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Original Paper

Life-course Trajectories of Work Productivity and Multidimensional Health: A Longitudinal Study of Childhood Socioeconomic Conditions in Aging Adults

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Abstract

Background: *Maintaining work productivity and good health is essential for healthy aging; however, their long-term co-developmental patterns remain insufficiently understood. This study aimed to identify the joint longitudinal trajectories of work productivity and multidimensional health among middle-aged and older adults and to examine their associations with childhood socioeconomic status.*

Methods: *A group-based dual trajectory model was employed to identify joint trajectories of work productivity and multidimensional health. Multinomial logistic regression was used to examine the associations between childhood socioeconomic status and trajectory membership.*

Results: *Three distinct trajectories of work productivity were identified: low, decreasing, and high. Multidimensional health trajectories were classified as decreasing, moderate, and high. Individuals with persistently high productivity were more likely to follow a high health trajectory. Notably, some individuals with low productivity trajectories also maintained high health trajectories. Childhood socioeconomic indicators, including parental occupation and primary residence, were significantly associated with a decreasing productivity trajectory in later life.*

Conclusions: *Work productivity and multidimensional health demonstrate distinct yet interconnected developmental trajectories across middle and later adulthood. Early-life socioeconomic circumstances play a significant role in shaping these long-term patterns. These findings underscore the importance of a life-course perspective in designing policies and interventions to support healthy and productive aging.*

Keywords

Aging, Productivity, Multidimensional health, Socioeconomic status, Trajectory model

1. Introduction

Population aging is accelerating worldwide, posing urgent challenges to public health systems, labor markets, and social welfare structures. Within the framework of life-course epidemiology, health and functional capacity in later life are viewed as the cumulative result of biological, social, and environmental exposures across the lifespan. Early socioeconomic conditions shape long-term health trajectories through mechanisms of cumulative disadvantage, social pathways, and biological embedding. Understanding how productivity and health co-develop over time in aging populations is essential for identifying critical intervention periods and promoting healthy aging at the population level.

Global population aging has accelerated since the beginning of the 21st century, and China is experiencing particularly rapid demographic change. From 2011 to 2022, the older adult population in China increased from 122.77 million to 209.78 million, while the old-age dependency ratio rose from 11.9% to 21.8% [1]. Population aging is associated with declining work productivity (WP), rising healthcare expenditures, and labor shortages [2]. At the same time, the participation and importance of middle-aged and older adults in the labor market are becoming increasingly prominent [3, 4]. WP represents not only a driver of economic growth and social development but also an important expression of self-worth and social engagement among older adults. Understanding the dynamic changes in WP and health among middle-aged and older populations, as well as their interrelationship, is therefore critical for developing effective aging policies and interventions.

Although prior research has examined the association between productivity and health, most studies rely on cross-sectional data [5] or short-term follow-up periods of only two years [6, 7]. Moreover, many studies describe productivity using population averages [8–11]which obscures substantial individual heterogeneity [12]. Consequently, evidence on the long-term co-variation between productivity and health in middle-aged and older adults remains limited. Existing data and analytical approaches are insufficient to capture the dual dynamic relationship between WP and health across the aging process. The group-based dual trajectory model (GBDTM) addresses these limitations by identifying latent subgroups with distinct developmental patterns [13], thereby enabling more targeted policy and intervention strategies. In addition, life-course theory suggests that adult health and career trajectories are shaped by childhood experiences through cumulative and critical period mechanisms [14–17]. Accordingly, this study examines the association between childhood socioeconomic status (SES) and later-life trajectories of productivity and health, providing insights relevant to early-life interventions.

2. Literature Review

2.1 Work Productivity and Health

Work productivity refers to the efficiency and effectiveness with which tasks and activities are performed

in a work environment [18]. It can be operationalized through indicators such as performance, absenteeism, attendance, and retirement, which reflect the time, effort, and effectiveness individuals invest in their work [7, 11]. WP is closely intertwined with health. The Job Demands–Resources (JD-R) model proposes a dual-pathway framework through which work influences individuals: a health impairment pathway and a motivational pathway [19, 20]. For example, retirement has been shown to improve oral function and mental health but may simultaneously increase susceptibility to lifestyle-related diseases among older Japanese men [21]. Conversely, delayed retirement or post-retirement re-employment has been associated with improved physical and mental health among older adults in China [22–24], as well as better physical functioning and cognitive performance [25].

This relationship also varies across social contexts and demographic groups. Reduced employment opportunities and working hours have been linked to deteriorating health among middle-aged and older rural men [23, 26]. Employment may enhance mental health and social networks among disadvantaged populations, reflecting the inclusiveness of labor markets and social systems [27, 28]. From a role accumulation perspective, engagement in productive activities—whether paid or voluntary—can slow mental health decline in older adults, as multiple social roles provide additional supportive resources [29]. Conversely, good physical and mental health, together with social adaptability, are essential for maintaining high WP. Poor mental health has been associated with increased sick leave [30] and is a major contributor to early retirement among middle-aged men [31]. Even mild depressive symptoms can negatively affect productivity [32]. Among middle-aged and older adults, increased sick leave is linked to declines in physical health, mental well-being, and social participation [7]. Health impairments not only reduce individual productivity but also compound personal economic burdens over time [33, 34]. Physical health plays a significant role in late-career workforce withdrawal among older adults [35], and the rising prevalence of chronic disease is associated with diminished work capacity and productivity, although this effect appears less pronounced in rural populations [5, 6, 36]. Beyond biological aging, age discrimination and labor market stereotypes further constrain employment opportunities for middle-aged and older adults[11, 37], potentially exacerbating health inequalities.

2.2 The Role of Socio-economic Status in Childhood

Socioeconomic status (SES) refers to an individual's or family's position within the social and economic hierarchy and is commonly measured using indicators such as income, education, and occupation [38, 39]. A substantial body of research indicates that adverse childhood experiences and low SES are associated with elevated risks of illness and disease progression across the life course [16, 38, 40]. However, findings are not universally consistent; for example, a study conducted in Utah reported higher incidence rates among individuals from higher childhood SES backgrounds [41]. Childhood SES has been linked not only to the development of chronic disease and functional limitations but also to later-life productivity, as reflected in working hours and income [42–44]. In addition, low childhood SES may amplify the adverse effects of unemployment on substance misuse in adulthood [45].

Childhood SES shapes access to educational opportunities and social resources, thereby influencing long-

term career development. For instance, childhood economic hardship has been shown to affect occupational decision-making in adulthood [46]. Nevertheless, the impact of childhood SES is complex and not uniformly negative. Indicators such as parental occupational status can exert lasting effects on adult career attainment [42, 47].Conversely, exposure to socioeconomic adversity in childhood may, in some cases, foster resilience and adaptive coping capacities that contribute to later career success [48]. Importantly, the relationship between childhood SES and later-life outcomes varies across racial and gender groups and across countries with different income levels [16, 49], underscoring the need for research spanning diverse populations and life stages.

2.3 Current Study

This study contributes to life-course epidemiology by integrating early-life socioeconomic exposures with longitudinal trajectories of work productivity and multidimensional health in aging adults. By examining heterogeneity in developmental pathways, the study moves beyond population averages to identify vulnerable subgroups and potential windows for intervention. Such evidence is essential for informing primary prevention strategies that support sustainable employment, reduce the burden of chronic disease, and promote equitable and healthy aging.

Active aging emphasizes enabling individuals to realize their physical, mental, and social potential throughout the life course [50].Using longitudinal cohort data spanning seven years, this study applies a group-based dual trajectory model (GBDTM) to examine long-term trajectories of work productivity (WP) and multidimensional health (MH), encompassing physical, mental, and social domains. The analysis further investigates the association between childhood socioeconomic status (SES) and membership in distinct trajectory groups. Consistent with prior recommendations emphasizing midlife as a critical period for preventive intervention [51], the study focuses on adults aged 45 years and older to inform strategies that promote sustained work capacity and early prevention.

1. to identify distinct trajectory groups of work productivity and multidimensional health among middle-aged and older adults;
2. to examine the dynamic interrelationship between work productivity and multidimensional health trajectories; and
3. to assess the association between childhood socioeconomic status and trajectory group membership.

3. Methods

3.1 Data and Participants

This study utilized data from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative survey of individuals aged 45 years and older in China. CHARLS collects detailed microdata on individuals and households, providing robust coverage of demographic, health, and socioeconomic variables. The baseline survey was conducted in 2011, with follow-up waves in 2013, 2015, and 2018. A multi-stage probability sampling design was employed, including four sampling stages: county/district, village/community, household, and individual. Probability-proportional-to-size sampling

was applied at both the county/district and village/community stages. CHARLS was approved by the Biomedical Ethics Committee of Peking University (IRB00001052-11015), and all participants provided informed consent [52].

For the present study, data from the 2011, 2013, 2015, and 2018 waves were used. Participants younger than 45 years at baseline were excluded, as were individuals with missing data on work productivity (WP), multidimensional health (MH), or key demographic variables. Only participants with at least one follow-up survey after baseline were included, resulting in a final sample of 7,910 middle-aged and older adults. Exclusion criteria are detailed in Supplementary Material A (Figure A1). Among the included participants, 2,099 individuals (26.5%) had complete WP and MH data for two waves, 2,697 individuals (34.1%) for three waves, and 3,114 individuals (39.4%) for all four waves.

3.2 Measures

3.2.1 Work Productivity

Work productivity (WP) was operationalized as a composite measure reflecting both work capacity and labor force attachment, an approach commonly used in public and occupational health research among middle-aged and older adults [7, 53]. In the context of large-scale population surveys and aging populations, WP was assessed using two indicators: retirement status and health-related work absence.

Retirement status was determined based on the question, “Have you completed retirement procedures, including early or voluntary retirement?” (0 = No, 1 = Yes). Among older adults, retirement status is widely employed as a proxy for reduced or discontinued work productivity, reflecting withdrawal from productive activities due to health limitations, institutional arrangements, or age-related changes in work capacity.

Health-related work absence was measured as the number of sick days in the past year, based on the question, “How many days in the past year have you been unable to work due to health reasons?” (range: 0–365 days). For respondents engaged in multiple forms of employment, the average number of sick days across all reported work types was calculated to capture overall productivity loss attributable to health problems [5]. Sick leave is consistently recognized in public health research as a reliable indicator of reduced work capacity and productivity.

3.2.2 Multidimensional Health

Multidimensional health (MH) was assessed across three domains: physical health, mental health, and social participation. Compared with limitations in activities of daily living (ADL), previous studies suggest that measuring physical health through functional limitations reduces cultural bias and enhances applicability in aging research [54, 55]. Accordingly, seven functional limitation items from CHARLS were used to evaluate physical health. Respondents reported difficulties in tasks such as “walking 100 meters” or “standing up after sitting for a long time” on a 4-point scale (1 = no difficulty, 4 = inability to perform the task). The total physical health score ranged from 7 to 28, with higher scores indicating greater functional impairment.

Mental health was assessed using the 10-item Center for Epidemiologic Studies Depression Scale

(CESD-10) [34, 56]. Items were rated on a 4-point scale (1 = rarely or none of the time, 4 = most of the time), yielding a total score of 10–40, with higher scores reflecting more severe depressive symptoms.

Social health was measured by participation in ten social activities, such as "interacting with friends" and "engaging in voluntary or charity work" [57]. Each activity was scored 1 for participation and 0 for non-participation, resulting in a total score ranging from 0 to 10, with higher scores indicating greater social engagement.

To derive composite MH and WP indices, secondary indicators were first min-max normalized to account for differences in scale. Since higher physical and mental health scores indicate worse status, their normalized values were reversed (1 – normalized score) to align with the direction of social participation. Following prior methods [26], the arithmetic mean of the normalized secondary indicators was calculated to generate the MH and WP indices. Higher WP scores indicate greater work productivity, while higher MH scores reflect better overall health. Detailed calculation formulas are provided in Supplementary Material A (Formulas A2 and A3), and measurement items are listed in Supplementary Material A, Table A1.

3.2.3 Socio-economic Status in Childhood

Childhood socioeconomic status (SES) was obtained from the 2014 CHARLS life history survey. Based on data availability and prior studies [15, 40], childhood SES was operationalized using six indicators: mother's occupation before age 16 (agricultural, non-agricultural), mother's education (illiterate, literate), father's occupation (agricultural, non-agricultural), father's education (illiterate, literate), self-perceived family economic status relative to the community (1 = much better, 5 = much worse), and residence before age 16 (urban, rural). Missing values ranged from 0.0% to 15.8% across indicators and were handled using five-fold multiple imputation, consistent with previous CHARLS studies [58].

3.2.4 Covariates

Baseline covariates included age, sex (male, female), marital status (married, unmarried), and educational attainment (illiterate, primary, secondary, or higher).

3.3 Statistical Analysis

Continuous variables were summarized using means and standard deviations, while categorical variables were described using counts and percentages.

Group-based trajectory modeling (GBTM) is a finite-mixture modeling technique that estimates latent trajectory groups based on nonparametric and semiparametric methods using maximum likelihood estimation [59]. In this study, a censored normal distribution was used to fit the models. The modeling process involved two main steps: first, determining the optimal number of trajectory groups, and second, selecting the polynomial order (linear, quadratic, or cubic) for each group. Model selection was guided by multiple criteria, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), average posterior probability (AvePP), and odds of correct classification (OCC) [60]. Models were considered acceptable if the smallest trajectory group included at least 3% of the sample, balancing model parsimony and interpretability [61, 62].

After identifying the optimal single-trajectory models for work productivity (WP) and multidimensional health (MH), we applied the group-based dual trajectory model (GBDTM) to examine the joint development of these outcomes. The dual-trajectory model was initialized using the number of groups from each single-trajectory model. Three types of conditional and joint probabilities were estimated: (a) the probability of membership in MH trajectory groups conditional on WP trajectory, (b) the probability of membership in WP trajectory groups conditional on MH trajectory, and (c) the joint probability of membership in both WP and MH trajectories.

To assess the influence of childhood socioeconomic status (SES) on trajectory group membership, multinomial logistic regression models were fitted. Associations were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was defined as $p < 0.05$ (two-tailed).

Sensitivity analyses were conducted to evaluate the robustness of the findings. Specifically, the primary analyses were repeated using only participants with complete data across all four waves, following methods established in previous studies [63].

4. Results

4.1 Trajectories of Work Productivity

A series of group-based trajectory models were fitted to identify distinct work productivity (WP) trajectories. Based on model fit indices and interpretability, three quadratic trajectory groups were selected (see Supplementary Material B, Tables B2–B4). The average posterior probability (AvePP) for each group exceeded 0.7, and the odds of correct classification (OCC) were greater than 0.5. The proportion of individuals assigned to each trajectory group, based on posterior probabilities, was greater than 4%. The three WP trajectories were labeled as “low” (4.8%), “decreasing” (5.2%), and “high” (90.1%), as illustrated in Figure 1.

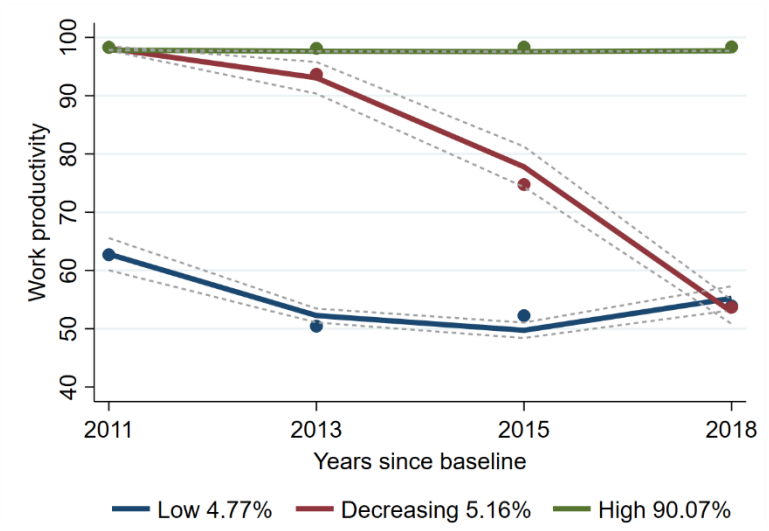

Figure 1. Trajectory of Work Productivity

4.2 Baseline Sample Characteristics by Work Productivity Trajectory

The analytic sample included 7,910 participants, of whom 53.5% were women and 46.5% were men, with a mean age of 55.9 years (SD = 7.6). Most participants had a primary school education (42.0%). Detailed sample characteristics are presented in Supplementary Material B, Table B1.

In the "low" WP group, 83.9% of participants had mothers who were illiterate during childhood (n = 329), whereas approximately half of the participants had fathers with non-illiterate education (50.8%). Most parents were engaged in agriculture (63.0% of mothers, 57.7% of fathers). Participants in the "low" WP group also reported the poorest childhood family economic conditions. Across the three WP trajectories, the majority of participants lived in urban areas before age 16: 310 (79.1%), 273 (86.9%), and 6,952 (96.5%), respectively (see Supplementary Material B, Table C1).

4.3 Work Productivity Trajectories and Childhood Socioeconomic Status

Table 1 presents the associations between WP trajectories and childhood socioeconomic status (SES). Compared to the "high" WP trajectory group, each additional year of age increased the likelihood of belonging to the "low" WP trajectory (OR = 1.13, 95% CI: 1.11–1.14) and the "decreasing" WP trajectory (OR = 1.03, 95% CI: 1.01–1.05). Participants whose parents worked in agriculture had higher odds of being in the "low" WP trajectory (OR = 0.50, 95% CI: 0.30–0.82). Participants with fathers employed in agriculture had higher probabilities of following the "low" (OR = 0.67, 95% CI: 0.48–0.93) or "decreasing" (OR = 0.66, 95% CI: 0.48–0.92) WP trajectories. Furthermore, participants who resided in rural areas before age 16 were more likely to be in the "low" (OR = 3.70, 95% CI: 2.36–5.80) and "decreasing" (OR = 2.51, 95% CI: 1.43–4.41) WP trajectories compared with the "high" trajectory.

Table 1. The Association between Childhood Socioeconomic Status and Work Productivity Trajectories

Subgroup	Low		Decreasing	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.13 (1.11-1.14)	<0.001	1.03 (1.01-1.05)	0.001
Sex	Ref		Ref	
Female				
Male	0.96 (0.75-1.23)	0.756	0.77 (0.6-0.98)	0.035
Education				
Illiterate	Ref		Ref	
Primary school	2.37 (1.61-3.47)	<0.001	1.61 (1.10-2.37)	0.015
Secondary school	6.58 (4.34-9.96)	<0.001	3.73 (2.48-5.61)	<0.001
Marital				
Unmarried	Ref		Ref	
Married	1.91 (1.16-3.16)	0.011	1.08 (0.66-1.76)	0.755

Childhood SES				
Mother's education				
Literate	Ref		Ref	
Illiterate	1.16 (0.82-1.65)	0.400	1.36 (0.93-2.01)	0.110
Father's education				
Literate	Ref		Ref	
Illiterate	0.82 (0.65-1.04)	0.102	0.89 (0.69-1.14)	0.359
Mother's occupation				
Non-agricultural	Ref		Ref	
Agricultural	0.50 (0.30-0.82)	0.006	0.98 (0.45-2.10)	0.95
Father's occupation				
Non-agricultural	Ref		Ref	
Agricultural	0.67 (0.48-0.93)	0.015	0.66 (0.48-0.92)	0.013
Primary residence				
Urban	Ref		Ref	
Rural	3.70 (2.36-5.80)	<0.001	2.51 (1.43-4.41)	0.002
Financial situation of the family	0.89 (0.78-1.02)	0.080	0.99 (0.86-1.14)	0.869

[a] Abbreviation. Ref: Reference; OR: Odds ratio; CI: Confidence interval; SES: Socio-economic status.

[b] Note. The "high" work productivity trajectory group is the reference group.

4.4 Trajectories of Multidimensional Health

Considering various indicators and the interpretability of models, we selected three MH trajectories, each comprising a cubic model. See Table C2-C4 in Supplementary material C for the evaluation of the fitting effects for each group. The three MH trajectory groups were "decreasing" (9.18%), "moderate" (36.90%), and "high" (53.93%), as illustrated in Figure 2.

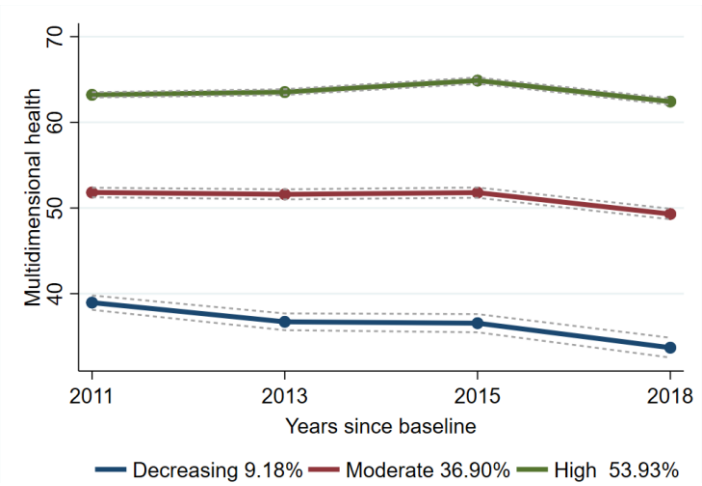

Figure 2. Trajectory of Multidimensional Health

4.5 Baseline Sample Characteristics by Multidimensional Health Trajectory

Participants in the "decreasing" MH trajectory had the highest mean age (58.8 ± 7.7 years). In this group, over half of participants' mothers (83.9%) and fathers (81.0%) were engaged in agriculture during childhood. In contrast, the "high" MH trajectory included the largest proportion of individuals reporting social support (73.9%), while a high proportion of parents were illiterate (mothers: 94.4%; fathers: 71.0%). Perceived childhood family economic status was highest in the "decreasing" MH trajectory (mean = 3.56 ± 0.96), compared with the "moderate" (3.66 ± 0.97) and "high" (3.45 ± 0.93) trajectories. Detailed characteristics are provided in Supplementary Material C, Table C1.

4.6 Multidimensional Health Trajectories and Childhood Socioeconomic Status

Table 2 presents associations between childhood SES and MH trajectory membership. Compared with the "high" MH trajectory, participants with illiterate mothers had higher odds of being in the "low" MH group (OR = 1.52, 95% CI: 1.04–2.23). Participants with illiterate fathers had increased probabilities of membership in the "low" (OR = 1.47, 95% CI: 1.06–2.03) and "moderate" (OR = 1.18, 95% CI: 1.06–1.32) MH trajectories. Participants whose fathers were engaged in agriculture had higher odds of being in the "decreasing" MH trajectory (OR = 1.16, 95% CI: 0.84–1.61). Participants residing in rural areas during childhood showed lower probabilities of belonging to the "decreasing" MH trajectory (OR = 0.16, 95% CI: 0.05–0.53) and moderate probabilities for the "moderate" MH trajectory (OR = 0.55, 95% CI: 0.38–0.78).

Table 2. The Association between Childhood Socioeconomic Status and Multidimensional Health Trajectories

Subgroup	Low		Moderate	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.05 (1.04-1.07)	<0.001	1.03 (1.03-1.04)	<0.001
Sex				
Female	Ref		Ref	
Male	0.26 (0.21-0.32)	<0.001	0.47 (0.42-0.53)	<0.001
Education				
Illiterate	Ref		Ref	
Primary school	0.78 (0.64-0.95)	0.014	0.91 (0.80-1.04)	0.169
Secondary school	0.3 (0.22-0.40)	<0.001	0.46 (0.39-0.54)	<0.001
Marital				
Unmarried	Ref		Ref	
Married	0.59 (0.44-0.79)	<0.001	0.77 (0.63-0.94)	0.011
Childhood SES				
Mother's education				

Literate	Ref		Ref	
Illiterate	1.52 (1.04-2.23)	0.032	1.10 (0.93-1.31)	0.262
Father's education				
Literate	Ref		Ref	
Illiterate	1.47 (1.21-1.79)	<0.001	1.18 (1.06-1.32)	0.003
Mother's occupation				
Non-agricultural	Ref		Ref	
Agricultural	0.93 (0.43-1.99)	0.842	1.02 (0.69-1.51)	0.920
Father's occupation				
Non-agricultural	Ref		Ref	
Agricultural	1.16 (0.84-1.61)	0.358	1.2 (1.02-1.43)	0.032
Primary residence				
Urban	Ref		Ref	
Rural	0.16 (0.05-0.53)	0.003	0.55 (0.38-0.78)	0.001
Financial situation of the family	1.38 (1.26-1.51)	<0.001	1.17 (1.10-1.23)	<0.001

[c] Abbreviation. Ref: Reference; OR: Odds ratio; CI: Confidence interval; SES: Socio-economic status.

[d] Note. The “high” multidimensional health trajectory group is the reference group.

4.7 Dual Trajectories of Work Productivity and Multidimensional Health

The joint trajectories of work productivity (WP) and multidimensional health (MH) are summarized in Table 3.

As shown in Part A, participants in the “low” WP trajectory had a 75.9% probability of belonging to the “high” MH trajectory. Those in the “decreasing” WP trajectory were most likely to follow the “moderate” MH trajectory (66.8%). Participants in the “high” WP trajectory had a 0% probability of being in the “decreasing” MH trajectory and an 86.1% probability of following the “high” MH trajectory.

Part B presents the conditional probabilities of WP trajectory membership given MH trajectories. Individuals in the “decreasing” MH trajectory were highly likely to belong to the “decreasing” WP trajectory (96.4%) and had a 0% probability of following the “high” WP trajectory. Conversely, participants in the “high” MH trajectory were most likely to follow the “high” WP trajectory (82.4%).

Part C illustrates the joint distribution of WP and MH trajectories over time. The largest subgroup (44.6%) comprised participants classified as “high” WP and “high” MH. The second-largest group (28.0%) included participants in the “decreasing” WP and “moderate” MH trajectories. The third-largest group (9.2%) represented participants with “low” WP and “moderate” MH trajectories, while the fourth-largest group (7.2%) also consisted of participants in the “low” WP and “moderate” MH trajectories. These results indicate long-term, mutually related patterns of change between work productivity and multidimensional health among middle-aged and older adults.

Table 3. Conditional and Joint Probabilities of Work Productivity and Multidimensional Health

Trajectory of work productivity	Trajectory of multidimensional health		
	Decreasing	Moderate	High
A) Probability of work productivity conditional on multidimensional health			
Low	5.4%	18.7%	75.9%
Decreasing	22.0%	66.8%	11.3%
High	0.0%	13.9%	86.1%
B) Probability of multidimensional health conditional on work productivity			
Low	3.6%	3.3%	8.9%
Decreasing	96.4%	77.0%	8.7%
High	0.0%	19.8%	82.4%
C)Probability of joint work productivity and multidimensional health			
Low	0.3%	9.2%	0.0%
Decreasing	1.2%	28.0%	7.2%
High	4.8%	4.7%	44.6%

4.8 Sensitivity Analysis

We replicated the main analysis using data from participants with complete measurements of WP and MH over all four rounds. The results, detailed in Supplementary material D, showed no significant changes compared to the principal analysis. Therefore, we can consider the research findings to be robust.

5. Discussion

This study applied a group-based dual-trajectory model to examine the long-term trajectories and dynamic associations of work productivity (WP) and multidimensional health (MH) among middle-aged and older adults, as well as the influence of childhood socioeconomic status (SES) on these trajectories. Over the seven-year follow-up, three distinct trajectories were identified for both WP ("low," "decreasing," and "high") and MH ("decreasing," "moderate," and "high"). The distribution of MH trajectories was consistent with previous analyses using CHARLS 2018, with most participants maintaining good health [57]. Similarly, most participants exhibited high work productivity. Overall, WP and MH trajectories tended to evolve in parallel, with higher WP associated with better health and "decreasing" MH trajectories corresponding to "decreasing" WP trajectories over time.

Notably, some individuals in the "low" WP trajectory also followed the "high" MH trajectory, suggesting that the relationship between work and health is complex and multidirectional [64]. Low productivity may mitigate exposure to workplace stressors, such as excessive demands or age-related discrimination [37], and, when income is sufficient to cover health expenses, it may contribute to better health outcomes. Therefore, consistent with prior studies [22, 25, 65], we argue that continued occupational engagement

in later life does not uniformly benefit health, and considerable heterogeneity exists across subgroups.

Childhood SES was significantly associated with WP trajectories, although the effects varied by specific SES indicators. Similar findings in Japan have shown that subjective social status, childhood victimization, and parental upbringing practices influence adult productivity, as reflected in work attendance [66–68].In this study, participants whose mothers or fathers worked in agriculture were less likely to follow the "low" or "decreasing" WP trajectories, potentially reflecting the transmission of strong work ethics from parents involved in agricultural labor [69, 70]. Conversely, participants who resided in rural areas before age 16 were more likely to belong to the "low" or "decreasing" WP trajectories, likely due to historically limited access to healthcare and nutrition, which can adversely affect long-term physical health and work capacity [15, 40], , where childhood malnutrition and inadequate healthcare could negatively impact physical health and long-term workability. For example, evidence from Guatemala demonstrates that childhood nutrition and healthcare directly influence adult productivity [71].No significant associations were observed between parental education and adult WP trajectories in this cohort.

Regarding MH trajectories, parental illiteracy was associated with a higher likelihood of following a "decreasing" mental health trajectory. Consistent evidence from China indicates that parental illiteracy may negatively impact adult health outcomes, such as lung function [39]. Limited parental education may contribute to adverse lifestyle and academic practices, with long-term implications for both physical and mental health [43, 72]. Interestingly, participants who lived in rural areas during childhood were less likely to experience "decreasing" or "moderate" MH trajectories. This finding aligns with prior research suggesting that childhood exposure to socioeconomic adversity may foster resilience, which can confer protective effects on later-life health, including dental outcomes [48]. Additionally, participants who perceived their childhood economic conditions as poorer were more likely to follow "decreasing" or "moderate" MH trajectories, possibly due to the cumulative impact of relative deprivation during childhood. Chronic psychological stress in such contexts can elevate cortisol levels and contribute to multiple health declines in adulthood [73, 74].

5.1 Theoretical Implications

Prior research has predominantly focused on the effects of retirement or early retirement on health outcomes, yet these approaches may have limited scope for broader inference. By incorporating both retirement status (including early and internal retirement) and health-related work absence (sick leave days), our study extends the existing literature and provides a more comprehensive perspective on work productivity in later life. While previous studies have established that physical and mental health negatively affect productivity, our analysis of longitudinal covariance trajectories across four waves further demonstrates how multidimensional health—including physical, mental, and social domains—interacts with work productivity over time. Notably, the inclusion of social participation as a health dimension offers a more holistic assessment of older adults' well-being, consistent with the World Health Organization's framework for active aging and health. Compared with previous latent class analyses of

multidimensional health among older adults [57], the group-based dual trajectory modeling approach employed here more accurately identifies latent trajectory groups and characterizes their development over time.

From a life-course perspective, individual development is a dynamic process shaped by early experiences, environmental exposures, and personal traits. Our findings indicate that childhood socioeconomic status significantly influences adult work productivity, providing empirical support for the life-course theory hypothesis that early-life conditions have long-term consequences for later-life functional and occupational outcomes.

5.2 Practical Implications

From a public health perspective, our findings support the objectives of sustainable and equitable aging as outlined in the United Nations Sustainable Development Goal 3. Childhood socioeconomic disadvantage exerts long-lasting effects on health and work productivity, highlighting the need for upstream social interventions. Policies aimed at reducing childhood inequality, improving access to education and healthcare, and promoting healthy work participation may yield long-term benefits across the life course and alleviate the burden of chronic disease in aging populations.

This study also identified distinct patterns of work productivity (WP) and multidimensional health (MH) among middle-aged and older adults in China. First, interventions should prioritize individuals experiencing declines in health and productivity. Compared with those consistently exhibiting low work productivity, participants with gradually decreasing efficiency often face broader health challenges. Although a healthy worker effect may exist, their health can deteriorate over time even under favorable labor-market conditions. Ensuring that older adults maintain good health is essential for sustaining productive engagement.

Second, policymakers should consider heterogeneity in productivity and health trajectories when designing retirement policies. Flexibility and targeted interventions are crucial for supporting diverse subgroups in the population. Finally, enhancing socioeconomic conditions during childhood can mitigate later-life declines in productivity and health, thereby reducing societal and economic burdens associated with population aging.

5.3 Limitations and Future Research

Several limitations should be acknowledged. First, this study examined only correlational relationships among the developmental trajectories of work productivity (WP) and multidimensional health (MH). While these associations indicate the direction and strength of co-variation over time, they do not establish causality. Future research should investigate causal mechanisms underlying these trajectories, potentially employing advanced methods such as GBTM for causal inference [75].

Second, missing data on key variables and baseline demographics led to the exclusion of some participants, which may have introduced selection bias and limited the representativeness of the sample. To address these issues, future studies should incorporate diverse data sources, including both qualitative and quantitative information, to obtain a more comprehensive and objective understanding of the long-

term development of productivity and health. Such approaches can reduce reliance on single datasets and mitigate potential biases.

6. Conclusion

This study demonstrates that older adults follow three distinct trajectories for both work productivity and multidimensional health, which are dynamically interrelated over time. In most cases, WP and MH trajectories progress in parallel; however, some individuals with low work productivity may maintain high levels of multidimensional health. Childhood socioeconomic status is associated with these developmental trajectories, highlighting the long-term influence of early-life conditions on later-life outcomes.

Given the global trend of population aging, understanding the heterogeneity and co-development of productivity and health among older adults, along with their association with childhood socioeconomic circumstances, is essential for designing effective, multifaceted interventions that promote healthy and productive aging.

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