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# Social isolation and likelihood of becoming centenarians: evidence from the Chinese longitudinal healthy longevity survey

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## Abstract

**Background** Social isolation, defined as an individual's lack of social connections, is particularly prevalent among older adults. However, its association with health outcomes among the oldest-old population (aged 80 and above) was understudied.

**Aims** To examine the association between social isolation and the likelihood of becoming a centenarian among the oldest-old people in China, aiming to provide novel insights into promoting healthy aging and longevity.

**Methods** Using data from The Chinese Longitudinal Healthy Longevity Survey, conducted in 22 provinces in mainland China since 1998, we performed a community-based, prospective nested case-control study. The primary outcome was survival to the age of 100 by 2018 (the end of follow-up). Information on social isolation and other covariates was collected via a questionnaire at baseline. The degree of social isolation was categorized as low, moderate, and high. Included ( $n=5,716$ ) were 1,584 identified centenarians and 4,132 controls (deceased before reaching 100 years), matched by age, sex, and year of entry. A conditional logistic regression model was used to evaluate the association between social isolation and the likelihood of becoming a centenarian, adjusting for demographic factors, lifestyle factors, chronic disease, potential disability, optimistic attitude, and perceived loneliness.

**Results** Individuals with the highest social isolation score had lower odds of becoming centenarians (adjusted OR:0.82; 95% CI: 0.68, 0.98), relative to those with the least social isolation ( $P$ -value  $< 0.05$ ), and this association persisted in sensitivity analyses. The association was more pronounced among ever smokers, compared to never smokers ( $P$ -value = 0.001). We did not observe significant interactions between social isolation and other covariates ( $P$ -value  $> 0.05$  for all).

**Conclusions** This study highlights the inverse association between social isolation and the likelihood of becoming a centenarian, emphasizing the need for public health initiatives to combat isolation in the older population.

**Keywords** Social isolation, Longevity, Case-control study, The oldest-old

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## Introduction

Aging is a natural and inevitable process with complex physiological changes associated with morbidity and mortality. Identifying aging-related modifiable risk factors is critical for coping with the public health challenges posed by the aging society, and developing intervention strategies to promote healthy aging. Social isolation, defined as an individual's lack of social connections, has become increasingly prevalent among the older population [1]. People aged 50 years or older are more likely to experience some life events or medical conditions that can cause or exacerbate social isolation, such as loss of family members or friends and chronic illness-related physical impairments [1]. Growing evidence has linked social isolation with poor health outcomes [2–4], such as a significantly higher risk for the development of cardiovascular disease [5], cognitive deterioration [6], infectious illness [7], and premature death [8, 9] even after controlling for a large number of known risk factors. However, existing research primarily focused on middle-aged (45+ years) [3, 10, 11] and/or older adults (60+ years) [12]. Although some studies have investigated the impact of social networks on mortality risk among individuals with advanced age (75+ years), the emotional feeling of loneliness and being physically socially isolated have not been well distinguished, and most studies had relatively small sample sizes and were conducted in Western populations. Given the potential distinct effect of loneliness and social isolation and the significant cultural differences between Asian and Western nations, there is an urgent need for research on the association between social isolation and health outcomes among the oldest-old (80+ years) population under other cultural contexts [13–16].

With the surging aging population and prolonged life expectancy, the oldest-old population has been expanding. Among them, centenarians are a unique group to study as a model of healthy aging [17], not only because of their extended longevity, but also due to their significant health advantages. Compared with their counterparts who did not survive to 100 years, centenarians postpone age-related morbidity and disability, tending to be healthier in their 80s and 90s and exhibiting signs of slower aging and greater resilience to diseases [18, 19]. Examining the association between social isolation and the survivorship of becoming a centenarian among the oldest-old could provide valuable information on promoting longevity and healthy aging.

Here, using data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), a nationwide representative cohort of the older population, we adopted a nested case-control study design with centenarians as cases, to prospectively investigate the association

between social isolation and the likelihood of becoming a centenarian in individuals aged 80 years and above.

## Methods

### Study design and population

The CLHLS is a nationally representative ongoing longitudinal study aimed at exploring factors involved in healthy longevity. Participants in the CLHLS were aged 60 years and older recruited from 22 of the 31 provinces in mainland China, covering approximately 85% of the population. The study was initiated in 1998, and was followed by 7 survey waves in 2000, 2002, 2005, 2008, 2011, 2014, and 2018. At each wave of survey, follow-up examinations of pre-existing participants and the recruitment of new participants were conducted. A detailed description of the study design can be found elsewhere [20]. Ethics approval was obtained from the Research Ethics Committees of Peking University and Duke University (IRB00001052-13074) and signed written consent forms were obtained from all participants or their legal representatives.

Cooperating with the nested case-control study design, in which living to be a centenarian was considered as case, we identified a total of 13,471 participants aged 80 years and above who were eligible to become centenarians by 2018 (the end of follow-up), during the first five waves of the survey (1998–2008), ensuring a minimum follow-up duration of 10 years until 2018 (Supplementary Fig. 1). We then excluded participants with incomplete data on social isolation measures ( $n=1,345$ ). Among the 12,117 eligible participants, we identified centenarians ( $n=1,584$ ) as cases and matched them with those who had deceased before turning 100 years old as controls, up to a 1:4 ratio with sex, entry years, and age ( $\pm 1$  year) at entry as matching variables, employing an optimal and computationally efficient algorithm [21].

### Construction of social isolation score

Adapting from prior studies [22, 23], the index of social isolation consisted of five elements representing different aspects of social networks. One point was assigned if participants met any of the following conditions: not married (including never married, separated, divorced, or widowed), living alone, having no contact with their children, having no contact with their siblings, and not participating in social activities. Having no contact with any of their children or siblings was defined as either having no children/siblings, the children/siblings being deceased, or not maintaining contact with any of them. Participating in social activities was defined as engaging in any one of the three social activities: playing chess or cards (asked in the 1998–2008 survey), attending a religious group (asked in the 1998–2002 survey), or any other social activities (asked in the 2002–2008 survey).

This resulted in a social isolation index ranging from 0 to 5, with higher scores indicating a higher degree of social isolation. We categorized the index into Low (0–2), Moderate [3], and High (4–5) based on the distribution and previous studies [22].

### Assessment of covariates

Sociodemographic factors, including age (y), sex (men, women), residence (urban dwellers, rural dwellers), and years of education (0, 1–9, > 9 years); medical conditions, including hypertension (yes, no), diabetes (yes, no), cardiovascular disease (CVD; yes, no), and cancer (yes, no); and lifestyle factors, including smoking status (never, former, current), drinking status (never, former, current), exercise status (never, former, current), and diet diversity (favorable, intermediate, unfavorable) were collected. Diet diversity was derived from the frequency of consuming seven food groups (fruits, vegetables, meat, fish, egg, beans, and tea) via a validated questionnaire [24, 25]. Participants reported consuming these foods “almost every day,” “except in winter or sometimes or occasionally,” or “rarely or never,” and each food item was assigned a score of 2, 1, or 0 accordingly, providing a total dietary diversity score ranging from 0 to 14. We then classified scores of 11–14 as favorable, 6–10 as intermediate, and 0–5 as unfavorable [26]. Weight and height were measured by trained medical staff during the physical examination. Body mass index (BMI) was calculated as weight (kg) / height squared ( $m^2$ ), and categorized as underweight ( $BMI < 18.5 \text{ kg}/m^2$ ), normal ( $18.5 \text{ kg}/m^2 \leq BMI < 24.0 \text{ kg}/m^2$ ), overweight/obese ( $BMI \geq 24.0 \text{ kg}/m^2$ ) [27]. Given that height measurements were unavailable in the first four waves of surveys, knee height was adopted to estimate individual height, using two validated equations for older Chinese (Men:  $\text{height} = 67.78 + 2.01 \times \text{knee height}$ ; women:  $\text{height} = 74.08 + 1.81 \times \text{knee height}$ ) [28]. Activities of daily living (ADL) disability (yes, no) was assessed by self-reported difficulty with six activities including eating, dressing, transferring, using the toilet, bathing, and continence. If participants needed assistance with any of the above activities, they were defined as possible disability. The optimistic attitude of participants was determined by one question, asking them how often they looked on the bright side of things. Similarly, loneliness was defined according to the answer “How often do you feel lonely or isolated”. This one-item measure was strongly correlated with multi-item loneliness evaluation scales and was used in previous studies [29, 30]. An optimistic attitude and loneliness were treated as dichotomous variables (yes, no). For both loneliness and optimistic attitude, participants who responded “sometimes”, “often”, or “always” were classified as “yes” and participants who responded “never” or “seldom” were classified as “no”. Cognitive function was measured using a minimum mental state

examination (MMSE) at baseline, with a threshold score of 18 used to define cognitive impairment. Mental health was defined based on the question “be happy as younger”. Participants who answered “seldom” or “never” were considered to have worse mental health conditions.

### Statistical analyses

All statistical analyses were performed using R version 4.2. A two-sided  $P$  value  $< 0.05$  was considered statistically significant. Baseline characteristics between centenarians (cases) and non-centenarians (controls) were compared using a t-test for continuous variables and a chi-square test for categorical variables.

Multivariable conditional logistic regression models were applied to examine the association between social isolation and living to be a centenarian. The results were reported as odds ratios (ORs) with 95% confidence intervals (CIs), adjusted for aforementioned covariates. We also treated social isolation score as a continuous variable and calculated the OR and 95% CI per unit increase to test for a linear trend. The association between each social isolation component and survivorship of becoming a centenarian was further evaluated, with other social isolation factors mutually adjusted. To evaluate the effect modification, we conducted stratified analysis and tested the multiplicative interactions between social isolation and all aforementioned covariates with the likelihood ratio test. To test the robustness of our results, we conducted several sensitivity analyses, including (1) a 2-y lag analysis by excluding cases who lived to 100 y within 2 years from baseline to reduce the potential reverse causation; (2) additional adjustment for mental health and cognitive function in regression models; (3) recalculating a weighted standardized social isolation score based on the  $\beta$  coefficient of each social isolation component from the multivariable adjusted conditional logistic regression model to account for the varied magnitudes of the associations between different social isolation factors and outcomes; (4) an updated analysis by replacing the original social isolation score with an updated score recalculated from the most recent follow-up before the endpoint (reaching 100 y for cases and deceased for controls) (5) leave-one-out analyses by excluding single social isolation factor one at a time and treating it as a confounder in the model; and (6) excluding participants with possible disability (ADL-defined disability).

### Results

We identified 1,584 centenarians and matched them with 4,132 controls who had deceased before 100 years of age during a median follow-up of 5 years (Table 1). Compared with the non-centenarians, the centenarians were more likely to be rural dwellers, non-smokers, current exercisers, and free of CVD. The basic characteristics of

**Table 1** Basic characteristics of participants who lived to be centenarian (case) and not to be centenarian (control)

Catalogue	Control (N=4,132)	Case (N=1,584)	P-difference
Age, year (Mean, SD)	94.1 (3.24)	94.95 (3.41)	<0.001
Sex, women (%)	2513 (60.8%)	994 (62.8%)	0.19
Residence, urban dweller (%)	1655 (40.1%)	591 (37.3%)	0.02
Educated year (%)			
0 y	2984 (72.2%)	1181 (74.6%)	0.002
1–9 y	1029 (24.9%)	341 (21.5%)	
>9 y	104 (2.5%)	60 (3.8%)	
Missing	15 (0.4%)	2 (0.1%)	
BMI (%)			
<18.5 kg/m <sup>2</sup>	1980 (47.9%)	784 (49.5%)	0.53
18.5–24.0 kg/m <sup>2</sup>	1696 (41.0%)	626 (39.5%)	
≥24.0 kg/m <sup>2</sup>	456 (11.0%)	174 (11.0%)	
Smoking status (%)			
Never	2939 (71.1%)	1195 (75.4%)	0.005
Former	571 (13.8%)	186 (11.7%)	
Current	622 (15.1%)	203 (12.8%)	
Drinking status (%)			
Never	2914 (70.5%)	1129 (71.3%)	0.32
Former	436 (10.6%)	146 (9.2%)	
Current	782 (18.9%)	309 (19.5%)	
Exercise (%)			
Never	2828 (68.4%)	1067 (67.4%)	<0.001
Former	389 (9.4%)	110 (6.9%)	
Current	915 (22.1%)	407 (25.7%)	
Diet diversity (%)			
Unfavorable	1427 (34.5%)	532 (33.6%)	0.49
Intermediate	2322 (56.2%)	899 (56.8%)	
Favorable	316 (7.6%)	125 (7.9%)	
Missing	67 (1.6%)	28 (1.8%)	
Perceived loneliness (%)	1238 (30.0%)	468 (29.5%)	0.78
Optimistic attitude (%)	3951 (95.6%)	1519 (95.9%)	0.69
Disability (%)	1690 (40.9%)	410 (25.9%)	0.09
Self-report CVD (%)	174 (4.2%)	42 (2.7%)	0.02
Self-report diabetes (%)	42 (1.0%)	16 (1.0%)	0.99
Self-report hypertension (%)	527 (12.8%)	202 (12.8%)	1
Self-report cancer (%)	17 (0.4%)	2 (0.1%)	0.16

Abbreviation: SD=standard deviation; BMI=body mass index; CVD=cardiovascular disease

participants according to their social isolation score were presented in Supplementary Table 1.

A higher social isolation score was associated with a lower likelihood of becoming a centenarian, in a dose-response manner ( $P$ -value<0.05) (Table 2). The adjusted OR for participants with the highest (4–5) social isolation score was 0.82 (95% CI: 0.68, 0.98) relative to the lowest (0–2) (Table 2). Among the individual social isolation components, not participating in social activities was significantly associated with lower odds of becoming a centenarian, whereas no significant associations were observed for not being married, living alone, or having no contact with their children or siblings (Fig. 1).

Stratified analyses suggested that the association between social isolation and becoming a centenarian was more pronounced in current or former smokers ( $P$ -interaction=0.001). The adjusted OR for the smoking group was 0.76 (95% CI: 0.62, 0.93), compared to 0.98 (95% CI: 0.89, 1.07) in the non-smoking group. In contrast, we did not observe significant interactions of the social isolation score with age at study entry, sex, residence, education level, drinking status, physical activity, BMI, diet diversity, chronic disease, potential disability, optimistic attitude, and perceived loneliness ( $P$ -value>0.05 for all, Supplementary Table 2).

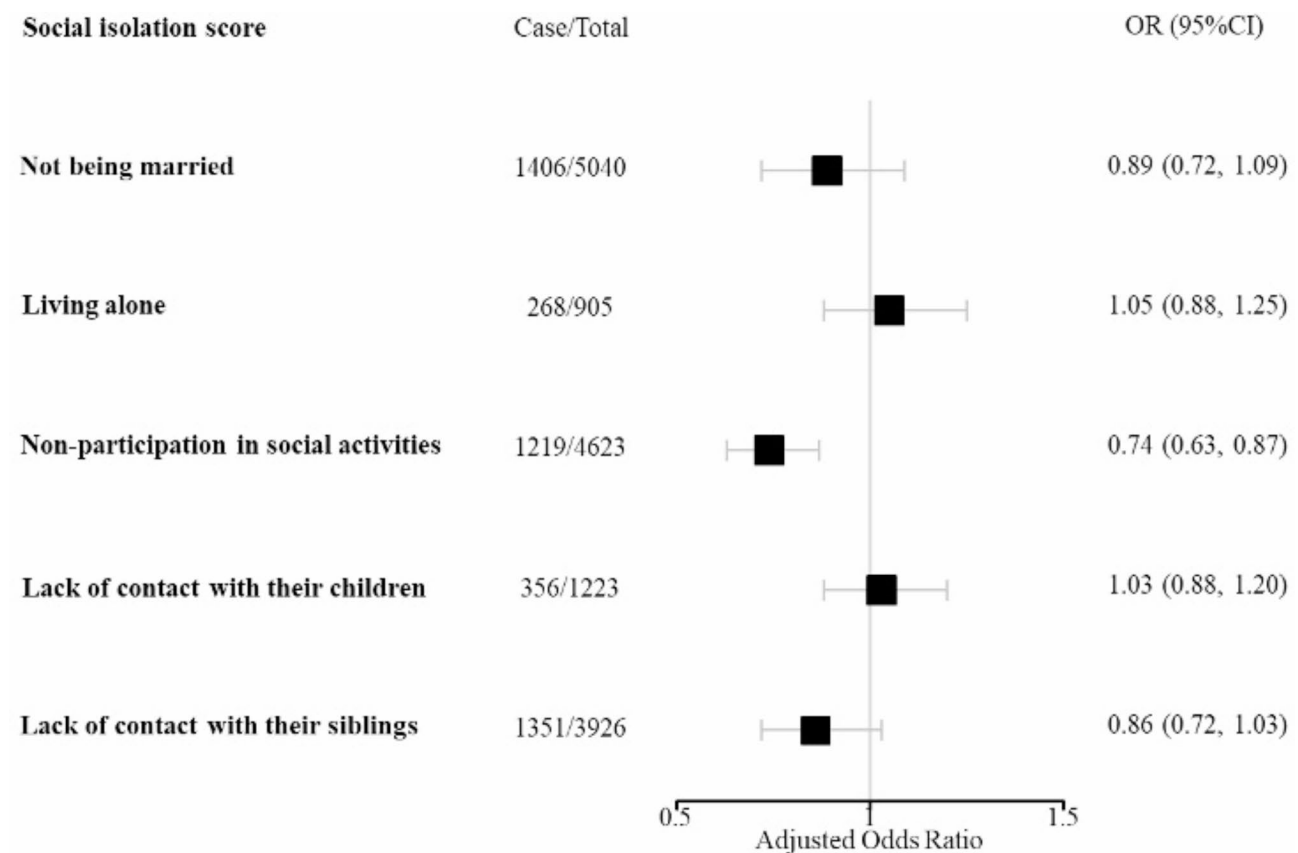
The robustness of the observed association in our main analysis was confirmed in sensitivity analyses (Table 3).

**Table 2** Odds ratios (ORs) and 95% confidence intervals (CIs) for association between social isolation score and becoming a centenarian

Social isolation score	Case/Total	OR (95%CI) <sup>a</sup>	Adjusted OR (95%CI) <sup>b</sup>
0–2	458/1599	Reference	Reference
3	752/2745	0.79(0.68, 0.91)	0.86 (0.74, 1.00)
4–5	374/1372	0.78(0.65, 0.92)	0.82 (0.68, 0.98)
Per unit increase	NA	0.88(0.82, 0.95)	0.91 (0.85, 0.98)
P-trend	NA	<0.001	0.01

a Crude model

b Adjusted for residence (urban, rural), schooling year (0, 1–9, > 9 years, missing), past smoker (never, former, current), past drinker (never, former, current), exercise (never, former, current), diet diversity (unfavorable, intermediate, favorable), BMI(< 18.5 kg/m<sup>2</sup>, 18.5–24.0 kg/m<sup>2</sup>, ≥ 24.0 kg/m<sup>2</sup>), potential disability (yes, no), optimistic attitude (yes, no), perceived loneliness (yes, no), hypertension (yes, no, missing), diabetes (yes, no, missing), cardiovascular disease (CVD) (yes, no, missing) and cancer (yes, no, missing)



**Fig. 1** Odds ratios (ORs) and 95% confidence intervals (CIs) for association between social isolation components and becoming a centenarian. Adjusted for residence (urban, rural), schooling year (0, 1–9, > 9 years, missing), past smoker (never, former, current), past drinker (never, former, current), exercise (never, former, current), diet diversity (unfavorable, intermediate, favorable), BMI(< 18.5 kg/m<sup>2</sup>, 18.5–24.0 kg/m<sup>2</sup>, ≥ 24.0 kg/m<sup>2</sup>), potential disability (yes, no), optimistic attitude (yes, no), perceived loneliness (yes, no), hypertension (yes, no, missing), diabetes (yes, no, missing), cardiovascular disease (CVD) (yes, no, missing) and cancer (yes, no, missing) and all variables adjusted mutually

After excluding centenarians who were followed for less than 2 years and their corresponding controls, the association was slightly attenuated but remained significant (adjusted OR for per unit change: 0.91; 95% CI: 0.84, 0.98). Similar associations were observed when using a weighted social isolation score, further adjusting for mental health and cognitive function, substituting with an updated social isolation score, or excluding participants with ADL-defined disability. When conducting

leave-one-out analyses by excluding the factors of not participating in social activities or not having contact with siblings from the combined social isolation score, the patterns persisted but without statistical significance (Table 3).

**Table 3** Sensitivity analysis for association between social isolation score and becoming a centenarian <sup>a</sup>

Sensitivity analysis		Social isolation score			Per unit increase
		0–2	3	4–5	
Excluding cases who lived to be centenarian within 2 years and their matched controls	Case/Total	363/1431	555/2306	265/1148	NA
	OR (95%CI)	Reference	0.93 (0.79, 1.10)	0.83(0.67, 1.00)	0.91 (0.84, 0.98)
Additionally adjusted for mental health <sup>b</sup>	Case/Total	458/1599	752/2745	374/1372	NA
	OR (95%CI)	Reference	0.86 (0.74, 1.00)	0.82 (0.69, 0.98)	0.91 (0.85, 0.98)
Additionally adjusted for cognitive function <sup>c</sup>	Case/Total	458/1599	752/2745	374/1372	NA
	OR (95%CI)	Reference	0.90 (0.77, 1.05)	0.85 (0.71, 1.02)	0.93 (0.86, 0.99)
Redefining a standardized weighted social isolation score <sup>d</sup>	Case/Total	367/1103	74/236	1143/4377	NA
	OR (95%CI)	Reference	0.85 (0.65, 1.10)	0.61 (0.49, 0.75)	0.89 (0.86, 0.93)
		0–2	3–4	≥4	Per unit increase
Excluding participants with disability	Case/Total	365/1127	535/1604	274/885	NA
	OR (95%CI)	Reference	0.90 (0.75, 1.09)	0.76 (0.61, 0.95)	0.90 (0.81, 0.97)
Updated analysis	Case/Total	424/1569	774/2778	386/1369	NA
	OR (95%CI)	Reference	0.87 (0.75, 1.01)	0.82 (0.69, 0.98)	0.92 (0.85, 0.99)
Excluding living alone <sup>e</sup>	Case/Total	538/1803	817/3077	229/836	NA
	OR (95%CI)	Reference	0.78 (0.67, 0.90)	0.77 (0.63, 0.94)	0.88 (0.81, 0.95)
		0–2	3	4	Per unit increase
Excluding not being married <sup>e</sup>	Case/Total	1193/4277	353/1295	38/144	NA
	OR (95%CI)	Reference	0.94 (0.91, 1.09)	0.74 (0.50, 1.12)	0.91 (0.84, 0.99)
Excluding non-participation in social activities <sup>e</sup>	Case/Total	1107/4069	421/1452	56/195	NA
	OR (95%CI)	Reference	1.02 (0.89, 1.18)	0.83 (0.59, 1.18)	0.96 (0.89, 1.04)
Excluding lack of contacting with children <sup>e</sup>	Case/Total	549/1882	880/3230	144/604	NA
	OR (95%CI)	Reference	0.84 (0.73, 0.97)	0.73 (0.58, 0.92)	0.87 (0.80, 0.95)
Excluding lack of contacting with siblings <sup>e</sup>	Case/Total	1159/4199	385/1360	40/157	NA
	OR (95%CI)	Reference	1.00 (0.86, 1.16)	0.76 (0.61, 1.12)	0.92 (0.85, 1.00)

<sup>a</sup> Adjusted for residence (urban, rural), schooling year (0, 1–9, > 9 years, missing), past smoker (never, former, current), past drinker (never, former, current), exercise (never, former, current), diet diversity (unfavorable, intermediate, favorable), BMI (< 18.5 kg/m<sup>2</sup>, 18.5–24.0 kg/m<sup>2</sup>, ≥ 24.0 kg/m<sup>2</sup>), potential disability (yes, no), optimistic attitude (yes, no), perceived loneliness (yes, no), hypertension (yes, no, missing), diabetes (yes, no, missing), cardiovascular disease (CVD) (yes, no, missing) and cancer (yes, no, missing)

<sup>b</sup> Mental health was defined based on the question “be happy as younger”. Participants who answered “seldom” or “never” were considered to have worse mental health conditions

<sup>c</sup> Cognitive function was measured using the Mini-Mental State Examination (MMSE), with a threshold score of 18 used to define cognitive impairment

<sup>d</sup> The standardized weighted social isolation score was redefined based on effect size of per score increase in each social isolation component

<sup>e</sup> Excluded social isolation component was additionally adjusted as the covariate

## Discussion

In this large prospective nested case-control study of 5,716 oldest-old Chinese, we found that a higher social isolation status estimated by 5 aspects (living alone, not being married, no participation in social activities, lack of contact with their children, and lack of contact with their siblings) was significantly associated with a lower likelihood of becoming a centenarian. Importantly, this association persisted even after accounting for major chronic diseases, lifestyle factors, functional disability, optimistic attitude, and loneliness. These findings suggested that identifying and ameliorating social isolation may be a potential and manageable strategy for promoting life expectancy and healthy aging.

Centenarians surpass the current human life expectancy by about 20–25 years and are considered a model for healthy aging [17]. However, most prior studies of

centenarians were based on cross-sectional surveys that only measured social connection at or around the age of 100 years [31, 32], thus limiting prospective analyses for the potential impact of social isolation in exceptionally long-lived individuals. The large sample size and thorough collection of social connections from this nationally representative survey of older Chinese enabled us to prospectively investigate the relationship between social isolation and reaching 100 years old in these oldest-old individuals.

Despite the various definitions and tools used in previous research on social isolation, the findings in our study were broadly consistent with other studies that considered mortality as an outcome. A recent meta-analysis of 90 cohort studies, involving more than 2 million adults of various age groups, systematically showed that social isolation increased the risk of all-cause mortality by 32%

(95% CI: 1.26, 1.39) [33]. Another population-based prospective study found that social isolation was associated with a 26% higher risk of mortality in countries at different economic levels [11]. In addition to mortality, centenarians serve as a unique model for studying healthy aging- not just their extended lifespan but their relatively healthier condition. Our study aligned with previous research that reported inverse associations between social isolation and risk of age-related diseases, such as cognitive decline [30], cardiovascular diseases [34], functional disability [35], and mental disorder [36], all of which affecting the quality of life in older age. This observed relationship underscores the significance of social connections not only in extending lifespan but also in enhancing the overall health status in the later years of life.

Among the five components of social isolation, no participation in social activities stood out as being significantly associated with the likelihood of reaching 100 years of age. A similar relationship has been observed previously [37, 38]. A recent study based on the CLHLS oldest-old population reported that frequent participation in social activities was associated with longer overall survival [39], suggesting that incorporating a broad range of social activities into the daily lives of the oldest-old could still be beneficial for longevity.

We found that the association between social isolation and likelihood of becoming centenarians was more pronounced in ever smokers, which aligned with previous studies that consistently demonstrated a strong association between smoking and a reduction in social connections, especially in older age [40, 41]. These findings underscore the need to consider smoking behavior not only as a direct risk factor for health but also as a factor that potentially influences an individual's social interactions and integration, emphasizing the importance of enhancing social participation among smoking populations.

The mechanisms linking social isolation with longevity might involve the following aspects. First, social isolation could stimulate the hypothalamic–pituitary–adrenal axis, leading to increased catecholamines and cortisol levels [42, 43]. Elevated cortisol levels can disrupt homeostasis, negatively impacting glucose metabolism, apoptosis, and the immune, reproductive, and cardiovascular systems [44]. Secondly, social isolation has been associated with various unfavorable behaviors and outcomes, including increased smoking and alcohol consumption, unhealthy dietary habits, and a rise in suicidal thoughts [45]. Finally, individuals experiencing social isolation often may have limited access to both emergency and routine medical care due to small social networks [23, 46].

## Limitations

Several limitations need to be addressed. The data on social isolation were self-reported, which could potentially cause misclassification. However, the multi-item assessment, derived from various aspects of individuals' social connections, provides a more comprehensive and nuanced measure, demonstrating a clear dose-response relationship, suggesting the potential misclassification does not significantly skew the overall trend. Similarly, medical conditions considered as confounding factors were also self-reported, possibly leading to an underestimation of disease prevalence and potential misclassification. However, this underestimation is likely to be global, potentially impacting the study population uniformly [47, 48]. Further, our definition of cases as those becoming centenarians meant that we stopped the follow-up once the participants reached 100 years of age, thereby limiting our ability to assess the association between social isolation and health outcomes beyond 100 years old. Future studies could extend follow-up period to explore how social isolation impacts health in the oldest-old group, providing insights into health trajectories and social needs in extremely old age. Importantly, social isolation was only measured at baseline for most of the participants, although we conducted an updated analysis trying to account for the possible changes in social isolation status during follow-up, it could still lead to misclassifications. Finally, the observational nature of the study design limited causal inference.

In the past decades, global social transition, aging, and urbanization has led to an unprecedented level of social isolation among a significant portion of the older population [49]. Accordingly, government task forces and policymakers need to pay more attention to the social isolation situation among older people, especially those living alone or in “empty nests”, and engage the welfare system, healthcare providers, and local community in developing strategies to strengthening social networks and interactions for the aging population, fostering an age-friendly environment to promote healthy aging and longevity.

## Conclusions

In this large sample of the oldest-old in China, a higher degree of social isolation was associated with lower odds of becoming a centenarian. This highlights an urgent public health issue, calling for strategies to increase awareness regarding the potential adverse health impacts of social isolation among the older population, even for the oldest-old. Equally critical is the development of interventions using innovative technologies that leverage support from family and community networks to mitigate social isolation. Further intervention studies need to

be conducted to determine if increasing social connections can contribute to health benefits.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12877-024-05417-z>.

Supplementary Material 1

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## Author contributions

YL, GJ and XG: wrote the manuscript; YL and GJ: analyzed or contributed to the interpretation of the data; YL, KW, YP, LS: provided critical study oversight and contributed to the critical revision of the manuscript for important intellectual content; XS and XG: designed the research; XG: had primary responsibility for the final content of the manuscript; and all authors: conducted the research and read and approved the final manuscript.

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## Data availability

Data are available to researchers on request for purposes of reproducing the results or replicating the procedure by directly contacting the corresponding author.

## Declarations

### Ethics approval and consent to participate

The biomedical ethics committee of Peking University approved the study (IRB00001052-13074), and all participants or their respondents provided written informed consent.

### Competing interests

The authors declare no competing interests.

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