

Living Arrangement Modifies the Associations of Loneliness with Adverse Health Outcomes in Older Adults: Evidence From the CLHLS

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Abstract

Background: Although it has been suggested that loneliness is a risk factor for adverse health outcomes, living arrangement may confound the association. This study aimed to investigate whether the associations of loneliness with adverse health outcomes differ in community-dwelling older adults according to different living arrangements.

Methods: In the 2008/2009 wave of Chinese Longitudinal Healthy Longevity Survey, 16255 community-dwelling older adults (≥ 65 years) were recruited. Living arrangements and feelings of loneliness were assessed. Health outcomes including cognitive and physical functions were assessed using MMSE, ADL/IADL scales and Frailty Index in the 2008/2009 and 2011/2012 waves; mortality was assessed in the 3-year follow-up from 2008/2009 to 2011/2012. The associations of loneliness with adverse health outcomes according to different living arrangements were estimated using logistic regression or Cox proportional hazards regression models. Interactions between living arrangement and loneliness on adverse health outcomes were also investigated.

Results: Older adults who were lonely (47.8% of those living alone and 25% of those living with others) had higher prevalence of cognitive impairment, frailty and 3-year mortality than older adults without loneliness, especially among those who lived with others (OR=1.31, 95% CI=1.15-1.51; OR=1.42, 95% CI=1.26-1.60; HR=1.16, 95% CI=1.07-1.26, respectively). In contrast, among the living alone older adults, loneliness was only associated with higher prevalence of frailty (OR=1.41, 95% CI=1.06-1.88). Living arrangement modified the associations of loneliness with prevalent cognitive impairment and mortality (P values for interactions=0.006 and 0.015, respectively).

Conclusions: Living arrangement modifies the associations of loneliness with adverse health outcomes in community-dwelling older adults, and those who lived with others but felt lonely had worse cognitive and physical functions as well as higher mortality. Special attention should be paid to this population to reduce adverse health outcomes.

Background

Older adults encounter transitions such as physical ageing, diminished resilience, decreased social relationships and loss of intimate relationships, which may reduce social connectedness or ability to participate in social network activities, and make them more susceptible to be lonely [1–3]. Loneliness can be explained as the lack of “meaningful” social relationships [1] or the discrepancy between one’s desired relationships and one’s actual relationships, either in quantity or quality [4]. It is conceptually tied to the magnitude of one’s social network, but mainly depends on how that individual subjectively perceives those relationships and how satisfied he/she is with the types of support received from those relationships, thus may also be unrelated to objective social conditions [3, 5]. Loneliness is a major source of suffering among older adults [6]. It has been found that loneliness increased the risk of developing dementia among older adults especially in men [7], and was associated with mental disorders such as depression, physical decline and increased risk of death [4, 8–9].

As filial piety of the Confucius culture prevails in China, co-residence is valued as the most desirable living arrangement for older adults in community [10]. However, with the development of our society and increasing preferences for individual privacy and independence, older adults’ recognition on living alone is changing. Some living alone older adults may have better socioeconomic status and prefer a life style of more freedom and privacy [11], while others may be childless widows and do not have anyone to live with [12]. Living alone is often accompanied by a decreased level of family/social support and health care utilization, leading to social isolation and life challenges for older adults [13–14]. Studies have found inconsistent associations of living alone with adverse health outcomes. Some found that living alone was a risk factor for cognitive impairment and mortality [15–16], and older adults living with others had better psychological well-being [17]; while other studies found that living alone older adults had fewer physical disabilities and lower mortality risk [12].

Although living alone older adults are more likely to be lonely compared with their counterparts, and there is considerable overlap between living alone and loneliness, they are distinct definitions [3, 12]: living alone is an objective measure of one’s living arrangements, while loneliness is a subjective emotional experience of one’s personal relationships [18]. For now, however, studies have seldomly investigated whether the impacts of loneliness on adverse health outcomes in community-dwelling older adults differ by living arrangements, and it remains unclear to what extent loneliness affects health in older adults who live alone or not. Therefore, our study aimed to assess the associations of loneliness with cognitive and physical functions and mortality, and to determine whether living arrangement modifies these associations among community-dwelling older adults aged 65 years or above in China.

Methods

1. Study design and participants

The Chinese Longitudinal Healthy Longevity Survey (CLHLS) is an ongoing, prospective cohort study of community-dwelling Chinese older adults [19-20]. It covers the majority of the provinces in China and aims to investigate the factors associated with healthy longevity of Chinese. Started in 1998, the follow-ups have been conducted every 2 to 3 years. To reduce attrition, new participants are continually enrolled as death and lost-to-follow-up are inevitable. Trained interviewers with a structured questionnaire conduct the survey from door to door. A weight of age-sex-residence in the sample with the distribution of the total population was employed to reflect the unique sampling design [21].

In the 2008/2009 wave (baseline), 16948 older adults were interviewed in total, the number of which was the most among different waves. We excluded 385 participants younger than 65 years and 308 participants living in an institution, and finally included 16255 community-dwelling older adults for cross-sectional analyses. Among these older adults, 50.3% survived, 34.0% died, and 15.7% were lost in the 3-year follow-up (the 2011/2012 wave, see Table S1 for detailed information). Generally, the sociodemographic factors, socioeconomic status, and physical and cognitive functions of older adults who were lost in follow-up fell in between those who survived and died. The flow chart of our study was shown in Figure S1.

2. Measurements

We used the data of living arrangements and feelings of loneliness at baseline, and assessed the association of loneliness with adverse health outcomes, including cognitive impairment, functional limitation and frailty at baseline and the 3-year follow-up, as well as 3-year mortality from 2008/2009 to 2011/2012, in the total sample and stratified by living arrangements.

Assessment of living arrangements and loneliness

Living arrangements were assessed using the question "Who do you live with?" with responses including 'living with family (including house maid)', 'living alone (LA)', or 'living in an institution'. The 1st was defined as "not living alone/living with others (NLA, 84.3%)". As only 308 (1.9%) older adults who were much older (93.1±9.1 years) lived in an institution, and institution living was different from 'living with family', 'living alone' and "community-dwelling", we excluded them from analysis.

Loneliness was assessed via the question "Do you feel lonely or isolated?" with answers 'always', 'often', 'sometimes', 'seldom', 'never' and 'not able to answer', which has been demonstrated to be feasible for loneliness assessment by previous studies [22-23]. For the purpose of statistical analysis, we recoded the responses into a trichotomous variable: 'always', 'often', and 'sometimes' were defined as "lonely (FL, 28.6%)", 'seldom' and 'never' as "not lonely (NFL, 56.8%)", and 'not able to answer' as "NA (14.6%)".

Adverse health outcomes

(1) Cognitive impairment

The CLHLS used the Chinese version of the Mini-mental State Examination (MMSE), validity and reliability of which have been verified [19-20], as a measure of cognitive function at each wave. The total scores range from 0 to 30, with higher scores representing better cognitive function. We used education-adjusted criteria to define "cognitive impairment": for participants without formal education, MMSE score ≤ 17 was defined as CI; for those with 1-6-year education, MMSE score ≤ 20 was defined as CI; for those with more than 6-year education, MMSE score ≤ 24 was defined as CI [24-25].

(2) Functional limitation

The Katz Basic Activities of Daily Living (ADL) Scale and Lawton Instrumental Activities of Daily Living (IADL) Scale were used to assess participants' physical function. Having difficulty in performing any one or more of the ADL tasks (6 items: bathing, dressing, toileting, transfers, continence and eating) was defined as having ADL limitation; having difficulty in performing any one or more of the IADL tasks (8 items: be able to go outside to visit neighbors, shop by oneself, make food by oneself, wash clothes by oneself, walk one kilometer, carry 5 kg weight, crouch and stand 3 times, take public transportation) was defined as having IADL limitation. Participants with either ADL or IADL limitation were defined as functional limitation.

(3) Frailty assessment

Our Frailty Index (FI) was the same as the previous CLHLS studies [26-27]. FI included 39 self-reported items, including functional limitations, cognitive function, self-reported health status, interviewer-rated health status, mental health, auditory and visual ability, heart rhythm, and chronic diseases. We scored each term as 0 (absence of deficit) or 1 (presence of deficit) for 38 of 39 terms, and scored 1 term as 2 if the participants reported 2 or more serious illnesses that caused hospitalization or being bedridden in the past 2 years. FI score was equal to the number of reported deficits divided by the total number of included deficits. It was a continuous variable ranging from 0 to 1, with a higher value indicating severer frailty. The continuous FI score was classified into non-frailty ($FI \leq 0.21$) and frailty ($FI > 0.21$) following a previous report [26-27].

(4) Mortality

Mortality was measured by survival status and duration of exposure to death. The survival status was measured by whether a respondent interviewed in the 2008/2009 wave died or survived at the 2011/2012 wave. The exposure duration for a survivor was measured by number of months between the interview date in the 2008/2009 and 2011/2012 waves. For those who died before the 2011/2012 wave, the exposure time was measured by the time interval between date of death and the interview date in the 2008/2009 wave. The date of death was collected from officially issued death certificates whenever available, otherwise the next-of-kin and local residential committees were consulted. The average follow-up period of all participants was 3.2 (± 1.5) years, with 1.5 (± 0.9) years for deceased participants, and 4.4 (± 0.2) years for survived participants. The data quality of mortality in the CLHLS has been proved to be high [26].

Covariates

Measures of sociodemographic characteristics at baseline included age, gender, race, marital status, residence, occupation, education, BMI, smoking, alcohol drinking, and socioeconomic status including sufficient financial support, economic independence, adequate medical service and public medical payment, dietary habits including fruit and vegetable eating, and tea drinking. Living preference was assessed via the question "What kind of living arrangement do you like best?", with answers 'living alone (or only with spouse) regardless of proximity to children', 'living alone (or only with spouse) with close proximity to

children', 'live with children'. The former two were combined as "prefer LA", and the 3rd as "prefer NLA". Social/leisure activity score was calculated in the way same as a previous study [24], with a high score representing a high frequency of social and leisure activities. Physical exercise was assessed via the question "Do you take exercise or not at present?" with answers 'yes' or 'no'. Self-reported health was assessed via the question "How do you rate your health status?" with answers 'bad' and 'very bad' defined as "poor self-reported health". Interviewer-rated health was assessed by interviewers, with 'moderately ill' and 'very ill' defined as "poor interviewer-rated health". Comorbidities was assessed via whether suffering from 24 common chronic diseases including hypertension, diabetes, heart disease and stroke. Serious illness in the past 2 years was defined as "illness that causes hospitalization or being bedridden all the year around". Hearing and visual ability were also assessed.

3. Statistical analysis

Categorical variables were presented as numbers (percentages), and continuous variables were presented as means (SD). Differences in the distribution of categorical variables among groups were tested by χ^2 test. For continuous variables, the F test or Kruskal-Wallis test was used for comparison between different groups. Logistic regression models were performed to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) of associations between loneliness and cognitive impairment, functional limitation and frailty (in the total sample or stratified by living arrangements), as well as the interaction terms between living arrangements and loneliness. Cox proportional hazards regression model was performed to calculate the hazard ratios (HRs) and 95% CIs between loneliness and 3-year mortality (in the total sample or stratified by living arrangements). The impacts of loneliness on adverse health outcomes were also measured within strata of age groups (<80 or \geq 80 years) and genders. OR estimates for prevalent cognitive impairment, functional limitation and frailty, and HR for 3-year mortality were adjusted for baseline values of age, gender, race, marital status, residence, occupation, education, BMI, smoking, alcohol drinking, living preferences, socioeconomic status, dietary habits, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidities (\geq 2), hypertension, diabetes, heart disease, stroke, serious illness in the past 2 years, hearing problem, and visual impairment. As many variables changed from 2008/2009 to 2011/2012, OR estimates for incident cognitive impairment, functional limitation and frailty were adjusted for age, gender, race, education, occupation, hypertension, diabetes, heart disease, stroke, and changes of other variables from 2008/2009 to 2011/2012. The acceptable level of significance was set as two-sided $P < 0.05$. Stata version 14.0 (StataCorp LP, College Station, TX, USA) was used for data analysis.

Results

1. Baseline characteristics by living arrangements and feelings of loneliness

As shown in Table 1, some of the factors associated with LA and FL were similar. In general, both LA and FL were more prevalent among older adults who were female and SDW, lived in rural, had less education, lower BMI, non-professional occupations, worse financial status, lower social/leisure activity score, and poor self-reported health. Meanwhile, fewer of the LA and FL older adults ate fruits and vegetables.

Compared with those who were NLA, LA older adults tended to be younger, more preferred LA and took physical exercise, fewer had poor interviewer-rated health, \geq 2 comorbidities (including heart disease and stroke), serious illness in the past 2 years, hearing problem, visual impairment, cognitive impairment, functional limitation and frailty. Compared with those who were NFL, FL older adults tended to be older and non-Han Chinese, fewer were currently smoking, drinking alcohol and tea, taking physical exercise, more preferred NLA, had poor interviewer-rated health, serious illness in the past 2 years, hearing problem, visual impairment, cognitive impairment, functional limitation and frailty. Participants with "NA" on feelings of loneliness had mostly consistent characteristics with the FL older adults but were generally worse.

2. Association and interaction between living arrangement and loneliness

Compared with NLA, LA was significantly associated with higher prevalence of loneliness at baseline (OR = 1.85, $P < 0.001$), as well as higher incidence of loneliness in the 3-year follow-up (OR = 1.38, $P = 0.007$) (Table 2). As shown in **Fig. 1**, living arrangement modifies the associations of loneliness with cognitive impairment (P value for interaction = 0.006) and mortality (P value for interaction = 0.015), especially for females (P values for interaction = 0.029 and 0.066, respectively) and older adults \geq 80 years (P values for interaction = 0.008 and 0.014, respectively, **Figure S2**).

Table 1
Baseline Characteristics by Living Arrangements and Feelings of Loneliness

Characteristics	Total Sample (N = 16255)	NLA 13709 (84.3)	LA 2546 (15.7)	P	NFL 9228 (56.8)	FL 4644 (28.6)	NA 2383 (14.6)	P
Socio-demographic								
Age (years)	87.4 (11.4)	87.5 (11.6)	86.5 (9.7)	<0.001	84.7 (11.4)	88.0 (10.4)	96.6 (7.7)	<0.001
Gender (female)	9371 (57.7)	7852 (57.3)	1519 (59.7)	0.025	4809 (52.1)	2816 (60.6)	1746 (73.3)	<0.001
Race (minority)	985 (6.1)	851 (6.2)	134 (5.3)	0.067	541 (5.9)	360 (7.8)	84 (3.5)	<0.001
Marital status (SDW)	11346 (69.8)	8825 (64.4)	2521 (99.0)	<0.001	5360 (58.1)	3850 (82.9)	2136 (89.6)	<0.001
Residence (rural)	9905 (60.9)	8266 (60.3)	1639 (64.4)	<0.001	5297 (57.4)	3018 (65.0)	1590 (66.7)	<0.001
Occupation (professional)	1113 (6.9)	981 (7.2)	132 (5.2)	<0.001	809 (8.8)	230 (5.0)	74 (3.1)	<0.001
Education (≥ 1 year)	5932 (36.6)	5091 (37.2)	841 (33.1)	<0.001	4049 (44.0)	1490 (32.2)	393 (16.6)	<0.001
BMI (kg/m ²)	20.3 (3.5)	20.3 (3.6)	19.9 (3.4)	<0.001	20.7 (3.6)	19.8 (3.4)	19.4 (3.5)	<0.001
Current smoker	2784 (17.1)	2321 (16.9)	463 (18.2)	0.123	1829 (19.8)	693 (14.9)	262 (11.0)	<0.001
Current alcohol drinker	2758 (17.0)	2334 (17.0)	424 (16.7)	0.646	1801 (19.5)	668 (14.4)	289 (12.1)	<0.001
Prefer living alone	5924 (36.4)	4185 (30.5)	1739 (68.3)	<0.001	4001 (43.4)	1617 (34.8)	306 (12.8)	<0.001
Socioeconomic status								
Sufficient financial support	12511 (77.0)	10678 (77.9)	1833 (72.0)	<0.001	7649 (82.9)	3183 (68.5)	1679 (70.5)	<0.001
Economic independence	4020 (24.7)	3468 (25.3)	552 (21.7)	<0.001	2915 (31.6)	886 (19.1)	219 (9.2)	<0.001
Adequate medical service	15008 (92.3)	12801 (93.4)	2207 (86.7)	<0.001	8838 (95.8)	4003 (86.2)	2167 (90.9)	<0.001
Public medical payment	2117 (13.0)	1836 (13.4)	281 (11.0)	0.001	1389 (15.1)	499 (10.8)	229 (9.6)	<0.001
Dietary habits								
Fruit eating	6243 (38.4)	5482 (40.0)	761 (29.9)	<0.001	4013 (43.5)	1438 (31.0)	792 (33.3)	<0.001
Vegetable eating	14214 (87.5)	12081 (88.1)	2133 (83.8)	<0.001	8301 (90.0)	3996 (86.1)	1917 (80.5)	<0.001
Tea drinking	6189 (38.1)	5227 (38.1)	962 (37.8)	0.755	3909 (42.4)	1804 (38.9)	476 (20.0)	<0.001
Physical health status								
Social/leisure activity score (point)	3.1 (3.1)	3.2 (3.1)	2.9 (2.8)	<0.001	3.9 (3.2)	2.7 (2.9)	1.1 (2.0)	<0.001
Physical exercise	4429 (27.2)	3687 (26.9)	742 (29.1)	0.019	3065 (33.2)	1070 (23.1)	294 (12.3)	<0.001
Poor self-reported health	2339 (16.4)	1898 (16.0)	441 (18.6)	0.002	1110 (12.0)	1117 (24.1)	112 (28.0)	<0.001
Poor interviewer-rated health	3035 (18.7)	2667 (19.5)	368 (14.5)	<0.001	953 (10.3)	1019 (21.9)	1063 (44.6)	<0.001
Comorbidities (≥ 2)	7528 (46.3)	6423 (46.9)	1105 (43.4)	0.001	4220 (45.8)	2206 (47.5)	1102 (46.3)	0.140
Hypertension	3133 (19.7)	2622 (19.5)	511 (20.6)	0.218	1875 (20.7)	940 (20.8)	318 (13.7)	<0.001
Diabetes	412 (2.6)	357 (2.7)	55 (2.2)	0.197	257 (2.8)	124 (2.8)	31 (1.3)	<0.001
Heart disease	1453 (9.1)	1268 (9.4)	185 (7.4)	0.001	870 (9.6)	390 (8.6)	193 (8.2)	0.051
Stroke	983 (6.2)	881 (6.5)	102 (4.1)	<0.001	487 (5.4)	250 (5.5)	246 (10.6)	<0.001
Serious illness in the past 2 years	2853 (17.6)	2494 (18.2)	359 (14.1)	<0.001	1459 (15.8)	833 (17.9)	561 (23.5)	<0.001
Hearing problem	4452 (27.4)	3965 (28.9)	487 (19.1)	<0.001	1273 (13.8)	1030 (22.2)	2149 (90.2)	<0.001
Visual impairment	3507 (21.8)	3025 (22.3)	482 (19.0)	<0.001	1252 (13.6)	992 (21.4)	1263 (55.8)	<0.001
Adverse health outcomes								
Cognitive impairment	4969 (30.6)	4395 (32.1)	574 (22.6)	<0.001	1451 (15.8)	1236 (26.7)	2282 (95.9)	<0.001
Functional limitation	8459 (52.0)	7391 (53.9)	1068 (42.0)	<0.001	3719 (40.3)	2574 (55.4)	2166 (90.9)	<0.001
Frailty	5120 (31.5)	4639 (33.8)	481 (18.9)	<0.001	1813 (19.7)	1501 (32.3)	1806 (75.8)	<0.001
<i>Note.</i> Data presented as n (%) or mean (SD). NLA, not living alone; LA, living alone; NFL, not feeling lonely; FL, feeling lonely; NA: not able to answer; SDW, Separated/Divorced/Widowed; MMSE: Mini-mental State Examination.								

Table 2
Associations of Living Alone with Prevalent and Incident Loneliness

	No. (%)	Loneliness		
		No. (%)	OR (95% CI)	P
Cross-sectional Analyses^a	N = 16255			
NLA	13709	3426 (25.0)	1.00	
LA	2546	1218 (47.8)	1.85 (1.65–2.07)	< 0.001
Longitudinal Analyses^b	N = 9228 *			
NLA	8115	1056 (22.3)	1.00	
LA	1113	217 (34.0)	1.38 (1.09–1.73)	0.007
<i>Note.</i> NLA, not living alone; LA, living alone. * For 9228 participants being not lonely at baseline.				
^a Adjusted for age, gender, race, marital status, residence, occupation, education, BMI, smoking, alcohol drinking, socioeconomic status, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidities (≥ 2), serious illness in the past 2 years, hearing problem, visual impairment, fruit and vegetable eating, tea drinking, hypertension, diabetes, heart disease and stroke.				
^b Adjusted for age, gender, race, education, occupation, hypertension, diabetes, heart disease, stroke, and changes in marital status, residence, BMI, smoking, alcohol drinking, socioeconomic status, dietary habits, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidity number, serious illness in the past 2 years, hearing problem, and visual impairment from 2008/2009 to 2011/2012.				

3. Associations of loneliness with adverse health outcomes in the total sample or stratified by living arrangements

As shown in Table 3, in cross-sectional analysis, after adjusted for confounders, FL was a risk factor for cognitive impairment and frailty in the total sample (OR = 1.22, 95% CI = 1.08–1.38, $P = 0.002$; OR = 1.42, 95% CI = 1.27–1.59, $P < 0.001$, respectively), and older adults with “NA” in feelings of loneliness showed higher ORs for cognitive impairment, functional limitation and frailty than the FL ones. When analyses were stratified by living arrangements, compared with the NFL older adults, FL was not associated with cognitive impairment in the LA older adults, but showed higher OR in the NLA older adults (OR = 1.31, 95% CI = 1.15–1.51, $P = 0.001$) than in the total sample (OR = 1.22, $P = 0.002$) or in the LA ones (OR = 0.82, $P = 0.199$); meanwhile, FL showed similar ORs for frailty in both NLA and LA older adults (ORs = 1.42 and 1.41, respectively). In the longitudinal analysis, after adjusted for confounders including changes of some variables from 2008/2009 to 2011/2012, compared with the NFL older adults, FL was a significant risk factor for 3-year mortality in the total sample (HR = 1.12, 95% CI = 1.04–1.21, $P = 0.003$), which kept being significant only in the NLA older adults (HR = 1.16, 95% CI = 1.07–1.26, $P < 0.001$) but not the LA ones (HR = 0.92, $P = 0.366$).

Age and gender also affected the associations of loneliness with adverse health outcomes in the total sample or stratified by living arrangements. FL was associated with higher prevalence of cognitive impairment especially in older adults ≥ 80 years and older males (both ORs = 1.23); when stratified by living arrangements, the associations kept being significant only in NLA older adults (especially NLA older adults ≥ 80 years and NLA males, ORs = 1.33 and 1.36, respectively) but not the LA ones. FL was also associated with incident cognitive impairment in the NLA older males (OR = 1.57, **Table S2**). For functional limitation, FL showed no significant association in both cross-sectional and longitudinal analyses (**Table S3**). For frailty, FL was associated with higher prevalence of frailty especially in older adults < 80 years and older males (ORs = 1.92 and 1.52, respectively); when stratified by living arrangements, the associations kept being significant in the NLA ones; in the LA ones, however, FL was associated with prevalent frailty only in females (OR = 1.67). Meanwhile, FL was also associated with incident frailty in females without stratifying living arrangements (OR = 1.28, **Table S4**). FL was associated with 3-year mortality especially in older adults < 80 years and older females (HRs = 1.50 and 1.15, respectively); when stratified by living arrangements, the associations were significant in both genders and age groups only in the NLA older adults (HRs = 1.14–1.59, **Table S5**).

Table 3
Associations of Loneliness with Prevalent and Incident Adverse Health Outcomes in Total Sample or Stratified by Living Arrangements

		Cognitive Impairment			Functional Limitation			Frailty			3-year Mortality ^c		
		No. (%)	OR (95% CI)	P	No. (%)	OR (95% CI)	P	No. (%)	OR (95% CI)	P	per 100 person-years	HR (95% CI)	P
Cross-sectional Analyses^a													
Loneliness		N = 15835*			N = 16255			N = 16255					
NFL		1405 (15.4)	1.00		3719 (40.3)	1.00		1813 (19.7)	1.00				
FL		1185 (26.0)	1.22 (1.08–1.38)	0.002	2574 (55.4)	1.08 (0.97–1.20)	0.170	1501 (32.3)	1.42 (1.27–1.59)	< 0.001			
NA		2034 (95.6)	5.80 (4.07–8.26)	< 0.001	2166 (90.9)	2.46 (1.60–3.77)	< 0.001	1806 (75.8)	4.02 (3.46–4.66)	< 0.001			
Living arrangements	Loneliness #	N = 15835*			N = 16255			N = 16255					
NLA	NFL	1241 (15.4)	1.00		3326 (41.0)	1.00		1676 (20.7)	1.00				
NLA	FL	978 (29.2)	1.31 (1.15–1.51)	0.001	2070 (60.4)	1.10 (0.98–1.25)	0.110	1268 (37.0)	1.42 (1.26–1.60)	< 0.001			
NLA	NA	1849 (96.1)	6.61 (4.49–9.74)	< 0.001	1995 (92.0)	2.12 (1.35–3.32)	0.001	1695 (78.2)	4.10 (3.49–4.80)	< 0.001			
LA	NFL	164 (14.8)	1.00		393 (35.3)	1.00		137 (12.3)	1.00				
LA	FL	207 (17.1)	0.82 (0.60–1.11)	0.199	504 (41.4)	0.98 (0.78–1.24)	0.871	233 (19.1)	1.41 (1.06–1.88)	0.019			
LA	NA	185 (91.6)	2.34 (0.90–6.09)	0.080	171 (79.5)	7.56 (1.89–30.2)	0.004	111 (51.6)	3.36 (2.16–5.23)	< 0.001			
Longitudinal Analyses^b													
Loneliness		N = 6670			N = 5188			N = 6841			N = 13695		
NFL		776 (16.0)	1.00		1229 (32.2)	1.00		1111 (22.9)	1.00		8.7	1.00	
FL		394 (22.3)	1.04 (0.84–1.30)	0.715	550 (43.5)	1.08 (0.89–1.30)	0.440	495 (28.5)	1.20 (0.99–1.46)	0.064	13.6	1.12 (1.04–1.21)	0.003
NA		13 (31.7)	0.78 (0.25–2.44)	0.673	58 (54.7)	1.57 (0.56–4.41)	0.392	129 (50.6)	1.40 (0.91–2.14)	0.121	29.7	1.00 (0.84–1.19)	0.995
Living arrangements	Loneliness #	N = 6670			N = 5188			N = 6841			N = 13695		

Note. NLA, not living alone; LA, living alone; NFL, not feeling lonely; FL, feeling lonely; NA: not able to answer. * Excluded 33 participants with missing MMSE score and 387 with dementia at baseline.

^a ^c Adjusted for age, gender, race, marital status, residence, occupation, education, BMI, smoking, alcohol drinking, living arrangements, living preferences, socioeconomic status, dietary habits, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidities (≥ 2), hypertension, diabetes, heart disease, stroke, serious illness in the past 2 years, hearing problem, and visual impairment. # Living arrangements were not adjusted.

^b Longitudinal analyses were performed on participants without baseline cognitive impairment, functional limitation or frailty for respective outcomes; adjusted for age, gender, race, education, occupation, living arrangements, hypertension, diabetes, heart disease, stroke, and changes in marital status, residence, BMI, smoking, alcohol drinking, living preferences, socioeconomic status, dietary habits, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidity number, serious illness in the past 2 years, hearing problem, and visual impairment from 2008/2009 to 2011/2012.

		Cognitive Impairment			Functional Limitation			Frailty			3-year Mortality ^c		
		No. (%)	OR (95% CI)	P	No. (%)	OR (95% CI)	P	No. (%)	OR (95% CI)	P	per 100 person-years	HR (95% CI)	P
NLA	NFL	675 (15.7)	1.00		1069 (31.8)	1.00		971 (22.8)	1.00		8.7	1.00	
NLA	FL	290 (24.2)	1.06 (0.83–1.36)	0.636	359 (43.4)	1.07 (0.86–1.33)	0.555	347 (29.8)	1.18 (0.95–1.48)	0.137	15.0	1.16 (1.07–1.26)	< 0.001
NLA	NA	11 (30.6)	0.83 (0.26–2.66)	0.758	44 (53.7)	1.41 (0.44–4.51)	0.560	111 (53.9)	1.73 (1.08–2.76)	0.022	30.6	1.01 (0.84–1.22)	0.894
LA	NFL	101 (17.9)	1.00		160 (34.8)	1.00		140 (23.8)	1.00		8.5	1.00	
LA	FL	104 (18.4)	0.91 (0.53–1.58)	0.745	191 (43.7)	1.10 (0.74–1.65)	0.635	148 (25.8)	1.08 (0.73–1.60)	0.710	10.0	0.92 (0.76–1.11)	0.366
LA	NA	2 (40.0)	-	-	14 (58.3)	9.31 (0.55–157)	0.121	18 (36.7)	0.92 (0.36–2.34)	0.867	22.1	0.82 (0.46–1.45)	0.493

Note. NLA, not living alone; LA, living alone; NFL, not feeling lonely; FL, feeling lonely; NA: not able to answer. * Excluded 33 participants with missing MMSE score and 387 with dementia at baseline.

^{a c} Adjusted for age, gender, race, marital status, residence, occupation, education, BMI, smoking, alcohol drinking, living arrangements, living preferences, socioeconomic status, dietary habits, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidities (≥ 2), hypertension, diabetes, heart disease, stroke, serious illness in the past 2 years, hearing problem, and visual impairment. # Living arrangements were not adjusted.

^b Longitudinal analyses were performed on participants without baseline cognitive impairment, functional limitation or frailty for respective outcomes; adjusted for age, gender, race, education, occupation, living arrangements, hypertension, diabetes, heart disease, stroke, and changes in marital status, residence, BMI, smoking, alcohol drinking, living preferences, socioeconomic status, dietary habits, social/leisure activity score, physical exercise, poor self-rated health, poor interviewer-rated health, comorbidity number, serious illness in the past 2 years, hearing problem, and visual impairment from 2008/2009 to 2011/2012.

For cognitive impairment, education was not adjusted as we used education-adjusted criteria to define “cognitive impairment”; for frailty, poor self-rated health, poor interviewer-rated health, serious illness in the past 2 years, hearing problem, visual impairment, hypertension, diabetes, heart disease and stroke were not adjusted as they were included in the calculation of FI score.

Discussion

Living alone and loneliness are related but distinct concepts. Our study found that community-dwelling LA or FL older adults shared some common characteristics, but also had respective related factors. LA older adults were relatively younger, more of who preferred LA and took physical exercise, as well as had better physical and cognitive functions; while older adults who felt lonely were on the contrary. Loneliness was more prevalent among older adults who lived alone (1218/2546, 47.8%) than those living with others (3426/13709, 25%) in our study, and the proportions were much higher than 24.9% and 5.6% in a French study [28], indicating that the situation of loneliness among Chinese older adults was severer. Meanwhile, living alone was also associated with higher incidence of loneliness in the longitudinal analysis.

In our study, nearly all the LA older adults were SDW (99%) and widowed older adults accounted for 96% in the SDW ones, which meant widowhood was the major cause for them to live alone. The death of a spouse signifies the loss of a significant attachment figure that likely provided a meaningful and intimate source of social support, and may lead to loneliness [29]. Actually, SDW older adults may also choose to live with others, as 78% (8825/11346) of the SDW older adults did not live alone and 67% (7604/11346) of them preferred NLA. It is reasonable for us to consider that living alone was most likely a kind of personal choice for some older adults, as nearly 70% (1739/2546) of the LA older adults preferred LA (much more than 36% in the total sample). For some NLA older adults, however, living with others may be a kind of reluctant actions, as about 30% (4185/13709) of the NLA older adults preferred LA, and up to 71% (4185/5924) of those who preferred LA could not achieve their preferences, while 94% (8699/9247) of older adults who preferred NLA achieved their preferences.

Consistent with previous studies [4, 8, 23], after adjusted for confounders, loneliness was a risk factor for prevalent cognitive impairment and frailty, as well as 3-year mortality in the total sample. Those with “NA” on feelings of loneliness had higher ORs of adverse health outcomes than the FL older adults, which was not surprising, as they were much older and had worst physical and cognitive functions. When stratified by living arrangements, we found that although the prevalence of loneliness was lower in the NLA older adults, the effects of loneliness in this population actually needed more attention, as they accounted for one-fifth in the total sample and encountered more and severer adverse health outcomes. Loneliness kept being a risk factor for prevalent cognitive impairment and mortality in the NLA older adults but not the LA ones, although the associations of loneliness with prevalent frailty were both significant in the

NLA and LA older adults. In addition to the modifying effect of living arrangement, age and gender could also modify the associations of loneliness with prevalent cognitive impairment, frailty and mortality: older adults ≥ 80 years and older males were especially more significantly associated with prevalent cognitive impairment, older adults < 80 years and older males for prevalent frailty, and older adults < 80 years and older females for mortality. These results were consistent with previous studies [7, 23, 9], but further demonstrated the role of age in the associations of loneliness with cognitive impairment, frailty and mortality. Therefore, our findings concluded that when managing the impacts of loneliness on different adverse health outcomes, not only living arrangement but also age and gender were necessarily to be considered to formulate individualized strategies.

As filial piety seems to be done when older adults live with other (mainly their children), loneliness in this population is easy to be neglected. One Singapore study has found that older adults who were more likely to feel lonely were those who lived with their children and perceived they failed to fulfill their responsibilities. The difference between perceived and expected amount of support they derived from their children led to the occurrence of loneliness [18]. Therefore, in community services, the range of loneliness screening should be expanded to find the "NLA but FL" older adults. Our study found that better socioeconomic status, higher social/leisure activity score and more physical exercise were generally not only associated with reduced loneliness, but also associated with reduced adverse health outcomes (data not shown). Therefore, measures including improving older adults' socioeconomic conditions, increasing their social/leisure activities and physical exercise, providing enough social support, listening to their true thoughts and satisfying their real demands should be adopted. Adult children play an irreplaceable role for managing loneliness in these older adults [30], thus individualized strategy should also be formulated based on the situation of each family to reduce loneliness so as to prevent adverse health outcomes.

An important contribution of this study is that we find living arrangement modifies the associations of loneliness with prevalent cognitive impairment and mortality, which has not been reported before. Loneliness has different impacts on older adults' health according to different living arrangements, as well as age and genders, which needs special attention from both familial and societal levels. However, some limitations still exist in our study. First, loneliness was assessed via one single question but not a scale, which made it hard for us to evaluate other dimensions of loneliness. Second, living arrangements and loneliness were both dynamic, and we only considered baseline living arrangements and loneliness, which may be the main reason for insignificant associations of loneliness with incident adverse health outcomes and may cause some bias. However, when analyzing the associations of loneliness with incident adverse health outcomes, changes in sociodemographic, socioeconomic, dietary habits, and physical characteristics were adjusted in our logistic regression models, which may guarantee the reliability of our results to some extent. In the future research, scales with good reliability and validity should be adopted to evaluate loneliness, and factors associated with dynamic changes of loneliness should be further investigated, so as to develop corresponding interventions to improve physical and cognitive functions and reduce mortality in community-dwelling older adults.

Conclusions

Living arrangement modifies the association of loneliness with adverse health outcomes in community-dwelling older adults, and those who lived with others but felt lonely had worse cognitive and physical functions as well as higher mortality. Special attention and more social service should be paid to this population to reduce adverse health outcomes, so as to improve their quality of life and promote successful aging.

Abbreviations

CLHLS: Chinese Longitudinal Healthy Longevity Study; NLA, not living alone; LA, living alone; NFL, not feeling lonely; FL, feeling lonely; NA: not able to answer; SDW, Separated/Divorced/Widowed; MMSE: Mini-mental State Examination; ADL: Activities of Daily Living; IADL: Instrumental Activities of Daily Living.

Declarations

Ethics approval and consent to participate

Written informed consent was obtained from all participants and/or their proxy respondents, and the study was approved by the Research Ethics Committee of Peking University (IRB00001052-13074).

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analyzed during the current study are available from Peking University Open Research Data Platform (<https://opendata.pku.edu.cn/dataverse/CHADS?from=timeline&isappinstalled=0>).

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Chunbo Li supervised and reviewed the data analysis, reviewed and revised the manuscript. Kai Wei planned the study, reviewed the literature, performed the data analysis, interpreted the results, and drafted and reviewed the manuscript. Yong Liu reviewed the literature, interpreted the results, and drafted and reviewed the manuscript. Junjie Yang, Nannan Gu, Xinyi Cao, Xudong Zhao and Lijuan Jiang reviewed the results, and revised the manuscript. All authors read and approved the final manuscript. They are entirely responsible for the scientific content of the paper.

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Figures

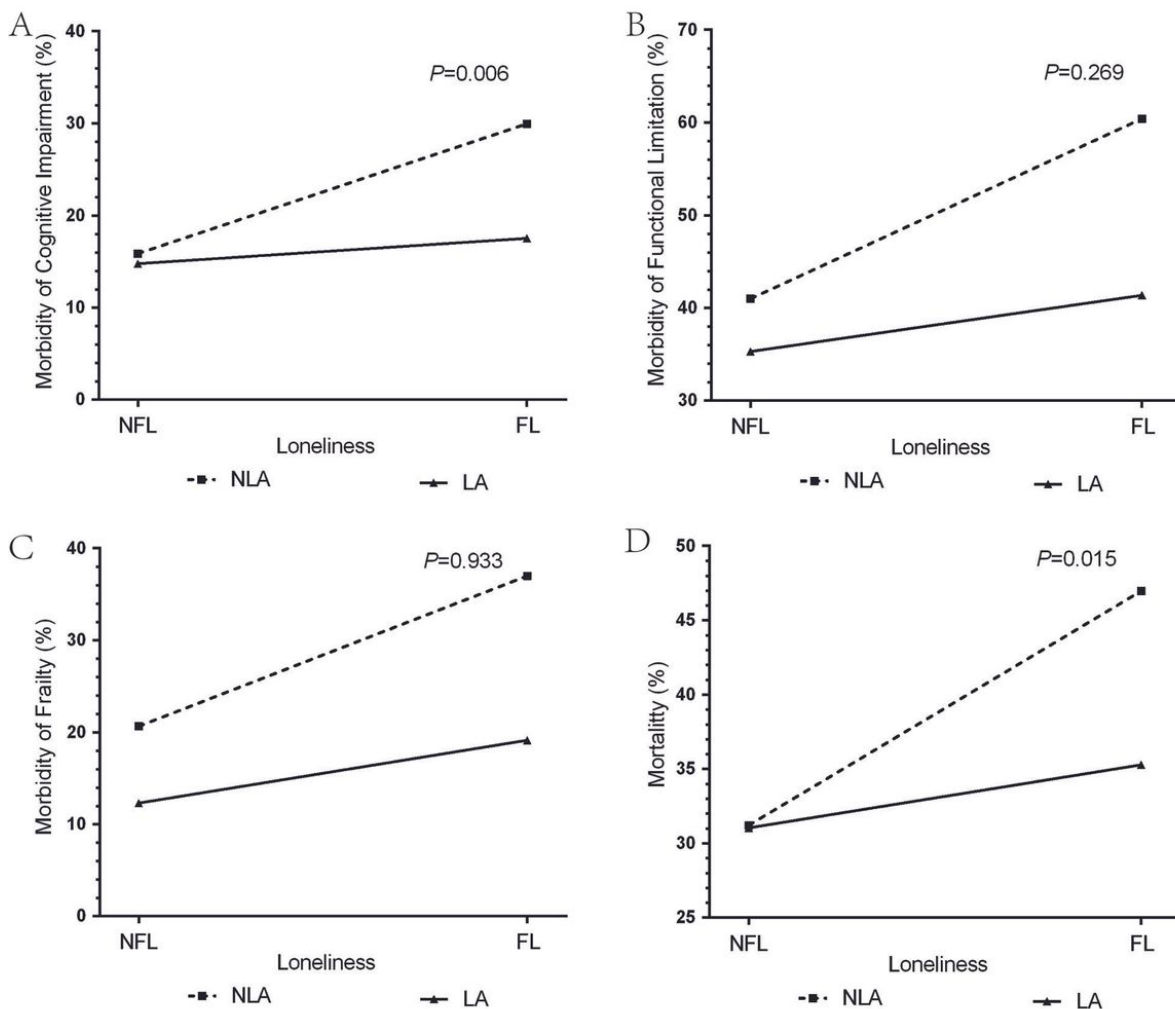


Figure 1

living arrangement modifies the associations of loneliness with cognitive impairment (P value for interaction=0.006) and mortality (P value for interaction=0.015), especially for females (P values for interaction=0.029 and 0.066, respectively) and older adults ≥ 80 years (P values for interaction=0.008 and 0.014, respectively, Figure S2).

Supplementary Files

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