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Effect of leisure activity on frailty trajectories among Chinese older adults: a 16-year longitudinal study

Xinyi Yang[1], Wenjuan Wang[2], Wensu Zhou[2] and Hui Zhang[1*]

Abstract

Background While the significant association between leisure activities and frailty risk among older adults is well-established, the impact of integrated leisure activity scores and different categories of them on frailty trajectories over time remains unclear.

Methods This study utilized longitudinal data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which enrolled participants aged 65 years and older between 2002 and 2018. Frailty trajectories were derived using group-based trajectory modelling, and based on these trajectories, subjects were classified into various categories. Leisure activity was measured by integrated scores as well as three distinct categories: physically, cognitively, and socially stimulating activity. The effect of leisure activity on frailty trajectories was examined using multinomial logistic regression.

Results By analysing data from 2,299 older adults, three frailty trajectories were identified: non-frail, moderate progressive, and high progressive. The results indicated that an increase in the score of integrated leisure activity was associated with 11% (odds ratio [OR] 0.89; 95% Confidence Interval [CI] 0.85–0.93) and 14% (OR 0.86; 95% CI 0.80–0.91) decrease in the likelihood of being in the moderate and high progressive frailty trajectories, respectively. Engaging in physically stimulating activity lowered the odds of belonging to the moderate and high progressive trajectory by 43% (OR 0.57; 95% CI 0.40–0.81; OR 0.57; 95% CI 0.36–0.92, respectively). Participation in socially stimulating activity showed a lower odd of being in the moderate progressive trajectory (OR 0.68; 95% CI 0.49–0.93) and the high progressive trajectory (OR, 0.61; 95% CI, 0.39–0.95). The effects of leisure activities on frailty trajectories were observed not to vary by age, education level and retirement status.

Conclusions This study suggests that older adults should be encouraged to increase both the amount and variety of their leisure activities. Physically stimulating activities should be considered the primary choice, followed by socially and cognitively stimulating activities.

Keywords Frailty, Frailty trajectory, Older adult, Leisure activity

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Background

Frailty is one of the most serious public health challenges of this century [1, 2], with the prevalence increasing from 10.7% [3] to 13.3% [4] over the past decade. Frailty is defined as a decline in physiological capacity followed by increased vulnerability to stressors [1, 5]. More importantly, it is a dynamic status [6] characterized by various processes (i.e., trajectories identified in previous studies)

such as stable non-frailty, moderate progressive frailty, and rapid progressive frailty [7–11]. This evidence indicates that the frailty status changes over time, underscoring the importance of examining the associated factors based on different trajectories.

Leisure activity is one of the most important factors affecting the risks of frailty [12]. It is defined as voluntary non-work activities engaged in leisure time [13]. An increasing number of studies have indicated that it is one of the effective interventions to improve frailty [14]. Published literature has suggested a positive association between engaging in leisure activities and a reduced risk of frailty [15, 16] and most previous studies have commonly calculated a continuous score of leisure activities based on their frequency to reflect the level of engagement in leisure activities, or analysed the effects of single types of activities on the risk of frailty. However, due to differences in cultural and social backgrounds, the types of activities varied, thus limiting the generalizability of the findings to the broader population to some extent. According to the self-perceived stimulation of older adults, leisure activity can be classified into physically, cognitively and socially stimulating activities, which provides a comprehensive framework for recognizing leisure activities [17, 18]. Indeed, some recent studies have found that not all activities showed the same effect on frailty risks. For example, Abe et al. [14] observed that cognitively and socially stimulating activities can significantly reduce the risk of frailty. A study in Switzerland found that socially stimulating activities protected older residents against increasing frailty risks [10], while other types of leisure activities were not presented significant effects in this study. Understanding the association between dynamic status of frailty and leisure activities is also important, however, only one study found that the risk of transition to a growing frailty trajectory increased with the frequency of leisure activity lower [19]. Therefore, previous studies were limited in two aspects - they not only failed to examine whether the effects of leisure activities were significantly associated with the progression of frailty, but they also less recognized the potential significance of physically, cognitively, and socially stimulating activities in relation to the trajectories of frailty. The guidance of appropriate leisure activities is necessary since it is difficult for older adults to participate in all types of leisure activities due to health limitations [20] and the financial burden of paid activities [21].

In summary, the current study aims to assess the association between leisure activity (i.e., scores of integrated leisure activities, and their types like physically, cognitively and socially stimulating activities) and different frailty trajectories among older adults. This may help improve frailty and provide specific leisure activity suggestions for older adults.

Materials and methods

Data and sample

We used data and questionnaire from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which was an open access database organized by Peking University and the China National Development Institute [22]. This questionnaire has been widely used in previous studies and the quality of data was reliable [23–25]. The CLHLS is a nationwide ongoing cohort survey focusing on community-dwelling older adults aged 65 and above [26]. To represent the entire Chinese population, a multi-stage sampling method was used. This involved selecting equal proportions of participants from over 500 sample sites located across 23 of China's 31 provinces, autonomous regions, and municipalities. These 23 regions collectively covered more than 85% of the total population in mainland China. Since 1998, the CLHLS has conducted interviews in 2000, 2002, 2005, 2008, 2011, 2014, and 2018. The CLHLS data was collected through face-to-face interviews with physical capacity tests at the interviewee's home [27]. It is available to the general public for research purposes. The dataset provides abundant information on sociodemographic characteristics, health status, lifestyle activities, treatment of disease and medical expenses of older people, making it possible to assess an individual's frailty status through Frailty Index (FI) [19]. The complete questionnaire can be downloaded from the National Archive of Computerized Data on Aging (NACDA) repository [28]. We have provided an illustration of the items in the questionnaire we used (Supplementary Table S1). Data for this study was collected in 2002, with subsequent surveys were conducted every 3 years (except the 6th wave). Participants or their proxy respondents have signed the informed consent before the face-to-face interview.

This study was a secondary analysis of CLHLS data. As we used the group-based trajectory modelling (GBTM) approach to extract frailty trajectories among older adults (detailed in the methods section), which required participants to have at least three frailty assessments [11, 29, 30] because the number of FI measurement may affect the formation of the frailty trajectory [31]. Consequently, we selected participants with at least four frailty assessments for our target sample population. Although CLHLS began in 1998, many variable information in that year was inconsistent with subsequent follow-ups, especially regarding leisure activities. Given the availability of comprehensive data for variables used in FI assessment and consistent information on leisure activities [15], we chose the 2002 wave as our baseline, with subsequent

surveys conducted every three years (except for the 6th wave). Participants were included if they: (1) were aged 65 years or above at baseline; (2) had no missing data on leisure activity at baseline; and (3) completed FI measurements in at least four out of six waves. Exclusion applied to those who were frail (FI was accessible and no less than 0.25) at baseline. Thus, from baseline to the latest interview in 2018, the longitudinal dataset included 16,064 respondents at baseline in 2002 (wave 1), followed by 8,175 in 2005 (wave 2), 4,191 in 2008 (wave 3), 2,513 in 2011 (wave 4), 1,681 in 2014 (wave 5), and 790 in 2018 (wave 6). Among them, 866 (37.7%) were interviewed four times, 868 (37.8%) were interviewed five times, and 565 (24.6%) were interviewed six times.

Tools and instruments

Frailty

FI proposed by Rockwood [32, 33] was used to assess frailty. This study included 38 health deficit indicators in 9 components (Supplementary Table S2): including cognitive impairment (determined using the Chinese version of the Mini-mental State Examination (CMMSE) [34, 35]), chronic diseases (11 items), the activity of daily living disability (6 items), the instrumental activity of daily living disability (8 items), functional limitations(5 items), self-rated health, hearing and visual impairment, psychological distress and other three health impairments. All items are included in the questionnaire. When calculating FI, the numerator was the actual score and the denominator was the sum of items. FI ranged from 0 to 1, and a higher score indicates frailer. Participants were divided into non-frailty (<0.25) and frailty (≥ 0.25) based on the FI score [5, 33], which is viewed as one criterion applied at baseline. The FI assessment approach used in our analysis has been widely used in previous studies [36–38]. It was well-documented as both reliable and valid, with high consistency and reliability confirmed by the published literature [39, 40].

Leisure activity

The CLHLS dataset included five frequencies of the above nine leisure activities: housework, agricultural activity, reading, playing cards or mahjong, watching TV/listening to the radio, social activities, growing flowers/keeping pets, outdoor activities and travelling (Supplementary Table S3). In this study, the frequencies of each activity were merged as "never", "sometimes", and "almost every day".

We measured leisure activity by two aspects: integrated leisure activities (numeric) and three types of leisure activity (categories variables). To evaluate the integrated leisure activities, the frequency for each activity was valued into: "never" (scored as 0 point), "sometimes" (scored as 1 point) and "almost every day" (scored as 2 points) [41]. The sum of scores theoretically ranged from 0 to 18, with higher scores representing more active participation in leisure activities. Second, the nine activities were grouped based on their functional stimulation into physically stimulating activity (housework, agricultural activity and growing flowers/keeping pets) [42], cognitively stimulating activity (reading, playing cards or mahjong, and watching TV) [43] and socially stimulating activity(social activities, outdoors activities and travelling) [44]. For each type of leisure activity, participants were recorded as engaging "never", "sometimes", or "almost every day". In our analysis, participants who engaged in any of the nine activities almost daily were classified as having daily participation in the "almost every day" category. Apart from those participants who had engaged in activities almost every day, if participants reported engaging in any one of the activities sometimes, they were classified as having a "sometimes" frequency in that specific leisure activity group. Participants were identified as "never" participating in physically, cognitively, or socially stimulating activities if they never engaged in all of the activities within each type.

Covariates

Several covariates were considered as potential confounders based on prior research [31]. Sociodemographic variables included age (65–79, 80 years and above), gender (male, female), residence (urban, rural), living arrangement (living with family members, alone, in nursing institutions), education level (educated, uneducated), marital status (with spouse, without spouse), household income (Yuan, RMB; divided from quartile), retirement (yes, no) and medical insurance (yes, no). Lifestyle variables included smoking (yes, no), drinking (yes, no), vitamins supplement (yes, no), regular fruit and vegetable supplement (regular, irregular), and physical activity (yes, no). Since participation in leisure activities was influenced by health constraints, and based on previous surveys [31, 45, 46], we included health-related control variables in our analysis. These health-related variables included BMI (normal (18.5–24.99 kg/m^2), underweight (<18.5 kg/m^2), overweight or obese ($>=25$ kg/m^2)), missing teeth (yes, no) and annual physical examination (yes, no). In particularly, regarding the information on the presence of underlying medical conditions, several variables were used to calculate the FI, including cognitive impairment, chronic diseases, the activity of daily living disability and self-rated health. In reference to previous studies that used the FI as a dependent variable [47, 48], the control variables did not include those used in the FI assessment. Data for the variables were gathered

from the self-reported questionnaire of all participants in the survey.

Statistical analysis

The GBTM model was applied to explore the frailty trajectories of older adults. It is an application of finite mixture modelling that identifies observations with similar development over time and assigns them to a specific group [10, 49]. A censored normal model was used to estimate the trajectories because FI is a continuous variable. GBTM assumes that the sample is composed of distinct cluster that are not identifiable in advance [50]. Thus we performed a standard procedure to identify latent clusters, starting with a two-class model and then specifying models with one additional class at a time [51]. Given to prior studies and the proportion of sample members in each class (usually more than 5%) [51], we estimated two to five group models to select the optimal number of groups. We then compared and selected the final model based on fit statistical indicators and practical considerations. The fit statistics included the Bayesian Information Criterion (BIC), the Akaike Information Criterion (AIC), and the Average posterior probability (AvePP). AvePP > 0.7 is indicative of good certainty of group assignments.

Baseline characteristics of different trajectories were described by frequency and percentage [N (%)] and compared using the Chi-square test. Two separate logistic regression analyses were conducted. The first examined the association between integrated leisure activity with frailty trajectories and the second accessed the effect of three types of leisure activities on frailty trajectories. We then explored potential differences in the associations between leisure activities and frailty trajectories, stratified by age, education, and retirement status, by including product terms between leisure activity variables and effect modifiers in the analysis. Statistical analysis was performed using STATA, version 16 (Stata Corp., College Station, TX), and the 'traj' package was used to estimate frailty trajectories. The statistical significance level is $p < .05$.

Results

Characteristics of the study sample

At baseline, the study sample included 2,299 participants with 1116 (48.5%) males and 1183 (51.5%) females. The majority of the older adults were between 65 and 79 years old (76.9%), lived in rural areas (83.4%), resided with family members (86.1%), were retired (79.0%), and did not have health insurance (85.6%) were in the majority. The average of integrated leisure activity scores was 7 (5, 8). Most participated engaged in physically, cognitively and socially stimulating activity on an almost daily basis (Table 1).

Frailty trajectories

A trajectory model consisting of three distinct trajectories showed the best fit using BIC, AIC, AvePP and interpretability in trajectory analysis (Supplementary Table S4). Figure 1 shows the trajectories labelled from the bottom up as non-frail, moderate progressive, and high progressive trajectories, respectively. Non-frail participants occupied the largest proportion (56.5%). The non-frail trajectory began with the smallest FI and sustained consistent non-frailty throughout the observed period. Moderate progressive trajectory (32.1%) gradually developed into a lower level of frailty over a decade. High progressive trajectory (11.4%) progressed rapidly over about 5 years, then tended to slow down. As shown in Table 1, there were significant differences among leisure activity participation (integrated score; physically, cognitively, and socially stimulating activity), age, residence, gender, living arrangement, education, marital status, household income, retirement, smoking, drinking, vitamin supplementation, physical activity, BMI, and missing teeth ($p < .05$).

Association between leisure activity and frailty trajectories

The results from multinomial logistic models are shown in Table 2. According to full adjusted results, we observed an increase in the score of integrated leisure activity was associated with 11% (odds ratio [OR], 0.89; 95% Confidence Intervals [95% CI], 0.85–0.93) and 14% (OR, 0.86; 95% CI, 0.80–0.91) decrease in the likelihood of being in the moderate and high progressive trajectories. Participants who took part in physically stimulating activity daily had 43% lower odds of belonging to the moderate progressive trajectory (OR, 0.57; 95% CI, 0.40–0.81) and 43% lower odds to the high progressive trajectory (OR, 0.57; 95% CI, 0.36–0.92) compared to none participation. Socially stimulating activity showed low OR of being in the moderate progressive trajectory (OR, 0.68; 95% CI, 0.49–0.93) and high progressive trajectory (OR, 0.61; 95% CI, 0.39–0.95) when taking part in daily. While cognitively stimulating activity had no effect on reducing the odds of developing in the progressive trajectories.

Stratified analysis

The stratified analyses are shown in Tables 3 and 4. According to Table 3, we found that the significant associations between integrated leisure activity and frailty trajectories did not appear to differ by age and education level. However, higher integrated leisure activity scores had a significant impact in reducing the risks of being in frailty trajectories among older adults who had retired,

Table 1 Characteristics according to Frailty trajectories at baseline [N (%)]

Variables	Overall (*N* = 2299)	Non-frail (*N* = 1299)	Moderate progressive (*N* = 737)	High progressive (*N* = 263)	*P*
Leisure activity					
Integrated score					*p* < .001
Median (IQR)	7 (5–8)	7 (6–9)	6 (5–8)	6 (4–8)	
Physically stimulating activity					*p* < .001
Never	236 (10.3)	95 (7.3)	98 (13.3)	43 (16.4)	
Sometimes	266 (11.6)	136 (10.5)	90 (12.2)	40 (15.2)	
Almost every day	1797 (78.1)	1068 (82.2)	549 (74.5)	180 (68.4)	
Cognitively stimulating activity					*p* < .001
Never	338 (14.7)	155 (11.9)	137 (18.6)	46 (17.5)	
Sometimes	587 (25.5)	325 (25.0)	190 (25.8)	72 (27.4)	
Almost every day	1374 (59.8)	819 (63.1)	410 (55.6)	145 (55.1)	
Socially stimulating activity					*p* < .001
Never	271 (11.8)	122 (9.4)	109 (14.8)	40 (15.2)	
Sometimes	404 (17.6)	198 (15.2)	161 (21.8)	45 (17.1)	
Almost every day	1624 (70.6)	979 (75.4)	467 (63.4)	178 (67.7)	
Sociodemographic variables					
Age					*p* < .001
65–79	1767 (76.9)	1171 (90.1)	469 (63.6)	127 (48.3)	
>=80	532 (23.1)	128 (9.9)	268 (36.4)	136 (51.7)	
Residence					0.008
Urban	381 (16.6)	214 (16.5)	107 (14.5)	60 (22.8)	
Rural	1918 (83.4)	1085 (83.5)	630 (85.5)	203 (77.2)	
Gender					*p* < .001
Male	1116 (48.5)	710 (54.7)	297 (40.3)	109 (41.4)	
Female	1183 (51.5)	589 (45.3)	440 (59.7)	254 (58.6)	
Living arrangement					*p* < .001
With family members	1979 (86.1)	1153 (88.7)	618 (83.9)	208 (79.1)	
Alone	283 (12.3)	136 (10.5)	102 (13.8)	45 (17.1)	
In nursing institutions	37 (1.6)	10 (0.8)	17 (2.3)	10 (3.8)	
Education level					*p* < .001
Educated	1097 (47.7)	727 (56.0)	279 (37.9)	91 (34.6)	
Uneducated	1202 (52.3)	572 (44.0)	458 (62.1)	172 (65.4)	
Marital status					*p* < .001
With spouse	1277 (55.5)	827 (63.7)	349 (47.3)	101 (38.4)	
Without spouse	1022 (44.5)	472 (36.3)	388 (52.7)	162 (61.6)	
Household income					0.016
0-1000	498 (21.7)	263 (20.3)	190 (25.8)	45 (17.1)	
1000–2000	589 (25.6)	338 (26.0)	182 (24.7)	69 (26.2)	
2000–4500	611 (26.6)	347 (26.7)	187 (25.4)	77 (29.3)	
>=4500	601 (26.1)	351 (27.0)	178 (24.1)	72 (27.4)	
Retirement					*p* < .001
Yes	1817 (79.0)	956 (73.6)	624 (84.7)	237 (90.1)	
No	482 (21.0)	343 (26.4)	113 (15.3)	26 (9.9)	
Medical insurance					0.383
Yes	330 (14.4)	198 (15.2)	97 (13.2)	35 (13.3)	
No	1969 (85.6)	1101 (84.8)	640 (86.8)	228 (86.7)	
Lifestyle-related variables					
Smoking					*p* < .001

Table 1 (continued)

Variables	Overall (*N* = 2299)	Non-frail (*N* = 1299)	Moderate progressive (*N* = 737)	High progressive (*N* = 263)	*P*
Yes	595 (25.9)	388 (29.9)	150 (20.3)	57 (21.7)	
No	1704 (74.1)	911 (70.1)	587 (79.7)	206 (78.3)	
Drinking					*p* < .001
Yes	568 (24.7)	371 (28.6)	139 (18.9)	58 (22.0)	
No	1731 (75.3)	928 (71.4)	598 (81.1)	205 (78.0)	
Vitamin supplement					*p* < .001
Yes	675 (29.4)	392 (30.2)	193 (26.2)	90 (34.2)	
No	1624 (70.6)	907 (69.8)	544 (73.8)	173 (65.8)	
Regular fruit supplement					0.153
Yes	781 (34.0)	463 (35.6)	233 (31.6)	85 (32.3)	
No	1518 (66.0)	836 (64.4)	504 (68.4)	178 (67.7)	
Regular vegetable supplement					0.255
Yes	2096 (91.2)	1194 (91.9)	668 (90.6)	234 (89.0)	
No	203 (8.8)	105 (8.1)	69 (9.4)	29 (11.0)	
Physical activity					0.009
Yes	890 (38.7)	511 (39.3)	259 (35.1)	120 (45.6)	
No	1409 (61.3)	788 (60.7)	478 (64.9)	143 (54.4)	
Health-related variables					
BMI					0.017
Normal	1151 (50.1)	689 (53.0)	339 (46.0)	123 (46.8)	
Underweight	1033 (44.9)	541 (41.7)	369 (50.1)	123 (46.8)	
Overweight or Obese	115 (5.0)	69 (5.3)	29 (3.9)	17 (6.4)	
Missing teeth					*p* < .001
Yes	1932 (84.0)	1029 (79.2)	660 (89.6)	143 (92.4)	
No	367 (16.0)	270 (20.8)	77 (10.4)	20 (7.6)	
Annual physical examination					0.651
Yes	1347 (58.6)	758 (58.3)	428 (58.1)	161 (61.2)	
No	952 (41.4)	541 (41.7)	309 (41.9)	202 (38.8)	

Pearson's chi-squared test for qualitative variables

compared to those who were not. Based on Table 4, physically stimulating activity had a protective influence on frailty trajectories in individuals aged 80 and above, those who were uneducated and retired, while socially stimulating activity had a protective effect in individuals aged 65 to 79, those who were educated and retired. The *p* value for interactions of age, education level and retirement status with three types of leisure activity were 0.425, 0.811, and 0.071, respectively. In our analysis, the results showed no significant interaction effects (*p* for all interactions > 0.05).

Discussion

This study focused on trajectories of frailty among older adults, and explored the relationship between scores of leisure activities and three distinct categories of leisure activities and different frailty trajectories. The analysis reveals that each one-unit increase in leisure activity score is associated with an 11% lower likelihood of transitioning to the moderate progressive frail trajectory and a 14% lower likelihood of transitioning to the high progressive frailty trajectory. Physically stimulating activities and socially stimulating activities are associated with transitions to both moderate and high progressive frailty trajectories. However, no significant relationship was found between cognitively stimulating activities and frailty trajectories.

In this study, we identified three frailty trajectories among older adults, this finding was similar with a prospective 12-year longitudinal study of German older adults [11]. Our study was inconsistent with previous studies conducted in China, which highlighted two frailty trajectories [19, 52]. This inconsistent finding might be due to the different population and shorter follow-up periods compared to our sample. According to the frailty trajectories we found, our observation

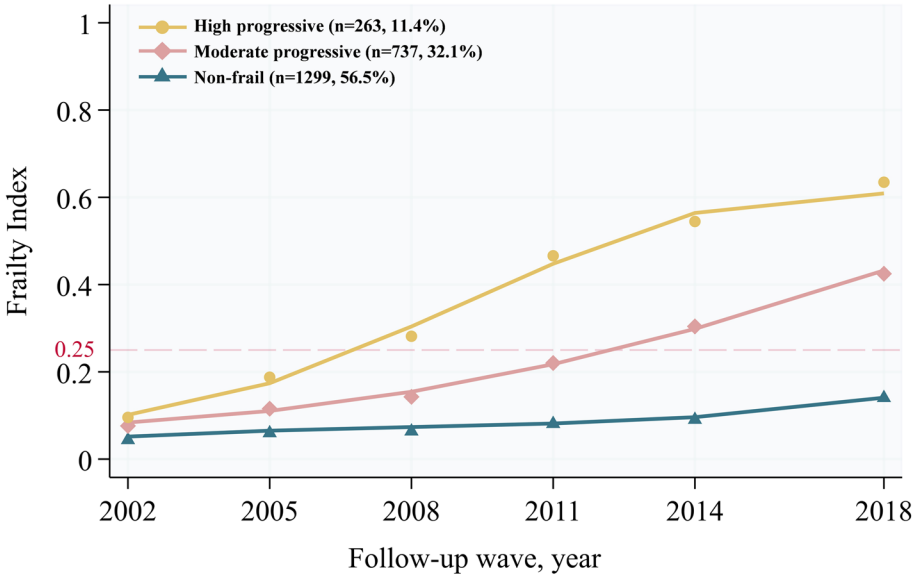

Fig. 1 Frailty trajectories during 2002–2018 in the CLHLS Survey

Table 2 Associations between frailty trajectories and leisure activity

Leisure activity	Moderate progressive vs. Non-frail	High progressive vs. Non-frail
	OR (95%CI)	OR (95%CI)
Integrated leisure activity[a]	0.89 (0.85,0.93)***	0.86 (0.80,0.91)***
Physically stimulating activity[b]		
Never	1	1
Sometimes	0.67 (0.44–1.03)	0.84 (0.48–1.48)
Almost every day	0.57 (0.40–0.81)**	0.57 (0.36–0.92)*
Cognitively stimulating activity[b]		
Never	1	1
Sometimes	0.83 (0.60–1.14)	0.85 (0.54–1.34)
Almost every day	1.02 (0.75–1.38)	0.88 (0.57–1.37)
Socially stimulating activity[b]		
Never	1	1
Sometimes	0.96 (0.67–1.38)	0.61 (0.36–1.04)
Almost every day	0.68 (0.49–0.93)*	0.61 (0.39–0.95)*

OR Odds Ratio, *CI* Confidence Intervals

Adjusted covariables included age, residence, gender, living arrangement, education level, marital status, household income, retirement, medical insurance, smoking, drinking, vitamin supplementation, regular fruit supplement, regular vegetable supplement, physical activity, BMI, missing teeth, and annual physical examination

[a] multinomial logistic regression separately for integrated leisure activity and frailty trajectories

[b] multinomial logistic regression separately for physically, cognitively, socially stimulating activity and frailty trajectories

*$p < .05$

**$p < .01$

***$p < .001$

Table 3 Associations between frailty trajectories and integrated leisure activity stratified by participants' characteristics

Integrated leisure activity	Moderate progressive vs. Non-frail	High progressive vs. Non-frail	*P* for Interaction
	OR (95%CI)	OR (95%CI)	
Age			0.280
65–79	0.89 (0.85–0.94)***	0.88 (0.80–0.95)**	
>=80	0.87 (0.79–0.95)**	0.81 (0.73–0.91)***	
Education			0.495
Yes	0.89 (0.84–0.95)***	0.87 (0.79–0.96)**	
No	0.88 (0.82–0.94)***	0.85 (0.78–0.92)***	
Retirement			0.697
Yes	0.89 (0.84–0.93)***	0.85 (0.80–0.91)***	
No	0.90 (0.80–1.01)	0.84 (0.68–1.04)	

Adjusted covariables included age, residence, gender, living arrangement, education level, marital status, household income, retirement, medical insurance, smoking, drinking, vitamin supplementation, regular fruit supplement, regular vegetable supplement, physical activity, BMI, missing teeth, and annual physical examination

**$p < .01$

***$p < .001$

further showed that the non-frail population may experience a 'safe period' lasting approximately five years after the initial assessment. Namely, this 'safe period' represents an important window of opportunity where interventions can be implemented to help the elderly reduce their risk of progressing to worse frailty status. Furthermore, we observed that the FI in individuals with a high

Table 4 Associations between frailty trajectories and three types of leisure activity stratified by participants' characteristics [OR (95%CI)]

Leisure activity	Moderate progressive vs. Non-frail						High progressive vs. Non-frail					
	Age		Education		Retirement		Age		Education		Retirement	
	65–79	>=80	Yes	No	Yes	No	65–79	>=80	Yes	No	Yes	No
Physically stimulating activity												
Never	1	1	1	1	1	1	1	1	1	1	1	1
Sometimes	0.75 (0.44–1.28)	0.56 (0.24–1.32)	0.59 (0.33–1.04)	0.72 (0.36–1.43)	0.72 (0.45–1.15)	0.37 (0.10–1.29)	0.71 (0.30–1.65)	0.78 (0.30–1.99)	1.13 (0.48–2.63)	0.75 (0.33–1.70)	0.82 (0.45–1.51)	0.96 (0.15–6.07)
Almost every day	0.66 (0.42–1.02)	0.38 (0.18–0.77) **	0.65 (0.41–1.02)	0.45 (0.25–0.80) **	0.59 (0.40–0.86) **	0.48 (0.18–1.30)	0.60 (0.30–1.17)	0.40 (0.18–0.89) *	0.71 (0.35–1.45)	0.46 (0.23–0.91) *	0.62 (0.38–1.02)	0.19 (0.03–1.04)
Cognitively stimulating activity												
Never	1	1	1	1	1	1	1	1	1	1	1	1
Sometimes	0.93 (0.65–1.35)	0.55 (0.27–1.10)	1.21 (0.60–2.44)	0.75 (0.52–1.09)	0.71 (0.49–1.02)	1.48 (0.74–2.95)	0.94 (0.52–1.72)	0.52 (0.23–1.18)	1.54 (0.49–4.89)	0.73 (0.44–1.22)	0.84 (0.51–1.40)	0.48 (0.15–1.60)
Almost every day	1.04 (0.74–1.48)	1.14 (0.55–2.37)	1.24 (0.65–2.37)	1.05 (0.73–1.51)	0.96 (0.68–1.36)	1.35 (0.68–2.68)	0.78 (0.43–1.40)	0.98 (0.43–2.25)	1.50 (0.51–4.46)	0.82 (0.50–1.36)	0.98 (0.60–1.60)	0.29 (0.08–1.04)
Socially stimulating activity												
Never	1	1	1	1	1	1	1	1	1	1	1	1
Sometimes	0.98 (0.65–1.48)	1.12 (0.46–2.70)	0.65 (0.35–1.23)	1.18 (0.74–1.87)	1.03 (0.68–1.56)	0.66 (0.28–1.55)	0.38 (0.18–0.81)*	0.96 (0.36–2.58)	0.43 (0.16–1.15)	0.72 (0.38–1.40)	0.62 (0.35–1.10)	0.37 (0.04–3.66)
Almost every day	0.71 (0.50–1.02)	0.65 (0.30–1.39)	0.51 (0.29–0.90) *	0.75 (0.51–1.11)	0.68 (0.47–0.97) *	0.59 (0.31–1.15)	0.55 (0.31–0.97)*	0.63 (0.26–1.49)	0.41 (0.17–0.99) *	0.71 (0.41–1.23)	0.53 (0.32–0.86) *	1.79 (0.34–9.39)

Adjusted covariables included age, residence, gender, living arrangement, education level, marital status, household income, retirement, medical insurance, smoking, drinking, vitamin supplementation, regular fruit supplement, regular vegetable supplement, physical activity, BMI, missing teeth, and annual physical examination

*$p < .05$

**$p < .01$

***$p < .001$

progressive frailty trajectory slowed down after reaching a specific threshold. This pattern had not been seen in previous studies of the Chinese population [19, 31, 52]. This verifies the existence of ceiling effects on the magnitude of FI growth [53, 54].

Our study further observed that higher levels of integrated leisure activity were associated with a lower likelihood of being in the moderate or high progressive frailty trajectories. Our findings suggest that it is advisable to not only increase the frequency but also diversify the types and amounts of leisure activity, as economic and time constraints permit. In particular, the measurement of integrated leisure activities was used in our study, which previously widely been utilized in studies of cognitive decline [41, 55], and has proven effective in predicting frailty trajectories in our research. Leisure activity is a domain of lifestyle over which people have significant control [56], and it plays a crucial role in preventing the development of frailty [16]. Shimada et al. [57] found that the higher total scores of leisure activities are significantly associated with a lower incidence of frailty [57]. Zhou et al. [15] confirmed that participation in leisure activities reduces the risk of frailty, with each unit increase in the leisure activity index correlating with a 12% reduction in the risk. Data from four waves of CLHLS found that, compared to older adults who engaged in leisure activities daily, individuals who participated often, occasionally or never had higher risks of being in the "rapid growth group" for frailty over the next ten years [19]. Our study is in line with previous findings and confirms the effect of leisure activity on frailty, extending current knowledge by focusing on frailty trajectories. We emphasize the beneficial effects of leisure activities throughout the life course, highlighting their role in delaying the progression of frailty.

Apart from analysing the effects of integrated leisure activity, we further examined the impact of distinct types of leisure activities on the development of frailty trajectories. Our analysis revealed that the effects vary significantly among different types. To be specific, physically and socially stimulating activity can prevent being in the moderate and high progressive frail trajectory. Indeed, previous studies have shown that physically stimulating activity is associated with a lower risk of frailty [47, 58]. The potential mechanism behind this is that such physically stimulating activity impacts the metabolic system, enhances muscle strength and improves physical frailty [13, 59, 60]. According to the recommendations from the U.S. Department of Health and Human Services for the elderly [61], increasing physical activity (even if it is low-intensity) and changing sedentary behaviours are helpful in maintaining muscle strength and overall health. This finding has significant practical implications, especially for older adults who may be restricted from participating in all types of leisure activities. They can prioritize physically stimulating activities, such as light housework, walking a dog, and gardening, rather than high-intensity exercises. These activities are cost-effective requiring minimal expenditure and suitable for older adults.

Socially stimulating activity showed a negative effect on being in the moderate and high progressive trajectory. A longitudinal study conducted in Switzerland revealed that socially stimulating activity is a protective factor against the adverse evolution of frailty [10]. Similarly, Takatori [62] et al. found that community-based socially stimulating activities protected older adults against the incidence of frailty. Research on social participation may explain our results. Social isolation and loneliness have been proven to be associated with an increased risk of frailty [63], while social, emotional and instrumental support can reduce future frailty levels [64]. Staying connected with others and engaged in the community is strongly linked with positive health and well-being among older adults [65]. In our study, social activities, outdoor activities, and traveling were included as aspects of socially stimulating activities. These activities are closely associated with interactions with others regarding their social attributes. Thus, socially stimulating activity can mitigate social frailty through strengthening social contact and establishing social identity [64, 66]. Therefore, engaging in socially stimulating activities are beneficial for older adults when their time and financial resources permit. Finally, cognitively stimulating activity had been found to decrease the risk of frailty outcome in prior literature [44, 57], but its impact on frailty trajectory transition was insignificant in our study. The potential explanations may be attributed to that most cognitively stimulating activities are sedentary, which increases the risk of frailty to some extent [67]. When older adults have limited time or financial resources, participating in cognitively stimulating activities may be considered last.

According to the stratified results, we observed that retired older residents are more likely to prevent frailty progression through increased participation in leisure activity. This may be due to the fact that they gain a new perspective on life and more leisure time after retirement [68]. For uneducated individuals especially at an advanced age, physically stimulating activities had a preventive effect against frailty. This suggests the need for more health education to prioritize physically stimulating activity in order to reduce the risk of frailty development

in this population. In turn, younger and educated older people tend to have better self-care ability and health status, thereby socially stimulating activity had a significant effect on them. Furthermore, educated participants may also have better social networks and economic status, which further promotes their social participation [69].

This study has several strengths. First, the sample was drawn from an ongoing nationally longitudinal cohort with a long follow-up period to establish stable frailty trajectories. The wealth of information provided the opportunity to adjust more covariates. Second, compared to the cross-sectional design, we used the GBTM model to explore development patterns of frailty. Third, we explored the influence of different types of leisure activities on frailty development, which increased the generalisation of the results. There are also several limitations. First, our leisure activity assessment was based on the self-reported questionnaire. The frequency is set roughly, and recall bias may exist. Second, based on self-perceived stimulation of older adults [17, 18], we categorized leisure activity into three types in our analysis. However, it may also be classified into different categories using other methods. Therefore, future research could consider exploring the relationship between alternative classification methods and the frailty trajectories. Third, for longitudinal data, a large proportion of participants were inevitably excluded due to loss of follow-up or death. There may be bias in the trajectory results. Fourth, we only verified the relationship between leisure activity and frailty trajectories at baseline, lacking the multi-year effect of leisure activity participation variation. Further studies could complement this through advanced methods.

Conclusions

In summary, we identified three distinct frailty trajectories among non-frail older adults in China. It is important to carry out frailty screening for implementing frailty prevention efforts in the "safe period". Meanwhile, older adults are encouraged to engage in a variety of activities and increase the amount of leisure activities, considering their time and financial conditions. Physically stimulating activities, such as light housework, walking a dog, and gardening, should be the primary choice, followed by socially and cognitively stimulating activity.

Abbreviations

CLHLS	The Chinese Longitudinal Healthy Longevity Survey
FI	Frailty Index
GBTM	The group-based trajectory modelling
BIC	The Bayesian Information Criterion
AIC	The Akaike Information Criterion
AvePP	The Average posterior probability

Supplementary Information

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Supplementary Material 1: Supplementary Table S1 Variables used in the CLHLS questionnaire. Supplementary Table S2 Health deficits included in calculating the Frailty Index. Supplementary Table S3 Leisure activities in the CLHLS. Supplementary Table S4 The fit statistics in trajectory analysis. Supplementary Figure S1 The original image of two frailty trajectories during 2002 - 2018 in the CLHLS Survey. Supplementary Figure S2 The original image of three frailty trajectories during 2002 - 2018 in the CLHLS Survey. Supplementary Figure S3 The original image of four frailty trajectories during 2002 - 2018 in the CLHLS Survey. Supplementary Figure S4 The original image of five frailty trajectories during 2002 - 2018 in the CLHLS Survey.

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Authors' contributions

XY: study design, analysis and interpretation of data, preparation of manuscript. WW: study design, validation. WZ: critical revision of the manuscript for important intellectual content, supervision. HZ: concept, obtained fundings, supervision. All authors reviewed the manuscript.

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Availability of data and materials

The datasets supporting during the study are available in the National Archive of Computerized Data on Aging (NACDA) repository, persistent web link: https://www.icpsr.umich.edu/icpsrweb/NACDA/series/487.

Declarations

Ethics approval and consent to participate

The CLHLS study was approved by the Research Ethics Committee of Peking University (IRB00001052-13074). All methods and research processes for this study were performed in accordance with the Declaration of Helsinki guidelines and regulations. All participants or their proxy respondents provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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