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Association of loneliness with the risk of pain in older Chinese adults

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This study investigates the long-term effects of loneliness on pain experiences in older Chinese adults, focusing on the mediating role of depression. Data from the China Health and Retirement Longitudinal Study (2013–2020) included 1,592 participants aged 60 and above. Using robust mixed-effects logistic regression models, the study found that lonely participants were more likely to experience 12 site pain: headache (OR 1.23; 95% CI 1.09–1.39), shoulder (OR 1.16; 95% CI 1.04–1.30), wrist (OR 1.14; 95%CI 1.01–1.28), finger (OR 1.14, 95% CI 1.02–1.28), chest (OR 1.26; 95% CI 1.10–1.44), stomach (OR 1.28, 95% CI 1.12–1.46), back (OR 1.23; 95% CI 1.00–1.51), waist (OR 1.46; 95% CI 1.17–1.83), buttock (OR 1.15, 95% CI 1.02–1.30), leg (OR 1.20, 95% CI 1.08–1.33), knee (OR 1.16; 95% CI 1.04–1.30), and toe (OR 1.18; 95% CI 1.04–1.34) than participants who were not lonely. No such finding was found for neck, arm, or ankle pain. The risk of pain due to loneliness did not decrease with an increase in the frequency of social activities. These findings emphasize the need to address mental health as a crucial factor in pain prevention and management.

Keywords Lonely, Pain, CHARLS, Depression, Older adults

Abbreviations

CHARLS	China Health and Retirement Longitudinal Study
CES-D	Center for Epidemiologic Studies Depression
BMI	Body mass index
ORs	Odds ratios
CIs	Confidence intervals
Interleukin-6	IL-6

Aging is a significant risk factor in musculoskeletal pain conditions[1]. China has one of the largest and fastest aging populations in the world, with 14.9% of the total population aged 65 or older in 2022, which is expected to rise to 26.1% by 2050[2]. As the aging trend intensifies, the prevalence of pain among older adults is increasing and is associated with widespread disability and higher healthcare costs[3–5]. In addition to impairing the ability to perform activities of daily living and quality of life in older adults, pain can also contribute to social isolation and depression based on previous studies[6–8]. The massive disease burden has made prevention and management a paramount public health challenge in China. Pain is an individualized experience shaped by various influences, such as physical, psychological, and social factors, rather than being exclusively related to organic issues like tissue injury or anatomical abnormalities[9]. Therefore, we need to move beyond traditional pathological perspectives when considering pain in older adults. While there is abundant literature regarding the effects of psychological (e.g., anxiety and depression) and physiological factors (e.g., anatomical changes)[10–12], the role of social factors in pain, especially among older adults, is not well documented. In the past three decades, changes in the social environment due to China's rapid urbanization have posed significant challenges for older adults. An increasing trend of young people migrating to urban centers for work is leading to millions of older Chinese adults living as empty-nesters[13,14]. More insight into how social risk factors affect older persons experiencing pain could direct future clinical practice and research toward preventative and treatment strategies.

Loneliness, a significant social risk factor for numerous adverse physical and mental health[15,16], is widely accepted to involve a person's assessment of their social relationships, highlighting their discontent with the number and quality of social interactions[17]. Notably, the relationship between loneliness and pain has garnered attention in recent years[18–20]. However, most studies have been conducted in developed countries[21–24], and few studies focused on China, which is facing enormous medical challenges from aging[25]. Furthermore, those who experience loneliness tend to have heightened levels of depression[26], which are closely related to pain. Findings

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from a prospective longitudinal study showed that elevated loneliness was associated with greater distress, with depression severity acting as a mediating factor in this association[27]. However, the relationship between pain in different sites and loneliness and whether depression has potential mediating effects in this relationship are not fully understood. Based on these findings and concerns, we used data from the China Health and Retirement Longitudinal Study (CHARLS) to investigate the effect of loneliness on pain in older adults.

Methods

Study participants

The CHARLS provided the data for this study, the sample of 17,708 individuals from 10,257 households across 450 villages and cities. Each household consists of at least one person aged 45 or older and their spouse[28]. This was followed by five waves of surveys in 2011, 2013, 2015, 2018, and 2020, which collected demographic information, health and psychological status, and physical and biological information of the participants by Computer-Assisted Personal Interview. Additional details about CHARLS can be found in previous study[28]. This longitudinal study utilized data from 2013 (wave 2), 2015 (wave 3), 2018 (wave 4), and 2020 (wave 5). Individuals with incomplete information about pain and loneliness, those with pain in 2013, and those who were under 60 years old in 2013 were excluded. Ultimately, 1,592 participants with information on at least one of the 15 pain information included in this study and complete data on loneliness components were included to evaluate the associations between loneliness and pain. The number of participants for each of the 15 pain and loneliness measures is shown in Fig. 1.

Measures

Pain and loneliness

According to the participants' answers, record whether they have pain: "Have you noticed any pain? Please indicate all parts of your body that are currently painful."

The degree of loneliness was primarily measured using the Center for Epidemiologic Studies Depression (CES-D) scale, specifically the questions related to the frequency of loneliness experienced by individuals in the past week, categorized as follows: (1) rarely or never (< 1 day); (2) some or a little of the time (1–2 days); (3) occasionally or moderately (3–4 days); (4) most or all the time (5–7 days). The degree of loneliness was positively associated with the score. These were further classified into two categories based on the duration of loneliness: "not lonely" for individuals who rarely or never experience loneliness, and "lonely" for those who feel lonely sometimes, occasionally, most of the time, or all the time.

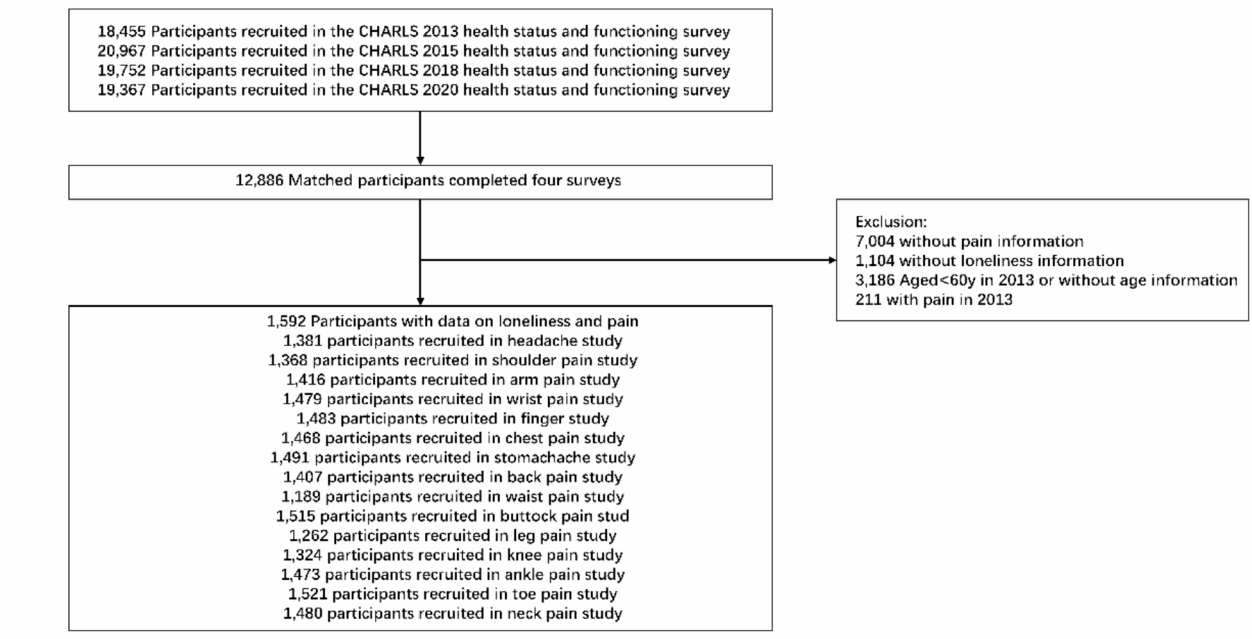

Fig. 1. Flowchart of study participant select.

Covariates

Socio-demographic characteristics

We consider gender (male and female), area of residence (rural and urban), marital status (married and unmarried), academic background (none, home school to primary school, and middle school and above) as categorical variables, and age as continuous variables.

Lifestyle

The lifestyle characteristics included smoking, drinking status, sleeping duration, and social activity. Smoking status was classified as either current or former smoker, or never smoker. Drinking status was evaluated using a three-category classification based on frequency: none, less than once a month, or more than once a month. Sleep duration was based on the average amount of time they actually slept at night (past month). We recorded the frequency of social activity in the last month as: not regularly, low frequency (almost every week), or frequent (almost daily).

Health and mental condition

Data about chronic diseases were collected based on whether participants had been diagnosed by a doctor with specific diseases. Health satisfaction was the participants' self-evaluation of their health status. Body mass index (BMI) was established from the body size measurements taken in 2015. The CES-D scale was implemented to determine depressive symptoms. The depression symptom threshold was defined as ≥3 points (details are shown in the supplementary file)[29]. These covariates were selected because they may influence loneliness and pain, thereby providing a comprehensive understanding of the factors affecting the associations under investigation[21,30].

Statistical analysis

A robust mixed-effects logistic regression model was adopted to examine the associations between pain and loneliness. The analysis involved five models: a crude model; model 2 accounting for age, sex, BMI, marital status, area of residence, and educational level; model 3 further adjusting for chronic diseases, health satisfaction, smoking, drinking, and sleep duration; model 4 additionally adjusting for social activity; and model 5 adjusting for depressive symptoms based on Model 4. Subgroup analyses stratified by gender, age, marital status, and social activity were conducted using the fully adjusted model. Sensitivity analyses were also performed: (1) excluding the item directly assessing loneliness and using a CES-D score ≥ 4 to define depression. By excluding the item that directly assesses loneliness, we aimed to isolate the impact of depression on pain without the influence of loneliness. At the same time, we used a CES-D score ≥ 4 to accurately define depressive symptoms, thereby maintaining a clear distinction from loneliness[24,31]. (2) the independent variable uses four categorical variables.

This strategy provides an opportunity to explore more thoroughly the link between various levels of loneliness and the risk of suffering from pain. Moreover, we tested the mediating effect of depression by constructing three regression models:

$$Y = cX + e, \tag{1}$$

$$M = aX + e \tag{2}$$

$$Y = c'X + bM + e \tag{3}$$

X, Y, and M represent loneliness, pain, and depressive symptom variables, respectively. Coefficient c in Eq. (1) represents the total effect of depression on pain, coefficient a in Eq. (2) is the effect of loneliness on depression, coefficient b in Eq. (3) is the effect of depression on pain after controlling for loneliness, and c′ indicates the direct effect of loneliness on pain after controlling for depression. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported. Statistical analysis was performed by Stata version 17.0, and $P < 0.05$ was considered statistically significant.

Result

Demographic features are shown in Table 1. The average age of the 1,592 participants was 65.35 years (standard deviations: 4.65), and 60.3% were female.

In 2013, the prevalence of different types of pain ranged from 4.67% (toe pain) to 33.89% (waist pain). In the main longitudinal analysis, 15 types of pain were significantly associated with loneliness. The OR ranged from 1.34 (95% CI 1.26–1.43) for neck pain to 1.48 (95% CI 1.37–1.59) for wrist pain, as shown in the robust analysis (Table 2).

The association between loneliness and pain weakened after taking into account factors (model 2) and the significant relationship between neck pain and loneliness disappeared (OR = 1.22; 95% CI 0.96–1.57; P value = 0.11). After further consideration for health satisfaction, smoking status, drinking status, sleeping time, chronic diseases, loneliness has nothing to do with arm pain (OR = 1.22; 95% CI 0.90–1.54; P value = 0.20) (model 3) and the association between ankle pain (OR = 1.12; 95% CI 0.99–1.28; P value = 0.08) and loneliness in controlling for depressive states was not significant in Model 5. To be specific, after adjusting for potential confounding factors, lonely participants were more likely to experience head, shoulder, wrist, finger, chest, stomach, back, waist, buttock, leg, knee, and toe pain than participants who were not lonely. The sensitivity analyses that excluded loneliness from the CES-D found that loneliness no longer demonstrated an increased risk of experiencing wrist pain (OR = 1.11, 95% CI 0.98–1.25, P value = 0.09), finger pain (OR = 1.10, 95% CI 0.98–1.23, P value = 0.10), and back pain (OR = 1.20, 95% CI 0.99–1.48, P value = 0.06) (see Supplementary Table S1 online). Further analysis of the four categorical variables of loneliness shows that participants who felt lonely

Characteristics	Not lonely	Lonely	Total	*P*-value
Age, year	65.36(4.64)	65.34(4.68)	65.35(4.65)	0.776
Gender				
Male	454(40.8%)	177(59.2%)	632(39.7%)	
Female	658(37.0%)	302(63.0%)	960(60.3%)	0.081
Marital status				
Unmarried	964(86.8%)	330(69.0%)	1294(81.49%)	
Married	146(13.2%)	148(31.0%)	294(18.51%)	< 0.001
Smoking				
Yes	74(6.7%)	27(5.6%)	101(9.36%)	
No	686(61.7%)	292(61.0%)	978(90.37%)	0.667
Drink status				
never had a drink	249(22.4%)	102(21.3%)	351(22.13%)	
less than once a month	78(7.0%)	38(7.9%)	116(7.31%)	
more than once a month	781(70.2%)	338(70.6%)	1119(70.55%)	0.864
Educational levels				
None	298(30.0%)	163(37.3%)	361(27.16%)	
Home School to Primary School	514(51.8%)	219(50.1%)	733(55.15%)	
Middle school and above	180(18.1%)	55(12.6%)	235(17.68%)	0.004
Chronic diseases				
None	14(15.4%)	3(11.5%)	17(13.39%)	
= 1	28(30.8%)	10(38.5%)	38(29.92%)	
≥ 2	49(53.8%)	13(50.0%)	72(56.69%)	0.780
Health satisfaction				
Good	182(16.6%)	51(11.5%)	233(15.12%)	
Fair	696(63.5%)	238(53.5%)	934(61.61%)	
Poor	218(19.9%)	156(35.1%)	374(24.27%)	< 0.001
Depressive symptoms				
None	637(57.4%)	83(17.4%)	720(45.34%)	
Depression	473(42.6%)	395(82.6%)	868(54.66%)	< 0.001
Social activity				
None	464(41.7%)	223(46.6%)	687(43.15%)	
Low frequency	251(22.6%)	106(22.1%)	357(22.42%)	
Frequent	397(35.7%)	150(31.3%)	547(34.36%)	0.157
Sleeping time	5.935(1.89)	5.354(2.03)	5.697(2.16)	< 0.001
Body mass index	23.55(3.87)	22.80(3.60)	22.93(4.81)	< 0.001
Headache	110(9.9%)	101(21.1%)	211(15.28%)	< 0.001
Shoulder pain	121(10.9%)	103(21.5%)	224(16.37%)	< 0.001
Arm pain	95(8.5%)	81(16.9%)	176(12.43%)	< 0.001
Wrist pain	61(5.5%)	52(10.9%)	113(7.64%)	< 0.001
Finger pain	62(5.6%)	47(9.8%)	109(7.35%)	0.003
Chest pain	59(5.3%)	65(13.6%)	124(8.45%)	< 0.001
Stomachache	52(4.7%)	49(10.2%)	101(6.77%)	< 0.001
Back pain	101(9.1%)	84(17.5%)	185(13.15%)	< 0.001
Waist pain	243(21.9%)	160(33.4%)	403(33.89%)	< 0.001
Buttock pain	37(3.3%)	40(8.4%)	77(5.08%)	< 0.001
Leg pain	191(17.2%)	139(29.0%)	330(26.15%)	< 0.001
Knee pain	159(14.3%)	109(22.8%)	268(20.24%)	< 0.001
Ankle pain	62(5.6%)	57(11.9%)	119(8.08%)	< 0.001
Toe pain	37(3.3%)	34(7.1%)	71(4.67%)	0.001
Neck pain	65(5.8%)	47(9.8%)	112(7.57%)	0.006

Table 1. Characteristics of participants. Continuous variables were expressed as mean and standard deviation, and categorical variables were expressed as number and percentage. The Kruskal–Wallis H test and χ^2 test were used to compare the characteristics among different groups for continuous and categorical variables, respectively.

	Loneliness	*P*-value	Robust	*P*-value
	OR (95% CI)		OR (95% CI)	
Model 1[a]				
Headache	1.45(1.36–1.54)	< 0.001	1.45(1.36–1.54)	< 0.001
Shoulder pain	1.37(1.29–1.45)	< 0.001	1.37(1.29–1.45)	< 0.001
Arm pain	1.38(1.30–1.47)	< 0.001	1.38(1.29–1.47)	< 0.001
Wrist pain	1.36(1.26–1.45)	< 0.001	1.36(1.26–1.45)	< 0.001
Finger pain	1.39(1.30–1.49)	< 0.001	1.39(1.30–1.49)	< 0.001
Chest pain	1.48(1.37–1.59)	< 0.001	1.48(1.37–1.59)	< 0.001
Stomachache	1.45(1.35–1.55)	< 0.001	1.45(1.35–1.55)	< 0.001
Back pain	1.40(1.32–1.49)	< 0.001	1.40(1.32–1.49)	< 0.001
Waist pain	1.36(1.29–1.44)	< 0.001	1.36(1.29–1.44)	< 0.001
Buttock pain	1.44(1.34–1.55)	< 0.001	1.44(1.34–1.55)	< 0.001
Leg pain	1.41(1.34–1.50)	< 0.001	1.41(1.34–1.50)	< 0.001
Knee pain	1.35(1.28–1.43)	< 0.001	1.35(1.28–1.43)	< 0.001
Ankle pain	1.37(1.27–1.47)	< 0.001	1.37(1.27–1.47)	< 0.001
Toe pain	1.39(1.30–1.50)	< 0.001	1.39(1.30–1.50)	< 0.001
Neck pain	1.34(1.26–1.43)	< 0.001	1.34(1.25–1.44)	< 0.001
Model 2[b]				
Headache	1.40(1.29–1.51)	< 0.001	1.40(1.29–1.51)	< 0.001
Shoulder pain	1.34(1.25–1.43)	< 0.001	1.34(1.24–1.43)	< 0.001
Arm pain	1.58(1.29–1.92)	< 0.001	1.58(1.28–1.94)	< 0.001
Wrist pain	1.31(1.20–1.42)	< 0.001	1.31(1.21–1.42)	< 0.001
Finger pain	1.33(1.23–1.44)	< 0.001	1.33(1.23–1.45)	< 0.001
Chest pain	1.37(1.25–1.49)	< 0.001	1.37(1.25–1.49)	< 0.001
Stomachache	1.39(1.28–1.51)	< 0.001	1.39(1.27–1.51)	< 0.001
Back pain	1.46(1.29–1.66)	< 0.001	1.46(1.29–1.66)	< 0.001
Waist pain	1.40(1.30–1.52)	< 0.001	1.40(1.29–1.52)	< 0.001
Buttock pain	1.36(1.25–1.48)	< 0.001	1.36(1.25–1.49)	< 0.001
Leg pain	1.40(1.31–1.51)	< 0.001	1.40(1.31–1.51)	< 0.001
Knee pain	1.35(1.25–1.46)	< 0.001	1.35(1.25–1.46)	< 0.001
Ankle pain	1.30(1.19–1.42)	< 0.001	1.30(1.19–1.42)	< 0.001
Toe pain	1.32(1.21–1.45)	0.001	1.32(1.21–1.45)	< 0.001
Neck pain	1.22(0.96–1.56)	0.097	1.22(0.96–1.57)	0.110
Model 3[c]				
Headache	1.34(1.19–1.50)	< 0.001	1.34(1.19–1.51)	< 0.001
Shoulder pain	1.22(1.10–1.36)	< 0.001	1.22(1.11–1.35)	< 0.001
Arm pain	1.22(0.91–1.63)	0.190	1.22(0.90–1.64)	0.203
Wrist pain	1.22(1.09–1.36)	< 0.001	1.22(1.09–1.36)	0.001
Finger pain	1.19(1.07–1.32)	0.002	1.19(1.07–1.32)	0.002
Chest pain	1.32(1.16–1.49)	< 0.001	1.32(1.16–1.49)	< 0.001
Stomachache	1.32(1.17–1.50)	< 0.001	1.32(1.17–1.50)	< 0.001
Back pain	1.26(1.04–1.52)	0.017	1.26(1.05–1.51)	0.013
Waist pain	1.27(1.13–1.43)	< 0.001	1.27(1.13–1.43)	< 0.001
Buttock pain	1.18(1.05–1.32)	0.004	1.18(1.05–1.32)	0.005
Leg pain	1.27(1.15–1.41)	< 0.001	1.27(1.15–1.41)	< 0.001
Knee pain	1.23(1.11–1.37)	< 0.001	1.24(1.11–1.38)	< 0.001
Ankle pain	1.17(1.03–1.32)	0.012	1.17(1.03–1.32)	0.013
Toe pain	1.25(1.11–1.41)	< 0.001	1.25(1.11–1.42)	< 0.001
Neck pain	1.06(0.76–1.48)	0.783	1.06(0.75–1.50)	0.748
Model 4[d]				
Headache	1.34(1.19–1.50)	< 0.001	1.34(1.19–1.50)	< 0.001
Shoulder pain	1.22(1.10–1.36)	< 0.001	1.22(1.11–1.35)	< 0.001
Arm pain	1.19(0.87–1.61)	0.273	1.19(0.87–1.62)	0.283
Continued				

	Loneliness	*P*-value	Robust	*P*-value
	OR (95% CI)		OR (95% CI)	
Wrist pain	1.21(1.08–1.36)	0.001	1.21(1.08–1.36)	0.001
Finger pain	1.18(1.06–1.31)	0.002	1.18(1.06–1.31)	0.002
Chest pain	1.31(1.16–1.49)	< 0.001	1.31(1.16–1.49)	< 0.001
Stomachache	1.33(1.18–1.51)	< 0.001	1.33(1.18–1.51)	< 0.001
Back pain	1.27(1.05–1.54)	0.015	1.27(1.06–1.53)	0.011
Waist pain	1.28(1.14–1.43)	< 0.001	1.28(1.13–1.44)	< 0.001
Buttock pain	1.18(1.06–1.33)	0.004	1.18(1.05–1.33)	0.004
Leg pain	1.27(1.15–1.40)	< 0.001	1.27(1.15–1.40)	< 0.001
Knee pain	1.25(1.12–1.39)	< 0.001	1.25(1.11–1.40)	< 0.001
Ankle pain	1.16(1.03–1.31)	0.015	1.16(1.03–1.31)	0.016
Toe pain	1.25(1.11–1.41)	< 0.001	1.25(1.11–1.41)	< 0.001
Neck pain	1.05(0.75–1.47)	0.775	1.05(0.74–1.50)	0.787
Model 5[e]				
Headache	1.23(1.09–1.39)	0.001	1.23(1.07–1.39)	0.001
Shoulder pain	1.16(1.04–1.30)	0.009	1.16(1.04–1.29)	0.008
Arm pain	1.16(0.84–1.60)	0.358	1.16(0.84–1.61)	0.367
Wrist pain	1.14(1.01–1.28)	0.036	1.14(1.01–1.28)	0.035
Finger pain	1.14(1.02–1.28)	0.026	1.14(1.02–1.24)	0.025
Chest pain	1.26(1.10–1.44)	< 0.001	1.26(1.11–1.43)	< 0.001
Stomachache	1.28(1.12–1.46)	< 0.001	1.28(1.12–1.45)	< 0.001
Back pain	1.23(1.00–1.51)	0.050	1.23(1.01–1.49)	0.036
Waist pain	1.20(1.06–1.36)	0.004	1.20(1.06–1.36)	0.005
Buttock pain	1.15(1.02–1.30)	0.025	1.15(1.02–1.30)	0.026
Leg pain	1.20(1.08–1.33)	0.001	1.21(1.09–1.34)	< 0.001
Knee pain	1.16(1.04–1.30)	0.010	1.16(1.03–1.30)	0.011
Ankle pain	1.12(0.99–1.28)	0.081	1.12(0.99–1.28)	0.080
Toe pain	1.18(1.04–1.34)	0.012	1.18(1.04–1.34)	0.011
Neck pain	0.98(0.68–1.42)	0.932	0.98(0.69–1.40)	0.930

Table 2. Relationship between loneliness and pain in community-dwelling older Chinese adults, 2013–2020. ORs, odd ratios; CIs, confidence intervals. [a]Model 1 was the crude model. [b]Model 2 was adjusted for age, sex, body mass index, marital status, area of residence and educational level. [c]Model 3 was adjusted for age, sex, body mass index, marital status, area of residence, chronic diseases, educational level, health satisfaction, smoking status, drinking, sleeping time. [d]Model 4 was adjusted for age, sex, body mass index, marital status, area of residence, chronic diseases, educational level, health satisfaction, smoking status, drinking, sleeping time, social activity. [e]Model 5 was adjusted for age, sex, body mass index, marital status, area of residence, chronic diseases, educational level, health satisfaction, smoking status, drinking, sleeping time, depressive symptoms, social activity.

a moderate amount of the time had a higher risk of buttock (OR = 1.75, 95% CI 1.15–2.66), leg (OR = 1.50, 95% CI 1.07–2.10), and knee pain (OR = 1.46, 95% CI 1.00–2.12) than participants who were not lonely (Table 3).

Participants who felt lonely most of the time had a non-significant increased risk of arm pain (OR = 2.64, 95% CI 0.89–7.81), buttock pain (OR = 1.39, 95% CI 0.95–2.04), ankle pain (OR = 1.34, 95% CI 0.88–2.02) and, neck pain (OR = 1.16, 95% CI 0.38–3.55).

As shown in Tables 4 and Table S2, loneliness is directly associated with an increased risk of various types of pain (head, shoulder, wrist, finger, chest, stomach, waist, buttock, leg, knee, ankle, and toe pain). However, after accounting for depression, the relationship between loneliness and ankle pain was similar to the main analysis (c' OR = 1.12, 95% CI 0.99–1.28; Fig. 2).

Stratified analyses of age, sex, and marital status supported the main analysis (Fig. 3). And the risk of pain from loneliness did not decrease as the frequency of social activity increased (see Supplementary Fig. S1).

Discussion

Consistent with previous research, lonely older adults are more likely to experience pain[18,24]. Although earlier studies have shown an inseparable relationship between depression and pain[32,33], our study found that even when controlling for depressive symptoms, loneliness was still associated with a higher risk of pain. In this 7-year follow-up cohort, the following types of pain were positively associated with loneliness: head, shoulder, wrist, finger, chest, stomach, back, waist, buttock, leg, knee, and toe pain. However, sensitivity analyses for wrist, finger, and back pain showed inconsistent results. Compared to a previous study from Japan, we identified both

		Some or a little of the time	Moderate amount of the time	Most or all the time
	Not-lonely	OR (95% CI)	OR (95% CI)	OR (95% CI)
Headache	Reference	0.89(0.60–1.33)	1.45(0.97–2.16)	1.90***(1.28–2.81)
Shoulder pain	Reference	0.94(0.64–1.39)	1.12(0.76–1.65)	1.66***(1.19–2.34)
Arm pain	Reference	0.52(0.13–2.08)	0.40(0.12–1.36)	2.64(0.89–7.81)
Wrist pain	Reference	1.25(0.84–1.86)	1.03(0.69–1.56)	1.58**(1.09–2.29)
Finger pain	Reference	1.06(0.71–1.59)	1.30(0.87–1.95)	1.47**(1.03–2.10)
Chest pain	Reference	1.46(0.93–2.29)	1.31(0.84–2.04)	2.11***(1.43–3.13)
Stomachache	Reference	1.33(0.87–2.02)	1.51(1.00–2.30)	2.14***(1.43–3.21)
Back pain	Reference	1.02(0.46–2.30)	1.27(0.66–2.44)	1.93**(1.06–3.49)
Waist pain	Reference	1.25(0.83–1.88)	1.40(0.95–2.07)	1.75***(1.16–2.63)
Buttock pain	Reference	0.99(0.62–1.59)	1.75***(1.15–2.66)	1.39(0.95–2.04)
Leg pain	Reference	1.32(0.93–1.88)	1.50**(1.07–2.10)	1.76***(1.26–2.45)
Knee pain	Reference	0.83(0.58–1.21)	1.46**(1.00–2.12)	1.53**(1.07–2.20)
Ankle pain	Reference	1.51(1.00–2.30)	1.49(0.98–2.26)	1.34(0.88–2.02)
Toe pain	Reference	1.08(0.68–1.72)	1.14(0.74–1.75)	1.74***(1.18–2.55)
Neck pain	Reference	0.26(0.05–1.45)	0.38(0.10–1.40)	1.16(0.38–3.55)

Table 3. Relationship between different degrees of loneliness and pain in older Chinese adults, 2013–2020. ORs, odd ratios; CIs, confidence intervals. The model was adjusted for age, sex, body mass index, marital status, area of residence, chronic diseases, educational level, health satisfaction, smoking, drinking status, sleeping time, depressive symptoms, social activity. *$P<0.01$, **$P<0.05$, ***$P<0.001$.

	a (OR)	95%CI	b (OR)	95%CI	c (OR)	95%CI	c' (OR)	95%CI
Headache	3.45	(2.90–4.10)	2.06	(1.54–2.76)	1.34	(1.19–1.51)	1.23	(1.09–1.39)
Shoulder pain	3.71	(3.08–4.47)	1.64	(1.26–2.13)	1.22	(1.11–1.35)	1.16	(1.04–1.29)
Arm pain	3.09	(1.89–5.03)	1.58	(0.64–3.93)	1.19	(0.84–1.69)	1.14	(0.80–1.63)
Wrist pain	3.63	(3.06–4.32)	1.76	(1.31–2.38)	1.21	(1.08–1.36)	1.14	(1.01–1.28)
Finger pain	3.66	(3.07–4.36)	1.45	(1.11–1.90)	1.18	(1.06–1.31)	1.14	(1.02–1.28)
Chest pain	3.59	(3.01–4.27)	1.69	(1.21–2.38)	1.31	(1.16–1.49)	1.26	(1.11–1.43)
Stomachache	3.70	(3.09–4.42)	1.87	(1.36–2.58)	1.33	(1.18–1.51)	1.28	(1.12–1.45)
Back pain	2.99	(2.20–4.08)	1.57	(0.95–2.59)	1.27	(1.06–1.53)	1.23	(1.01–1.49)
Waist pain	3.42	(2.86–4.10)	1.70	(1.29–2.24)	1.28	(1.13–1.44)	1.20	(1.06–1.36)
Buttock pain	3.59	(3.02–4.26)	1.39	(1.02–1.89)	1.18	(1.05–1.33)	1.15	(1.02–1.30)
Leg pain	3.55	(2.95–4.28)	1.60	(1.25–2.03)	1.27	(1.15–1.40)	1.21	(1.09–1.35)
Knee pain	3.63	(3.01–4.37)	1.72	(1.33–2.21)	1.24	(1.11–1.38)	1.16	(1.03–1.30)
Ankle pain	3.61	(3.03–4.30)	1.42	(1.03–1.96)	1.16	(1.03–1.32)	1.12	(0.99–1.28)
Toe pain	3.56	(3.00–4.21)	1.77	(1.27–2.46)	1.25	(1.11–1.41)	1.18	(1.04–1.34)
Neck pain	3.21	(2.00–5.18)	1.97	(0.46–8.53)	1.05	(0.74–1.50)	0.98	(0.69–1.40)

Table 4. Mediation analysis of depression. ORs, odd ratios; CIs, confidence intervals. The relationship between loneliness and depression (path a) and pain (path b). The relationship between loneliness and pain (path c) and adjusting the effect of depressive symptoms on pain (path c'). The depression assessment not exclude the item that directly asked individuals about their feelings of loneliness.

parallels and divergences in the pain associated with loneliness[22]. Unlike the Japanese study, our research did not find an association between loneliness and neck pain. In terms of lower limb, lonely individuals were more susceptible to experiencing hip, knee and toe pain, but not ankle pain.

Studies have found that loneliness is a risk factor for respiratory and gastrointestinal diseases, which can lead to chest and stomach pain, respectively[34,35]. Ghadimi et al. found that self-reported loneliness had significant effects on sixth-month pain[36]. Similar findings were found in our study, where older adults who were lonelier at baseline were more likely to experience pain. However, the mechanisms by which loneliness influences these symptoms remain unclear, they may resemble processes associated with depressive symptoms[22].

Our study found a positive association between the degree of loneliness and the risk of waist and back pain in the spine region, while no such association was observed for neck pain. This aligns with findings from another study, which indicated that individuals experiencing loneliness were more prone to waist pain[19]. Additionally, Batley et al. reported that those with any spinal pain, encompassing the cervical, thoracic, and lumbar regions,

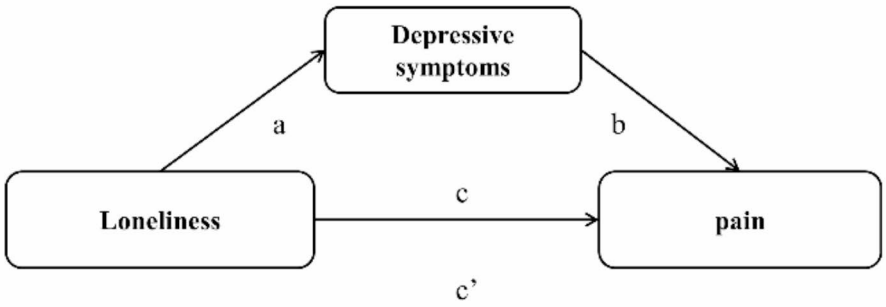

Fig. 2. Conceptual model of depression as a mediator between loneliness and pain. The relationship between loneliness and depression (path a) and pain (path b). The relationship between loneliness and pain (path c) and adjusting the effect of depressive symptoms on pain (path c').

tended to exhibit higher levels of loneliness. However, it's important to note that their study focused on adolescents rather than the older adults[37].

The mechanisms connecting loneliness to pain are not yet fully understood. Loneliness, as a form of social pain, may share neurocognitive substrates with physical pain, since experiencing social pain can activate neural regions involved in processing physical pain[38]. Specifically, in the nervous system, the insula is a part of physiological and social pain[39], particularly in the formation of pain perception[40], whereas the frontal pole is engaged in the affective networks of the social-physical pain matrix[41,42]. Alternatively, loneliness is associated with proinflammatory gene expression and heightened inflammatory responses to stress[43]. In turn, this increased inflammation sensitizes pain pathways and peripheral pain receptors[44,45]. For instance, elevated levels of the inflammatory cytokine interleukin-6 (IL-6) are often detected in individuals who report feeling more isolated[46]. This rise in IL-6 may promote the development of mechanical allodynia and thermal hyperalgesia[47]. Thus, the pro-inflammatory effects of IL-6 associated with loneliness could play a crucial role in the connection between social and physical pain experiences[21].

A surprising finding was that frequent social activity did not affect the association between loneliness and pain. While social activity frequency was assessed, loneliness was self-perceived. In other words, pain was associated with loneliness, but social engagement was not associated with pain[48]. In China, family constitutes the principal source of social support, succeeded by friends, which has been demonstrated to enhance subjective well-being and mental health[49]. However, the 'one child' policy and urban migration have reduced companionship and care for children. Consequently, older adults may perceive less social support despite being socially active[50–52].

Topic-related studies have been dedicated to the amount and intensity of pain, rather than pain at specific sites[53]. Results from this research substantiate the relationship between loneliness and pain in older adults. Consequently, reducing and preventing loneliness in older adults is necessary to mitigate pain. Increasing social engagement alone may be insufficient to alleviate loneliness, and it is also necessary to cultivate an individual's sense of social self-efficacy. Interventions that target coping strategies, such as cognitive behavioral therapy may influence social behavior and self-efficacy to improve loneliness[54].

There are some limitations to the study. The binary "yes/no" measure, lacks details on pain intensity, quality, and frequency, preventing a comprehensive understanding of pain experiences. Loneliness is assessed with a single-item question, risking an incomplete capture of this multidimensional construct. Employing more robust loneliness scales could provide deeper insights. The study population was restricted to those aged 60 and above from China, limiting generalizability. Reliance on self-reported data, except for BMI, introduces potential biases. Incorporating objective measures would strengthen the analysis. Although we employed robustness and sensitivity analyses to ensure the reliability of our results, the relatively small sample size of this study may limit statistical power, and the interactions between various covariates may not have been adequately addressed. Therefore, future research should consider conducting similar analyses with larger sample sizes to enhance the

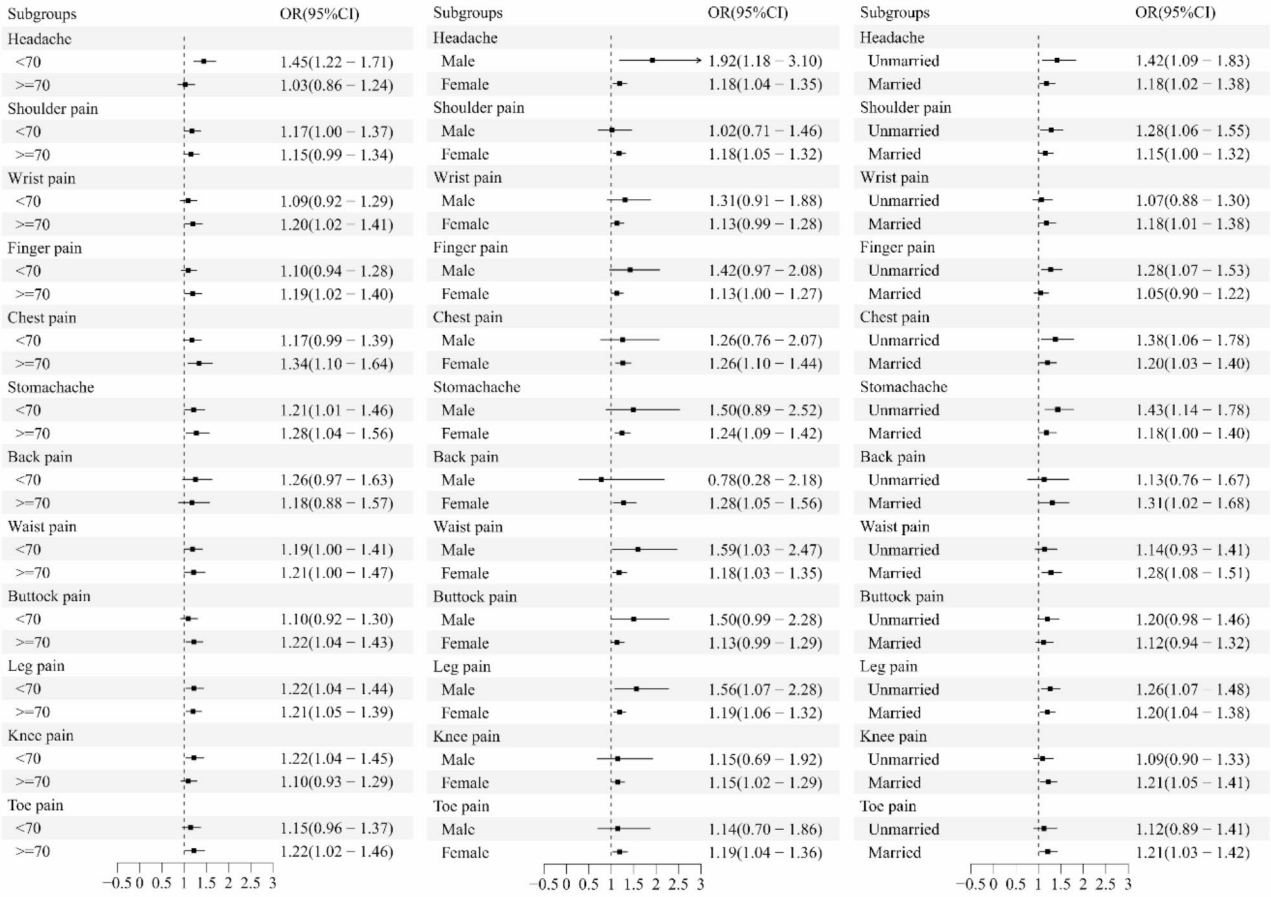

Fig. 3. Association between pain and loneliness by age, gender and marital status. ORs, odd ratios; CIs, confidence intervals. The model was adjusted for age, sex, body mass index, marital status, area of residence, chronic diseases, educational level, health satisfaction, smoking, drinking status, sleeping time, depressive symptoms, social activity.

reliability of the findings. Overall, while the central finding challenges the assumption that increased social engagement can alleviate the relationship between loneliness and pain, the limitations in measurement and sample scope constrain the ability to fully elucidate this complex relationship. Further research using more comprehensive assessments and diverse populations would help clarify the nuances involved.

Conclusions

The results have significant implications for the association between loneliness and negative health outcomes in older adults in China. Loneliness and a range of pain types are strongly linked, suggesting that addressing older adults' subjective mental state may be critical for pain prevention and management. Longer-term longitudinal studies across age cohorts and diverse populations could elucidate the causal mechanisms, such as inflammatory, neuroendocrine, and immune factors. Evaluating the effects of psychological and behavioral interventions on both loneliness and pain would identify effective strategies. The study is one piece of evidence supporting the importance of considering mental health and well-being as well in older adults. Expanding research in this area can inform more holistic approaches to supporting healthy aging and quality of life.

Data availability

The data that support the findings of this study are available from CHARLS project site, subject to registration and application process. Further details can be found at https://charls.charlsdata.com/.

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Author contributions

Conceived and designed the research: A.J.S. and S.J. Wrote the paper: A.J.S. and S.Y.Y. Analyzed the data: S.Y.Y. and J.S. Revised the paper: J.S., Z.Y.G. and Y.S. All authors reviewed the manuscript. A.J.S. and S.Y.Y. have contributed equally to this work and share first authorship. All authors contributed to the article and approved the submitted version.

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Declarations

Ethics approval and consent to participate

The CHARLS was approved by the Institutional Review Board of Peking University (IRB00001052-11015) and all participants gave written informed consent.

Competing interests

The authors declare no competing interests.

Additional information

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