RESEARCH

Open Access

Relationships of social isolation and loneliness with healthy aging among older adults

Meng-Yuan Miao^{1,2}, Fei Fang¹, Jie-Qiong Lyu¹, Zhong-Yue Liu¹, Zhong-Xiao Wan¹, Li-Qiang Qin¹, Guo-Chong Chen^{1,2*} and Hai-Peng Wang^{1,3*}

Abstract

Background Social isolation and loneliness have been recognized as important psychosocial factors affecting human health. We aimed to examine the relationships of social isolation and loneliness with the likelihood of healthy aging among older women and men.

Methods The prospective study included 13,782 female and 11,838 male participants who were aged 64 years or older and had no major chronic diseases during recruitment of the UK Biobank (2006–2010). All participants were eligible to survive to age 80 before the latest follow-up (December 2021). Healthy aging was defined as survival to age 80 without major chronic diseases. Multivariable logistic regression models were used to evaluate the associations of social isolation, loneliness and their combination with the likelihood of healthy aging.

Results A total of 9130 women (58.77%) and 6406 men (41.23%) achieved healthy aging. After adjusting for age and race/ethnicity, social isolation was associated with a significantly 20% and 14% lower likelihood of healthy aging among women and men, respectively, whereas among both sexes the associations for loneliness were similar but statistically non-significant. Among women, the association between loneliness and healthy aging varied by social isolation status ($P_{\text{interaction}} = 0.031$), with an inverse association limiting to women who were socially isolated (OR = 0.61; 95% CI: 0.43–0.87). Women with both social isolation and loneliness had a 48% (OR = 0.52; 95% CI: 0.37–0.73) lower likelihood of healthy aging as compared with women with neither, and this association remained after adjusting for a wide arrange of sociodemographic, behavioral, biological, and female-specific risk factors (OR = 0.63; 95% CI: 0.44–0.90). Such a joint relationship was not observed among men.

Conclusions A coexistence of social isolation and loneliness was associated with a substantially lower likelihood of healthy aging among women. Our findings highlight the importance of social support in extending women's healthspan beyond the management of traditional risk factors.

Keywords Healthy aging, Interaction, Loneliness, Prospective cohort study, Social isolation

*Correspondence: Guo-Chong Chen gcchen@suda.edu.cn Hai-Peng Wang sonnywang83@gmail.com Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

Introduction

Globally, it is projected that 59 countries will surpass a life expectancy of 80 years by 2040 [1]. However, this increase in longevity has not resulted in a longer healthspan, because of the occurrence of chronic diseases and impairments in physical and cognitive function among older adults [2]. Therefore, identifying modifiable risk factors is essential for effectively managing elderly health and developing strategies to extend both lifespan and healthspan.

With social and demographic changes, social isolation and loneliness have become increasingly common among older adults [3, 4]. Social isolation refers to being objectively alone or having infrequent social connections, whereas loneliness generally reflects a subjective, unpleasant emotional experiences linked to the quality of social connections [5]. Social connection has been identified as a key predictor of human health [6]. Individuals who were socially isolated or feel lonely have been found to be at a higher risk for developing cardiovascular diseases [7], dementia [8], depression [9], and premature mortality [10], suggesting a crucial role of social connection in human lifespan and healthspan. However, there is limited and inconclusive epidemiological evidence concerning the relationship of social isolation and loneliness with healthspan [11–13]. No study, to the best of our knowledge, has assessed social isolation or loneliness in relation to the likelihood of healthy aging. Social isolation and loneliness are weakly correlated but independent aspects of social disconnection [14], while the joint association of social isolation and loneliness with healthy aging remains unclear.

To address these knowledge gaps, utilizing data from a large nationwide population-based prospective cohort study (UK Biobank), we aimed to elucidate the independent and joint relationships of social isolation and loneliness with the likelihood of healthy aging among older adults. Considering that women and men follow different survival patterns [13], all analyses were stratified by sex.

Methods

Study population

The UK Biobank is a large population-based longitudinal study which recruited more than 500,000 participants aged 37 to 73 years from 22 assessment centers across England, Scotland, and Wales. From 2006 to 2010, participants completed various questionnaires, underwent a range of physical measures, and provided biological samples.

For the present analysis, we excluded participants who were expected to be younger than 80 years old before the latest follow-up (December 2021, n = 453,798), participants with major chronic diseases (MCDs) at baseline

(n = 20,507), those without complete information on social isolation or loneliness (n = 2440), and those lost to follow-up before age 80 or before the onset of major chronic diseases (n = 46). Finally, 25,620 apparently healthy older adults (13,782 women and 11,838 men) aged 64 years or older were included (Fig. 1).

Assessment of social isolation and loneliness

As described in Supplemental Table S1, the statuses of social isolation and loneliness were evaluated using touchscreen-based questionnaires [15]. Social isolation was assessed by the following three questions: (1) "Including yourself, how many people are living together in your household?"; (2) "How often do you visit friends or family or have them visit you?"; and (3) "Which of the following (leisure/social activities) do you engage in once a week or more often? You can select more than one." Participants were assigned 0 or 1 point for each of the questions, and the total score ranged from 0 to 3 with a higher score indicating a higher degree of social isolation. Participants were then classified as being not isolated (0-1 point) or isolated (2–3 points).

Loneliness was assessed by the following two questions: "Do you often feel lonely?" and "How often are you able to confide in someone close to you?". The loneliness score ranged from 0–2 points and only those with 2 points were deemed to have loneliness.

Assessment of healthy aging

The primary outcome was healthy aging and the secondary outcomes including all-cause mortality and incident MCDs. By focusing on an essential aspect of disease-free survival, healthy aging was defined as survival to age 80 without being diagnosed with any MCDs, which included cancer (except for nonmelanoma skin cancer), type 2 diabetes, major cardiovascular diseases (coronary heart disease including myocardial infarction and other major coronary events, stroke, heart failure, and atrial fibrillation), neurodegenerative diseases (dementia, Parkinson's disease, and multiple sclerosis), depression, sever liver (cirrhosis, decompensated liver disease, and liver transplantation) or kidney diseases (end-stage renal disease), chronic lung diseases (chronic obstructive pulmonary disease, emphysema, and bronchitis), and hip fracture. A full list of codes defining these MCDs are reported in Supplemental Table S2.

Covariates

We considered the following characteristics as the potential covariates or factors mediating the assessed relationship of social isolation and loneliness with healthy aging: (1) demographic characteristics, including age and race/ ethnicity; (2) socioeconomic factors, including Townsend



Fig. 1 Flow chart of participant selection

deprivation index, education level, and annual household income; (3) lifestyle factors, including tobacco consumption, alcohol consumption, physical activity, sleep pattern, sedentary behavior, and diet quality; (4) metabolic risk factors, including use of lipid-lowering drugs or antihypertension drugs, body mass index, waist circumference, systolic blood pressure, total cholesterol, and C-reactive protein; and (5) female-specific factors, including menopause status, number of live births, and ever use of hormone replacement therapy. More details of the covariates are provided in Supplemental Table S3.

Statistical analysis

Sex-specific descriptive statistics were calculated for all covariates, according to the combined status of social isolation and loneliness. Continuous variables were presented as mean ±standard deviation and categorical variables as frequencies (%). Multiple imputations were performed for missing covariates using the Markov chain Monte Carlo method.

We used Logistic regression models to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) for the associations of social isolation and loneliness with the likelihood of healthy aging among women and men, adjusting for age and race/ethnicity. The interaction between social isolation and loneliness on healthy aging was tested by using the likelihood ratio test. We further assessed the joint relationship of social isolation and loneliness with the likelihood of healthy aging among women and men. In addition to the basic model adjusted for age and race/ethnicity, various multivariable models were employed to increasingly adjust for the above-listed socioeconomic factors, lifestyle behaviors, metabolic risk factors, and female-specific factors. A sensitivity analysis was conducted by excluding the above MCDs individually to redefine healthy aging.

In addition, we performed a secondary analysis to assess the relationships of social isolation and loneliness with the risk of aforementioned MCDs and allcause mortality. For this analysis, Cox proportional hazards regression models were used to calculate the corresponding hazard ratios with 95% CIs. The statistical analysis was conducted using SAS statistical software (version 9.4; SAS Institute) and all *P* values were 2-tailed with a significance level of 0.05.

Results

Baseline characteristics of the study population

Mean age was 68.0 (1.1) years both for the 13,782 women and for the 11,838 men. Baseline participant characteristics according to the combined status of social isolation and loneliness are presented in Table 1. Regardless of sex, individuals with both isolation and loneliness, as compared with those with neither, were less likely to be ethnically white, were more socioeconomically deprived, and tended to have a lower education level, lower household income, and unhealthy lifestyles.

Social isolation, loneliness, and the likelihood of healthy aging

There were 9130 (58.77%) women and 6406 (41.23%) men successfully survived to age 80 without being diagnosed with MCDs. After age and race/ethnicity adjustment, social isolation was significantly associated with a lower likelihood of healthy aging among both sexes (Fig. 2A). Compared with participants who were no isolated, the adjusted OR of healthy aging was 0.80 (95% CI: 0.72–0.90) for isolated women and 0.86 (95% CI: 0.77–0.96) for isolated men. Loneliness was inversely but non-significantly associated with the likelihood of healthy aging both among women (OR = 0.84; 95% CI: 0.70–1.01) and men (OR = 0.83; 95% CI: 0.68–1.03) (Fig. 2A).

Among women, there was an interaction between social isolation and loneliness on the likelihood of healthy aging ($P_{\text{interaction}} = 0.031$) (Fig. 2B). Loneliness was associated with a 39% (OR =0.61; 95% CI: 0.43–0.87) lower likelihood of healthy aging among women who were isolated, but not among those who were not isolated (OR =0.98; 95% CI: 0.80–1.22). When stratified by loneliness status, the association of social isolation with healthy aging remained significant in both subgroups, but was particularly stronger among lonely women (Supplemental Figure S1). Such an interaction between social isolation and loneliness was not observed among men.

We then assessed the joint association of social isolation and loneliness with healthy aging (Fig. 3). Among women, compared with those with neither social isolation nor loneliness, women with both had a 48% (95% CI: 27%- 63%) lower likelihood of healthy aging. Such a joint association was not observed among men (OR =0.84; 95% CI: 0.60-1.19). We performed further analyses with stepwise adjustment for a wide arrange of risk factors that may potentially mediate the relationship of social isolation and loneliness with healthy aging, including socioeconomic, lifestyle, metabolic, and femalespecific factors (Table 2). With all risk factors being simultaneously added to the model, the joint association among women was only slightly attenuated and remained significant (OR = 0.63; 0.44–0.90). Social isolation alone (without loneliness) was associated a lower likelihood of healthy aging among women (OR = 0.84; 95% CI: 0.75–0.94), whereas the association was attenuated after adjusting for socioeconomic factors and no longer significant after further adjusting for specific lifestyle factors (e.g., smoking or alcohol consumption) (Table 2).

The joint association of social isolation and loneliness with healthy aging was similar after excluding any single MCD from the definition of healthy aging (Supplemental Tables S4-S5).

Social isolation, loneliness, and incident MCDs and all-cause mortality

In a secondary analysis with age and race/ethnicity adjustment, we explored the sex-specific relationship of social isolation and loneliness with incident MCDs and all-cause mortality. Social isolation was associated with a higher risk of chronic lung diseases and all-cause mortality among both sexes, with type 2 diabetes and severe liver diseases among women only, and with dementia and depression among men only (Supplemental Table S6). Loneliness was associated with a higher risk of depression and chronic lung diseases among both sexes, with atrial fibrillation among women only, and with a higher risk of myocardial infarction, heart failure, and all-cause mortality among men only (Supplemental Table S7).

Discussion

In this prospective cohort study of apparently healthy older adults, we found that social isolation was significantly associated with a lower likelihood of healthy aging (i.e., survival to age 80 without developing MCDs) among both sexes. Loneliness showed inverse but statistically non-significant associations with healthy aging among both sexes. Among women, the association between loneliness and the likelihood of healthy aging appeared to vary by social isolation status, with an inverse association limiting to women who were socially isolated. As a result, women with both social isolation and loneliness had a 48% lower likelihood of healthy aging as compared with women with neither. Notably, such a joint association remained after adjusting for a wide arrange of sociodemographic, behavioral, biological, and female-specific risk factors.

Existing studies have suggested social isolation and loneliness as important psychosocial factors associated with adverse health outcomes [7, 8, 16]. For example, longitudinal observational studies reported that social isolation and loneliness both were associated with a higher risk of cardiovascular diseases [7, 17]. In the English Longitudinal Study of Ageing (ELSA) of adults aged 50 years or older, loneliness was associated with a higher risk of
 Table 1
 Baseline participant characteristics according to the combined status of social isolation and loneliness among women and men

	Women			Men		
	Not isolated and no loneliness	Isolated and loneliness	Not isolated and no loneliness	Isolated and loneliness		
Characteristics	(<i>n</i> = 11,862)	(<i>n</i> = 133)	(<i>n</i> = 10,168)	(<i>n</i> = 130)		
Sociodemographic factors						
Age, y	68.00 ± 1.06	67.95 ± 1.12	68.02 ± 1.07	68.14±0.97		
Race/ethnicity						
White	11,655 (98.25)	127 (95.49)	9977 (98.12)	124 (95.38)		
Asian or Asian British	65 (0.55)	1 (0.75)	48 (0.47)	3 (2.31)		
Black or Black British	84 (0.71)	2 (1.50)	96 (0.94)	3 (2.31)		
Other or mixed	58 (0.49)	3 (2.26)	47 (0.46)	0 (0)		
Education						
College or university degree	2528 (21.31)	18 (13.53)	2800 (27.54)	26 (20.00)		
A levels/AS levels or equivalent	1040 (8.77)	7 (5.26)	776 (7.63)	7 (5.38)		
O levels/GCSEs or equivalent	2737 (23.07)	32 (24.06)	1673 (16.45)	17 (13.08)		
Other qualifications	5557 (46.85)	76 (57.14)	4919 (48.38)	80 (61.54)		
Townsend deprivation index ^a	-1.87 ± 2.74	-0.17 ± 3.38	-2.00 ± 2.72	0.36 ± 3.86		
Annual household Income, £						
< 18.000	5525 (46.58)	101 (75.94)	3499 (34.41)	83 (63.85)		
18 000-30 999	4106 (34 61)	24 (18 05)	3688 (36 27)	30 (23 08)		
31 000-51 999	1619 (13 65)	6 (4 51)	2042 (20.08)	11 (8 46)		
> 52.000	612 (5.16)	2 (1.50)	939 (9.23)	6 (4.62)		
Lifestyle factors	012 (0110)	2 (1.50)	555 (5.25)	0 (1102)		
Never	7433 (62 66)	68 (51 13)	4541 (44 66)	54 (41 54)		
Former	3922 (33.06)	53 (39.85)	4879 (47 98)	55 (42 31)		
Current: < 10 pack-years	63 (0 53)	0 (0)	167 (1 64)	2 (1 54)		
Current: 10–50 pack-years	391 (3 30)	10 (7 52)	470 (4.62)	9 (6 92)		
Current: > 50 pack-years	53 (0.45)	2 (1 50)	111 (1 09)	10 (7.69)		
Alcohol consumption	55 (0.15)	2 (1.50)	111 (1.05)	10 (7.09)		
Never	842 (7 10)	11 (8 27)	276 (2 71)	7 (5 38)		
Former	387 (3.26)	7 (5 26)	213 (2.00)	7 (5.38)		
Current: < 1 drink/week	32/17 (27.37)	55 (A1 35)	1301 (12.08)	32 (24 62)		
Current: 1 2 drinks/wook	2042 (27.37)	10 (14 20)	2501 (24.60)	22 (24.02)		
Current: > 3 drinks/week	2,742 (24.00)	11 (20.83)	5877 (57.80)	62 (17.60)		
Total physical activity MET-b/wook	51.31 ± 41.02	41 (30.03)	53 21 + 45 60	02(47.03)		
Healthy sloop score < 4	J1.J1 ±41.92	40.15 ±45.55	JJ.21 ±45.09	42.13 ± 44.11 61 (46.02)		
Sodoptary time $> 6 h/day$	4210 (33.30)	30 (20 32)	3115 (33.88)	50 (45.38)		
Healthy diat score > 4	2494 (21.03) 4527 (29.16)	55 (25.52)	2249 (22.00)	21 (72 05)		
Motabolic factors	4327 (36.10)	22 (29.62)	2540 (25.09)	31 (23.03)		
Linid lowering drugs	2200 (10 61)	DE (10.00)	2621 (2E 70)	25 (26 02)		
Aptibupartanciva drugs	2200 (10.01)	ZJ (10.00) 45 (22.02)	2021 (23.76)	33 (20.92) 40 (20.77)		
Pody mass index kg/m ²	26.04 + 4.22	43 (33.03)	27.26 + 2.52	40 (30.77)		
Waist circumforance cm	20.94 ± 4.33	20.UI ± 0.07	27.20 ± 0.02	∠1.20 ±4.22 07 75 ± 11 16		
waist circumierence, cm	00.09 ± 10.93	00.01 ± 12.74	90.33 ± 9.97	97.73 ± 11.10		
Tatal ab a lastaval mars al "	140.10 ± 20.02	100.43 ± 20.15	149.81 ± 19./3	100.38 ± 20.43		
Iotal Cholesterol, mmol/L	0.14 ± 1.11	0.14±1.12	5.48 ± 1.05	5.33 ± 1.09		
C-reactive protein, mg/L	3.04 ± 4.63	3.42 ± 4.80	2.82 ±4.60	3.30 ± 0.08		
	11 736 (00 0 4)	122 (00 25)		NIA		
Postmenopausal	11,/36 (98.94)	132 (99.25)	NA	NA		

Table 1 (continued)

	Women		Men	
	Not isolated and no loneliness	Isolated and loneliness	Not isolated and no loneliness	Isolated and loneliness (n = 130)
Characteristics	(<i>n</i> = 11,862)	(<i>n</i> = 133)	(<i>n</i> = 10,168)	
Number of live births				
0	1225 (10.33)	30 (22.56)	NA	NA
1	1130 (9.53)	28 (21.05)	NA	NA
2	5329 (44.92)	50 (37.59)	NA	NA
3 or more	4178 (35.22)	25 (18.80)	NA	NA
HRT use	6625 (55.85)	71 (53.38)	NA	NA

Data are mean \pm SD or % unless otherwise indicated

Abbreviations: HRT Hormone replacement therapy

^a A higher Townsend deprivation index indicates a greater degree of deprivation (or lower socioeconomic status)





Fig. 2 Association of social isolation and loneliness with the likelihood of healthy aging. A: Association of social isolation and loneliness with the likelihood of healthy aging among women and men. B: Associations of loneliness with the likelihood of healthy aging stratified by social isolation status among women and men. Results were from Logistic regression model adjusted for age and race/ethnicity

depression during 12 years of follow-up [18]. Systematic reviews concluded that the associations of social isolation and loneliness with risk of premature mortality were similar to the associations for other well-established risk factors [10, 16]. In the present study of apparently healthy older adults, social isolation and/or loneliness were also associated with a higher risk of certain health conditions (e.g., cardiometabolic diseases, dementia, depression, and

Women			Men			
Categories	Cases/Total	OR (95% CI)		Cases/Total	OR (95% CI)	-
No isolated						
No loneliness	7926/11,862	1.00 (Ref)		5559/10,168	1.00 (Ref)	•
Loneliness	258/389	0.98 (0.79-1.21)		121/245	0.81 (0.63-1.05)	
Isolated						
No loneliness	878/1398	0.84 (0.75-0.94)		660/1295	0.86 (0.76-0.96)	
Loneliness	68/133	0.52 (0.37-0.73)	_	66/130	0.84 (0.60-1.19)	
			·			
		. ,	0.3 0.8 1.	3	× ×	,

Fig. 3 Joint association of social isolation and loneliness with the likelihood of healthy aging. Results were from Logistic regression model adjusted for age and race/ethnicity

Table 2 Odds ratios (95% confidence intervals) of healthy aging associated with a combination of social isolation and loneliness

	Not isolated		Isolated	
	No loneliness	Loneliness	No loneliness	Loneliness
Age-race/ethnicity adjusted	1.00 (Ref)	0.98 (0.79–1.21)	0.84 (0.75–0.94)	0.52 (0.37–0.73)
+ TDI	1.00 (Ref)	0.98 (0.79-1.21)	0.87 (0.77-0.98)	0.55 (0.39–0.78)
+ Education	1.00 (Ref)	1.00 (0.81-1.24)	0.84 (0.75-0.94)	0.53 (0.38–0.75)
+ Annual household income	1.00 (Ref)	1.01 (0.81-1.25)	0.87 (0.77–0.97)	0.55 (0.39–0.77)
All above	1.00 (Ref)	1.01 (0.81-1.25)	0.88 (0.79–0.99)	0.58 (0.41-0.81)
+ Tobacco consumption	1.00 (Ref)	1.00 (0.81-1.25)	0.91 (0.81-1.03)	0.60 (0.42-0.85)
+ Alcohol consumption	1.00 (Ref)	1.01 (0.82-1.26)	0.90 (0.80-1.01)	0.59 (0.41–0.83)
+ Physical activity	1.00 (Ref)	1.00 (0.81-1.25)	0.89 (0.79-1.00)	0.58 (0.41–0.82)
+ Sleep pattern	1.00 (Ref)	1.03 (0.83-1.28)	0.89 (0.79-1.00)	0.59 (0.42-0.83)
+ Sedentary behavior	1.00 (Ref)	1.01 (0.82-1.26)	0.89 (0.79-1.00)	0.58 (0.41-0.82)
+ Diet quality	1.00 (Ref)	1.01 (0.82-1.25)	0.88 (0.78-0.99)	0.57 (0.41-0.81)
All above	1.00 (Ref)	1.04 (0.84-1.29)	0.93 (0.83-1.05)	0.62 (0.44-0.88)
+ Lipid-lowering drugs	1.00 (Ref)	1.03 (0.83-1.28)	0.94 (0.83-1.06)	0.62 (0.44-0.88)
+ Antihypertensive drugs	1.00 (Ref)	1.03 (0.83-1.29)	0.93 (0.83-1.05)	0.63 (0.44-0.89)
+ Body mass index	1.00 (Ref)	1.03 (0.83-1.29)	0.93 (0.83-1.05)	0.63 (0.44-0.90)
+ Waist circumference	1.00 (Ref)	1.04 (0.84–1.29)	0.94 (0.83-1.06)	0.64 (0.45-0.91)
+ Systolic blood pressure	1.00 (Ref)	1.03 (0.83-1.28)	0.94 (0.83-1.05)	0.63 (0.44-0.89)
+ Total cholesterol	1.00 (Ref)	1.04 (0.84–1.29)	0.93 (0.83-1.05)	0.62 (0.44–0.88)
+ C-reactive protein	1.00 (Ref)	1.04 (0.84-1.30)	0.93 (0.83-1.05)	0.62 (0.44–0.89)
All above	1.00 (Ref)	1.04 (0.83-1.29)	0.94 (0.83-1.06)	0.64 (0.45-0.91)
+ Menopausal status	1.00 (Ref)	1.04 (0.83-1.29)	0.94 (0.83-1.06)	0.64 (0.45-0.91)
+ Number of live births	1.00 (Ref)	1.04 (0.83-1.29)	0.94 (0.84-1.06)	0.64 (0.45-0.91)
+ Ever use of HRT	1.00 (Ref)	1.04 (0.84–1.30)	0.94 (0.83-1.06)	0.64 (0.45-0.91)
Fully adjusted	1.00 (Ref)	1.05 (0.84–1.30)	0.93 (0.83–1.05)	0.63 (0.44–0.90)

Results were from Logistic regression model with an increasing adjustment for different covariates

Abbreviations: HRT Hormone replacement therapy, TDI Townsend deprivation index

chronic lung diseases) and premature mortality, although some of the associations appeared to be sex-dependent.

The associations of social isolation and loneliness with poor health outcomes and shorter health span

might involve the following aspects: physiological, behavioral, and psychological. Firstly, social isolation and loneliness have been shown to increase activity of the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system [19], leading to elevated levels of catecholamines and cortisol [20, 21]. Elevated cortisol levels can disrupt homeostasis, and further enhance the proinflammatory responses [22, 23], immune dysregulation [24], resulting in the development of chronic diseases and premature death [25]. Animal studies have suggested that changes in oxidoreductase activity and reactive oxygen species accumulation are the causal basis of the shortened lifespan associated with social isolation [26]. Secondly, individuals experiencing social isolation and loneliness are more likely to engage in unhealthy behaviors, such as smoking, alcohol consumption or physical inactivity [27]. Finally, social disconnection may restrict older adults from getting social support or seeking health care and resources [28].

To the best of knowledge, our study is the first to assess the association of social isolation and loneliness with healthy aging among apparently heathy older women and men. In the U.S. Health and Retirement Study, social isolation and loneliness both were associated with severe deficits in healthy aging, including premature mortality, disability, and chronic diseases [11]. Several populationbased longitudinal studies reported that loneliness was associated with a shorter lifespan and decreased odds of aging well [12, 29]. In the Longitudinal Aging Study Amsterdam, while social isolation was associated with a lower likelihood of longevity (survival to age 90 years) among women, loneliness was not associated with longevity among either sex [13].

In the present study, we found that social isolation was significantly associated with a lower likelihood of healthy aging among both sexes. For loneliness, its relationship with healthy aging appeared to be dependent on the status of social isolation among women. Consistently, the objective lack of social connection was reported to be more important in relation to a variety of health outcomes for the elderly, compared with the subjective disconnection [28, 30-33]. Social isolation is more likely to lead to subjective feelings of loneliness, and the association between loneliness and mortality was found to be stronger at higher levels of social isolation [34]. These observations suggest that social isolation appears as a stronger risk marker for lifespan and healthspan than loneliness. In the present study, the interaction between social isolation and loneliness on healthy aging was not observed among men. Results from the ELSA and the Brazilian Longitudinal Study of Ageing also indicated that the burden of loneliness affected healthy aging more significantly among older women than men [35]. Such a sex-specific pattern may be attributable to the apparent physiological and sociocultural differences between older women and men [36]. Certain chronic diseases are more commonly present in older women compared to men,

such as dementia, hip fracture, and depression [37, 38]. Moreover, besides inequitable access to education and economic resources, women generally have a longer life expectancy than men, making them more likely to live alone during later years, and thus may be more vulnerable to the adverse health effects of social isolation and loneliness [39].

We observed a joint association of social isolation and loneliness with the likelihood of healthy aging among women. Notably, this association largely persisted after the multistage adjustment for a wide arrange of sociodemographic, behavioral, biological, and female-specific risk factors. Our findings may provide new psychosocial insights on understanding the processes of healthy aging and the management for geriatric healthcare. As social disconnection increases with the aging process, routine screening for social isolation and loneliness in clinical care could facilitate early identification of potential health risk. Future strategies across individual and societal levels should be implemented to strengthen objective and subjective social connections.

Strengths and limitations

Our study is featured by the inclusion of a relatively large number of older adults without MCDs at baseline. The comprehensive information on the various participants' phenotypic characteristics allowed us to assess the potential mediating role of other common disease risk factors on the examined relationship of social isolation and loneliness with the likelihood of healthy aging.

Several potential limitations of our study need to be acknowledged. Firstly, the World Health Organization defines healthy aging as "the process of developing and maintaining functional ability that enables well-being in old age", which emphasizes the importance of physical, cognitive, and social functioning in achieving a high quality of life in later years [40, 41]. Because of the lack of data on functional ability, we used disease-free survival (survival to age 80 without being diagnosed with any major chronic diseases) as a proxy for healthy aging. This definition captures an essential aspect of healthy aging by focusing on the absence of significant health conditions that could impair both quality of life and functional ability. Secondly, information on social isolation and loneliness was self-reported at baseline. As such, potential measurement errors and misclassification of exposure are possible, and the influence of longitudinal changes in social isolation and loneliness on healthy aging remains unaddressed. Thirdly, demographic factors such as marital and migration status, which may affect the risk of social isolation and loneliness, were not collected in the UK Biobank, limiting further investigation of their role in the examined associations. Finally, participants in UK

Biobank are predominantly of white ethnic background, which may lead to potential healthy volunteer selection bias [42].

Conclusions

In summary, our findings suggest that social isolation is associated with a lower likelihood of healthy aging among both sexes. A coexistence of social isolation and loneliness was associated with a particularly lower likelihood of healthy aging among women, independently of other known risk factors for major chronic diseases. Social connection needs to be strengthened, especially for women with concomitant social isolation and loneliness. Our findings may have great public health significance by highlighting the importance of social connection and social support in extending women's healthspan beyond the management of traditional risk factors.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-05941-6.

Supplementary Material 1

Acknowledgements

The authors thank the UK Biobank participants. This research has been conducted using the UK Biobank Resource under Application Number 90087. This work uses data provided by patients and collected by the NHS as part of their care and support.

Clinical trial number

Not applicable.

Authors' contributions

Meng-Yuan Miao: Visualization, Formal analysis, Writing—original draft, Writing—review& editing. Fei Fang: Formal analysis. Jie-Qiong Lyu: Formal analysis. Zhong-Yue Liu: Data curation. Zhong-Xiao Wan: Writing- review & editing. Li-Qiang Qin: Writing—review & editing. Guo-Chong Chen: Conceptualization, Visualization, Writing—review & editing. Hai-Peng Wang: Conceptualization, Visualization, Writing—review & editing.

Funding

None.

Data availability

The UK Biobank data during the current study are available upon application to the UK Biobank (www.ukbiobank.ac.uk/).

Declarations

Ethics approval and consent to participate

The study was approved by the Northwest Multi-Centre Research Ethics Committee (REC reference for UK Biobank 11/NW/0382). All study participants provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Department of Nutrition and Food Hygiene, School of Public Health, The First Affiliated Hospital of Soochow University, Suzhou Medical College of Soochow University, 199 Ren'ai Road, Suzhou 215123, China. ²MOE Key Laboratory of Geriatric Diseases and Immunology, Jiangsu Key Laboratory of Preventive and Translational Medicine for Major Chronic Non-Communicable Diseases, Suzhou Medical College of Soochow University, Suzhou, China. ³Department of Cardiology, The First Affiliated Hospital of Soochow University, 188 Shizi Street, Suzhou 215006, China.

Received: 26 December 2024 Accepted: 11 April 2025 Published online: 23 April 2025

References

- Foreman KJ, Marquez N, Dolgert A, Fukutaki K, Fullman N, McGaughey M, Pletcher MA, Smith AE, Tang K, Yuan CW, et al. Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016–40 for 195 countries and territories. Lancet (London, England). 2018;392(10159):2052–90.
- Beard JR, Officer A, de Carvalho IA, Sadana R, Pot AM, Michel JP, Lloyd-Sherlock P, Epping-Jordan JE, Peeters G, Mahanani WR, et al. The World report on ageing and health: a policy framework for healthy ageing. Lancet (London, England). 2016;387(10033):2145–54.
- Hoang P, King JA, Moore S, Moore K, Reich K, Sidhu H, Tan CV, Whaley C, McMillan J. Interventions Associated With Reduced Loneliness and Social Isolation in Older Adults: A Systematic Review and Meta-analysis. JAMA Netw Open. 2022;5(10):e2236676.
- Cudjoe TKM, Roth DL, Szanton SL, Wolff JL, Boyd CM, Thorpe RJ. The Epidemiology of Social Isolation: National Health and Aging Trends Study. J Gerontol B Psychol Sci Soc Sci. 2020;75(1):107–13.
- Elovainio M, Hakulinen C, Pulkki-Råback L, Virtanen M, Josefsson K, Jokela M, Vahtera J, Kivimäki M. Contribution of risk factors to excess mortality in isolated and lonely individuals: an analysis of data from the UK Biobank cohort study. The Lancet Public health. 2017;2(6):e260–6.
- Holt-Lunstad J, Robles TF, Sbarra DA. Advancing social connection as a public health priority in the United States. Am Psychol. 2017;72(6):517–30.
- Valtorta NK, Kanaan M, Gilbody S, Ronzi S, Hanratty B. Loneliness and social isolation as risk factors for coronary heart disease and stroke: systematic review and meta-analysis of longitudinal observational studies. Heart (British Cardiac Society). 2016;102(13):1009–16.
- Samtani S, Mahalingam G, Lam BCP, Lipnicki DM, Lima-Costa MF, Blay SL, Castro-Costa E, Shifu X, Guerchet M, Preux PM, et al. Associations between social connections and cognition: a global collaborative individual participant data meta-analysis. The lancet Healthy longevity. 2022;3(11):e740–53.
- Sbarra DA, Ramadan FA, Choi KW, Treur JL, Levey DF, Wootton RE, Stein MB, Gelernter J, Klimentidis YC. Loneliness and depression: bidirectional mendelian randomization analyses using data from three large genomewide association studies. Mol Psychiatry. 2023;28(11):4594–601.
- Holt-Lunstad J, Smith TB, Baker M, Harris T, Stephenson D. Loneliness and social isolation as risk factors for mortality: a meta-analytic review. Perspect Psychol Sci. 2015;10(2):227–37.
- Crowe CL, Domingue BW, Graf GH, Keyes KM, Kwon D, Belsky DW. Associations of Loneliness and Social Isolation With Health Span and Life Span in the U.S. Health and Retirement Study. J Gerontol A Biol Sci Med Sci. 2021;76(11):1997–2006.
- 12. Klein J, von dem Knesebeck O, Lüdecke D. Social Inequalities and Loneliness as Predictors of Ageing Well: A Trend Analysis Using Mixed Models. Int J Environ Res Public Health. 2020;17(15):5314.
- Brandts L, van Tilburg TG, Bosma H, Huisman M, van den Brandt PA. Loneliness in Later Life and Reaching Longevity: Findings From the Longitudinal Aging Study Amsterdam. J Gerontol B Psychol Sci Soc Sci. 2021;76(2):415–24.
- Coyle CE, Dugan E. Social isolation, loneliness and health among older adults. J Aging Health. 2012;24(8):1346–63.
- Elovainio M, Komulainen K, Sipilä PN, Pulkki-Råback L, Cachón Alonso L, Pentti J, Nyberg ST, Suominen S, Vahtera J, Lipsanen J, et al. Association of social isolation and loneliness with risk of incident hospital-treated

infections: an analysis of data from the UK Biobank and Finnish Health and Social Support studies. The Lancet Public health. 2023;8(2):e109–18.

- Wang F, Gao Y, Han Z, Yu Y, Long Z, Jiang X, Wu Y, Pei B, Cao Y, Ye J, et al. A systematic review and meta-analysis of 90 cohort studies of social isolation, loneliness and mortality. Nat Hum Behav. 2023;7(8):1307–19.
- Liang YY, Chen Y, Feng H, Liu X, Ai QH, Xue H, Shu X, Weng F, He Z, Ma J, et al. Association of Social Isolation and Loneliness With Incident Heart Failure in a Population-Based Cohort Study. JACC Heart failure. 2023;11(3):334–44.
- Lee SL, Pearce E, Ajnakina O, Johnson S, Lewis G, Mann F, Pitman A, Solmi F, Sommerlad A, Steptoe A, et al. The association between loneliness and depressive symptoms among adults aged 50 years and older: a 12-year population-based cohort study. The Lancet Psychiatry. 2021;8(1):48–57.
- Cacioppo JT, Cacioppo S, Capitanio JP, Cole SW. The neuroendocrinology of social isolation. Annu Rev Psychol. 2015;66:733–67.
- Gouin JP, Zhou B, Fitzpatrick S. Social integration prospectively predicts changes in heart rate variability among individuals undergoing migration stress. Ann Behav Med. 2015;49(2):230–8.
- McNeal N, Scotti MA, Wardwell J, Chandler DL, Bates SL, Larocca M, Trahanas DM, Grippo AJ. Disruption of social bonds induces behavioral and physiological dysregulation in male and female prairie voles. Auton Neurosci. 2014;180:9–16.
- Yang YC, McClintock MK, Kozloski M, Li T. Social isolation and adult mortality: the role of chronic inflammation and sex differences. J Health Soc Behav. 2013;54(2):183–203.
- Smith KJ, Gavey S. NE RI, Kontari P, Victor C: The association between loneliness, social isolation and inflammation: A systematic review and meta-analysis. Neurosci Biobehav Rev. 2020;112:519–41.
- Cacioppo S, Grippo AJ, London S, Goossens L, Cacioppo JT. Loneliness: clinical import and interventions. Perspect Psychol Sci. 2015;10(2):238–49.
- 25. Yang YC, Boen C, Gerken K, Li T, Schorpp K, Harris KM. Social relationships and physiological determinants of longevity across the human life span. Proc Natl Acad Sci USA. 2016;113(3):578–83.
- 26. Koto A, Tamura M, Wong PS, Aburatani S, Privman E, Stoffel C, Crespi A, McKenzie SK, La Mendola C, Kay T, et al. Social isolation shortens lifespan through oxidative stress in ants. Nat Commun. 2023;14(1):5493.
- Hakulinen C, Pulkki-Råback L, Virtanen M, Jokela M, Kivimäki M, Elovainio M. Social isolation and loneliness as risk factors for myocardial infarction, stroke and mortality: UK Biobank cohort study of 479 054 men and women. Heart (British Cardiac Society). 2018;104(18):1536–42.
- Steptoe A, Shankar A, Demakakos P, Wardle J. Social isolation, loneliness, and all-cause mortality in older men and women. Proc Natl Acad Sci USA. 2013;110(15):5797–801.
- Malhotra R, Tareque MI, Saito Y, Ma S, Chiu C-T, Chan A. Loneliness and health expectancy among older adults: A longitudinal population-based study. J Am Geriatr Soc. 2021;69(11):3092–102.
- Wang S, Zhang H, Lou Y, You Q, Jiang Q, Cao S. Association of social isolation and loneliness with the risk of hypertension in middle aged and older adults: Findings from a national representative longitudinal survey. J Affect Disord. 2024;349:577–82.
- Holt-Lunstad J, Steptoe A. Social isolation: An underappreciated determinant of physical health. Curr Opin Psychol. 2022;43:232–7.
- Guo L, An L, Luo F, Yu B. Social isolation, loneliness and functional disability in Chinese older women and men: a longitudinal study. Age Ageing. 2021;50(4):1222–8.
- 33. Yu B, Steptoe A, Chen Y, Jia X. Social isolation, rather than loneliness, is associated with cognitive decline in older adults: the China Health and Retirement Longitudinal Study. Psychol Med. 2021;51(14):2414–21.
- Beller J, Wagner A. Loneliness, social isolation, their synergistic interaction, and mortality. Health Psychol. 2018;37(9):808–13.
- Torres JL, Vaz CT, Pinheiro LC, Braga LS, Moreira BS, Oliveira C, Lima-Costa MF. The relationship between loneliness and healthy aging indicators in Brazil (ELSI-Brazil) and England (ELSA): sex differences. Public Health. 2023;216:33–8.
- Grami N, Tuazon JR, Kalia S, Lawson A, Li J, Savage RD, Rochon PA. Promoting healthy aging in older women: A call to action. J Am Geriatr Soc. 2022;70(3):928–31.
- Lopez-Lee C, Torres ERS, Carling G, Gan L. Mechanisms of sex differences in Alzheimer's disease. Neuron. 2024;112(8):1208–21.

- Altemus M, Sarvaiya N, Neill Epperson C. Sex differences in anxiety and depression clinical perspectives. Front Neuroendocrinol. 2014;35(3):320–30.
- Livingston G, Huntley J, Sommerlad A, Ames D, Ballard C, Banerjee S, Brayne C, Burns A, Cohen-Mansfield J, Cooper C, et al. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. Lancet (London, England). 2020;396(10248):413–46.
- Rudnicka E, Napierała P, Podfigurna A, Męczekalski B, Smolarczyk R, Grymowicz M. The World Health Organization (WHO) approach to healthy ageing. Maturitas. 2020;139:6–11.
- Bautmans I, Knoop V, Amuthavalli Thiyagarajan J, Maier AB, Beard JR, Freiberger E, Belsky D, Aubertin-Leheudre M, Mikton C, Cesari M, et al. WHO working definition of vitality capacity for healthy longevity monitoring. The Lancet Healthy longevity. 2022;3(11):e789–96.
- Fry A, Littlejohns TJ, Sudlow C, Doherty N, Adamska L, Sprosen T, Collins R, Allen NE. Comparison of Sociodemographic and Health-Related Characteristics of UK Biobank Participants With Those of the General Population. Am J Epidemiol. 2017;186(9):1026–34.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.