3	10.4	739
High level	15.4	12.9	10.5	13.2	1,012

identify the patterns of frailty trajectories over time, we utilized group-based trajectory models (GBTM) (Proc Traj in SAS). As the dependent variable, FI was a continuous variable between 0 and 1, and we specified it as having a censored normal distribution in the model. Initially, we fitted models with 0–5 groups, with all groups set to second order (quadratic). Subsequently, we determined the optimal number of groups by the Bayesian information criterion (BIC) (near 0), the proportion of the sample in each trajectory (more than 5%), and average posterior probabilities (near 1.0). Because the BIC showed continued improvement as the number of groups increased in our study (Supplementary Figure S1), we finally utilized the latter two criteria (Supplementary Table S3) and epidemiological meaningfulness to identify the optimal number of groups (Nagin, 2005). Multinomial logistic regression models were used to estimate associations between cSEP and frailty trajectory for all participants and separate stratified analyses. To investigate whether aSEP mediates the association between cSEP and frailty progression, we employed causal mediation analysis based on a counterfactual framework (SAS CAUSALMED procedure; Valeri & Vanderweele, 2013). This method allows for simultaneous assessment of mediation and interaction, providing a comprehensive understanding of the overall effect. Given its inability to handle multi-categorical variables as an outcome, we combined the three trajectories into two, representing "stable trajectory" and "rising trajectory." To determine statistical significance, a p value < .05 was used.

Results

Table 1 displays the descriptive statistics for the sample and further stratifies them based on cSEP. Among the 7,200 respondents aged 50 years and older, 3,582 (48.9%) were men, and 3,618 (51.1%) were women. Almost half of the respondents (48.9%) were between 50 and 59 years old. Nearly 59.8% of the participants resided in rural areas. Notably, those with high cSEP were more likely to be women, Eastern China residents, urban inhabitants, never smokers, and physically inactive.

Figure 1 shows the frailty trajectories with 95% confidence intervals (95% CI). The analysis identified three distinct frailty trajectories: the "Low and stable trajectory/LT" (56.8%), "Moderate and increasing trajectory/MT" (34.4%), and "High and increasing trajectory/HT" (8.8%).

Figure 2 showed the associations between cSEP and frailty trajectory for all participants and separate stratified analyses. Compared to participants with high cSEP, the odds ratio (OR) for MT of participants with low and moderate cSEP were 1.47 (95% CI: 1.28–1.69) and 1.22 (95% CI: 1.03–1.43), respectively. Even after adjusting for aSEP, the significant association between low cSEP and MT persisted (adjusted OR = 1.39, 95% CI: 1.21–1.60). Correspondingly, low cSEP was significantly associated with HT frailty (OR = 1.76, 95% CI: 1.38–2.23; adjusted OR = 1.55, 95% CI: 1.22–1.97).

Stratified analyses displayed similar associations across different age groups, which revealed that low cSEP was associated with MT and HT even after the adjustment for aSEP. The association between cSEP and HT remained even when the analysis stratified for sex and residence. However, it seemed that sex and residence might modify the effect of the association of moderate cSEP and MT as the association was only statistically significant among men (OR = 1.34, 95% CI: 1.03–1.74; adjusted OR = 1.33, 95% CI: 1.03–1.73) and rural residents (OR = 1.27, 95% CI: 1.04–1.56).

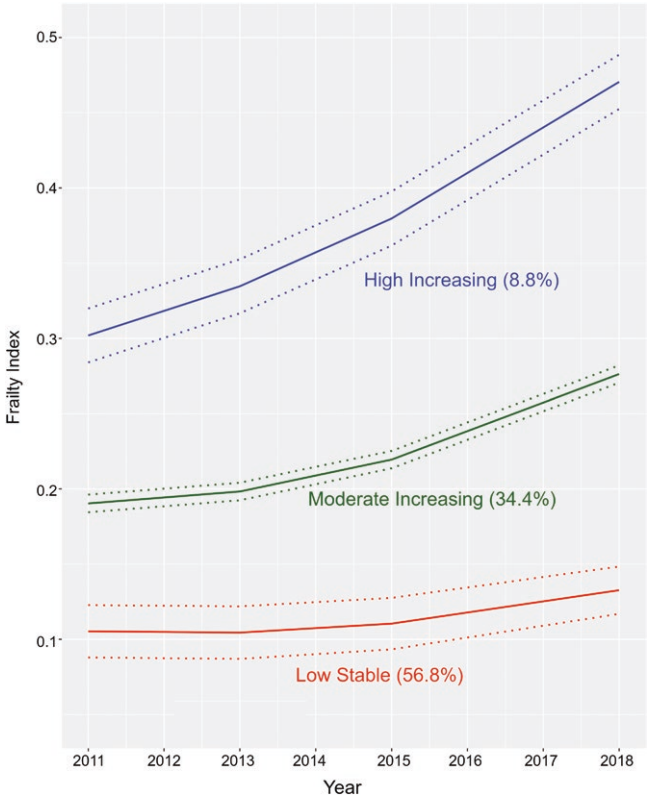

Figure 1. Frailty Index's groups and trajectories among older adults aged 50+ in China during 2011–2018. This figure is adapted from Guo Y et al. Innov Aging *Innovation in Aging*, 2024, igad131, https://doi.org/10.1093/geroni/igad131.

The mediation analysis showed that about 30% (95% CI: 17.7%, 44.2%) of the cSEP effect on the development of frailty is mediated through the aSEP, with 18% among men and 51% among women. The percentage of the total effect attributed to the interaction between cSEP and aSEP is approximately 6.8%, relatively small in comparison (Table 2).

Discussion

In a nationally representative sample of Chinese adults, we observed three distinct trajectories of frailty progression. We discovered that individuals with a lower cSEP experienced a rapid advancement of frailty in later life. Moreover, it was evident that aSEP partially mediated this association. Notably, our findings revealed a significant gender disparity in the mediating effect of aSEP.

Impact of cSEP on the Frailty Progression in Later Life

A growing body of research supports the link between low cSEP and frailty in later life (Agahi et al., 2014; Tampubolon, 2016). A study revealed that lower cSEP increased the risk of developing frailty, mediated by aSEP (Van der Linden et al., 2020). Another cross-sectional study from China suggested that unfavorable SEP and worse health conditions in childhood and adolescence may increase the risk of late-life frailty amongst older Chinese adults (Li et al., 2020). Still, the study

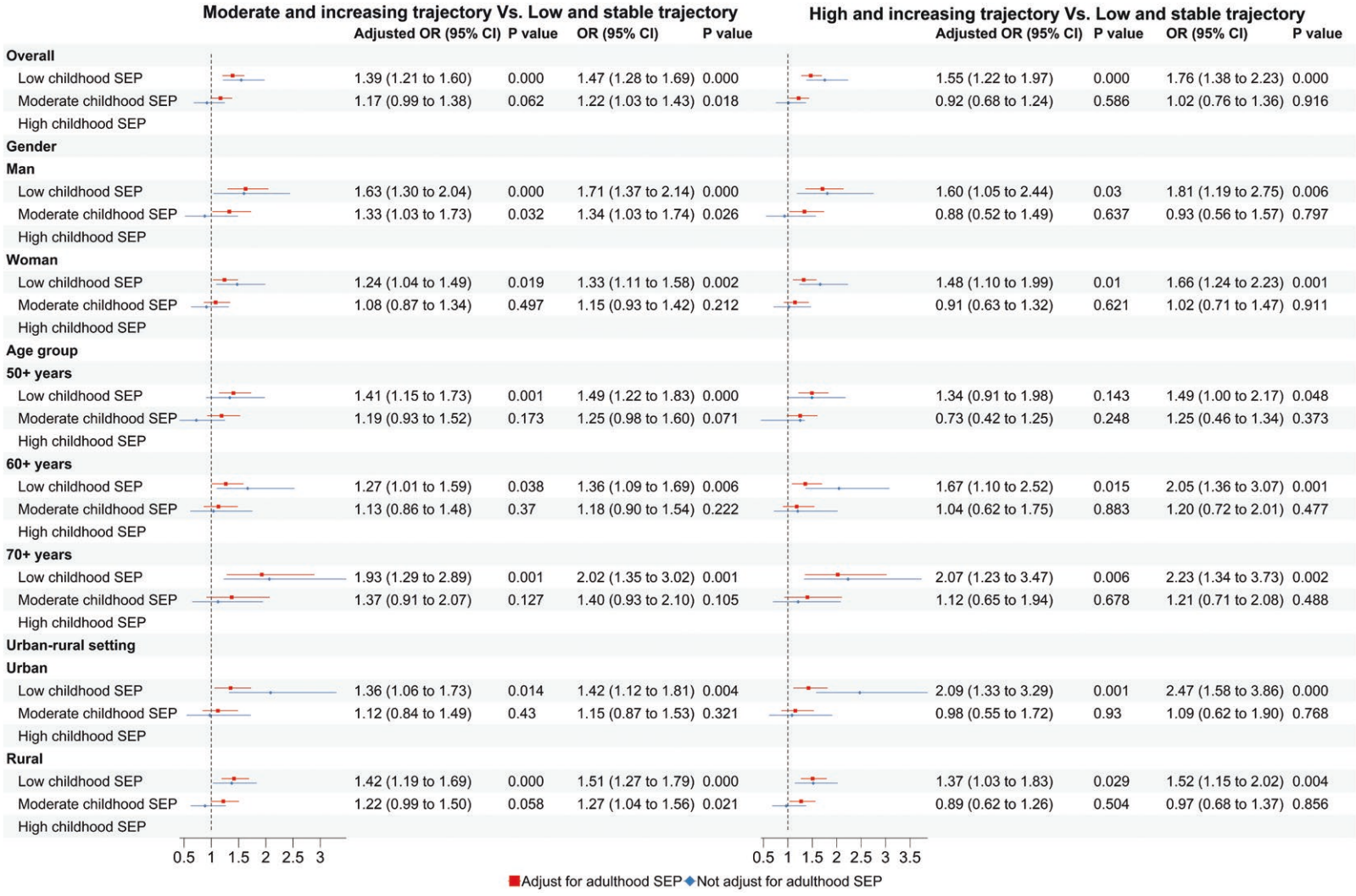

Figure 2. Multinomial logistic regression results.

Table 2. Summary of Causal Effects With Interaction Effects on Rising Frailty Trajectory by Gender

Variable	Estimate	95% CI		Pr > |Z|
Overall				
Total effect	0.9871	0.9823	0.9919	<.0001
CDE	0.9918	0.9873	0.9962	.0003
NDE	0.9911	0.9863	0.9959	.0003
NIE	0.996	0.9949	0.997	<.0001
Total excess relative risk	−0.01291	−0.01774	−0.00808	<.0001
Excess relative risk due to CDE	−0.00796	−0.01232	−0.0036	.0003
Excess relative risk due to NDE	−0.00891	−0.01374	−0.00409	.0003
Excess relative risk due to NIE	−0.004	−0.00502	−0.00298	<.0001
Percentage mediated	30.9708	17.6923	44.2492	<.0001
Percentage due to interaction	6.76	2.0144	11.5055	.0052
Percentage eliminated	38.3196	24.4531	52.1861	<.0001
Man				
Total effect	0.9809	0.9732	0.9887	<.0001
CDE	0.9856	0.9783	0.9929	.0001
NDE	0.9844	0.9766	0.9921	<.0001
NIE	0.9965	0.995	0.998	<.0001
Total excess relative risk	−0.01909	−0.02683	−0.01134	<.0001
Excess relative risk due to CDE	−0.01393	−0.02107	−0.00679	.0001
Excess relative risk due to NDE	−0.01564	−0.02339	−0.0079	<.0001
Excess relative risk due to NIE	−0.00344	−0.00493	−0.00195	<.0001
Percentage mediated	18.04	7.859	28.221	.0005
Percentage due to interaction	8.2753	2.1678	14.3827	.0079
Percentage eliminated	27.0081	13.2254	40.7908	.0001
Woman				
Total effect	0.9915	0.9852	0.9979	.0087
CDE	0.9961	0.9902	1.0019	.1878
NDE	0.9959	0.9895	1.0022	.2015
NIE	0.9956	0.9942	0.997	<.0001
Total excess relative risk	−0.00848	−0.01481	−0.00214	.0087
Excess relative risk due to CDE	−0.0038	−0.00946	0.001863	.1885
Excess relative risk due to NDE	−0.00413	−0.01048	0.002209	.2015
Excess relative risk due to NIE	−0.00434	−0.00573	−0.00296	<.0001
Percentage mediated	51.2456	11.2194	91.2718	.0121
Percentage due to interaction	3.6151	−5.9284	13.1587	.4578
Percentage eliminated	55.2114	19.2163	91.2066	.0026

Note: CDE = controlled direct effect; NDE = natural direct effect; NIE = natural indirect effect. The major decompositions of effects on rising frailty trajectory on both the odds ratio (OR) scale and the excess relative risk scale. The total effect percentage is displayed only on the excess relative risk scale.

did not consider that frailty is a dynamically progressive process. Our findings indicate that individuals with low cSEP are more likely to belong to the "High and increasing trajectory" group, although this association is somewhat attenuated after adjusting for aSEP. These results highlight the role of aSEP in this relationship, aligning with studies in other populations (Laaksonen et al., 2005; Lawlor et al., 2005). Lower cSEP is often linked to poor nutrition, limited access to healthcare, lower levels of education, and unhealthy behaviors, which can have lasting health consequences that increase the risk of frailty later in life. In accordance with cumulative disadvantage theory (Ben-Shlomo & Kuh, 2002; Dannefer, 2003), unfavorable socioeconomic conditions in early-life can accumulate over the life course, leading to a compounding effect on health disparities. This means that individuals who start with lower cSEP may experience a trajectory of increasing vulnerability to frailty as they age.

The Mediating Role of aSEP

Adult socioeconomic position is an important explanatory factor in assessing the link between cSEP and frailty progression. Our study extends this knowledge by demonstrating that this relationship is partially explained by aSEP, which acts as a mediator. This aligns with previous studies that suggested that early-life SEP is associated with frailty and that adult SEP only partially explains this association (Rogers et al., 2021). Our findings support the chain of risk model within the life course framework, where early events have an influence on later life experiences, which in turn affect the risk of disease (Kuh et al., 2003). Childhood socioeconomic status can influence adult

socioeconomic status through several mechanisms, including access to education, employment opportunities, and social networks. Adult socioeconomic status, in turn, can affect frailty through various pathways, including access to healthcare, lifestyle factors, and exposure to environmental risks (Kuh & Ben-Shlomo, 2004). In addition, we observed a significant sex disparity in the extent to which aSEP mediates the association between cSEP and frailty progression. Differential exposure to risk factors, variations in coping strategies, and differences in access to resources and opportunities between men and women may contribute to this gender difference observed in our study population (Gita et al., 2023).

Interaction Between aSEP and cSEP

Because of the long period between exposures and outcomes, one of the complexities of life course research is that in addition to the effect of single exposures and mediators on health outcomes, their interactions may also strongly modify the effect. Causal mediation analysis allows us to quantify the strength of the interaction effect. We found that the percentage of total effect due to the interaction between the cSEP and the aSEP is about 6.8%. Consistent with our findings, Nettle & Bateson (2017) modeled the associations of cSEP and aSEP with self-rated health at three ages (23, 33, and 42) and found that aSEP and cSEP may affect their health interactively as people age (Nettle & Bateson, 2017). Although the percentage of total effect due to the interaction between the exposure and mediator was relatively small in this study, it suggests that the interaction between childhood and adult socioeconomic position occurs when the impact of one factor on health outcomes is modified by the other. For example, individuals who experienced disadvantaged childhood socioeconomic conditions but achieved upward social mobility in adulthood may have different frailty progression compared to those who experienced disadvantaged childhood conditions and remained socioeconomically disadvantaged in adulthood.

Methodological Considerations

Most statistical models used to analyze developmental trajectories, such as hierarchical modeling (Lake, 2006) and latent curve analysis (McArdle & Epstein, 1987), are designed to accommodate individual variability around an average trajectory. Our study employs group-based trajectory modeling to identify distinct developmental progressions within frailty subgroups from a taxonomic perspective. Instead of employing separate or multiple socioeconomic indicators like education, income, and occupation, as seen in other studies, this research utilizes PCA to generate composite cSEP and aSEP separately. The use of multiple, often correlated socioeconomic indicators can lead to issues such as multicollinearity, potentially biasing the estimates in the analysis. The socioeconomic groups identified through PCA enable a relative comparison of outcomes across groups, irrespective of which indicators are included in the PCA. This approach, by controlling for contextual differences in socioeconomic indicators, allows for cross-regional comparisons of the studied phenomenon.

In addition, utilizing a causal mediation analysis within a counterfactual framework presents two key advantages over traditional methods. First, by concurrently evaluating mediation and interaction, the counterfactual approach provides a more comprehensive insight into the overall effect (Valeri & Vanderweele, 2013). Second, traditional mediation analysis encounters limitations in addressing nonlinear effects and disregards the influence of covariates on the mediation effect.

Strengths and Limitations

One notable strength of our study lies in its utilization of a large, nationally representative population in China, equipped with a wealth of life history information. This broad scope allows our findings to be applicable to the entirety of the Chinese population. Nonetheless, our study does have certain limitations that warrant acknowledgement. First, the assessment of cSEP is susceptible to recall bias, particularly concerning income. This potential bias might lead to misclassification of cSEP, thereby influencing the estimates of the association between cSEP and frailty trajectory. Second, our study may be affected by survival bias, wherein individuals who are frail or have poorer health outcomes might be more prone to mortality and consequently not included in the study. This situation could potentially underestimate both the prevalence of frailty and the effects reported in our study (see Supplementary Table S4). Third, our investigation only focused on aSEP as a single mediator and did not encompass other potential mediators, such as chronic diseases, which could also play a role in the relationship between childhood socioeconomic status and frailty. Prior studies have identified numerous additional factors, including health behaviors, social support, and exposure to environmental toxins, that influence this relationship (Stolz, Mayerl, Waxenegger, & Freidl, 2017). It is imperative for future studies to consider these additional factors to attain a more comprehensive understanding of the mechanisms linking childhood socioeconomic status to frailty in later life.

Conclusion

Our study highlights a significant relationship between cSEP and the progression of frailty in later life, with this relationship being partially mediated through aSEP. Our findings suggest that policies that initially benefit children will yield well-being benefits as they reach adulthood. Promoting ongoing cSEP advantages increases the likelihood of delaying frailty progression in later life. In conclusion, this study underscores the critical importance of addressing social determinants of health throughout one's life course to foster healthy aging and diminish health disparities in later stages of life.

Supplementary Material

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

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Conflict of Interest

None.

Data Availability

This study was not preregistered. Data are available upon reasonable request. https://charls.charlsdata.com/users/sign_in/en.html

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Ethics Approval

Ethical approval for all the CHARLS waves was granted from the Institutional Review Board at Peking University. The IRB approval number for the main household survey, including anthropometrics, is IRB00001052-11015.

Author Contributions

All authors contributed to the study concept and design, acquisition, analysis, or interpretation of data. Y. Guo did the statistical analyses. Y. Guo conducted the literature search and wrote the first draft of the manuscript. All authors critically revised the manuscript for important intellectual content and approved the final version.

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