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Relationships between physical frailty and cognitive decline over 8 years: A longitudinal study among community-dwelling older Chinese immigrants

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Abstract

Objectives: To examine patterns of physical frailty changes, their sociocultural correlates, and associations with initial cognitive functioning and cognitive decline over an eight-year observation period among community-dwelling older Chinese immigrants.

Design: An 8-year follow-up longitudinal study.

Setting and participants: 2,835 community-dwelling adults aged 60 and above living in Chicago, who self-identified as Chinese, with a mean age of 72.5 years at baseline.

Measurements: Frailty was assessed using five indicators across the five waves, and patterns of change were identified through repeated measures latent class analysis (RMLCA). Cognitive functioning was assessed using the Chinese Mini-Mental State Examination (C-MMSE). The associations between frailty patterns and cognitive change trajectories were evaluated using latent growth curve modeling (LGCM), adjusted for sociodemographic, health, and immigration covariates.

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CRediT authorship contribution statement
FT: Funding acquisition. Writing – original draft; Conceptualization; Methodology. QY: Writing – original draft; Writing - review & editing. WD: Formal analysis. Data Curation. GJ: Writing - review & editing. YJ: Writing - review & editing.

Ethics approval and consent to participate
Informed consent was obtained from all participants, and research protocols were previously approved by the Institutional Review Board at Rush University Medical Center in Chicago, Illinois (IRB 10090203). This secondary analysis study has been approved by Institutional Review Boards at the University of Pittsburgh (IRB EXT20030031) and Rutgers, The State University of New Jersey (IRB Pro2018001578).

Declaration of Generative AI and AI-assisted technologies in the writing process
We confirm that we did not use AI or AI-assisted technologies in the writing process. However, we utilized ChatGPT solely for editing purposes to enhance readability.

Declaration of competing interest
The authors have no conflicts of interest to declare.

Results: Four distinct frailty patterns were identified: least frail (53%), decreased frailty (21%), increased frailty (15%), and constantly frail (11%), with differential sociodemographic and immigration profiles. Compared to the least frail class, respondents in the increased frailty class (intercept: $B = -0.108$, $p < .05$; slope: $B = -0.073$, $p < .001$) and the constantly frail class (intercept: $B = -0.150$, $p < .01$; slope: $B = -0.043$, $p < .001$) showed poorer initial cognitive functioning and faster rates of cognitive decline after controlling for covariates. No significant differences in cognitive outcomes were observed between the least frail and the decreased frailty classes. Compared to Cantonese speakers, Mandarin speakers experienced a slower rate of cognitive decline ($B = 0.033$, $p < .001$).

Conclusions: These findings demonstrate that physical frailty is associated with cognitive decline, particularly among older Chinese immigrants who remain constantly frail or experience increasing frailty over time. Clinical interventions should prioritize addressing both physical frailty and cognitive decline, with special attention to vulnerable subgroups within this population.

Keywords

Cognitive decline; Frailty; Immigration; Minority aging

1. Introduction

Physical frailty is an increasingly pressing public health concern, affecting about 15% of community-dwelling older adults in the United States [1,2]. This medical syndrome, marked by aging-related declines in physiological capacities, increases older adults' vulnerability to both internal and external stressors [3,4]. Research indicates that physical frailty is associated with numerous adverse health outcomes, including falls, injuries, disability, morbidity, and mortality [5,6]. In particular, growing evidence suggests the intricate relationship between physical frailty and cognitive functioning in later life. Physical frailty appears to increase the risk of cognitive impairment and accelerate cognitive decline [7,8]. Furthermore, studies have identified frailty as a significant risk factor for the onset and progression of dementias, including Alzheimer's disease, vascular dementia, and all-cause dementia among community-dwelling older adults [9]. Epidemiological evidence suggests a link between physical frailty and cognitive decline, with potential mechanisms involving inflammatory responses, nutritional deficits, vascular dysfunction, and metabolic imbalances [10,11].

Most studies documenting the negative association between frailty status and cognitive performance have been cross-sectional [8]. Longitudinal studies are limited and often vary in their methods of measuring physical frailty and cognitive outcomes, typically over relatively short follow-up periods. These methodological differences may contribute to the inconsistent findings reported in the literature [5,12,13]. For instance, Chen et al. [5] found that physical frailty, assessed using the Fried frailty phenotype (unintentional weight loss, low grip strength, exhaustion, slow gait speed, and low physical activity), was associated with declining global cognitive functioning in non-demented older Japanese adults over two years. In contrast, Auyeung et al. [12] used a different set of frailty indicators (underweight BMI < 18.5 kg^2, weak handgrip strength, impaired neuromuscular performance, low muscle mass, slow timed chair-stand test, slow walking speed, and short step length) and reported a less consistent relationship with cognitive decline, particularly among women in a sample of non-demented older Chinese adults in Hong Kong. These discrepancies may stem from the use of different frailty assessments and insufficient consideration of the diverse demographic, socioeconomic, and cultural characteristics of the study populations.

A limited number of studies indicate a higher prevalence of frailty among older immigrants compared to their native-born counterparts, likely due to the immigration experiences and accumulated health vulnerabilities [1,14]. A systematic review of mixed-method research over the past two decades reported frailty prevalence rates among older immigrants from low- and middle-income countries to high-income countries ranging from 16.6% to 61.9%, depending on the assessment methods (e.g., Frailty Phenotype, Frailty Index) and geographic locations [15]. In Europe, frailty trends in older immigrants reflect a complex interplay of migration-related factors, including country of birth, current country of residence, and duration of residence [3]. These findings underscore the significant influence of social and environmental factors across the lifespan on frailty risk [3]. Frailty-related disparities are particularly pronounced among older immigrants with lower educational attainment or those experiencing social isolation [16]. Given the heterogeneity of older immigrant populations, with frailty risk factors varying considerably across groups [15], further research is needed to investigate the unique experiences and factors associated with frailty within specific minority immigrant groups to inform targeted interventions.

Research on Asian immigrants in the U.S., including middle-aged and older Korean immigrants, highlights the compounded effects of acculturation challenges and social adaptation difficulties on frailty risk [17]. Global studies have similarly identified frailty vulnerabilities among Chinese immigrants, linking these risks to their migration experiences [18,19]. Older Chinese immigrants, in particular, face heightened risks due to language barriers, limited healthcare access, and cultural adaptation difficulties, which can exacerbate frailty and contribute to cognitive decline [18]. From their perspective, frailty is marked by ill health, medical morbidities, physical weakness, reduced physical functioning, cognitive decline, and related psychological and social health issues [18]. However, much of the existing research is cross-sectional, providing a static view of frailty that fails to capture its longterm change trajectory and associations with cognitive decline. Longitudinal studies are essential for understanding the dynamic relationship between physical frailty and cognitive change. Currently, data on frailty prevalence and progression, especially among understudied minority groups including Chinese immigrants, remain scarce. Addressing this knowledge gap is crucial for improving healthy aging among this underserved population. This study aims to investigate patterns of physical frailty change, their sociocultural correlates, and the association between physical frailty patterns and cognitive functioning among older Chinese immigrants in the U.S. We hypothesize that distinct patterns of physical frailty progression over time are associated with initial cognitive status and rate of cognitive decline over time.

2. Materials and methods

2.1. Study settings and participants

This study was part of the Population Study of Chinese Elderly in Chicago (PINE), a population-based epidemiological study of Chinese adults aged 60 and above residing in the greater Chicago area [20]. Given the sparse distribution of Chinese immigrants outside of Chinatown, the PINE research team adopted a community-based participatory research approach, recruiting participants in collaboration with over 20 community organizations, including social service agencies, healthcare providers, advocacy groups, community centers, faith-based organizations, and senior apartments [20]. Through sharing outreach channels and field experiences with these organizations, the research team effectively identified, engaged, and invited eligible older adults from a wide geographical area in Greater Chicago [20].

Between 2011 and 2013, 3,157 out of 3,452 eligible community-dwelling Chinese older adults approached participated in the study, yielding a response rate exceeding 91%. More than 99% of the participants were born outside of the U.S. All participants were provided with comprehensive research information, detailed explanations, and opportunities for comprehension, reflection, and the option of consultation with family members before providing informed consent. Interviews were conducted in the Chinese dialect of each participant's choice: Cantonese, Mandarin, or Taishanese. Four follow-up assessments were conducted: Wave 2 (2013–2015, $N = 2{,}713$; response rate 86%), Wave 3 (2015–2017, $N = 2{,}373$; response rate 75%), Wave 4 (2017–2019, $N = 2{,}227$; response rate 71%), and Wave 5 (2019–2020, $N = 2{,}155$; response rate 68%). During the follow-up period, 544 participants were deceased. A random block census study of the Chinese community in Chicago [21], compared with U.S. census data, confirmed that the PINE sample was representative of older Chinese adults in the greater Chicago area [21]. The final sample comprised 2,835 adults who provided data for at least three waves.

Sensitivity analyses were conducted to compare participants who included in our analytic sample ($n = 2{,}835$) with those who were excluded from the analyses ($n = 322$). The excluded participants were older, had more medical conditions, greater depressive symptoms, more IADL limitations, higher frailty, and lower baseline cognitive scores. They were also more likely to have migrated either before age 35 or at age 65 or older, had higher levels of acculturation, and reported less social support compared to those who remained in the study. These results are available upon request.

2.2. Physical frailty

Physical frailty was evaluated using the following variables: (1) exhaustion, measured by the respondent’s self-report of fatigue being or having been treated (1 = yes, 0 = no); (2) weakness, measured by the respondent’s self-report of weakness being or having been treated (1 = yes, 0 = no); (3) shrinking, indicated by a body mass index (BMI) of less than 18.5 kg/m^2 (1 = yes, 0 = no); (4) slowness in walking, determined by gait speed over an 8-ft distance (1 = in the bottom quintile, 0 = above the bottom quintile); and (5) physical limitations, assessed using the NAGI Index of Basic Physical Activities [22]. The

NAGI index evaluates daily physical functioning as a component in geriatric assessment of physical frailty [23]. The questions were about difficulties in performing various physical activities (e.g., pulling or pushing large objects) on a scale from 0 (no difficulty at all) to 5 (just unable to do it). The NAGI score was dichotomized as 1 (the bottom quintile) or 0 (above the bottom quintile). Frailty scores (ranging from 0 to 5) were calculated by summing these five variables at each of the five waves, with higher scores indicating greater frailty.

2.3. Cognitive functioning

Cognitive functioning was assessed across five waves using the Chinese Mini-Mental State Examination (C-MMSE), adapted from the widely used MMSE [24] and validated in Chinese aging populations with good reliability and validity [25]. The MMSE is a sensitive and reliable 30-item screening tool for detecting cognitive impairment and quantifying its severity, with strong test-retest reliability and correlations with other dementia assessment tools across diverse populations [26,27]. The C-MMSE consisted of 30 items assessing five cognitive domains: orientation to time and place, registration/repetition, attention/calculation, recall, and language. Previous analyses revealed a unidimensional general factor underlying these items, reflecting a single construct of cognitive capacity, with a baseline reliability score of 0.88 [28]. Baseline C-MMSE scores were standardized, and z-scores were calculated for each participant in subsequent waves using their standardized baseline score as the reference. This method allowed for the measurement of cognitive changes relative to each participant's initial performance. These z-scores across five waves were used to model cognitive change trajectories with two latent factors: an intercept, representing initial cognitive functioning, and a slope, representing the rate of cognitive change over time.

2.4. Covariates

We controlled for baseline covariates when predicting cognitive outcomes. Sociodemographic variables included age (years), sex (0 = male, 1 = female), education (years), annual income (ranging from 1 = less than $5,000 to 10 = $45,000 or more), and marital status (0 = not married, 1 = married). Medical conditions were assessed by the total number of self-reported physician-diagnosed and treated conditions, including stroke, hypertension, diabetes, cancer, lung, and heart diseases. Depressive symptoms were measured using the 9-item Patient Health Questionnaire (PHQ-9). Each item assessed the severity of degressive symptoms over the past two weeks and was scored as follows: 0 = not at all, 1 = several days, 2 = a week or more, or 3 = nearly every day. A total score was calculated by summing the individual item responses, with higher scores indicating greater severity of depressive symptoms (Cronbach's $\alpha = 0.81$) [29].

Limitations in instrumental activities of daily living (IADL) were assessed using a scale measuring difficulties in performing various IADLs (Cronbach's $\alpha = 0.90$) [30]. Sociocultural variables included age at migration (years), dialect preference (Cantonese, Mandarin, or Taishanese), social support (measured by a six-item summary score assessing reliance on spouse, family, and friends; Cronbach's $\alpha = 0.75$), and acculturation (measured by the 12-item adapted Short Acculturation Scale; Cronbach's $\alpha = 0.92$) [31].

2.5. Statistical analysis

Two primary analytic procedures were used: repeated measures latent class analysis (RMLCA) and latent growth curve modeling (LGCM). To identify patterns of physical frailty changing over time, RMLCA with full information maximum likelihood (FIML) was applied. This approach identified latent classes of physical frailty trajectories across five waves, grouping individuals with similar frailty levels and change patterns into the same class. Models with two to six classes were estimated, and the optimal number of classes was selected based on model fit indices, including lower Bayesian Information Criterion (BIC) values, a significant Lo–Mendell–Rubin (LMR) test, and a higher entropy value [32]. Statistical criteria were evaluated alongside the interpretability of the latent classes [33]. Missing frailty data were handled using FIML [34]. RMLCA can reveal meaningful longitudinal patterns by accounting for measurement error (e.g., discrepancies between observed reports and class assignments) and missing data [35]. After determining the optimal number of frailty latent classes, these classes were compared across sociodemographic, health, and cultural factors using bivariate analyses, including ANOVA and chi-square tests.

To examine the association between frailty patterns and cognitive functioning, LGCM was used to capture the cognitive change trajectory with two latent factors: the intercept factor, indicating initial cognitive status, and the slope factor, reflecting the rate of change over time. Unconditional (without covariates) linear and quadratic models were first estimated for C-MMSE z-scores across five waves, with time points fixed at 0, 2, 4, 6, 8 for the linear slope, and 0, 4, 16, 36, 64 for the quadratic slope. The final unconditional LGCM was selected based on the model fit indices and model parsimony [36]. Next, a conditional LGCM was estimated by incorporating physical frailty latent classes and covariates. Models were considered to have a good fit to data with comparative fit index (CFI) ≥ 0.95 and root mean square error of approximation (RMSEA) ≤ 0.06, and acceptable fit with CFI ≥ 0.90 and RMSEA ≤ 0.08 [37]. Missing C-MMSE data were handled using FIML [38]. Analyses were performed using STATA 18.0 and Mplus 7.4.

3. Results

3.1. RMLCA analysis of physical frailty patterns

Table 1 presents the model fit statistics for RMLCA models with two to five latent classes, excluding the six-class model, which failed to converge. While the BIC values decreased across all models, the LMR tests and entropy values for the four- and five-class models were comparable. After careful evaluation, the four-class model was selected for subsequent analyses due to its greater parsimony and more interpretable substantive patterns. The four classes were labeled based on the frailty score distribution across five waves and visualized in Fig. 1 as follows: **least frail** (53%), **decreased frailty** (21%), **increased frailty** (15%), and **constantly frail** (11%). The least frail class (Class 1) consistently exhibited the lowest frailty levels, with mean scores below 1 over all five waves. The decreased frailty class (Class 2) initially showed the highest frailty score, but demonstrated a decline followed by stabilization over time. Conversely, the increased frailty class (Class 3) exhibited a progressively rising frailty score over time. Finally, the constantly frail class (Class 4) maintained the highest frailty levels, with mean scores around 3 over the study period.

3.2. Sample descriptives

Table 2 presents the sample characteristics and differences among the four latent classes of physical frailty. At baseline, the mean age of study participants was 72.5 years, and 58.3% were female. Participants had an average of 8.7 years of education, and about 7.6% reported three or more diagnosed medical conditions. The mean number of IADL limitations was 3.5, and the mean depressive symptom score was 2.6. About two-thirds of participants had immigrated to the U.S. at age 50 or older. Regarding language preference, more than half preferred speaking Cantonese, 22.2% preferred Mandarin, and 25.2% preferred Taishanese.

3.3. Comparison among four latent classes of physical frailty

Bivariate analyses revealed significant differences among the four latent classes of physical frailty across all sociodemographic, health, and cultural variables. Vulnerability indices progressively increased from the least frail to the decreased frailty, increased frailty, and constantly frail classes. The constantly frail class was the most vulnerable, characterized by the oldest mean age ($M = 78.7$, $SD = 8.6$) and a predominantly female composition (73.3%). Members of this class typically had lower levels of education, income, and acculturation, and were more likely to be unmarried. They had the lowest baseline cognitive score ($M = 21.62$, $SD = 6.51$) and experienced the fastest rate of cognitive decline ($M = -0.18$, $SD = 0.01$), which was the same as that of the decreased frailty class. Additionally, they had higher rates of medical conditions, more limitations in IADL, and more frequent depressive symptoms. This group was also more likely to have migrated later in life, preferred speaking Taishanese, and reported lower levels of social support. The least frail class, in contrast, was characterized by the youngest mean age ($M = 70.5$, $SD = 7.3$), the highest proportion of males (47.5%), and the highest levels of education, income, acculturation, and social support among the four classes. This group also demonstrated the most favorable overall health status.

3.4. Associations of physical frailty and cognitive functioning

Both the unconditional linear model [χ^2 ($N = 2{,}831$, $df = 14$) = 199.73, $p < .001$, CFI = 0.98, RMSEA = 0.07] and the quadratic model [χ^2 ($N = 2{,}831$, $df = 10$) = 111.47, $p < .001$, CFI = 0.99, RMSEA = 0.06] demonstrated good model fit. However, the mean of the quadratic slope was not statistically significant, suggesting no substantial fluctuation in the change rate of cognitive decline. Thus, the linear model was selected for further conditional analysis. In the unconditional linear model, the mean intercept (initial cognitive functioning) was −0.043 ($p < .05$), and the mean slope (cognitive decline rate) was −0.103, indicating that C-MMSE scores declined by 0.103 units per year over the eight-year study period ($p < .001$).

Table 3 presents the results of the conditional model with covariates. Compared to the least frail class, respondents in the increased frailty class (intercept: $B = -0.108$, $p < .05$; slope: $B = -0.073$, $p < .001$) and the constantly frail class (intercept: $B = -0.150$, $p < .01$; slope: $B = -0.043$, $p < .001$) exhibited lower initial cognitive functioning and faster rates of cognitive decline after controlling for covariates. However, there was no significant difference in the intercept or slope of C-MMSE between the least frail and the decreased frailty classes. Fig. 2 depicts the trajectories of cognitive change across the four latent classes of physical frailty after adjusting for baseline age and IADL.

In addition, older age, female sex, lower education, less social support, higher levels of IADL limitations, and more depressive symptoms were associated with poorer initial cognitive functioning. Specific risk factors for cognitive decline included older age ($B = -0.006$, $p < .001$) and more limitations in IADL ($B = -0.003$, $p < .001$). Language preference also was a significant predictor of cognitive performance. Compared to Cantonese speakers, respondents who preferred speaking Mandarin ($B = -0.098$, $p < .05$) or Taishanese ($B = -0.246$, $p < .001$) exhibited lower initial cognitive functioning. However, Mandarin speakers experienced a slower rate of cognitive decline ($B = 0.033$, $p < .001$).

4. Discussion

This study, leveraging data from the largest population-based epidemiological study of Chinese older adults in the U.S., examined latent patterns of physical frailty change and their associations with cognitive decline over eight years. The analysis identified four distinct frailty patterns. Over half of the participants (53%) maintained consistently low frailty levels, while 21% experienced decreasing frailty. The remaining participants were classified either as persistently frail (11%) or exhibiting increasing frailty (15%). These latter two groups faced significant socioeconomic and cultural vulnerabilities, being older, predominantly female, less educated, less acculturated, and having lower income and less social support. They reported more IADL limitations, depressive symptoms, and medical conditions. They were also more likely to be late-life immigrants or prefer speaking Taishanese.

It is noted that one in five study participants exhibited decreasing frailty over time, with initial functioning and rate of cognitive decline comparable to the consistently healthy group. This potential for positive change may be attributed to lifestyle modifications, such as regular exercises and a healthy diet [39,40], particularly when frailty is detected early. Some older adults may also possess greater resilience and adaptability, which enable them to better manage age-related changes. Exposure to low-level stressors, such as physical challenges and mild environmental factors, may induce adaptive responses that enhance resilience to more significant stressors, ultimately improving health and functionality over time [41]. Additionally, the perception and experience of frailty among older immigrants are multifaceted and may be buffered by social support and cultural belongingness [15]. Further, improvements in psychosocial wellness and the sustained engagement with the study itself may have positively influenced participants' self-reported frailty status. It is also possible that regression to the mean is a contributing factor, where extreme scores at baseline tended to move close to the average mean over time. These potentials factors support the possibility of frailty reversal in some older adults, demonstrating that frailty status is not fixed and can fluctuate depending on various circumstances. Therefore, preventive health interventions could play a crucial role in reversing frailty and promoting healthy aging [42].

Understanding distinct frailty patterns offers valuable insight into the negative impact of frailty on cognitive decline. Our study revealed that older adults in the increased frailty and constantly frail groups exhibited lower initial cognitive functioning and experienced accelerated cognitive decline compared to the least frail group. In contrast, no significant differences were observed between the least frail and the decreased frailty groups. These findings align with previous research demonstrating that chronically frail older adults are at greater risk for cognitive decline, mild cognitive impairment, and dementia [13]. Given the shared pathogenesis and the role of physical impairment in the onset and progression of dementia [12], recognizing physical frailty as a potential precursor or concurrent condition of cognitive decline is crucial. Physical and cognitive impairment often co-occur and interact, mutually exacerbating their negative effects on health [43]. Frailty should be considered in clinical care and management, as individuals with even low levels of Alzheimer's disease pathology may be at increased risk for dementia in the presence of high frailty levels [44]. Further, evidence indicates a positive association between frailty and dementia risk, with accelerated frailty trajectories often preceding the clinical onset of dementia [45]. This highlights the importance of incorporating frailty measurement into strategies for identifying high-risk populations for dementia prevention and treatment [45]. Therefore, a comprehensive, multidimensional approach to frailty assessment and prevention is essential to address physical, psychological, and social domains to facilitate early intervention [43]. Such strategies hold significant implications for maintaining and optimizing both physical and cognitive functioning in the aging population [46].

Further, our study revealed language preference as a significant predictor of cognitive decline, independent of established risk factors such as age and functional limitations. While both Mandarin and Taishanese speakers exhibited lower baseline cognitive functioning compared to Cantonese speakers, Mandarin speakers demonstrated a slower rate of cognitive decline. This finding underscores the linguistic diversity and cultural identities across Chinese immigrant generations. Language preference may be linked to factors such as immigration timing, acculturation, and socioeconomic conditions. Historically, Taishanese was the primary language among early Chinese immigrants, while Cantonese has been dominant for a longer period, especially in established Chinese communities. Early immigrants often had lower English proficiency and education levels compared to recent Mandarin-speaking immigrants [47]. These dialect differences may reflect variations in cognitive performance, education, acculturation, and the historical contexts of Chinese immigrant generations.

This study has several strengths, including its longitudinal, population-based cohort design, an average eight-year follow-up period, and the examination of frailty change patterns and associated cognitive trajectories. However, several limitations should be noted. First, due to data limitations in the PINE study, frailty was assessed using self-reported exhaustion, slowness in walking, self-reported weakness, low BMI, and the NAGI scale, rather than the widely recognized Fried criteria. Although low BMI reflects aspects of nutritional status and physical decline commonly associated with frailty, it is distinct from unintentional weight loss [48]. Self-reported measures are susceptible to social desirability and recall bias, potentially undermining their reliability. Despite these limitations, our approach was informed by existing literature [1,7,12], including studies on Chinese immigrants [18], where frailty is often associated with physical weakness and declining physical function. Although not identical to the Fried criteria, the selected measures may provide a valid and contextually relevant assessment of frailty in this study.

Second, the study lacks a comprehensive assessment of frailty syndromes, which include accumulated symptoms, disease states, abnormal test results, and disabilities, limiting its ability to fully capture the relationship with cognitive impairment [49,50]. Our post-hoc analysis revealed that individuals with persistent frailty were more likely to have diagnoses of stroke, cancer, and heart disease, suggesting potential links between frailty and medical morbidities. Third, the study lacks data on participants' physical activity levels and does not account for other potentially influential factors such as genetics, environment, nutrition, and lifestyle habits, which likely affect both frailty and cognition [11]. Yet, the NAGI scores provide valuable information about one's ability to engage in and perform necessary tasks – a key element in frailty [51]. Fourth, the generalizability of the findings is limited due to the use of a regional sample, requiring validation in other Chinese populations in the US and internationally. Moreover, the cohort of older adults was not recruited through random population sampling and consisted entirely of community-dwelling, relatively non-frail or healthy individuals. This sampling approach may introduce a bias toward individuals with no physical or cognitive impairments and may not fully represent the broader population of Chinese older adults in Greater Chicago, particularly those less connected to community centers or less socially engaged. Lastly, the exclusion of participants with incomplete data at three or more time points may have introduced selection bias. These excluded individuals were older, reported higher frailty levels, and exhibited worse cognitive health compared to the analytic sample, potentially underestimating the observed associations.

5. Conclusion

The study identified four distinct patterns of physical frailty change: least frail, decreased frailty, increased frailty, and constantly frail, with differential sociodemographic and immigration profiles. Compared to the least frail group, older adults in the increased frail and constantly frail groups demonstrated poorer initial cognitive functioning and faster cognitive decline over the eight-year study period. Advanced age, IADL limitations, and language preference were also significantly associated with cognitive decline among older Chinese immigrants. These findings, along with previous research [e.g., 18,50,52] suggest that physical frailty is potentially modifiable, and maintaining physical functioning may help prevent or even reverse cognitive decline. Given the increasing global immigration trends, it is important to incorporate cultural perspectives when addressing complex health issues and the unique challenges faced by minority immigrant populations in research and practice. Future research should investigate the underlying biological and psychosocial mechanisms linking physical frailty and cognitive decline, including the specific impacts of immigration-related stressors on the association. A comprehensive understanding of these pathways and factors can inform the development of targeted, culturally relevant interventions for immigrant populations.

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Data availability statement

The Data is not publicly available, and the data access is managed by Rutgers Institute for Health, Health Care Policy and Aging Research Survey/Data Core. The study protocol and analytic code are available upon request at (fet7@pitt.edu). Restrictions may apply.

Abbreviations:

PINE	Population Study of Chinese Elderly in Chicago
C_MMSE	Chinese Mini-Mental State Examination
IADL	Instrumental Activities of Daily Living
BMI	body mass index
RMLCA	Repeated Measures Latent Class Analysis
LGCM	Latent Growth Curve Model
ANOVA	Analysis of Variance

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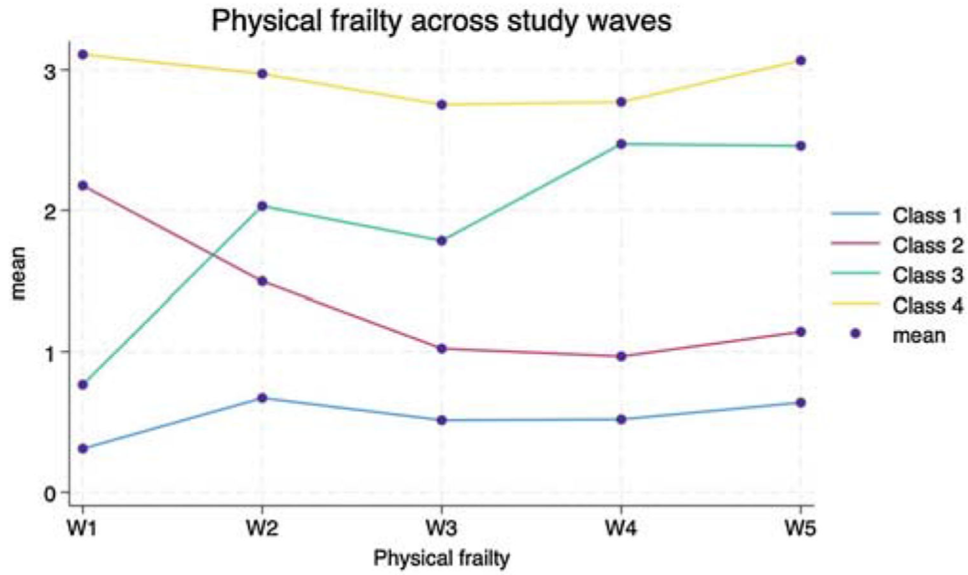

Fig. 1. Latent Classes of Physical Frailty.

Note: Class 1 – Least frail; Class 2 – Decreased frailty; Class 3 – Increased frailty; Class 4 – Constantly frail.

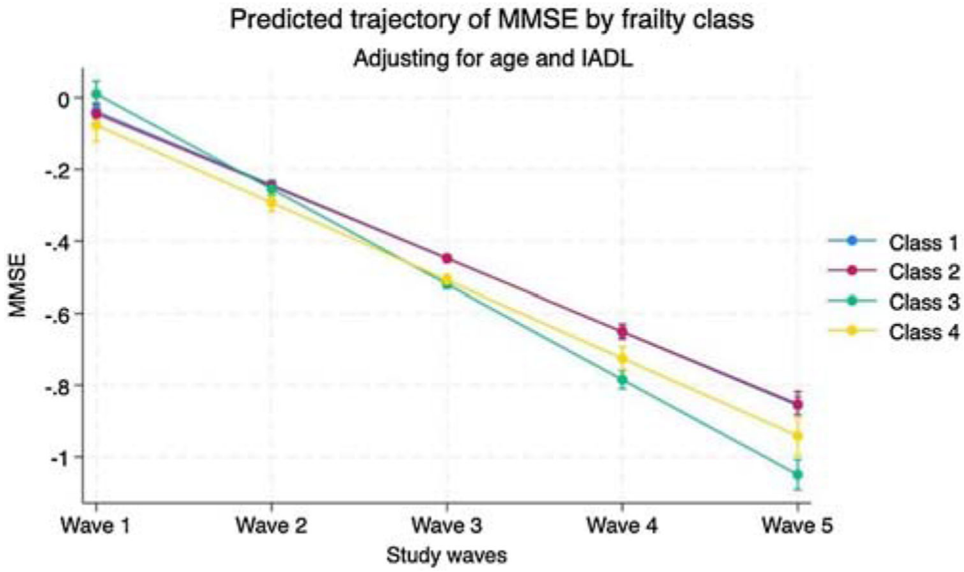

Fig. 2. Cognitive Functioning Change Trajectories by Latent Classes of Physical Frailty after Adjusting for Baseline Age and IADL.

Note: Class 1 – Healthy; Class 2 – Decreased frailty; Class 3 – Increased frailty; Class 4 – Constantly frail; MMSE = Mini-Mental State Examination; IADL = instrumental activities of daily living.

Table 1

Model fit statistics of repeated measure latent class analysis (RMLCA) of physical frailty patterns (*N* = 2,835).

Statistics	2 Classes	3 Classes	4 Classes	5 Classes
Log-likelihood	−18140	−17899	−17722	−17604
df	16	22	28	34
BIC	36407	35973	35668	35478
Entropy	0.826	0.744	0.801	0.808
LMR test	2897	472	345	233
p-value	<.001	<.001	<.001	<.001
Class distribution	74%	60%	53%	19%
	26%	28%	21%	49%
		12%	15%	14%
			11%	9%
				9%

Note. df = degree of freedom; BIC = Bayesian Information Criterion; LMR = Lo-Mendell-Rubin.

Table 2

Sample descriptives and comparison among four latent classes of physical frailty.

Sample Descriptive	Least frail	Decreased frailty	Increased frailty	Constantly frail	
(Mean/SD)/(%)	**Mean (SD)/%**	**Mean (SD)/%**	**Mean (SD)/%**	**Mean (SD)/%**	**Bivariate test**
Age (72.48/8.11)[a]	70.45 (7.27)	72.40 (7.95)	75.16 (7.62)	78.68 (8.59)	F (3, 2831) = 125.60 ***
Female (58.31)	52.47	60.73	64.49	73.25	χ^2 (3) = 59.43 ***
Education (8.70/5.03)[a]	9.21 (4.79)	8.96 (5.12)	7.86 (5.15)	6.90 (5.29)	F (3, 2819) = 23.83 ***
Income (1.94/1.12)[a]	2.05 (1.31)	1.83 (0.95)	1.82 (0.76)	1.79 (0.60)	F (3, 2801) = 10.08 ***
Married (71.12)	78.11	71.55	61.02	50.76	χ^2 (3) = 123.10 ***
Medical conditions					χ^2 (9) = 147.71 ***
0 (33.40)	40.03	28.80	27.05	18.84	
1 (39.72)	40.16	41.01	41.06	33.74	
2 (19.29)	14.55	21.64	24.40	30.70	
3+ (7.58)	5.27	8.55	7.49	16.72	
IADL (3.46/5.93)[a]	1.51 (3.07)	3.93 (5.80)	4.07 (5.59)	11.19 (9.33)	F (3, 2749) = 312.60 ***
Depressive symptoms (2.58/4.04)[a]	1.27 (2.48)	3.80 (4.60)	2.69 (3.75)	6.35 (5.79)	F (3, 2819) = 199.65 ***
Social support (12.79/3.04)[a]	13.35 (2.98)	12.38 (3.01)	12.34 (2.95)	11.48 (2.90)	F (3, 2827) = 45.76 ***
Age at migration					χ^2 (9) = 48.91 ***
<35 (9.42)	11.13	9.25	5.80	6.38	
35–49 (25.57)	27.72	24.96	21.74	21.58	
50–64 (50.72)	49.77	50.96	54.35	50.15	
65+ (14.29)	11.39	14.83	18.12	21.88	
Preferred dialect					χ^2 (6) = 24.26 ***
Cantonese (52.59)	55.09	47.98	54.48	46.81	
Mandarin (22.21)	21.36	27.24	19.85	20.36	
Taishanese (25.20)	23.55	24.78	25.67	32.83	
Acculturation (15.18/4.93)	15.54 (5.34)	15.35 (4.99)	14.35 (3.96)	14.31 (3.55)	F (3, 2831) = 10.21 ***
Baseline cognition (25.44/4.50)	26.38 (3.47)	25.56 (4.24)	24.51 (4.86)	21.62 (6.51) ***	F (3, 2747) = 109.43 ***
Cognitive decline	−0.07 (0.004) ***	−0.09 (0.007) ***	−0.18 (0.008) ***	−0.18 (0.010) ***	na

Note. IADL = instrumental activities of daily living. na = not applicable.

Continuous measures, mean and standard deviation (SD) are reported.

All statistical results were derived from baseline raw data, except for the latent variables representing cognitive decline slopes, which were estimated using structural equation modeling (SEM) across Waves 1–5 and tested for deviation from zero, with coefficient (standard errors) reported.

* $p<.05$.

** $p<.01$.

*** $p<.001$.

Table 3

Latent Growth Curve Modeling of Longitudinal Relationship between Physical Frailty and Cognitive Functioning (*N* = 2,835).

Characteristics	Intercept Estimate	*SE*	Slope Estimate	*SE*
Age	−0.013 ***	0.002	−0.006 ***	0.000
Female	−0.065 *	0.031	0.005	0.006
Education	0.080 ***	0.004	0.001	0.001
Income	0.022	0.013	−0.002	0.003
Married status	0.035	0.038	0.003	0.008
Acculturation	0.001	0.003	0.001	0.001
IADL	−0.059 ***	0.003	−0.003 ***	0.001
Depressive symptoms	−0.009 *	0.004	0.002	0.001
Social support	0.014 **	0.005	0.000	0.001
Medical conditions: 0 – reference group				
1	0.047	0.033	−0.002	0.007
2	0.033	0.041	0.007	0.008
3+	0.020	0.057	−0.006	0.012
Age at migration: <35 – reference group				
35–49	0.051	0.055	0.013	0.012
50–64	0.054	0.055	−0.005	0.011
65+	−0.121	0.067	0.003	0.014
Preferred dialect: Cantonese – reference group				
Mandarin	−0.098 *	0.043	0.033 ***	0.009
Taishanese	−0.246 ***	0.034	−0.007	0.007
Physical frailty classes:least frail – reference group				
Decreased frailty	0.026	0.037	−0.007	0.008
Increased frailty	−0.108 *	0.042	−0.073 ***	0.009
Constantly frail	−0.150 **	0.055	−0.043 ***	0.012

Note. IADL = instrumental activities of daily living.

* $p<.05$.

** $p<.01$.

*** $p<.001$.