Geriatrics & Gerontology International

ORIGINAL ARTICLE

EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Longitudinal Interplay Between Cognitive Impairment and Frailty: A Dual Trajectory Analysis Among Chinese Older Adults

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Received: 21 January 2026 | **Revised:** 2 April 2026 | **Accepted:** 28 April 2026

Keywords: bidirectional associations | cognitive impairment | dual trajectories | frailty | risk factors

ABSTRACT

Background: Cognitive impairment and frailty are prevalent in older adults, yet their longitudinal interplay and determinants remain underexplored, particularly in Chinese populations. This study aims to characterize the trajectories of cognitive function and frailty, examine their bidirectional associations, and identify the risk factors driving their progression.

Methods: We analyzed data from 4805 adults aged ≥ 65 years from the Chinese Longitudinal Healthy Longevity Survey (2011–2018). Cognitive function was assessed using the Chinese Mini-Mental State Examination, and frailty status was measured according to the modified Fried criteria. Group-based trajectory modeling was applied to identify longitudinal patterns, and trajectories were named according to validated cutoff values. Dual-trajectory analysis was employed to examine their interrelationships, and multinomial logistic regression was utilized to identify predictors of adverse trajectories.

Results: Three cognitive trajectories were identified: stably high cognition (82.6%), progressive cognitive decline (12.3%), and persistently low cognition (5.1%). Five frailty trajectories were found: non-frail (48.1%), fluctuating pre-frailty (17.2%), reversible frailty (6.9%), progressive frailty (11.4%), and stable frailty (16.4%). Cognitive impairment was more strongly associated with frailty progression than the reverse. Advanced age and female sex were shared risk factors for adverse trajectories. Among those with cognitive impairment, poverty and multimorbidity were associated with adverse frailty. Among frail participants, illiteracy, hearing loss, and poor sleep increased the risk of cognitive decline.

Conclusions: This study emphasized that cognitive impairment showed a stronger link to frailty progression than vice versa. Targeting key modifiable risk factors, such as poverty, illiteracy, multimorbidity, hearing loss, and sleep problems may help delay cognitive impairment and frailty, particularly among older women.

1 | Introduction

With the accelerating trend of global population aging, cognitive impairment and frailty in older adults have garnered increasing attention. Against this backdrop, the concept of cognitive frailty was proposed, defined as the simultaneous presence of frailty and cognitive impairment while excluding concurrent Alzheimer's disease or other forms of dementia [1]. This conceptual framework highlights the potential interrelationships between cognitive impairment and frailty. Research indicates that older adults with cognitive impairment are at high risk of experiencing frailty [2, 3]. Similarly, frail individuals tend to have lower baseline cognitive function and exhibit more rapid cognitive decline compared to their non-frail counterparts [4, 5].

Despite the known associations between these two conditions, the longitudinal dynamics of how they mutually relate to each other remain insufficiently understood. Group-based trajectory modeling (GBTM) has emerged as a robust method for characterizing developmental courses of health conditions over time [6]. GBTM is particularly effective in identifying heterogeneous subgroups within populations, revealing complex patterns of change, and capturing the mutual dynamics between overlapping conditions, such as cognitive decline and frailty. Previous studies in populations, including Mexican-Americans, Japanese older adults, and American nursing home residents, have demonstrated significant associations between cognitive and frailty trajectories [7–9]. These studies consistently found that a significant proportion of individuals following the progressive frailty trajectory also experience rapid cognitive decline, while other subgroups show patterns of stability. Notably, the identification of subgroups showing improvement highlights the potential reversibility of these conditions [9]. These applications of GBTM collectively highlight its utility in elucidating the complex relationships between cognitive impairment and frailty trajectories.

In China, several longitudinal studies have employed dual trajectory models to examine the co-development patterns of cognitive impairment and frailty. Two Chinese longitudinal studies demonstrated a co-development pattern between cognitive impairment and frailty, characterized by either synchronous stability or simultaneous decline [10, 11]. These studies also identified factors associated with such progression. However, a key limitation of these studies is their use of restricted dual trajectory models that assume symmetric development. Unlike the complete model that links trajectories through three sets of conditional probabilities [12], restricted models fail to capture the potential asymmetric mutual association, wherein one domain may be more strongly related to the other. This methodological limitation obscures the true nature of their dynamic relationship and hinders the identification of high-risk population subgroups with specific trajectory combinations. Therefore, a significant gap remains in understanding the dynamic changes within the Chinese aging population.

This study aimed to characterize the longitudinal trajectories of cognitive function and frailty among Chinese older adults and examine their bidirectional associations, while also identifying factors associated with adverse cognitive impairment and frailty trajectories. By addressing these objectives, our findings will provide crucial evidence for developing targeted prevention strategies tailored to the unique needs of China's rapidly aging population.

2 | Methods

2.1 | Design and Data Sources

The data for this study were obtained from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), the world's largest longitudinal survey of older adults, conducted by the Peking University Center for Healthy Aging and Development. The baseline survey was launched in 1998, covering 23 provinces, municipalities, and autonomous regions across China, and enrolling participants aged 65 years or older. Follow-up surveys were subsequently conducted in 2000, 2002, 2005, 2008, 2011, 2014, and 2018. This analysis specifically employed data from the 2011, 2014, and 2018 waves of CLHLS to capture longitudinal changes during 2011–2018.

This study utilized the 2011 CLHLS cohort as the baseline, with a total of 9765 participants. The inclusion criteria were: (1) aged 65 years or older at baseline; (2) completed at least one follow-up survey in 2014 or 2018. The exclusion criteria were: (1) diagnosed with dementia at baseline; (2) missing key variables on cognitive function or frailty status. The final sample consisted of 4805 participants.

2.2 | Measures

2.2.1 | Cognitive Function

Cognitive function was assessed using the Chinese version of the Mini-Mental State Examination (MMSE) [13]. MMSE is a widely used screening questionnaire for cognitive impairment in clinical and community settings. It consists of simple tasks spanning multiple domains, including orientation to time and place, word recall, arithmetic, language use and comprehension, and basic motor skills [14]. Scores range from zero to 30, with higher scores indicating better cognitive function. Based on previous CLHLS studies, a total MMSE score below 24 points was used as the criterion for qualitative classification labels of cognitive trajectories [15, 16].

2.2.2 | Frailty Status

Frailty status was assessed using the modified Fried criteria, one of the two main frailty assessment instruments [17], including shrink, weakness, exhaustion, inactivity, and low physical activity [18]. Body mass index (BMI) $<18.5\,kg/m^2$ was defined as shrink. Responding "some difficulty" or "cannot" to the question "Can you lift a five kg object?" was defined as weakness. Responding "always", "often", or "sometimes" to the question "Do you feel old and useless?" was defined as exhaustion. Inactivity was defined as participating in household, outdoor, or social activities once per week or less. Low physical activity was defined as being unable or having difficulty walking 1 kilometer continuously [19]. Each component was treated as a dichotomous variable, with "yes" responses scored as 1 point and "no" responses as zero points. The total score ranged from zero to five, where zero indicated robust, one to two indicated prefrailty, and three or above indicated frailty.

2.2.3 | Covariates

Covariates collected at baseline included age, sex, education level, residence, marital status, economic status, multimorbidity, drinking status, smoking status, vision impairment, hearing impairment, regular exercise, and quality of sleep. Marital status

TABLE 1 | Participant's baseline characteristics ($N = 4805$).

Characteristics	*N* (%)
Age	
65–74	1629 (33.90)
75–85	1626 (33.84)
> 85	1550 (32.26)
Sex	
Female	2510 (52.24)
Male	2295 (47.76)
Education	
Illiterate	2528 (52.61)
Literate	2277 (47.39)
Residence	
Rural area	2580 (53.69)
City	2225 (46.31)
Marital status	
Unmarried	2476 (51.53)
Married	2321 (48.30)
Missing	8 (0.17)
Economic status	
Poor	721 (15.01)
Normal	3212 (66.85)
Rich	850 (17.69)
Missing	22 (0.46)
Multimorbidity	
No	3319 (69.07)
Yes	1486 (30.93)
Drinking status	
No	3838 (79.88)
Yes	927 (19.29)
Missing	40 (0.83)
Smoking status	
No	3781 (78.69)
Yes	1010 (21.02)
Missing	14 (0.29)
Vision impairment	
No	3448 (71.76)
Yes	1316 (27.39)
Missing	41 (0.85)
Hearing impairment	
No	3029 (63.04)
Yes	1765 (36.73)
Missing	11 (0.23)
Regular exercise	
No	2878 (59.90)
Yes	1876 (39.04)
Missing	51 (1.06)
Quality of sleep	
Bad	620 (12.90)
General	1182 (24.60)
Good	3001 (62.46)
Missing	2 (0.04)

was categorized as married or unmarried, with unmarried including separated, divorced, widowed, or never married [15]. Multimorbidity was assessed based on self-reported physician-diagnosed diseases, including hypertension, diabetes, heart disease, and 21 other conditions. Each reported disease was scored one, otherwise zero, with a total score equal to or greater than two indicating multimorbidity. "Blindness", "unable to see clearly" and "unable to distinguish the gap in a circle" were defined as vision impairment. Self-reported hearing difficulty was defined as hearing impairment.

2.3 | Statistical Analysis

Participant characteristics were described using frequencies and percentages. GBTM was employed to identify trajectories of cognitive function and frailty status among participants from 2011 to 2018. GBTM is a model-based clustering approach designed to identify latent heterogeneous subgroups with similar longitudinal developmental trajectories within a population [20]. Model fit was evaluated using the Bayesian Information Criterion (BIC), average posterior probability of assignment (APPA), smallest group%, odds of correct classification (OCC), and entropy. Smaller absolute values of BIC indicate better balance between model goodness-of-fit and complexity. APPA > 0.7 for all trajectories and smallest group% exceeding five% demonstrated good model adequacy [12]. Entropy close to one [21] and OCC greater than five for all trajectories [9] indicated high classification accuracy. After determining the number of trajectories, guided by the validated critical values of cognitive impairment [15] and frailty [18], qualitative labels were assigned to each trajectory.

Full dual trajectory model was used to quantify the bidirectional associations between cognitive trajectories and frailty trajectories [6]. This model linked the membership of the cognitive function trajectories and frailty trajectories through three sets of conditional probabilities [12]: (1) the probability of following each cognitive function trajectory conditional on each frailty trajectory; (2) the probability of following each frailty trajectory

conditional on each cognitive function trajectory; and (3) the joint probability of following the given frailty and cognitive function trajectories [9].

A multinomial logistic model was used to analyze frailty-related factors in the subgroup with adverse cognitive impairment and cognitive impairment-related factors in the subgroup with adverse frailty. $P<0.05$ were considered statistically significant. All analyses were performed using R 4.4.2. This study followed the Guidelines for Reporting on Latent Trajectory Studies (GRoLTS) checklist [22] (Table S1).

3 | Results

3.1 | Baseline Characteristics of Participants

This study included 4805 participants with comparable proportions across age groups (Table 1). Approximately half of the participants were female, illiterate, living in rural areas, and married. The majority reported normal economic status. Multimorbidity was present in 30.93% of participants, while 27.39% had vision impairment and 36.73% had hearing impairment. Most participants reported being non-smokers and non-drinkers. Only 39.04% engaged in regular exercise, and 62.46% reported good sleep quality.

To assess attrition-related selection bias, baseline characteristics of included and excluded participants were compared (Table S2). Excluded individuals were older, female, illiterate, unmarried, had multimorbidity or sensory impairments, engaged in less exercise, and were less likely to smoke or drink alcohol.

3.2 | Number of Trajectories of Cognitive Function and Frailty

GBTM with two to six trajectories was evaluated to determine the optimal number of trajectories for cognitive function and frailty (Table S3). Increasing the number of trajectories to four yielded the smallest group % of 4.70%, confirming suboptimal model adequacy. The three-group solution exhibited the highest entropy, closest to one, with the minimal classification error, establishing it as the optimal choice for cognitive function trajectories. As shown in Figure 1, the distribution patterns comprised 82.62% of stably high cognition, 12.28% of progressive cognitive decline, and 5.10% of persistently low cognition.

For frailty, expanding to six trajectories led to an APPA of 0.57 and an OCC of 4.55, reflecting insufficient model adequacy and poor classification quality. Five trajectories were consequently retained, including 48.12% non-frailty, 17.15% fluctuating pre-frailty, 6.93% reversible frailty, 11.40% progressive frailty, and 16.40% stable frailty (Figure 1).

3.3 | Full Dual Trajectory Model of Cognitive Function and Frailty

The full dual trajectory model revealed varying degrees of mutual associations between cognitive impairment and frailty (Figure 2). Within each frailty trajectory, the probability of following the stably high cognition trajectory was consistently the highest, followed by the progressive cognitive decline trajectory, and finally the persistently low cognition trajectory. Conversely, among participants in the stably high cognition trajectory, 55.97% followed the non-frailty trajectory. In contrast, the other two cognitive function trajectories showed the highest probabilities of following the stable frailty trajectory, with fluctuating pre-frailty being the second most common pattern. Notably, 46.24% of participants followed both stably high cognition and non-frailty trajectories simultaneously.

3.4 | Associated Factors of Adverse Trajectory

This study examined factors linked to frailty progression in the adverse cognitive cognition trajectory, using the non-frailty

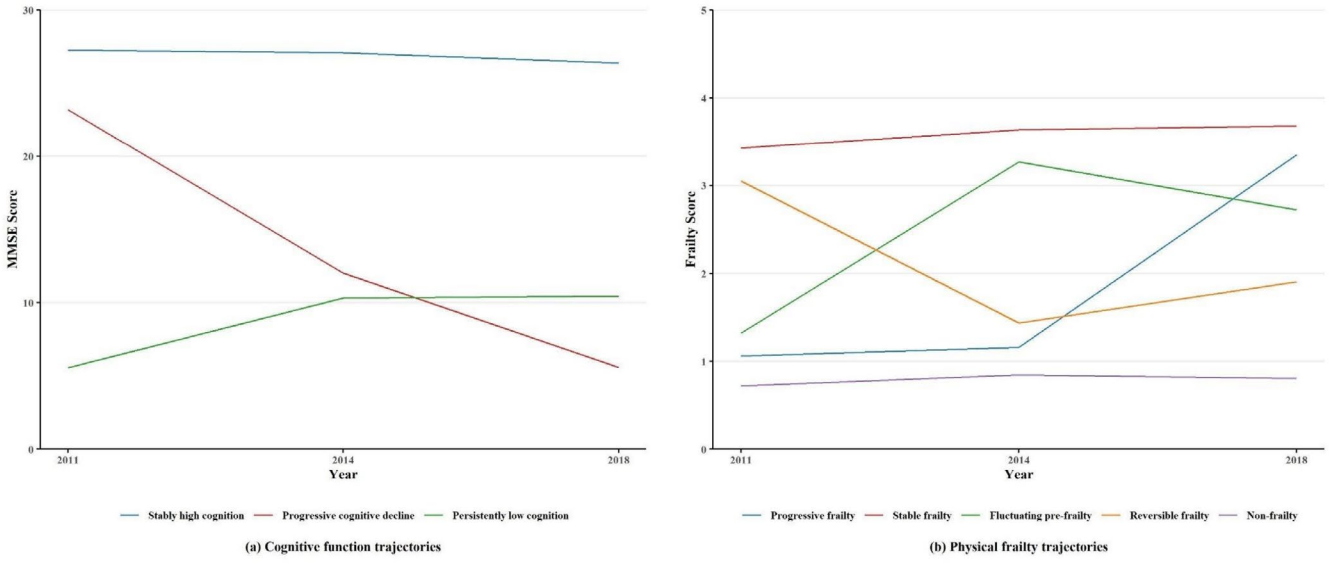

FIGURE 1 | The trajectories of cognitive function and frailty from 2011 to 2018, MMSE: Mini-mental state examination.

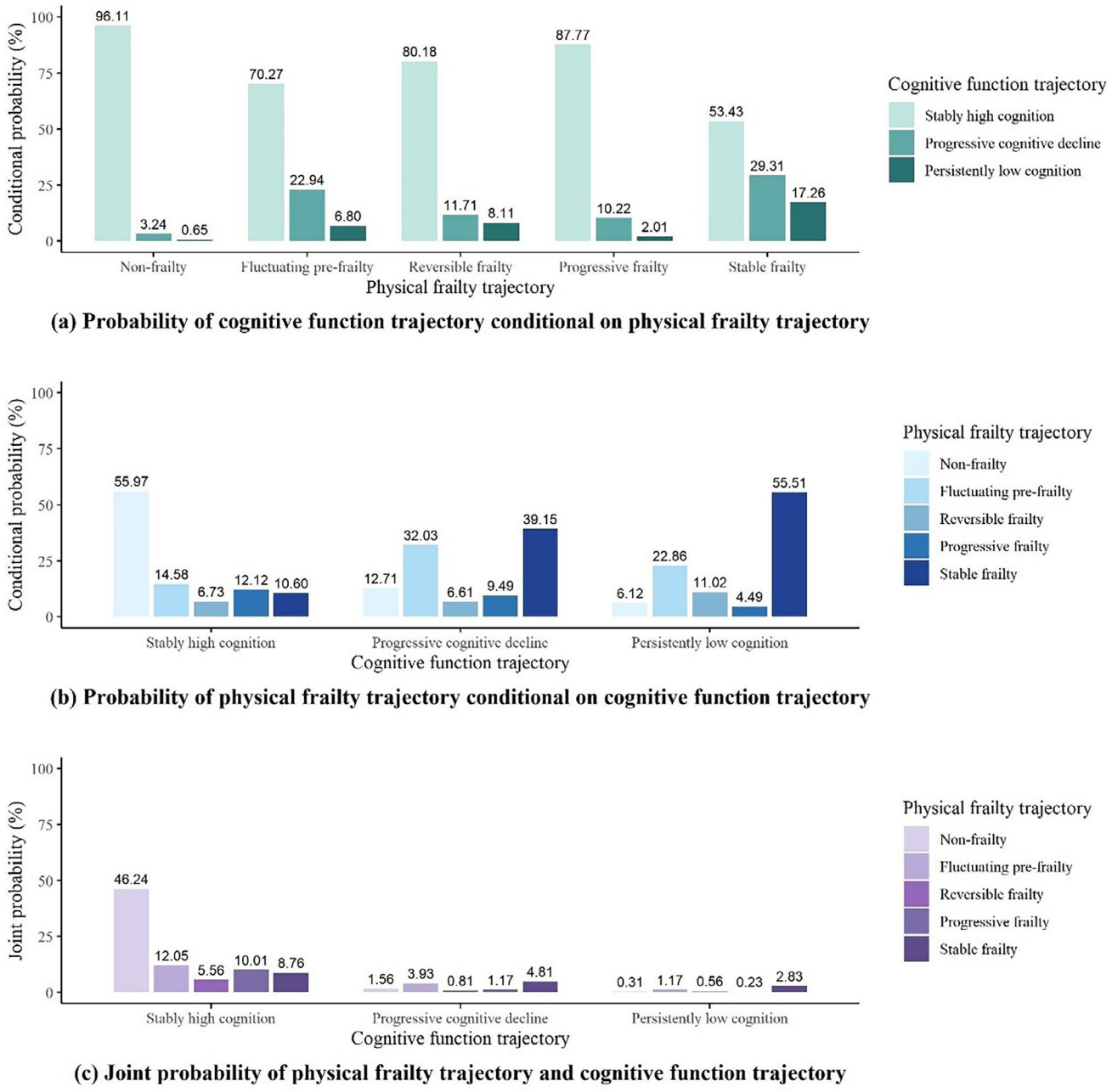

FIGURE 2 | Full dual trajectory model of cognitive function and frailty.

trajectory as the reference (Table 2). Dynamic frailty (characterized by combined fluctuating pre-frailty and reversible frailty trajectories) and persistent frailty (characterized by combined progressive and stable frailty trajectories) were significantly associated with advanced age, female sex, poverty, and multimorbidity. Participants over 85 years old had higher risks of dynamic (OR: 4.33, 95% CI: 1.61–11.57) and persistent frailty (OR: 6.96, 95% CI: 2.43–19.98) compared to those aged 65–74. Women had elevated risks (dynamic: OR: 2.15, 95% CI: 1.06–4.37; persistent: OR: 4.12, 95% CI: 2.00–8.48) versus men. Poor economic status increased the likelihood of dynamic (OR: 3.29, 95% CI: 1.33–8.14) and persistent frailty (OR: 2.56, 95% CI: 1.02–6.40), while multimorbidity was associated with higher risks (dynamic: OR: 2.01, 95% CI: 1.00–4.04; persistent: OR: 2.34, 95% CI: 1.16–4.72).

Similarly, cognitive impairment risk factors in the adverse frailty trajectory were analyzed using the stably high cognition trajectory as reference, with progressive cognitive decline and persistently low cognition trajectories combined as the cognitive impairment group (Table 3). Compared with stably high cognition, cognitive impairment showed significant associations with advanced age, female sex, illiteracy, hearing impairment, and poor sleep quality. Specifically, participants aged 75–85 years had 4.27 times higher risk (95% CI: 1.49–15.63) and those over 85 years had 9.91 times higher risk (95% CI: 3.42–36.64) relative to those aged 65–74 years. Women exhibited 2.12-fold greater risk than men (95% CI: 1.03–4.51). Hearing impairment was associated with a 4.10 times higher risk (95% CI: 2.21–7.81). Conversely, literate participants showed substantially lower risk compared to illiterates (OR = 0.25, 95% CI: 0.12–0.53), while

TABLE 2 | Frailty-related factors in the adverse cognitive function trajectory.

	Physical frailty trajectories (ref: Non-frailty)			
	Dynamic frailty		Persistent frailty	
Variables	**OR**	**95% CI**	**OR**	**95% CI**
Age				
65–74	(ref)		(ref)	
75–85	2.05	(0.80, 5.24)	2.72	(0.98, 7.55)
>85	4.33**	(1.62, 11.57)	6.96***	(2.43, 19.98)
Sex				
Male	(ref)		(ref)	
Female	2.15*	(1.06, 4.37)	4.12***	(2.00, 8.48)
Education				
Illiterate	(ref)		(ref)	
Literate	1.40	(0.71, 2.76)	1.13	(0.56, 2.28)
Residence				
Rural area	(ref)		(ref)	
City	0.70	(0.39, 1.23)	0.62	(0.35, 1.10)
Marital status				
Unmarried	(ref)		(ref)	
Married	1.11	(0.56, 2.19)	1.26	(0.63, 2.55)
Economic status				
Normal	(ref)		(ref)	
Poor	3.29*	(1.33, 8.14)	2.56*	(1.02, 6.40)
Rich	0.93	(0.43, 2.01)	1.02	(0.47, 2.22)
Multimorbidity				
No	(ref)		(ref)	
Yes	2.01*	(1.00, 4.04)	2.34*	(1.16, 4.72)
Drinking status				
No	(ref)		(ref)	
Yes	0.71	(0.35, 1.46)	0.46*	(0.21, 0.99)
Smoking status				
No	(ref)		(ref)	
Yes	1.12	(0.53, 2.34)	1.05	(0.48, 2.26)
Vision impairment				
No	(ref)		(ref)	
Yes	0.92	(0.50, 1.71)	1.58	(0.85, 2.91)
Hearing impairment				
No	(ref)		(ref)	
Yes	0.93	(0.52, 1.66)	1.12	(0.62, 2.02)

(Continues)

TABLE 2 | (Continued)

	Physical frailty trajectories (ref: Non-frailty)			
	Dynamic frailty		Persistent frailty	
Variables	**OR**	**95% CI**	**OR**	**95% CI**
Regular exercise				
No	(ref)		(ref)	
Yes	0.75	(0.42, 1.34)	0.60	(0.33, 1.08)
Quality of sleep				
Poor	(ref)		(ref)	
General	1.34	(0.47, 3.82)	1.10	(0.40, 3.05)
Good	1.79	(0.70, 4.58)	1.26	(0.50, 3.14)

Abbreviations: CI: Confidence interval, OR: Odds ratio.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

participants reporting general sleep quality had reduced risk compared to those with poor sleep quality (OR = 0.31, 95% CI: 0.10–0.92).

4 | Discussion

This study identified three distinct cognitive function trajectories and five frailty trajectories among Chinese older adults, revealing an asymmetric, bidirectional association in which cognitive impairment had a stronger link to frailty progression than the reverse. Advanced age and female sex emerged as shared risk factors for adverse trajectories of both conditions. Within the adverse cognitive function trajectory, frailty progression was associated with poverty and multimorbidity, whereas within the adverse frailty trajectory, cognitive impairment was associated with illiteracy, hearing impairment, and poor sleep quality.

The trajectory variations identified in this study highlight the complexity of cognitive function and frailty in older adults. However, the use of diverse assessment tools across studies presents challenges for making direct comparisons [23]. Some studies have focused solely on specific dimensions, such as memory or temporal orientation [9, 10], whereas the frailty index incorporates both physical frailty and cognitive components [21]. In addition, it is important to acknowledge construct overlap between commonly used frailty assessment tools and psychiatric diagnostic criteria. Some criteria of frailty, particularly weight loss and exhaustion, overlap significantly with the diagnostic criteria for conditions such as major depressive episode and generalized anxiety disorder [24]. This overlap may introduce confounding factors, as exhaustion reflects not only physical function but also psychological states, including depression, which is a known confounding factor that affects cognitive function and frailty. Notably, unlike previous Chinese trajectory studies that used restricted models, this study identified a unique subgroup with a reversible frailty trajectory. 93.69% of participants in this subgroup transitioned from frail to non-frail status. Among the five criteria, inactivity showed the highest improvement rate (86.13%), highlighting the importance of physical activity. This finding is consistent with previous studies, underscoring the potential reversibility of frailty [25]. Improvements in frailty may be associated with increased physical activity, better management of chronic diseases, and more frequent social participation [26, 27]. However, as all covariates in this study were measured at baseline and time-varying factors were not captured, it is not possible to directly identify the specific interventions or environmental changes contributing to these improvements. Although no reversible cognitive trajectory was identified in our cohort, meta-analysis findings indicate that cognitive impairment reversion does occur, with reported rates of 8.7% in clinical settings and 28.2% in population-based studies [28]. This may be attributed to the slower progression of brain structural changes and metabolic decline [29]. Collectively, these findings emphasize the critical role of early identification and targeted interventions to mitigate cognitive impairment and frailty [30].

A key finding of this study is the asymmetric bidirectional association between cognitive impairment and frailty, with cognitive impairment showing a stronger link to frailty progression than the reverse. This observed asymmetry may reflect fundamental differences in the underlying pathophysiology of the two conditions. Cognitive impairment is driven by accumulated neuropathological changes such as amyloid beta plaques, which persistently disrupt systemic functioning once established [31]. Additionally, cognitive reserve may have a potential protective effect against the onset and deterioration of frailty [32] and could mitigate the risk of cognitive impairment associated with frailty and pre-frailty [33]. In contrast, frailty is a dynamic imbalance of physiological functions, which is easily detectable and can be improved through targeted exercise interventions [34, 35]. These findings are consistent with prior state transition studies, which show a greater transition probability from cognitive impairment to cognitive frailty than from frailty, underscoring the importance of targeting the cognitive impairment stage in early preventive strategies [36, 37].

This study focused on identifying key risk factors in two high-risk populations: those with adverse cognitive function and those with adverse frailty. Advanced age and female sex emerged as shared demographic risk factors for both conditions, consistent with prior

TABLE 3 | Cognitive impairment-related factors in the adverse frailty trajectory.

	Cognitive function trajectories (ref: stably high cognition)	
	Cognitive impairment	
Variables	**OR**	**95% CI**
Age		
65–74	(ref)	
75–85	4.27*	(1.49, 15.63)
> 85	9.91**	(3.42, 36.64)
Sex		
Male	(ref)	
Female	2.12*	(1.03, 4.51)
Education		
Illiterate	(ref)	
Literate	0.25***	(0.11, 0.53)
Residence		
Rural area	(ref)	
City	1.02	(0.55, 1.90)
Marital status		
Unmarried	(ref)	
Married	0.96	(0.48, 1.89)
Economic status		
Normal	(ref)	
Poor	0.75	(0.31, 1.71)
Rich	0.92	(0.40, 2.01)
Multimorbidity		
No	(ref)	
Yes	1.13	(0.57, 2.19)
Drinking status		
No	(ref)	
Yes	0.83	(0.35, 1.89)
Smoking status		
No	(ref)	
Yes	0.67	(0.25, 1.65)
Vision impairment		
No	(ref)	
Yes	1.75	(0.91, 3.32)
Hearing impairment		
No	(ref)	
Yes	4.10***	(2.21, 7.81)
Regular exercise		
No	(ref)	
Yes	1.32	(0.72, 2.45)
Quality of sleep		
Poor	(ref)	
General	0.31*	(0.10, 0.92)
Good	0.90	(0.38, 2.28)

Abbreviations: CI: Confidence Interval, OR: Odds ratio.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

study [38]. The sex disparity is likely attributed to differences in hormonal profiles and inflammatory response mechanisms [7]. Among those with an adverse frailty trajectory, illiteracy, hearing impairment, and poor sleep quality were significantly associated with cognitive impairment. Educational attainment provides skills and knowledge to preserve executive function and memory, offering protection against cognitive impairment [21]. Hearing loss impairs auditory processing in noisy environments, leading to psychosocial stress and social isolation [10]. Poor sleep quality has been shown to mediate the frailty-cognition relationship, possibly through mechanisms like oxidative stress and insulin resistance [39, 40]. Conversely, among individuals with an adverse impairment trajectory, poverty and multimorbidity were significant predictors of concurrent frailty progression. Lower socioeconomic status limits access to healthcare services and healthy behaviors, accelerating physical functional decline [41]. As previous studies have shown, multimorbid older adults face greater challenges in maintaining physical activity, which exacerbates frailty severity [42, 43]. These findings provide evidence for the development of targeted intervention strategies.

This study further elucidated the mutual associations between cognitive function and frailty trajectories in Chinese older adults. By employing the full dual trajectory model, this study quantified many-to-many relationships between these trajectories, achieving refined risk stratification.

However, this study has some limitations. First, the high attrition rate during follow-up might attenuate the validity of our findings. Furthermore, selection bias due to attrition may limit the generalizability of our findings, as our sample is more representative of a relatively young and healthy population. Nevertheless, the GBTM method we used can handle randomly missing data [44]. Second, the construction of frailty variables relied on self-reported questionnaires, which may introduce recall bias. While the naming of trajectories is inherently subjective, it is guided by the

data-driven patterns identified through GBTM. Despite this limitation, self-reporting remains a valuable and practical method for community-based data collection [10]. Third, although participants diagnosed with dementia at baseline were excluded, participants with low MMSE scores might have developed clinically undiagnosed dementia. This possibility should be considered when interpreting trajectory associations. Fourth, MMSE may exhibit a ceiling effect, as 21.71% of participants scored the maximum of 30 at baseline. This limited variability may underestimate the decline in individuals with high cognitive function. In addition, cognitive impairment was not classified according to educational level, which may influence MMSE performance in this cohort. Finally, the three to four-year assessment intervals might have missed short-term fluctuations, possibly underestimating accurate progression rates. Despite this, the clear identification of heterogeneous trajectories confirms that our modeling approach captured clinically meaningful patterns.

5 | Conclusion

This study demonstrated a distinct asymmetric bidirectional association between cognitive function and frailty trajectories among Chinese older adults, with cognitive impairment showing a stronger link to frailty progression than the reverse. Additionally, advanced age and female sex were identified as factors associated with adverse trajectories of both conditions, while poverty and multimorbidity were found to accelerate frailty in the adverse cognitive trajectory. Illiteracy, hearing impairment, and poor sleep quality were shown to exacerbate cognitive impairment in an adverse frailty trajectory. These findings underscore the importance of early identification and targeted intervention for cognitive frailty, which can mitigate its progression in older adults and promote healthy aging.

Author Contributions

Yingxin Xu: conceptualization, data curation, methodology, software, visualization, writing – original draft, writing – review and editing. **Dorina Cadar:** supervision, validation, writing – review and editing. **Jing Liao:** project administration, supervision, validation, writing – review and editing.

Acknowledgments

We thank the staff of the CLHLS cohorts for generating the valuable dataset and making it publicly available to the research community.

Funding

The authors have nothing to report.

Disclosure

We confirm that we did not use AI or AI-assisted technologies in the writing process. However, we utilized ChatGPT solely for checking grammar to enhance readability.

Ethics Statement

The CLHLS study was approved by the Research Ethics Committee of Peking University (IRB00001052-13074). All participants provided written informed consent.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in CLHLS at https://opendata.pku.edu.cn/.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** The GRoLTS checklist in the study. **Table S2:** Characteristics of participants included and excluded. **Table S3:** Model search process in group-based trajectory modeling of cognitive function and frailty.