

New insights into social isolation and loneliness, volume II

Edited by

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New insights into social isolation and loneliness, volume II

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Editorial: New insights into social isolation and loneliness, volume II

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KEYWORDS

social isolation, loneliness, mental health, older adults, social support

Editorial on the Research Topic

New insights into social isolation and loneliness, volume II

This collection is the 2nd volume of the Research Topic, *New Insights into Social Isolation and Loneliness*. Social isolation is generally recognized as a major public health problem and is widely recognized to have detrimental consequences for people's health, including reduced mental health, increased risk of disease (e.g., hypertension, cardiovascular disease, cancer), mortality, and cognitive decline. It is widely recognized that social isolation is a major cause of death. Combined with the recent COVID-19 and other changes in social conditions, social isolation, and loneliness are becoming an increasing concern. Social isolation can occur regardless of gender or age, and the occurrence process and related factors warrant further investigation.

The primary objective of this Research Topic is to deepen our understanding of social isolation and loneliness. A secondary objective is to explore their neurobiological underpinnings and provide insights that may inform the development and implementation of targeted prevention and intervention strategies for high-risk populations.

Out of the 24 manuscripts submitted by international researchers, 13 were accepted for publication following a rigorous peer review process. Below is a summary of the main findings from each of the accepted papers.

In the first article in this Research Topic, [Worsley et al.](#) examined the mental health of university students early in the COVID-19 pandemic and identified academic, non-academic, and COVID-19-related factors influencing depression and anxiety. Surveying 3,817 students, it found high rates of depression and anxiety (over 50%). Key risk factors included academic stress, social isolation, intolerance of uncertainty, and negative attitudes toward remote learning, while a strong sense of university belonging was protective. These findings offer valuable insights for developing targeted mental health support for students during future crises.

In the next article, [Luo et al.](#) conducted a systematic review and meta-analysis examining the link between living alone and suicidal behaviors using data from over 3.6 million participants across nine prospective studies. Their results showed that living alone was associated with a significantly higher risk of both suicide attempts and suicide death, even after adjusting for confounding factors. With increasing rates of living alone worldwide, these findings highlight the importance of addressing living arrangements in suicide prevention efforts.

Zhao and Kou investigated the relationship between loneliness and short video addiction among 388 college students, focusing on the mediating roles of social support and physical activity. Their results showed that loneliness directly increased short video addiction, with social support and physical activity independently mediating this effect. Additionally, social support and physical activity together formed a chain mediation between loneliness and addiction. These findings offer new insights and suggest effective strategies to reduce short video addiction among college students.

Meneguzzo et al. examined whether loneliness mediates the link between childhood trauma and eating disorder (ED) symptoms in 230 individuals with EDs. Their analysis showed that childhood trauma predicted higher loneliness, which in turn was associated with more severe ED symptoms. Loneliness partially mediated this relationship, suggesting that addressing loneliness in treatment could help reduce the impact of childhood trauma on ED severity. These findings highlight the potential of social connection-focused interventions in ED care.

Dong et al. investigated how social isolation mediates the relationship between stigma and work ability in young and middle-aged stroke patients. Their study found that higher stigma was associated with greater social isolation and reduced work ability. Social isolation partially mediated the negative impact of stigma on work ability, accounting for about 22% of the effect. These results highlight the importance of addressing both stigma and social isolation to improve work outcomes in stroke survivors.

Chen et al. developed a stacked ensemble machine learning model to predict Major Depressive Disorder (MDD) in adults living alone using health data from over 2,600 US participants. Their model showed strong accuracy (AUC = 0.85). Key factors positively associated with MDD included sleep disorders, medication use, and certain health conditions, while age and some dietary factors were negatively associated. This approach improves identification of MDD risk among adults living alone, aiding targeted mental health interventions.

Li et al. studied 4,819 middle-aged and older women who participated in square dance exercise to examine its impact on attitudes toward aging. Their analysis showed that square dance positively influenced aging attitudes, with loneliness reduction and improved quality of life acting as key mediators. Quality of life had the strongest mediating effect. These findings suggest that square dance exercise promotes positive aging attitudes and enhances well-being in this population.

Liu et al. studied 223 individuals with chronic schizophrenia to examine how psychotic symptoms affect social functioning. They found that impaired interpersonal trust mediates the relationship between psychotic symptoms and reduced social functioning. These results suggest that interventions aimed at improving interpersonal trust could enhance social functioning and outcomes in schizophrenia patients.

Mohammed Ali et al. validated the Three-Item UCLA Loneliness Scale (UCLALS3) for dementia family caregivers (N=571). The scale showed strong reliability and validity, with a cutoff score of ≥ 6.5 effectively identifying caregivers experiencing

high loneliness linked to greater caregiving burden and distress. This short measure can help detect caregivers in need of targeted social support interventions.

Meehan et al. conducted a 12-year longitudinal study in Australia examining community-level factors influencing loneliness and social isolation (SI) among younger (18–30) and older (60+) adults. They found that low community engagement was the strongest risk factor for both loneliness and SI across all ages. Additionally, low neighborhood social cohesion significantly increased loneliness and SI, especially in older adults. The study emphasizes the importance of community-focused interventions to effectively reduce loneliness and social isolation beyond individual-level approaches.

Ju et al. studied loneliness in stroke patients aged 60 and older, finding moderate levels of loneliness influenced by income, activity, community resources, social participation, and illness duration. Family resilience directly reduced loneliness, and this effect was partially mediated by social support, family functioning, and psychological capital. The findings suggest that enhancing family resilience and support can effectively alleviate loneliness in elderly stroke survivors.

Wenig et al. conducted a large cross-sectional study of 12,874 German university students to assess loneliness and its associated factors. They found that 28.2% of students experienced loneliness, with higher risk among gender-diverse individuals, males, and those with poor health. Positive social relationships and strong university connectedness reduced loneliness, while weak ties increased it. Students at universities of applied sciences reported less loneliness. The study highlights the need for individual and institutional efforts to foster social connections and community engagement to combat loneliness in universities.

Finally, Gorman et al. examined how the Veterans Socials program, a community-based social support initiative for U.S. veterans, transitioned from in-person to virtual gatherings during COVID-19. The study highlights how partnerships between private and government organizations enabled the program to maintain social connections, reduce isolation, and improve healthcare access during the pandemic. Their findings emphasize the critical role of community collaboration in sustaining support and disseminating vital information during emergencies.

In conclusion, this Research Topic provides comprehensive and multi-faceted insights into the complex issue of social isolation and loneliness across diverse populations and contexts. Spanning different age groups—from university students and middle-aged adults to elderly stroke survivors and dementia caregivers—and geographic regions, the research highlights both common and unique risk factors, including individual, interpersonal, and community-level determinants.

Key findings emphasize the critical role of social support, family resilience, and community engagement in mitigating loneliness and its adverse mental and physical health consequences. Several studies underline the importance of targeted interventions tailored to specific populations, such as trust-building in schizophrenia patients, physical activity programs for older women, and technology-facilitated social connection for veterans.

Moreover, the integration of neurobiological, psychological, and social ecological perspectives enriches our understanding of the mechanisms driving loneliness and social isolation. This knowledge informs innovative approaches, including predictive modeling and mediation analyses, which can guide effective prevention and treatment strategies.

Overall, this Research Topic reinforces that addressing social isolation and loneliness requires holistic, multi-level strategies that consider individual vulnerabilities alongside broader social and environmental factors. As social dynamics continue to evolve, especially under challenges like the COVID-19 pandemic, these findings offer valuable guidance for policymakers, healthcare providers, and communities aiming to promote social inclusion and improve well-being.

Author contributions

YK: Writing – original draft, Writing – review & editing.

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Academic and non-academic predictors of common mental health difficulties among university students during the COVID-19 pandemic

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Introduction: Public concern for the mental health of university students has been rising over recent years. Newly arising stressors associated with the COVID-19 pandemic could contribute to further mental health burden for students. This study aimed to understand the mental health status of university students at an early stage in the pandemic and to identify academic, non-academic, and COVID-19-related predictors of common mental health difficulties at this time.

Methods: This study examined how academic and non-academic predictors relate to common mental health difficulties using a cross-sectional sample of university students ($n = 3817$).

Results: There were high levels of depression and anxiety during the pandemic, with more than 50% experiencing levels above the clinical cut offs. Academic stress, social isolation, intolerance of uncertainty, and more negative attitudes towards remote teaching and learning predicted higher levels of depression and anxiety. University identification predicted lower levels of depression whereas receiving a diagnosis of COVID-19 was associated with higher levels of depression.

Discussion: This study identified COVID-19-related factors that uniquely contributed to students' distress during the pandemic, over and above social connectivity variables. As COVID-19 factors, such as the uncertainty surrounding the pandemic, may have driven an increase in distress levels among students, these findings provide insights that could help universities and policymakers develop targeted interventions to support the mental health and well-being of university students during future crises.

KEYWORDS

COVID-19 pandemic, student mental health, social isolation, academic stress, intolerance of uncertainty

1 Introduction

The COVID-19 pandemic has posed risks to public mental health worldwide. Although public concern for the mental health of university students has been rising over recent years, the COVID-19 pandemic posed further challenges, including the suspension of in-person teaching as well as restrictions on traveling which forced many students to leave their term-time residences (1). Early evidence assessing the mental health implications of COVID-19 has

identified a heightened prevalence of distress. For example, Chen and Lucock (2) reported high levels of depression and anxiety in a UK student sample, with more than 50% experiencing levels above the clinical cut offs. Longitudinal studies in Italy, Switzerland, and the UK reported poorer mental health and wellbeing outcomes following the onset of the COVID-19 pandemic (3–5).

Academic programs are demanding due to challenging curricula, rigorous workloads, as well as both intellectual and emotional demands. As a result, researchers have applied frameworks such as the Job Demands-Resources model (JD-R) to academic contexts [e.g., (6, 7)]. In the JD-R framework, demands lead to strain whereas resources are those aspects of the environment that reduce demands and help individuals to achieve work goals (8). Using the JD-R model, Pluut and colleagues examined the impact of stressors and resources on student wellbeing and academic performance and found that academic stressors contributed to low wellbeing among university students (7). Consistent with the JD-R model, McIntyre and colleagues found that university students are subjected to a range of stressors that contribute to distress (6). Assessment stress consistently emerged as the strongest academic predictor of poor mental health (6). The change to remote learning and loss of daily student life routines potentially intensified pre-existing academic stress, contributing to further mental health burden for students (9).

In a recent longitudinal study exploring psychosocial and lifestyle variables, university connectedness was found to be the most notable predictor of internalizing symptom trajectories in a sample of first-year undergraduate students (10). Aspects of university connectedness encompasses one's relationship with their peers, as well as involvement in group activities, events, and sports on campus. When examining both academic and non-academic predictors of student psychological distress, loneliness was identified as the strongest predictor of depression and anxiety while university friends were the most important social group with whom to identify in order to protect against depression and anxiety (6). In accordance with the Social Cure Model of health (11), a group has the potential to enhance health outcomes when individuals feel as though they bond with the members in the group and the group becomes incorporated into their sense of self through the process of social identification (12). Consistent with this model, identifying with more groups has been associated with reduced depression and anxiety among university students during stressful periods (13). Once an individual identifies with a group, they are more likely to receive and benefit from social support provided by this group (14). Taken together, this evidence suggests that enabling students to form a sense of identification with their peers and their institution may represent a psychological resource that improves mental health. However, as the COVID-19 pandemic has resulted in substantial reductions in recreational and leisure opportunities for students (10), the pandemic-associated restrictions are likely to have made it harder for students to identify with the university and their peers (15).

Perhaps the most obvious psychological mechanism associated with the COVID-19 pandemic is the uncertainty that defines the extent and timescale of the lifestyle restrictions. In general, high intolerance of uncertainty is associated with higher levels of mental distress, particularly anxiety (16). The intolerance of uncertainty model suggests that individuals whose tolerance for uncertainty is low have the tendency to respond negatively to situations that are uncertain (17). The COVID-19 pandemic is, by definition, an

uncertain event of global significance that has no clear end date or outcome for individuals or societies. When combined with multiple lockdowns, uncertainty intolerance has been found to increase mental distress (18). Indeed, students have faced a number of further uncertainties during this time, including inadequate information regarding exams and graduation, losing their part-time jobs, and difficulties in managing their new study life (19). This suggests that the increase in mental distress reported by students may be linked to the extent to which they tend to tolerate uncertain situations and circumstances.

We aimed to understand the mental health of university students during the COVID-19 pandemic and identify academic and non-academic predictors of student psychological distress. In line with our previous findings [see (6)], we expected that (1) higher levels of academic stress and expectations stress, (2) low sense of identification with university and university friends, and (3) higher levels of social isolation would be associated with higher levels of depression and anxiety. Further, in the context of the pandemic, we expected that (4) intolerance of uncertainty, (5) having contracted COVID-19, and (6) dissatisfaction with online teaching would be associated with higher levels of depression and anxiety.

2 Methods

2.1 Ethical approval

Ethical approval was received from the Institute of Population Health Sciences (IPHS) Research Ethics Committee. All participants have given consent for their data to be used in the research.

2.2 Design

The cross-sectional online survey was conducted during the latter part of October 2020 and the first part of November 2020.

2.3 Procedure

An online survey link was sent via email to all students registered at one of two large universities in the North of England. The online survey was open to all students of these institutions. The survey was designed to be completed within approximately 20 min. To ensure broad participation, a reminder email was sent out 1 week after the initial invitation. Participation was voluntary, and students were informed that their responses would be anonymous and confidential. The survey was accessible for a period of 2 weeks, during which students could complete it at their convenience. The data collection was conducted in the period between 29.10.2020 and 12.11.2020. To put this in context, England entered the first national lockdown in March 2020. Following partial lockdown lifting in Summer 2020, restrictions were reintroduced in England during September 2020 (e.g., indoor and outdoor gatherings of six or more people were banned and there was a return to working from home). The second national lockdown in England was announced (on 31st October 2020) and implemented (on 5th November 2020) while data collection was ongoing.

2.4 Participants

In total, 3,817 university students completed the survey. The majority of participants were female (71%). The mean age was 23 years (± 5.87), and the majority were from a white ethnic background (85%).

2.5 Measures

2.5.1 Generalized Anxiety Disorder-7

The Generalized Anxiety Disorder-7 (GAD-7; 20) is a 7-item scale that assesses the occurrence of anxious symptoms over the last 2 weeks. For example, “feeling nervous, anxious or on edge.” Responses are recorded on a 4-point scale (0 = *not at all* to 3 = *nearly every day*), with higher scores indicating higher levels of anxiety. The cut off points for mild, moderate, and severe levels of anxiety are scores of 5, 10, and 15, respectively. The internal consistency of the GAD-7 in this study was excellent, $\alpha = 0.92$.

2.5.2 Patient Health Questionnaire

The Patient Health Questionnaire (PHQ-9; 21) is a 9-item scale that assesses frequency of depressive symptoms over the last 2 weeks. Example items include “feeling down, depressed, or hopeless” and “thoughts that you would be better off dead.” All items are scored on a 4-point scale (0 = *not at all* to 3 = *nearly every day*), with higher scores suggesting higher levels of depressive symptoms. Cut off points of 5, 10, and 15 were used to represent mild, moderate, and moderately severe/severe depression. The internal consistency of the PHQ-9 in this study was excellent, $\alpha = 0.90$.

2.5.3 The UCLA Loneliness Scale

The UCLA loneliness scale (ULS; 22) consists of statements which measure an individual's feelings of loneliness. Example items include: “I feel left out” and “I lack companionship.” Responses were measured on a 4-point scale (1 = *never* and 4 = *always*), with higher scores indicating higher levels of perceived loneliness. The internal consistency for this study was $\alpha = 0.85$.

2.5.4 Adapted version of the Academic Stress Scale

An adapted 5-item version of the Academic Stress Scale (ASS; 23) measures an individual's academic stress. An example question was the extent to which the individual was stressed about “excessive workload.” Some of the original items (e.g., forgetting pencil/pen) were either dropped or adapted to reflect modern learning environments. Response options ranged from 1 = *not at all stressed* to 5 = *extremely stressed*, and higher scores suggest higher levels of academic stress. The internal consistency for this study was $\alpha = 0.78$.

2.5.5 The Academic Expectations Stress Inventory

Single items were taken from the Academic Expectations Stress Inventory (AESI; 24), which tapped stress related to students own expectations and those of others (e.g., teachers and parents). Example items included “I feel stressed when I am disappointed in my grades” and “I feel stressed when I know others are disappointed in my grades.” Response options ranged from 1 = *never true* to 5 = *always true*. The internal consistency for this study was $\alpha = 0.63$.

2.5.6 The Social Identity Scale

The Social Identity Scale (SIS; 25) consists of four items which assess the individual's identity with their university friends. Example items include: ‘I identify with my university friends’ and ‘I am glad to be part of my university friendship group.’ Response options ranged from 1 “*strongly disagree*” to 5 “*strongly agree*.” Higher scores suggest higher levels of identity. The internal consistency for this study was $\alpha = 0.94$.

2.5.7 The School Climate and School Identification Measure-Student

An adapted version of the School Climate and School Identification Measure-Student (SCASIM-St; 26) scale was used to assess university identity. The word “school” was replaced with “university.” Example items include: “I feel I belong at this university” and “I identify with this university.” Higher scores suggest higher levels of university identification. The SCASIM-St scale comprises 6 items scored on a 7-point scale (1 = “*strongly disagree*” to 7 = “*strongly agree*”). The internal consistency for this study was $\alpha = 0.93$.

2.5.8 The Exeter Identity Transition Scale

The 3-item Exeter Identity Transition Scale (EXITS; 27) measures multiple group membership. For example, “I am a member of lots of different groups at university.” Response options range from 1 = *do not agree* to 7 = *agree completely*. The internal consistency for this study was $\alpha = 0.87$.

2.5.9 The Intolerance of Uncertainty Scale

The 12-item Intolerance of Uncertainty Scale (IUS; 28) measures reactions to uncertain events. For example, “it frustrates me not having all the information I need.” This measure was included in 2020 dataset only. Responses options range from 1 = “*not at all a characteristic of me*” to 5 = “*entirely characteristic of me*.” The greater the overall score, the higher the intolerance of uncertainty. The internal consistency for this study was $\alpha = 0.91$.

2.5.10 Attitudes toward online teaching and learning

To ascertain students' feelings toward online teaching and learning, a single-item was included: “How are you finding remote delivery of teaching and learning this semester?” Response options ranged from 1 “*I really dislike it*” to 5 “*I really like it*.”

2.5.11 Diagnosis of COVID-19

To establish whether students have been diagnosed with COVID-19, a single item was included: “Have you had COVID-19 (coronavirus)?” Responses were categorized as “formal diagnosis” or “no formal diagnosis.”

2.6 Statistical analyses

Hierarchical regression analyses were conducted to assess the contributions of academic and non-academic predictors in explaining common mental health difficulties. Hierarchical regression is robust enough to tolerate violations of normality (29). We included depression and anxiety as dependent variables. Following McIntyre et al. (6), predictor variables were entered into the model at different blocks. Each block represented a distinct cluster of associated predictors. Predictor

variables were entered into the model as follows: Block 1: demographic variables (age, sex, ethnicity, higher education institution); Block 2: academic stressors (expectations and academic stress); Block 3: social identification variables (university friends identification, university identification, and multiple group membership); Block 4: social isolation; and Block 5: COVID-19 variables (intolerance of uncertainty, attitudes toward online learning, and COVID-19 diagnosis).

3 Results

3.1 Extent of mental health issues

As shown in Figure 1, using the published criteria for moderate anxiety (10–14) and depression (10–14), the proportion of students above these cut offs was 54.9% for anxiety and 58.1% for depression. Using the published criteria for severe anxiety (GAD-7: 15–21), 32.0% met the criteria for severe anxiety during the COVID-19 pandemic. Using the published criteria for moderately severe and severe depression (PHQ-9: 15–19 moderately severe and 20–27 severe), 36.6% met the criteria for moderately severe/severe depression during the COVID-19 pandemic.

3.2 Academic and non-academic predictors of common mental health difficulties

To understand how an accumulation of factors impact on mental health, a series of hierarchical regressions were conducted to determine which predictors were the most important determinants of symptoms. Descriptive statistics of the final sample ($n=3,817$) are shown in Table 1.

3.2.1 Predicting symptoms of depression during the COVID-19 pandemic

The overall regression model predicted 46% of the variance in depression [$R^2=0.46$, $F(13, 3,145)=208.88$, $p<0.001$]. As reported in Table 2, at Block 1 the demographic variables explained a significant portion of variance in depression. Together, the demographic variables

predicted approximately 4% of the variance in depression. Sex and ethnicity were unrelated to depression; however, age and HEI were significant predictors with higher symptoms of depression in younger students and those studying at a post-92 institution. At Block 2, academic stressors contributed significantly to the model predicting depression. Together, the academic stressors accounted for approximately 24% of the variance in depression scores. Higher levels of academic stress and expectations stress predicted higher levels of depression. At Block 3, the social identification variables contributed significantly to the model. Combined, the three social identity variables explained approximately 5% of the variance in depression scores. University identification emerged as the only significant predictor of depression symptoms. Stronger identification with university predicted lower levels of depression. Block 4 accounted for approximately 11% of the variance in depression scores. Feeling isolated was strongly associated with higher levels of depression. At Block 5, COVID-19 related variables contributed significantly to the model. Together, the three COVID-19 variables accounted for approximately 3% of the variance in depression scores. While this block added less unique variance compared to the previous blocks, it still played a role in predicting depression scores. High intolerance of uncertainty and having contracted COVID-19 were associated with higher levels of depression. Students who disliked online teaching and learning also reported higher levels of depression.

In sum, the R^2 change for Block 2 underscores the importance of academic stressors as predictors of depression. As Block 2 has the largest R^2 change, this suggests it is the most crucial in predicting depression scores. Block 3, which included social identity variables, also contributed significantly, though to a lesser extent. The additional variance explained by Block 4 highlights the significance of social isolation. Although Block 5 explained the least amount of variance, the significant contribution of intolerance of uncertainty, contracting COVID-19, and more negative attitudes toward online learning indicates that COVID-19 related variables also affect depression scores. Thus, academic stress, academic expectations, university identification, social isolation, intolerance of uncertainty, contracting COVID-19, and more negative attitudes toward online teaching were all significant predictors of depression when controlling for all academic and non-academic stressors (see Table 2).

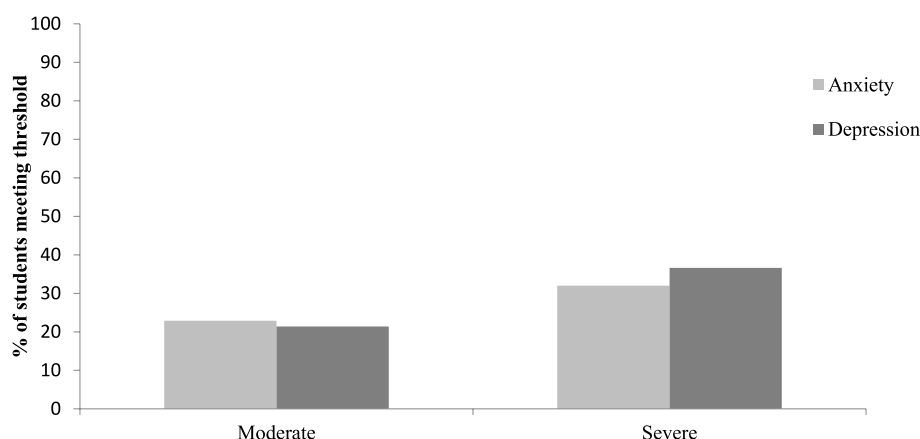


FIGURE 1
Proportion of students meeting the criteria for moderate and severe mental health symptoms.

TABLE 1 Descriptive statistics.

	Mean	Standard deviation
Academic stress	16.79	±4.54
Academic expectations	8.72	±1.59
University friends identification	13.95	±4.13
University identification	29.36	±7.82
Group membership	6.82	±4.33
Social isolation	18.99	±5.14
Intolerance of uncertainty	35.64	±10.19
Online teaching	2.56	±1.21
Anxiety	11.98	±7.31
Depression	10.95	±6.33

3.2.2 Predicting symptoms of anxiety during the COVID-19 pandemic

The overall regression model predicted 49% of the variance in anxiety [$R^2=0.49$, $F(13, 3,145)=231.71$, $p<0.001$]. As reported in Table 3, at Block 1 the demographic variables explained a significant portion of variance in anxiety. Together, the demographic variables predicted approximately 3% of the variance in anxiety. Age, sex and ethnicity were unrelated to anxiety; however, those studying at a post-92 institution reported higher levels of anxiety. At Block 2, academic stressors contributed significantly to the model predicting anxiety. Combined, the academic stressors accounted for approximately 29% of the variance in anxiety scores. Higher levels of assessment stress and expectations stress were associated with higher levels of anxiety. Although Block 3 accounted for approximately 2% of the variance, none of the social identification variables reached significance. At Block 4, social isolation contributed significantly to the model. Block 4 accounted for approximately 9% of the variance in anxiety scores. Feeling isolated was strongly associated with higher levels of anxiety. At Block 5, COVID-19 related variables contributed significantly to the model. Together, the three COVID-19 variables accounted for approximately 7% of the variance in anxiety scores. While there was no effect of having contracted COVID-19, intolerance of uncertainty was associated with higher levels of anxiety, and students who disliked online teaching and learning reported higher levels of anxiety.

In sum, the R^2 change for Block 2 underscores the importance of academic stressors as predictors of anxiety. As Block 2 has the largest R^2 change, this suggests it is the most crucial in predicting anxiety scores. The additional variance explained by Block 4 highlights the significance of social isolation. While Block 5 added less unique variance compared to Block 2 and Block 4, it still played a role in predicting anxiety. Thus, academic stress, academic expectations, social isolation, intolerance of uncertainty, and more negative attitudes toward online teaching were all significant predictors of anxiety when controlling for all academic and non-academic stressors (see Table 3).

4 Discussion

The current study aimed to investigate the mental health of university students during the COVID-19 pandemic and identify academic and non-academic predictors of common mental health

TABLE 2 Regression analysis showing the academic and non-academic predictors for depression.

Variable	Cumulative		Simultaneous	
	R ² change	F-change	β	p
Block 1				
Age	0.04	$F(4, 3,154)=34.47^*$	−0.03	0.024
Sex			0.01	0.519
Ethnicity			0.01	0.428
HEI			0.11	<0.001
Block 2				
Academic stress	0.24	$F(2, 3,152)=512.60^*$	0.22	<0.001
Academic expectations			0.06	<0.001
Block 3				
University friends identity	0.05	$F(3, 3,149)=69.34^*$	0.00	0.993
University identification			−0.07	<0.001
Multiple group membership			0.00	0.966
Block 4				
Social isolation	0.11	$F(1, 3,148)=620.62^*$	0.35	<0.001
Block 5				
Intolerance of uncertainty	0.03	$F(3, 3,145)=58.30^*$	0.17	<0.001
Diagnosis of COVID-19			−0.04	0.007
Online teaching			−0.11	<0.001

* $p<0.001$.

difficulties. Further, we aimed to determine if factors unique to the COVID-19 pandemic (e.g., attitudes toward online teaching and COVID-19 diagnosis) predicted symptoms over and above social connectivity variables. In line with previous research [e.g., (2, 15)], there were high levels of depression and anxiety during the COVID-19 pandemic, with more than 50% experiencing levels above the clinical cut offs. In fact, nearly a third of students scored above the cut off for severe anxiety (32%), while just over a third of students scored above the cut off for moderately severe depression (36.6%). These levels of depression and anxiety are higher than those reported in our previous research using data collected via an online survey in October 2016, as we found that 20.9% met criteria for severe anxiety and 11.3% met criteria for severe depression [see (6)]. Also, according to the Adult Psychiatric Morbidity Survey in 2014, one in six people report experiencing a common mental health problem (anxiety or depression) in a given week in England (30). Thus, the incidence of common mental health problems was much higher in this student sample during the early stages of the pandemic.

Consistent with previous work [e.g., (6)], academic stress and expectations stress were associated with higher levels of depression

TABLE 3 Regression analysis showing the academic and non-academic predictors for anxiety.

Variable	Cumulative		Simultaneous	
	R ² change	F-change	β	p
Block 1				
Age	0.03	<i>F</i> (4, 3,154) = 28.17*	0.00	0.833
Sex			0.02	0.184
Ethnicity			−0.02	0.120
HEI			0.06	<0.001
Block 2				
Academic stress	0.29	<i>F</i> (2, 3,152) = 659.29*	0.23	<0.001
Academic expectations			0.09	<0.001
Block 3				
University friends identity	0.02	<i>F</i> (3, 3,149) = 24.44*	0.02	0.125
University identification			−0.01	0.619
Multiple group membership			0.01	0.418
Block 4				
Social isolation	0.09	<i>F</i> (1, 3,148) = 469.95*	0.26	<0.001
Block 5				
Intolerance of uncertainty	0.07	<i>F</i> (3, 3,145) = 139.68*	0.31	<0.001
Diagnosis of COVID-19			−0.00	0.867
Online teaching			−0.10	<0.001

**p* < 0.001.

and anxiety. Of the academic variables, academic stress was most predictive of mental distress. Our findings are consistent with previous research by Plut and colleagues who applied the JD-R model to students, finding that academic stressors contributed to low well-being and performance (7).

Although university identification was associated with lower levels of depression, identification with university friends and multiple group memberships were not associated with lower levels of depression or anxiety. These findings contrast to previous research which suggested that identification with university friends confers protection against psychological distress (6). It is possible that some students found it challenging to identify or relate to their university friends during the pandemic due to physical separation, lack of in-person interaction, and limited shared experiences, such as extracurricular activities, attending lectures and/or seminars, or socializing on campus.

Consistent with previous research [e.g., (6, 31, 32)], feelings of isolation consistently emerged as a strong predictor of poor mental health. In fact, as isolation was identified as the strongest predictor of depressive symptoms in our student sample, this aligns with the findings reported by Liu et al. (32) as social isolation had the largest

effect on Australian students' psychological wellbeing. Although social isolation was the strongest overall predictor of depression, intolerance of uncertainty was the strongest overall predictor of anxiety. Students who were intolerant of uncertainty may have found it particularly difficult to cope with the unpredictable nature of the COVID-19 pandemic, leading to heightened anxiety and depression.

Receiving a COVID-19 diagnosis was associated with higher levels of depression. Dealing with the uncertainty about recovery and the potential for experiencing on-going symptoms can be challenging and contribute to feelings of hopelessness and despair. The pivot to remote teaching and learning contributed to higher levels of common mental distress as those who disliked online teaching and learning reported higher levels of depression and anxiety. Indeed, remote learning disrupted established routines that provide stability and support for students and presented various challenges such as increased pressures to study and learn independently combined with reduced motivation levels (9). Thus, alongside the loss of usual routines of attending lectures on campus, the lack of in-person interaction with lecturers and peers may have hindered academic engagement, contributing to feelings of distress.

Our findings are consistent with the JD-R model as we found that students are subjected to a range of academic and non-academic demands that contribute to common mental health difficulties. Nevertheless, HEIs also provide resources such as opportunities to form a sense of identification with the university. Our findings suggest that enabling students to form a sense of identification their institution represents a psychological resource that improves symptoms of depression. As social isolation consistently emerged as a contributor to poor mental health, our findings suggest that fostering connections and a sense of identification within the university is important to buffer students against symptoms of common mental distress. Simply returning to campus is only a partial solution. Instead, university policy promoting connectedness is required. Wider social determinant interventions may be important in this context (33). For example, Groups 4 Education (G4E) is an evidence-based psychological intervention that directly targets mental distress that results from loneliness and social isolation (34). The implementation of such interventions in a university context would be likely to improve social wellbeing by providing students with the knowledge, skills, and confidence to increase their social connectedness. In addition to this, as remote teaching and learning contributed to higher levels of common mental distress, in any future pandemic and associated lockdowns, it would be beneficial for HEIs to cater for socially distanced in-person teaching and learning as soon as it is safe to do so. However, small changes to curricula should be implemented to increase university identification and identification with the course itself, such as embedding belonging-focussed learning activities throughout curricula and implementing more group-based projects (35). Thus, by identifying specific predictors of mental health difficulties, the study provides actionable insights related to curriculum design and student belonging interventions for universities and policymakers.

Our findings should be considered in light of several limitations. As the sample comprised students attending two universities in the North of England, generalisability is limited. Our participants may represent a specific subset of the population as they were all self-selected volunteers. The high proportion of females also suggests our sample may not be representative of the entire student population. It is also important to note that the second national lockdown in England was announced (on 31st October 2020) and implemented (on 5th November 2020) while

data collection was ongoing, which may have impacted levels of distress. In addition, the proposed causal relationships should be interpreted with caution given the cross-sectional nature of the data. Last, our findings should be treated with caution due to the inclusion of abbreviated measures and single items. For example, the use of a single item for diagnosis of COVID-19 only covers the potential impact of a medical diagnosis on psychological health outcomes, rather than covering the potential influence of the fear of contagion and also the continuum of severity. Nevertheless, examining a wide range of academic and non-academic predictors meant striking a balance between including multiple predictors and examining those predictors in detail. Future research could adopt the COVID-19 Student Stress Questionnaire (developed and validated after the launch of our student survey in 2020) as this tool covers specific sources of stress featuring university students' experiences during the pandemic, with three subscales including Relationship and Academic Life, Isolation, and Fear of Contagion (36).

To summarize, the study found high levels of self-reported symptoms of depression and anxiety among university students during the early stages of the COVID-19 pandemic. The study also comprehensively examined both academic and non-academic predictors as well as novel predictors of distress related to the COVID-19 pandemic, providing a holistic understanding of the various influences on students' mental health. Although feelings of isolation consistently emerged as a strong predictor of poor mental health, our findings show that social-psychological pandemic-related factors other than social isolation may affect mental health, such as intolerance of uncertainty and attitudes toward online teaching. These findings therefore provide insights that could help universities and policymakers develop targeted interventions to support the mental health and well-being of university students during future crises. Following the disruption to teaching, learning and university life, together with other stressors placed on young people from the COVID-19 pandemic, there is an urgent need to support this vulnerable population both socially and academically.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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Ethics statement

The studies involving humans were approved by Institute of Population Health Sciences (IPHS) Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JW: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. AD: Formal analysis, Writing – original draft. JM: Writing – review & editing. RC: Conceptualization, Supervision, Writing – review & editing.

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Assessment of the relationship between living alone and suicidal behaviors based on prospective studies: a systematic review and meta-analysis

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Suicide, a global health concern, can be influenced by living arrangements. Hence, the objective of this systematic review was to assess the extent of the association between living alone and suicidal behaviors. We conducted a comprehensive search across eight databases for prospective studies. Hazard ratios (HR) and 95% confidence intervals were pooled using Stata software. Nine large-scale prospective studies with 3,663,205 participants proved eligible. The results of the meta-analysis showed that the pooled prevalence of living alone was 32%. Living alone was associated with suicide attempts and suicide death even after adjusting for all potential confounding factors (AHR = 1.45, 95% CI: 1.13–1.77; AHR = 1.27, 95% CI: 1.06–1.48). Compared to people who live with others, living alone increases the risk of suicide behaviors. Given the anticipated global rise in suicide rates and the growing prevalence of living alone, it is recommended to explore this issue on a broader scale.

Systematic review registration: PROSPERO, identifier: CRD42023464684, https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42023464684.

KEYWORDS

living alone, suicide behaviors, prospective studies, systematic review, meta-analysis

Introduction

Living alone represents a prevalent global social and psychological concern in contemporary society, constituting a significant element within the realm of negative social indicators. Over the past few decades, the prevalence of living alone has consistent global rise, this trend of living alone is particularly pronounced in developed nations. For instance, in European countries like Norway and Sweden, single-person households now constitute nearly half of all households (1). Between 1940 and 2020, there was a remarkable shift in the United States, with the overall proportion of individuals living alone surging from 7.7 to 27.6% (2). Furthermore, as per data from the 2021 China Statistical Yearbook, the year 2020 saw “one-person households” surpassing 125 million, accounting for more than a quarter of the total number of households (3).

Existing research indicate that there has been a growing interest in exploring the connection between living alone and individual health outcomes. Individuals who live alone are at an elevated risk of experiencing social isolation and loneliness, which can significantly

undermine their psychological well-being, ultimately increasing the risk of premature mortality by roughly 30% (4).

Suicide is also a global health challenge, with over 800,000 people dying by suicide annually worldwide (5). In some countries, one in nine young individuals report having engaged in suicidal behaviors (6). Despite five decades of research, there has been limited progress in enhancing the prediction of suicidal behaviors. This underscores the urgent need for more targeted investigations into identifying specific risk factors associated with suicidal behavior (7). According to the interpersonal theory of suicide, individuals who live alone may experience failed belongingness due to unmet interpersonal needs and a lack of social connections, leading to psychological distress that heightens suicide risk (8). An increasing number of studies have noted that suicide risk varies with living arrangements, changes in family structure may contribute to the increase in suicide rates, and living alone may be an important objective risk factor for suicidal behaviors (9–12). A Danish follow-up study showed that living alone was a risk factor for subsequent suicide in men and women whose partners die (13). In addition, studies in Finland (14), the United Kingdom (15), and the Netherlands (16) have consistently reported that living alone is an independent risk factor for suicide.

While research has demonstrated that men are three times more likely to die by suicide than women, the specific nature of the relationship between gender, living alone, and suicidal behaviors remains unclear (17). Moreover, variations in social and cultural environments may influence living habits among individuals who live alone, potentially affecting the development of suicidal thoughts or behaviors (18). Research has shown that older adults individuals living alone who suffer from physical or mental illness are at a higher risk of suicide, particularly in the absence of social support and effective treatment (19, 20). Additionally, major negative life events, such as unemployment or financial difficulties, may serve as triggers for suicide among those living alone. A prospective study, a type of longitudinal research design, follows a cohort of similar individuals who differ in only one research factor over time, allowing researchers to examine the impact of that factor on outcomes such as death or disease progression. A longer follow-up period increases the number of observed outcome events, reveals long-term effects, and enables better control of bias and confounding variables, thereby enhancing the study's accuracy and reliability.

Current aims

This systematic review aimed to synthesize evidence on the relationship between living alone and suicidal behavior, and to quantify the strength of this association. The specific objectives of the review were to:

- i Identify the prevalence of living alone based on prospective studies;
- ii Determine the extent of the association between living alone and suicidal behaviors based on prospective studies;
- iii Determine whether the relationship between living alone and suicidal behaviors varies with sociodemographic factors, follow-up years, or geographic location.

Methods

The design and write of this review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (21, 22). Additionally, the PROSPERO number is CRD42023464684.

Search strategy

Major English and Chinese databases were systematically searched between January 1, 2000, and September 15, 2023, which include PubMed, Embase, Web of Science, Scopus, ProQuest, PsycINFO, CNKI, and WANFANG database. The search methodology used Boolean operators, combining 'and' with two core search terms: firstly, a set comprising 'living alone', 'live alone', 'lives alone', and 'unaccompanied' as alternatives; secondly, utilizing the wildcard 'suicid*' to capture a broad range of suicide-related concepts. A detailed retrieval strategy is provided in [Supplementary material S1](#). The search was confined to prospective cohort studies published in either English or Chinese. To ensure the thoroughness of our literature search, we manually examined the reference lists of relevant systematic reviews or meta-analyses and also conducted an independent search on Google Scholar.

Eligibility criteria

The inclusion criteria were as follows: (1) Population: individuals aged sixteen years and older, who do not live with others; (2) Exposure: living alone as a predictor of suicidal behaviors; (3) Outcome: reported measure of suicidal behaviors, include suicide attempt and suicide death; (4) Study design: prospective cohort studies.

The exclusion criteria were as follows: (1) Studies in languages other than English or Chinese; (2) Studies with were cross-sectional, case-control, qualitative, expert opinions, reviews, conference abstracts or those lacking available full texts, as well as duplicate studies; (3) Studies that offered incomplete data that could not be analyzed.

Data extraction

Following the removal of duplicates via Endnote 20, we conducted a literature screening in Rayyan, a web application (23). The first and second authors independently assessed the eligibility articles based on the titles and abstracts. Subsequently, full text of the remaining studies will be scrutinized against all inclusion criteria, which required studies to provide information regarding the association between living alone and suicidal behaviors. To guarantee the reliability of the screening process, we mandate that the two authors must achieve an agreement rate of at least 95% during any evaluation stage. In instances where uncertainty arises, we immediately engage a third reviewer for discussion. If, after thorough deliberation, a consensus is still not reached, we escalate the matter to the corresponding author for a definitive resolution. This process ensures that every decision made throughout the evaluation is rigorous and well-founded. To ensure the accuracy and consistency of our data, we have adopted the following methods: Firstly, we clarify the extraction standards and rules prior to data extraction, ensuring a

unified understanding among the two reviewers regarding the content to be extracted. Secondly, both reviewers independently extract data from the same segment, and their results are subsequently compared for consistency. Any discrepancies identified are discussed and resolved to reach a consensus. Lastly, we regularly arrange for a review session, where a third reviewer or expert verifies the extracted results. Finally, the following information was extracted independently by two reviewers: study characteristics (author, year of publication, country, cohort designation, follow-up duration); participant characteristics (age, sample size and sample type); outcome characteristics (the prevalence of living alone, the measure, forms and prevalence of suicidal behaviors). Furthermore, effect measures pertaining to the associations between living alone and suicidal behaviors were also be extracted. In cases of missing or unclear data, we initiated correspondence with the researchers, seeking further elaboration on both the methods and/or the results as dictated by the need for accuracy and completeness.

Risk of bias assessment

Two independent reviewers assessed the methodological quality of the included studies, and any discrepancies resolved through consensus. The methodological risk of bias the included prospective studies was evaluated using the Newcastle-Ottawa Quality Assessment Scale (NOS) (24), which assigns scores ranging from 0 to 9 points, with scores of ≥ 7 points classified as indicative of high quality (25, 26). Meanwhile, we used Egger's tests to identify publication bias.

Statistical analysis

STATA software (version 17.0) was used for all statistical analyses, and a qualitative synthesis was conducted to summarize the characteristics of the included articles. If two or more adjusted effect size were provided in the same article, we would choose the most comprehensive adjusted effect size for pooling. Subgroup analyses were performed considering gender, continent, sample type and follow-up lengths. All ratios used in the subgroup analysis were adjusted for potentially confounding factors. The Cochrane Q test and I^2 statistic were the two most often used indicator of heterogeneity. The model selected (fixed or random-effect) would depend on the magnitude of heterogeneity: A value of 0–25% indicates low heterogeneity and 26–50% indicates moderate heterogeneity, a fixed effects model was chosen; 51–100% indicates substantial heterogeneity, a random effects model was adopted (27, 28). Furthermore, the stability of the results was tested by leave-one-out sensitivity analyses, and a significance level of $p < 0.05$ (2-tailed) was taken as robustness after removing any observation.

Results

Search results

Figure 1 depicts the process of literature screening and selection using a PRISMA flow chart. Removal of the duplications left 983

records. After screening the title and abstract, 140 articles in the full-text evaluation stage, of which 9 studies were included in qualitative synthesis and meta-analyses.

Studies characteristics

Table 1 provides an overview of the nine included studies. These studies were all prospective and were published between 2011 and 2021. The majority of them were conducted in European countries, with one study each from Canada (29) and Japan (18). The follow-up duration for these studies ranged from a minimum of 5 years to a maximum of 23 years, with an average duration of 11.2 years. The sample sizes varied considerably, ranging from 12,850 to 2,685,400 individuals, totaling 3,663,205 participants. Notably, except for one study that did not report specific gender counts (29), female participants outnumbered male participants in the remaining studies. In terms of the study populations, four studies focused on individuals diagnosed with various common mental disorders (14, 30–32), while another four investigated samples from the general population (15, 18, 29, 33). Only one study had a sample comprising stroke patients (34). Regarding living arrangements, the proportion of individuals living alone varied significantly, ranging from 4.51 to 55.55%. Data on suicidal behaviors were sourced from database registries or medical records in all the included studies, with suicide death consistently identified as the primary outcome measure. Additionally, three of the studies also simultaneously examined suicide attempts (31, 32, 34). The prevalence of suicide death in these studies ranged from 0.05 to 4.55%, while the prevalence of suicide attempt ranged from 0.45 to 5.8%.

Assessment quality of studies

The quality of included studies was assessed by the Newcastle Ottawa scale (NOS) for cohort studies. All the studies included in our analysis received quality assessment scores exceeding 7 points, classifying them as high-quality literature. However, four of these articles did not receive scores regarding the representativeness of their included samples due to their focus on specific disease populations (Supplementary Table S1).

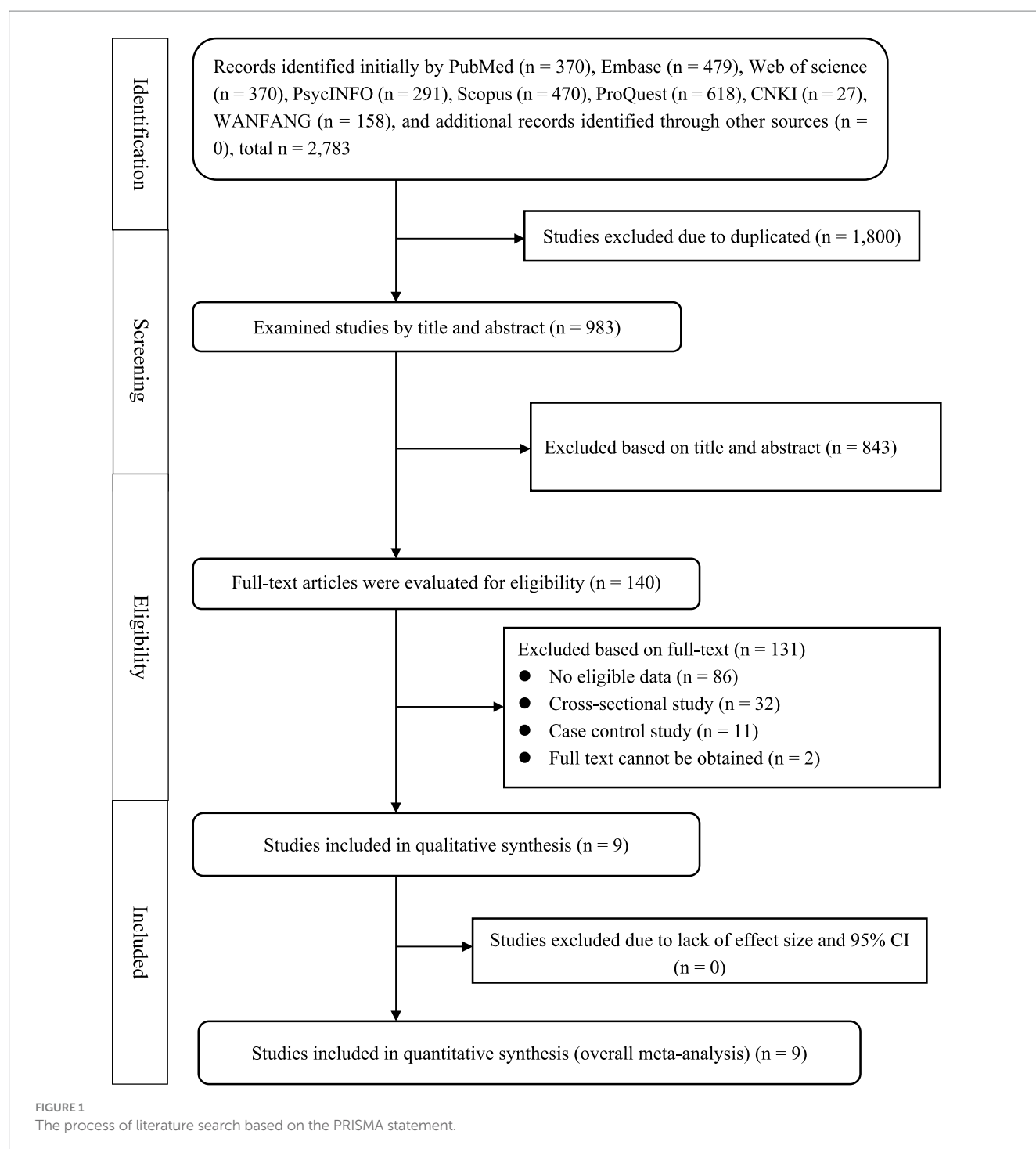
Results of meta-analysis

The prevalence of living alone

All included studies provided the proportion of people living alone. The results of the meta-analysis showed that the pooled prevalence of living alone was 32% (95% CI: 19–44%, $I^2 = 100\%$) (Table 2 and Supplementary Figure S1).

The association between living alone and suicidal behaviors

Table 2 presents the combined crude and adjusted Hazard Ratio (HR) estimates for the relationship between living alone and both suicide attempt and suicide death. This meta-analysis includes data



from three studies, involving a total of 288,177 participants (31, 32, 34). The results reveal that, even after adjusting for all potential confounding factors, individuals who live alone exhibit a substantially higher risk of suicide attempt compared to those who do not live alone, the pooled adjusted HR (AHR) is 1.45 (95% CI: 1.13–1.77, $P=77.31\%$). Additionally, eight studies, involving a combined sample of 3,442,869 participants, investigated the association between living alone and suicide death (14, 15, 18, 29–33). Table 2 illustrates these findings, living alone is linked to the subsequent suicide death, with an AHR of 1.27 (95% CI: 1.06–1.48, $P=59.48\%$) (Supplementary Figure S2).

Subgroup analyses of the extent of the relationship between living alone and suicide death

Subgroup analyses were performed to assessment suicide death, considering factors such as gender (Female/Male), continent (Europe/America/Asia), sample type (The general population/Patients with psychiatric problems), and follow-up durations (≤ 10 / >10 years). The consistent findings reveal that males who live alone face a significantly elevated risk of suicide death in comparison to those who do not, with an AHR of 1.26 (95% CI: 1.15–1.37, $P=59.56\%$). Significant difference was observed between females and males ($p=0.02$). Furthermore, the study results did not exhibit significant variability across continents,

TABLE 1 Characteristics of included studies.

Authors, year	Country	Design	Follow-up duration	Cohort designation	Sample (% Male)	Age/ range Mean (SD)	Sample type	Living alone (%)	Suicide evaluation		
									Measure	Forms	Prevalence (%)
Aaltonen et al. (14)	Finland	Prospective study	24 years	Finnish population-based cohort	56,826 (44.32)	≥18	Patients with depressive disorder	29.40	Register data	SD	4.55
			1991–2014								
Burrows et al. (18)	Canada	Prospective study	10.6 years	Canadian census mortality follow-up study cohort	2,685,400	≥25	The general population	11.25	Census	SD	1.50
			1991–2001								
Eriksson et al. (34)	Sweden	Prospective study	12 years	The Swedish stroke register	220,336 (51.26)	≥18	Patients with stroke	47.49	Register data	SA	0.45
			2001–2012							SD	0.12
Hansson et al. (30)	Sweden	Prospective study	10 years	Swedish national quality register for bipolar affective disorder	12,850 (37.70)	47.8 ± 16.0	Patients with bipolar disorder	55.55	Register data	SD	0.70
			2004–2014								
Poudel-Tandukar et al. (18)	Japan	Prospective cohort study	13.2 years	The Japan public health center	104,528 (47.48)	40–69	The general population	4.51	Register data	SD	Male: 0.58
			1990–2005								Female: 0.21
Rahman et al. (31)	Sweden	Prospective cohort study	5 years	Nationwide register data	46,745 (33.68)	18–64	Patients with common mental disorders	41.90	Register data	SA	2.20
			2006–2010							SD	0.40
Schneider et al. (33)	Germany	Prospective cohort study	12 years	MONICA/KORA Augsburg surveys	12,888 (50.10)	25–74	The general population	21.31	Medical records	SD	0.30
Shaw et al. (15)	UK	Prospective cohort study	9 years	UK Biobank cohort	502,536 (46.50)	37–73	The general adult population	18.49	Register data	SD	0.05
			2006–2018								
Wang et al. (32)	Sweden	Prospective cohort study	5 years	Population-based prospective cohort	21,096 (40.05)	16–64	Patients with depressive disorders	53.40	Register data	SA	5.80
			2006–2010							SD	0.70

SD, Suicide death; SA, Suicide attempt; BDI, Beck Depression Inventory.

TABLE 2 Meta-analytic findings on the extent of the association between living alone and suicidal behaviors.

Estimate	K	N	Effect size	Pooled	95%CI	Q_{within}	$I^2(\%)$	Tau	Tau ²
Living alone	9	3,663,205	Prevalence	0.32	0.19–0.44	189882.63	100	0.2	0.04
Suicide attempt	3	288,177	Crude HR	1.58	1.18–1.98	8.20	82.66	0.30	0.09
	3	288,177	Adjusted HR	1.45	1.13–1.77	10.51	77.31	0.24	0.06
Suicide death	5	596,115	Crude HR	2.07	1.22–2.91	29.45	79.00	0.89	0.80
	8	3,442,869	Adjusted HR	1.27	1.06–1.48	22.15	59.48	0.22	0.05

K = Number of studies; N = Number of respondents; AHR: Adjusted Hazard Ratio; 95% CI = 95% Confidence Interval.

TABLE 3 Subgroup analysis of the magnitude of the association between living alone and suicide death.

Subgroup	K	N	AHR	95% <i>CI</i>	<i>Q</i> _{within}	<i>I</i> ² (%)	<i>P</i> for difference
Gender							
Female	5	367,948	1.07	0.93–1.20	1.57	0	0.02
Male	5	308,792	1.26	1.15–1.37	9.89	59.56	
Continent							
Europe	6	652,941	1.40	1.01–1.80	13.80	66.04	0.80
America	1	2,685,400	1.23	0.88–1.58	–	–	
Asia	1	104,528	1.21	0.24–2.19	–	–	
Sample type							
The general population	4	3,305,352	1.33	1.05–1.61	11.26	47.14	0.71
Patients with psychiatric problems	4	137,517	1.23	0.80–1.67	6.98	64.30	
Length of follow-up (year)							
≤10	4	583,227	1.49	0.95–2.02	10.83	61.10	0.32
>10	4	2,859,642	1.20	1.01–1.39	10.43	51.20	

K = Number of studies; N = Number of respondents; AHR: Adjusted Hazard Ratio; 95% CI = 95% Confidence Interval. Bold values mean that the *P* value is < 0.05.

sample types, and follow-up durations. Nonetheless, it's noteworthy that individuals living alone in Europe exhibit a higher likelihood of suicide compared to those not living alone (AHR = 1.40, 95% CI: 1.01–1.80, I^2 = 66.04%). In the general population, living alone was similarly associated with an increased risk of suicide compared to those not living alone (AHR = 1.33, 95% CI: 1.05–1.61, I^2 = 47.14%). Furthermore, studies with follow-up periods exceeding 10 years indicated that individuals living alone are more likely to die by suicide than those not living alone (AHR = 1.20, 95% CI: 1.01–1.39, I^2 = 51.20%). For further details, please refer to Table 3 and Supplementary Figures S3–S6.

Sensitivity analyses and publication bias

The results of the sensitivity analysis indicated that the estimated prevalence of living alone remained within the 95% confidence interval of the overall combined prevalence, regardless of the exclusion of any individual study. Furthermore, the sensitivity analysis revealed that the prevalence of living alone, upon the exclusion of each study, ranged from 0.28 (95% CI: 0.16–0.41) to 0.35 (95% CI: 0.23–0.47), with all *p*-values being 0.00 (Supplementary Figure S7). Similarly, after excluding each study, the hazard ratio between living alone and suicide death ranged from 1.21 (95% CI: 1.03–1.38) to 1.33 (95% CI: 1.05–1.61), and all *p*-values

were 0.00 (Supplementary Figure S8). The results of Egger's publication bias test for both the prevalence of living alone and the adjusted hazard ratio between living alone and suicide death were p = 0.053 and p = 0.177, respectively. Consequently, there was no clear evidence of publication bias (Supplementary Figures S9, S10).

Discussion

Our study constitutes a systematic review of nine large-scale prospective studies conducted worldwide. The primary purpose was to examine whether living alone can predict subsequent suicidal behavior and to determine the strength of this association. This review emphasizes that, as the duration of living alone increases, individuals who live alone are more likely to engage in suicidal behavior compared to those who do not. Additionally, our meta-analysis reveals how factors such as gender, continent, sample type, and follow-up duration influence the extent of the association between living alone and suicide death.

The global prevalence of living alone

A meta-analysis of nine large-scale prospective studies found that the prevalence of living alone was 32% (95% CI: 19–44%, I^2 = 100%, p < 0.001),

which is similar to previous findings, especially in the middle-aged and older adults population (35, 36). With declining birth rates and an aging global population, social arrangements have undergone significant changes. Many older adults individuals choose to live alone following the death of a spouse, particularly those without children or whose children live far away, leading to a marked increase in single-person households (37, 38). In some European countries, traditional family structures are shifting, with nuclear and single-person households becoming more common, while intergenerational cohabitation has become relatively rare. This cultural shift reflects society's growing acceptance of independent and autonomous living (39, 40). Furthermore, values that emphasize individualism and self-fulfillment have heightened the demand for independent living, as people increasingly prefer to maintain a self-directed lifestyle. Economic improvements, particularly in developed countries, along with extensive social welfare systems, have fostered economic independence, contributing to a preference for living alone (41–43). Overall, social changes, growing economic independence, shifting cultural values, and other factors have all contributed to the increasing prevalence of living alone in modern society.

Although this study confirmed the prevalence of living alone, the high heterogeneity and narrow confidence intervals revealed by the I^2 statistic have affected the credibility of our meta-analysis results. This significant heterogeneity may be attributed to the large sample sizes included in the analysis, which encompass a broad range of populations and span various age and gender distributions. Additionally, the diversity in living arrangements and sociocultural customs across different regions may also contribute to the observed heterogeneity. Given the presence of high heterogeneity, we employed a random effects model in our meta-analysis to better manage and account for the variability between studies, thereby enhancing the robustness and applicability of the analysis results.

Living alone had long-lasting effects on suicidal behaviors

Previous studies have found that living alone increases the risk of suicidal behaviors, however, given the limitation that these analyses were based on cross-sectional studies, we will examine for the first time the relationship between living alone and the risk of suicidal behaviors in the context of longitudinal study data. The findings from this study suggest that, over time, living alone increases the risk of suicide attempts and suicide death by 45 and 27%, respectively. The association remained statistically significant even after controlling for a comprehensive set of covariates to the greatest extent possible, indicating that living alone maintains its independent influence.

The Interpersonal Theory of Suicide, developed by psychologist Thomas Joiner, provides a framework for understanding how living alone contributes to suicidal behavior (44). This theory emphasizes that suicidal thoughts arise from two interrelated but distinct factors: unmet belongingness and the perception of being a burden to others or society. It outlines the progression from 'experiencing dangerous events' to 'developing suicidal thoughts' and ultimately to 'engaging in suicidal behavior' (45). While individuals living alone may enjoy greater freedom and personal space, they are also at risk of experiencing loneliness, a key predictor of suicidal ideation. Prolonged loneliness can lead to a lack of belonging and feelings of hopelessness

(46, 47). Additionally, those living alone may avoid social activities due to factors such as social anxiety or poor social skills, resulting in social isolation. This isolation not only exacerbates loneliness but also weakens social support networks, making it harder for individuals to seek help in times of need (48, 49). Furthermore, living alone may facilitate the means and opportunity for engaging in suicidal behavior.

However, there was significant heterogeneity in the association between living alone and suicide mortality. To address this, we conducted subgroup analyses to explore the sources of heterogeneity and discussed in detail the impact of potential confounders on the study results.

Subgroup analysis revealed that men living alone are more likely to die by suicide than women, consistent with previous research findings (50, 51). One valuable and important finding was that gender difference was statistically significant for the relationship between living alone and death by suicide. This disparity may be attributed to differences in social support, help-seeking behaviors, choice of suicide methods, and the impact of health and economic factors. Some studies have indicated the divergent preferences for suicide methods between men and women (52), men are more likely to choose highly lethal methods, such as jumping or hanging, while women are more inclined to use less fatal methods, such as drowning or medication overdose (14). Additionally, men living alone, especially older men, are more prone to undiagnosed or untreated physical and mental health issues, such as depression and alcohol dependence (53, 54), both of which are strongly associated with suicide risk.

Another subgroup analysis was related to geographic location. The majority of the included studies were from Europe, with only one study each from America and Asia. Therefore, caution is advised when interpreting the association between living alone and suicide mortality across different regions. Individuals living alone in Europe face a higher risk of suicide compared to those in America and Asia. This disparity may be attributed to a combination of sociocultural factors, including social isolation caused by individualistic culture, limited family support, the hidden of mental health issues, and reduced participation in social activities, particularly among older adults (55, 56). Many European countries are facing significant challenges related to population aging (57). As life expectancy increases, more and more older adults people choose to live alone or have to live alone. These older adults people often face problems such as widowhood, deteriorating physical health, and loss of social roles, which are recognized risk factors for suicide. In some European countries, suicide is historically or culturally viewed as a personal choice, and societal attitudes toward suicidal behavior are relatively tolerant (58). Similarly, in the Americas, many people who live alone place a high value on individualism and free will, which can influence their perspectives on suicide (59, 60). In some cases, suicide might be viewed as the ultimate expression of control over one's own destiny. While this is not a mainstream belief, it reflects the cultural emphasis on personal freedom and autonomy. In Asia, particularly in Japanese culture, suicidal behavior is sometimes given a special meaning, especially under the influence of the "Bushido" spirit (61). This cultural concept may make it easier for some people to choose suicide as a solution when faced with difficulties or despair. Although modern society broadly promotes suicide prevention, this cultural legacy may subconsciously influence societal attitudes toward suicide, potentially resulting in inadequate prevention efforts or delayed social interventions.

Our subgroup results showed a puzzling finding that the association between living alone and suicide death was significant in

the general population but not in those with psychiatric problems. This may be due to living alone has a stronger independent effect on suicide risk in the absence of other significant risk factors, whereas among people with mental problems, mental illness itself is the main driver of suicide risk. Therefore, the effect of living alone on suicide risk in these populations may be less prominent than the effect of mental illness. In other words, the presence of mental illness masks the effect of living alone. In the general population, living alone may be seen as a sign of isolation and helplessness, and psychological crises are not easily discovered by the outside world, increasing the risk of suicide. However, people with mental problems are usually considered a high-risk group, so society and family members may be more likely to be alert and intervene.

The results showed that variations in the length of follow-up did not exert a significant impact on the risk of suicide death among individuals living alone. The impact of follow-up time on suicidal behavior among individuals living alone may be obscured or weakened by various factors, including the individual's living conditions, the effectiveness of intervention measures, and the methods of data collection and analysis. It's crucial to emphasize that prolonged living alone does not necessarily lead to suicidal behaviors, and many individuals effectively manage the challenges associated with living alone while maintaining positive mental health (36).

Strengths and limitations

In this study, we conducted a meta-analysis to assess the extent of the relationship between living alone and suicidal behaviors, aiming to draw a powerful conclusion. This meta-analysis providing comprehensive insights into the impact of living alone on the risk of suicidal behaviors. The study's strengths include the following aspects: (1) We carried out a comprehensive search across eight major databases and included nine large-scale prospective studies, involving a cumulative total of 3,663,205 participants. The large population size enhances the generalizability of our findings; (2) All data included in the meta-analysis were sourced from database registries or medical records, enhancing the credibility of the study's findings; (3) We conducted a range of subgroup analyses to identify potential sources of heterogeneity, and the pooled the crude and adjusted effect sizes separately, minimizing the probability of bias.

This study has some limitations. First, there is heterogeneity across cohort designs, such as sample size, duration of follow-up, etc., and the possibility of confounding by other unmeasured factors cannot be ruled out, so the interpretation and generalizability of the results will be limited. Secondly, lack of evidence to explore other subgroup effects that may be of interest, and considerable clinical heterogeneity in some subgroup analyses. For example, age and income should be considered as important factors affecting suicidal behaviors. However, subgroup analyses were not conducted due to inadequate original data. This might conceal some valuable information that affects the association between living alone and suicidal behavior. Furthermore, apart from considering the crude effect size, we chose to focus exclusively on the fully adjusted effect sizes for pooling, which may appear to overlook a substantial amount of information. Finally, the analysis was based on the dichotomous

status of living alone or not, without discussion of the quality, commitment, or types of relationships people may be in, which may limit the generalizability of the findings.

Conclusion

This study founded that compared to people who live with others, living alone increases the risk of suicide behaviors. The subgroup analysis revealed that gender, continent, sample type, and follow-up years were potential sources of heterogeneity, indicating that further research should focus on these factors. Additionally, future studies should thoroughly investigate the impact of age, economic status, and sociocultural factors on suicidal behavior among individuals living alone. Given that both living alone and suicide are significant social and psychological issues, future studies need to reveal the relationship between living alone and suicide in detail from the perspective of mixed-methods.

Public health departments should develop targeted policies and plans to improve social welfare systems. These should include enhancing the social support networks for individuals living alone to reduce loneliness and social isolation, strengthening education and publicity on suicide prevention to raise public awareness of the suicide risks of people living alone, and providing easily accessible psychological counseling and support services to assist individuals living alone in managing emotional distress and crises.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary material](#), further inquiries can be directed to the corresponding author.

Author contributions

ZL: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Software. JW: Writing – original draft, Conceptualization, Investigation, Methodology. XC: Data curation, Investigation, Software, Methodology, Writing – original draft. DC: Methodology, Software, Visualization, Writing – review & editing. YZ: Conceptualization, Software, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2024.1444820/full#supplementary-material>

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Effects of loneliness on short video addiction among college students: the chain mediating role of social support and physical activity

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Loneliness is a common public health problem that affects physical and mental health. Prior research has demonstrated a connection between internet addiction and loneliness. Short video addiction is a novel internet addiction. It is necessary to study the potential psychological mechanisms between loneliness and short video addiction. This study investigated the associations between loneliness and short video addiction, as well as the mediating roles played by social support and physical activity.

Methods: A sample of 388 college students was selected, and the questionnaires included the Loneliness Scale Short Version, the Short Video Addiction Scale, the Social Support Scale, and the Physical Activity Scale. The data were analyzed using SPSS for correlation analysis and PROCESS macros for mediation effect analysis.

Results: (1) Loneliness significantly positively affected short video addiction. (2) The association between loneliness and short video addiction was independently mediated by social support. (3) Physical activity independently mediated loneliness and short video addiction. (4) Social support and physical activity play a chain mediating role in the association between loneliness and short video addiction. Our research improves the literature on loneliness and short video addiction, enhances comprehension of the impacts, and offers college students effective ways to combat the addiction.

KEYWORDS

college students, loneliness, short video addiction, social support, physical activity

1 Introduction

Since the birth of short videos, short video apps such as TikTok have proliferated worldwide. Short video apps have quickly become one of the most essential mobile apps for people's lives, entertainment, and socialization. China had 1.012 billion short video consumers in December 2022; among them, the proportion of teenagers who had viewed short videos was 65.6%, while the percentage of active users reached 20% (1). The youth group represented by college students represents one of the most common consumers of short videos. Moderate use of short video applications can make people's lives more exciting and convenient, whereas excessive and uncontrolled use can have serious adverse effects (2). Short video addiction involves the excessive use of short video apps and may be a type of internet addiction (3, 4). Researchers have shown that the college student population has higher-than-average levels of short video

addiction (5). Similar to internet-addictive behaviors, short video addictive behaviors can cause physical and emotional harm such as attention disorders, sleep disorders, and loneliness (6–8). Interestingly, mind stream experience and cognitive lock-in make consumers want to use short video apps even after experiencing negative consequences (9).

Although digital technology has created social media platforms like YouTube and TikTok, which have enriched the social life of college students, loneliness among college students is still severe (10). The incidence of loneliness in the college student population is as high as 60.2% (11). The increase in daily smartphone use among adolescents has made them feel lonelier and more anxious (12). Research has revealed a worrisome connection between loneliness and internet addiction (13). Loneliness and internet addiction levels are positively correlated in a moderate way (14). As loneliness increases, internet addiction increases (15). Short video addiction is a new internet addiction, and the relationship between loneliness and short video addiction is unclear. The aim of this study was to determine the effect of loneliness on short video addiction and analyze the mediating roles of social support and physical activity.

2 Literature review

2.1 Loneliness and short video addiction

Short video addiction refers to overindulgence in short video-mediated activities, which is uncontrollable and leads to significant physiological, psychological, and social impairments in individuals (16). Short video apps' tailored big-data recommendation methods create a closed-loop interaction between TikTok addiction and algorithmic optimization, worsening users' addiction (17). Loneliness is the discrepancy between a person's desired degree of social ties and the level of social relationships obtained (18). Loneliness is a common phenomenon in the adolescent population. As the internet and smartphones have continued to develop, more research has linked loneliness to internet and smartphone addiction (19, 20). People experiencing social phobia or loneliness may overuse smartphones and other online technologies (21). Loneliness leads to escapism to some extent, and escapism leads to TikTok addiction (22). Therefore, loneliness may also be an essential factor influencing short video addiction. Hypothesis H1: Loneliness can significantly and positively predict short video addiction.

2.2 The mediating role of social support

Social support refers to how interpersonal relationships may buffer a person from stressful situations (23). People often actively seek social networks to obtain social support to avoid loneliness and fulfill the need for social interaction (24). Research has shown that increased loneliness among college students of different birth cohorts is associated with decreased perceived social support (primarily objective social support) (25). According to an additional study, social support influences the associations among loneliness, anxiety, depression, and physical symptoms (26). With the increasing popularity of the internet and

smartphones in the college population, college students' access to social support has gradually been categorized into online and offline forms. Online social support may harm mental health, but offline support may help to mitigate this issue (27). Research shows that offline social support is adversely connected with internet addiction, while online social support is positively correlated with internet addiction (28). Smartphone addiction can be reduced by realistic social support (29). Recent research has also indicated that offline social support negatively predicts short video addiction (30). Hypothesis H2: Social support independently mediates the association between loneliness and short video addiction.

2.3 The mediating role of physical activity

Due to their academic requirements, college students often sit for long periods and generally lack physical activity (31). Research has shown that loneliness may reduce physical activity (32). A longitudinal study showed that loneliness predicted lower odds of physical activity for a period of up to 2 years, with a greater likelihood of shifting from physical activity to inactivity (33). Adolescent loneliness and physical exercise are negatively correlated (10). Research has shown that for sedentary students, the frequent use of social media is associated with a lower likelihood of vigorous daily exercise (34). Students who lacked physical activity had higher total scores and frequencies of internet addiction than did students who were regularly physically active (35). A previous study found that physical activity levels are directly and negatively correlated with internet-addictive behaviors (36). Hypothesis H3: Physical activity mediates the association between loneliness and short video addiction.

2.4 The chain mediating effect of social support and physical activity

Most studies favorably connect social support with teenage physical activity (37). Social support, including encouragement, role modeling, and logistical help, encourages teenagers' physical activity (38). Studies have demonstrated that students have good attitudes toward physical activity and rely primarily on social support to change their behavior (39). Social support and sociability can moderate or modulate the relationship between physical activity and loneliness (40). Loneliness also reduces social motivation to engage in physical activity (41). When peer ties are weaker, mobile phone addiction negatively impacts physical activity (42). Poor physical activity increases the degree of smartphone addiction risk (43). Adolescents who lack physical activity are more likely to be problematic internet users (44). According to the theory of compensating internet use, when a subject is experiencing hardship and suffering from psychological problems, they may shift the focus of their life to the smartphone to maintain self-esteem, escape pain, and dissipate stress (45). Lonely college students may have less social support and physical activity, so they spend much of their time using short video apps to relieve loneliness and obtain social support, which leads to addiction. Hypothesis 4: Social support and physical activity play a chain mediating role in the association between loneliness and short video addiction.

3 Materials and methods

3.1 Participants

The survey for this study was performed from June–July 2024. The study included 420 first-year to junior college students from a central Chinese university. This study used the online questionnaire platform Wenjuanxing. Several school teachers provided the university students with the website's QR code in order to fill out the questionnaire. Online informed consent was displayed on the questionnaire homepage, and the students could choose to give their consent before proceeding to the next step; if they did not consent, they could stop completing the questionnaire at any time. This online questionnaire was conducted anonymously, voluntarily, and confidentially. After eliminating invalid surveys, we collected valid data from 388 students. The participants' average age was 19.95 ($SD = 1.02$) years. The sample included 121 (31.2%) boys and 267 (68.8%) girls. There were 124 (32%) first-year students, 211 (54.4%) sophomores, and 53 (13.6%) juniors.

3.2 Measures

3.2.1 Loneliness scale (ULS-8)

The UCLA Loneliness Scale (ULS-8) was used in this study, developed by Hays and DiMatteo (46). A four-point Likert scale (1 = never, 4 = always) has 8 items. The scale has six positively ordered "lonely" items and two negatively ordered "nonlonely" items, with the positively stated items scored in reverse order. The scale is rated on a scale of 8–32, with higher scores indicating a greater degree of loneliness. Cronbach's alpha was 0.81 in this study.

3.2.2 Short video addiction scale

The College Student Short Video Addiction Scale by Qin (47) consists of 14 questions in 4 areas: withdrawal, loss of control, avoidance and ineffectiveness. We used a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Stronger total scores suggest a stronger potential to become addicted to short videos. Cronbach's alpha was 0.93 in this study.

3.2.3 Social support rating scale

The SSRS developed by Xiao was utilized in this study to assess perceived social support (48). The scale comprises 10 entries, encompassing three aspects: objective support (3 entries), subjective support (4 entries), and support utilization (3 entries). The total scores range from 12 to 66. Greater levels of support are indicated by higher scores. In this study, Cronbach's alpha was 0.78.

3.2.4 Physical activity rating scale (PARS-3)

Physical activity was tested via the PARS-3, revised by Liang (49). The scale examines physical activity in three ways: intensity, time, and frequency of participation in physical activity. Exercise amount = intensity $\times$ (time-1) $\times$ frequency. Each entry is scored from 1

to 5. The total score ranges from 0 to 100. The Cronbach's alpha was 0.70 in this study.

3.3 Data analysis

Descriptive and Spearman's correlation analyses were conducted via SPSS 26.0. For the mediation analysis, Hayes' PROCESS macro program in SPSS was used. We used Harman's one-way test to test for common method bias. The results revealed 14 factors with a characteristic root > 1 . The variation explained by the 1st factor was 18.57%, which was lower than the critical value of 40%. Therefore, there was no significant common method bias in this study.

4 Results

4.1 Description and correlation

The results of the correlation analysis between the main variables are shown in Table 1. College students' loneliness was negatively correlated with social support and physical activity ($r = -0.495$, $p < 0.01$; $r = -0.292$, $p < 0.01$) and positively correlated with short video addiction ($r = 0.507$, $p < 0.01$); short video addiction was negatively correlated with social support and physical activity ($r = -0.372$, $p < 0.01$; $r = -0.341$, $p < 0.01$); and social support was positively correlated with physical activity ($r = 0.323$, $p < 0.01$).

4.2 Analysis of the mediating effect

According to Wen and Ye's mediation effects test methodology (50), the significant correlation between the variables indicated that the next step of mediation effects testing could be conducted. Bootstrap-based mediation effects were tested via Hayes' SPSS Macro Tools Model 6 (51). The results of the regression analyses (Table 2), controlling for age, sex, and grade level, were as follows. Loneliness positively predicted short video addiction ($\beta = 0.489$, $p < 0.001$), negatively predicted social support ($\beta = -0.484$, $p < 0.001$), and negatively predicted physical activity ($\beta = -0.161$, $p < 0.01$). Social support was a significant positive predictor of physical activity ($\beta = 0.203$, $p < 0.001$). After adding social support and physical activity to the regression equation, short video addiction was negatively predicted by physical activity ($\beta = -0.166$, $p < 0.001$) and social support ($\beta = -0.119$, $p < 0.05$) and positively predicted by loneliness ($\beta = 0.388$, $p < 0.001$).

We further tested the mediating effect (Table 3; Figure 1). With a total mediating effect value of 0.101, social support and physical activity mediated 20.65% of the total effect of loneliness on short video addiction (0.489). This mediating effect consists of three paths: first, loneliness $\rightarrow$ social support $\rightarrow$ short video addiction, with a 0.058 mediating effect value (11.86%); second, loneliness $\rightarrow$ physical activity $\rightarrow$ short video addiction, with a 0.027 mediating effect value (5.52%). Third, loneliness $\rightarrow$ social support $\rightarrow$ physical activity $\rightarrow$ short video addiction, with a 0.016 mediating effect value (3.27%).

TABLE 1 Correlation analysis between the variables.

	M	SD	Loneliness	Short video addiction	Social support	Physical activity
Loneliness	17.48	4.71	1	–	–	–
Short video addiction	39.49	12.09	0.507**	1	–	–
Social support	35.44	7.07	–0.495**	–0.372**	1	–
Physical activity	6.32	2.72	–0.292**	–0.341**	0.323**	1

** $p < 0.01$.

TABLE 2 Regression analysis between the variables.

Regression equation		Overall fit index			Significance of regression coefficient	
Result variable	Predictive variable	R	R2	F	β	t
Short video addiction	Gender	0.529	0.279	37.134	0.148	3.321*
	Age				0.061	1.141
	Grade				–0.073	–1.385
	Loneliness				0.489	11.203***
Social support	Gender	0.517	0.267	34.929	–0.092	–2.060*
	Age				–0.006	–0.102
	Grade				–0.112	–2.091*
	Loneliness				–0.484	–10.990***
Physical activity	Gender	0.444	0.197	18.783	–0.264	–5.585***
	Age				0.024	0.430
	Grade				–0.009	–0.161
	Loneliness				–0.161	–3.048**
	Social support				0.203	3.788***
Short video addiction	Gender	0.565	0.319	29.715	0.090	1.979*
	Age				0.064	1.231
	Grade				–0.092	–1.772
	Loneliness				0.388	7.855***
	Social support				–0.119	–2.383*
	Physical activity				–0.166	–3.513***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

5 Discussion

According to the study’s findings, loneliness significantly positively predicts short video addiction. Much research has established the influence of loneliness on internet addiction. According to a cross-national study, teenage compulsive internet use was substantially correlated with loneliness (52). Loneliness makes smartphone users more likely to use their smartphones addictively (53). Previous relationships between loneliness and internet addiction provide us with ample experience and evidence. Our findings imply that college students’ loneliness increases short-video addiction, which harms their physical and mental health. Therefore, for college students, loneliness is a potential risk factor for short video addiction, and we must pay attention to the prevention of loneliness among college students.

We discovered that social support plays an independent mediating role in this study, verifying Hypothesis H2. Loneliness may elevate the level of short video addiction by decreasing social support. Studies have indicated that lonely people may have low social support (54, 55). Lonely individuals usually separate themselves from social communication (56). Loneliness reduces limbic and striatal activation and functional connections between the anterior insula and occipito-parietal areas, which reduces emotional reactions to pleasant social contacts (57). Teenagers who lack access to essential social networks grow lonelier and rely too heavily on the internet to cope with their emotions (58). When people cannot obtain social support in the real world, they also get social support from the online world (59). Cognitive-behavioral models show that contextual factors such as social isolation and poor social support cause maladaptive cognitions and compulsive usage (60). Therefore, the more isolated college students feel, the lower their social support level will be, raising the level of short video addiction. Helping college students acquire more

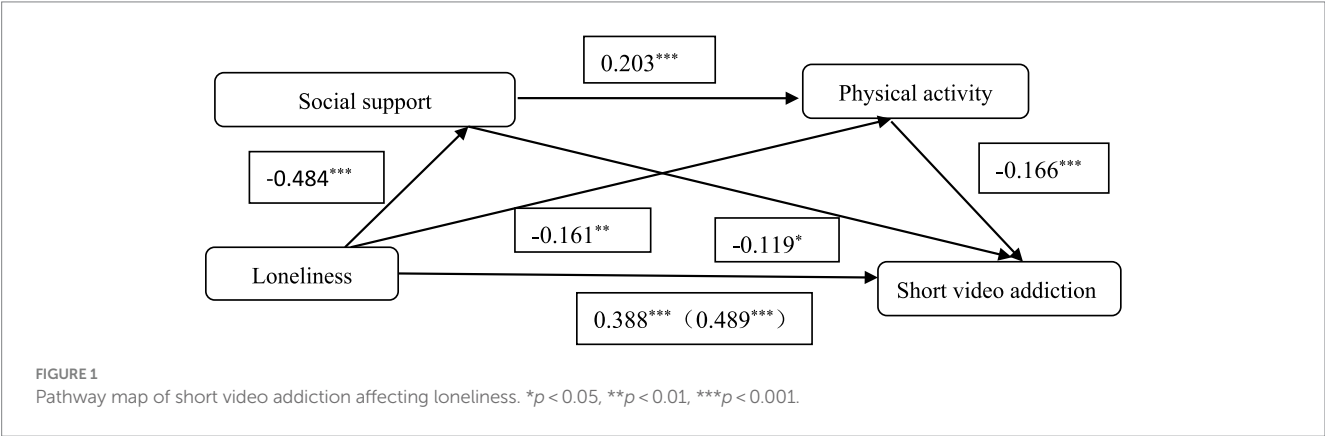


TABLE 3 Mediation effect tests according to Bootstrap.

Benefit type	Effect value	BootSE	Bootstrap 95% CI		Proportion of relative effect
			Boot LLCI	Boot ULCI	
Indirect effect1	0.058	0.028	0.003	0.111	11.86%
Indirect effect2	0.027	0.011	0.008	0.051	5.52%
Indirect effect3	0.016	0.007	0.006	0.032	3.27%
Total indirect effect	0.101	0.028	0.045	0.157	20.65%

real-life social support will help alleviate loneliness’s effect on short video addiction.

Our findings suggest that physical activity mediates the association between loneliness and short video addiction. Hypothesis H3 was tested. Thus, loneliness may have led to increased levels of short video addiction by decreasing physical activity levels. Previous research has found that high levels of sedentary behavior and physical inactivity are positively associated with loneliness (61). In other words, individuals who experience high levels of loneliness tend to be less physically active. Moreover, physical inactivity leads to more internet addiction behaviors (62). As a negative experience, loneliness affects the motivation and persistence of physical activity. Loneliness can have a negative impact on college students’ physical activity, and lower physical activity levels can enhance the level of short-video addiction to a certain extent (63). For college students with high levels of loneliness, physical activity is suitable for their mental health and reduces loneliness and short video addiction.

These findings suggest that loneliness can have an impact on short video addiction through the chain-mediated effects of social support and physical activity. By reducing social support and physical exercise, loneliness may exacerbate short video addiction. Teenagers may depend more on the instant gratification of cell phones than on social interactions or future rewards because of their neurological immaturity (64). Teens with internet and smartphone addiction experience significant levels of loneliness as well as unsatisfactory

social relationships (65). Baumeister et al.’s ego depletion theory (66) states that ego activity depletes psychological energy, lowering executive functioning. The theory suggests that human psychological energy is limited, self-regulation and self-control weaken when psychological energy is drained. Loneliness was found to be positively correlated with cyber laziness, with ego depletion mediating this relationship (67). Thus, loneliness may drain college students’ psychological energy, reducing their self-control in realistic social and physical activities and increasing their dependence on short video applications’ instant rewards, leading to addiction. Previous research has shown that online social support partially mediates between cell phone dependence and loneliness, and can be altered to change the level of loneliness among college students who are cell phone dependent (68). In an intervention trial, loneliness was linked to perceived social support from other physical activity course members (69). Social contact during exercise impacts social support perception (70). Therefore, raising the amount of social support and physical activity can interrupt the effects of loneliness on short video addiction. For college students, establishing positive and healthy interpersonal environments and physical activity habits can help reduce their loneliness and prevent short video addiction.

6 Limitations and future research

This study has several limitations. First, this study was a cross-sectional study with one-time data collection, and the prediction results did not disclose the underlying causal links. A longitudinal study is needed. Second, because the variables were measured on a self-reported questionnaire, typical problems of methodological bias may have arisen. Future research could add interviews and applications that effectively measure short video addiction. Third, due to the large number of factors affecting explanatory variables, only social support and physical activity were mediating variables in this study. Future research needs to explore other potential influences in depth.

7 Conclusion

The findings suggest that loneliness can significantly and positively predict short video addiction and that social support and physical

activity can mediate this relationship. Loneliness can affect short video addiction through the chain mediating effect of social support and physical activity. The study indicates that obtaining more social support and increasing physical activity are effective strategies for college students to cope with short video addiction. Interventions targeting loneliness may also provide a more comprehensive solution to alleviate short video addiction. These findings are essential for the development of targeted intervention strategies for short video addiction. This study provides new insights into the association between loneliness and short video addiction and also emphasizes the critical role of social support and physical activity in this association. These findings provide insights for effectively ameliorating short video addiction among college students and have a positive effect on encouraging college students to participate in real-life social activities and physical activity.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by School of Marxism, Shangqiu Normal University. The studies were conducted in accordance with the local legislation and institutional requirements.

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Bridging trauma and eating disorders: the role of loneliness

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Introduction: Eating disorders (EDs) are complex and often linked to traumatic childhood experiences. While childhood trauma is known to increase the risk of EDs, the role of loneliness remains underexplored. This study investigates whether loneliness mediates the relationship between childhood trauma and ED symptoms.

Methods: A total of 230 individuals with EDs completed the Childhood Trauma Questionnaire, the UCLA Loneliness Scale, and the Eating Disorders Examination Questionnaire. Mediation analysis was conducted to assess if loneliness mediates the relationship between childhood trauma and ED severity.

Results: Childhood trauma significantly predicted higher levels of loneliness ($p < 0.001$), which was associated with more severe ED symptoms ($p = 0.001$), with age and BMI as covariates. Mediation analysis showed loneliness partially mediated the relationship between childhood trauma and ED severity (indirect effect $b = 0.003$, 95%CI [0.001, 0.006]).

Conclusion: Loneliness partially mediates childhood trauma and ED symptoms, highlighting the need to address loneliness in treatment to mitigate the impact of childhood trauma on ED severity. These findings suggest the possible role of social connection-focused interventions in ED care and contribute to understanding the mechanisms underlying the development of EDs. Future research should explore additional mediators and moderators to provide a more comprehensive perspective.

KEYWORDS

trauma, loneliness, mediation, child trauma, psychopathology, eating disorders

Introduction

Eating disorders (EDs), which encompass conditions such as anorexia nervosa (AN), bulimia nervosa (BN), and binge-eating disorder (BED), represent a significant public health concern due to their profound physical, psychological, and social consequences (1–3). These disorders are marked by persistent disturbances in eating behavior, accompanied by distressing thoughts and emotions related to food, body weight, and shape (1). In line with the biopsychosocial model, this complex etiology underscores the importance of considering social and environmental factors, alongside biological and psychological influences, in understanding and addressing EDs (4). Among environmental factors, childhood traumas have emerged as a critical area of focus, given their long-lasting impact on mental health (5, 6). Recent studies report varying prevalence rates of EDs, with lifetime prevalence ranging from 2.2% for men to 8.4% for women (7, 8). These rates vary by region, with higher point prevalence observed in America (4.6%) and Asia (3.5%) compared to Europe (2.2%), suggesting that eating disorders are highly prevalent worldwide, particularly among women, and that the incidence of these disorders has been increasing over time. The distribution of ED varies widely, with AN typically being more prevalent in clinical settings, particularly in inpatient facilities, while BN and BED are often more common in outpatient or community samples (9). The prevalence of each diagnosis is also influenced by factors such as gender, age, and geographical region (10).

Traumatic childhood experiences, including physical, emotional, and sexual abuse, as well as neglect and household dysfunction, have been extensively documented as significant risk factors for the development of various psychological disorders (11, 12). These early adversities disrupt the normal developmental trajectory, leading to maladaptive coping mechanisms and alterations in neurobiological stress response systems (13). Research has consistently shown that individuals with a history of childhood trauma are at a heightened risk for developing eating disorders, as these individuals may turn to disordered eating behaviors as a means to exert control, manage negative emotions, or dissociate from traumatic memories (14). Recently, various studies have suggested the possible presence of an echophenotype in individuals with eating disorders who have a history of trauma, indicating more severe clinical conditions and physical changes that constitute a different and specific manifestation of the disorder (15, 16).

Social support, a key element in the biopsychosocial model, plays a crucial role in mental health by providing emotional resources that help individuals manage stress and adversity (17). Supportive relationships can buffer the impact of trauma, fostering resilience and promoting healthier coping strategies (18, 19). Conversely, a lack of social support or experiences of social isolation can heighten vulnerability to psychological distress, intensifying the risk of developing or worsening symptoms of mental health conditions, including eating disorders (18, 20).

Loneliness and social isolation also play critical roles in eating disorders across diagnostic categories. Social isolation, defined as a lack of meaningful social interactions, is a frequent experience among individuals with eating disorders and can heighten the sense of

disconnection from others (21). This is particularly relevant given that social withdrawal is common in ED populations, where shame and stigma surrounding eating behaviors may lead to avoidance of social situations (22, 23). Such isolation exacerbates feelings of loneliness—a perceived deficit in social connections—and has been associated with the maintenance and severity of eating disorder symptoms across various diagnoses, including AN, BN, and BED (24–26). In addition to the effects of childhood trauma, the role of loneliness as a mediation feature has gained increasing attention in the context of mental health outcomes, in different disorders and different contexts (27–29). Individuals who have experienced childhood trauma often report higher levels of loneliness, stemming from difficulties in forming and maintaining secure attachments and trusting relationships (30). This chronic sense of isolation and social disconnection can exacerbate the psychological distress associated with eating disorders, creating a vicious cycle that reinforces maladaptive eating behaviors (31). Furthermore, loneliness has recently been identified as a potential factor that may contribute to the worsening of physical conditions in people with eating disorders, calling for further investigations (24).

The intersection of childhood trauma, loneliness, and eating disorder psychopathology represents a compelling area for investigation. While the link between childhood trauma and EDs has been well-established (32), the mediating role of loneliness in this relationship remains underexplored. Understanding how loneliness mediates this relationship can provide crucial insights into the underlying mechanisms that contribute to the development and persistence of eating disorders. This knowledge can inform the design of targeted therapeutic interventions aimed at alleviating loneliness, thus potentially mitigating the impact of childhood trauma on the symptoms of eating disorders.

This study aims to explore the mediating effect of loneliness in the relationship between traumatic childhood experiences and eating disorder psychopathology. By employing a mediation analysis approach, we seek to elucidate the pathways through which early adverse experiences influence EDs symptoms, highlighting the critical role of loneliness. Our findings are expected to contribute to the growing body of literature regarding the etiology of eating disorders and offer practical implications for enhancing treatment strategies to address loneliness in individuals with a history of childhood trauma.

Methods

Participants

The study involved 230 individuals diagnosed with eating disorders, recruited from four national clinics, specialized in the treatment of these disorders, at the onset of their inpatient treatment. Diagnoses were established by experienced eating disorder clinicians using the semi-structured clinical interview based on DSM-5 criteria, which is standard in clinical practice. The high proportion of AN participants is due to the recruitment setting within inpatient clinics. The exclusion criteria were the

presence of a severe psychiatric acute comorbidity like psychosis or mania, or the presence of cognitive deficits. All participants identified as cisgender, with the majority being white (95.9%). All participants filled out a written informed consent to participate at the study.

Measures

Data were collected within one week of admission for the EDs group as part of routine service evaluation. The survey package included the Eating Disorders Examination Questionnaire (EDE-Q), the revised University of California Los Angeles Loneliness Scale (UCLA), and the Childhood Trauma Questionnaire (CTQ). All three instruments demonstrated good internal consistency ($\alpha > 0.80$).

The EDE-Q is a 28-item self-report measure designed to assess the severity of eating disorder psychopathology (33). Participants respond using a 7-point Likert scale, with higher scores indicating greater severity of symptoms. The EDE-Q provides a global score and four subscales: restraint, eating concerns, shape concerns, and weight concerns.

The UCLA Loneliness Scale is a 20-item questionnaire that evaluates subjective feelings of loneliness and social isolation (34). Responses are rated on a 4-point Likert scale, with higher scores reflecting elevated levels of loneliness. This scale is widely used and validated for assessing loneliness in various populations.

The CTQ is a retrospective self-report inventory that measures the extent of traumatic experiences during childhood (35). It includes 28 items, each rated on a 5-point Likert scale, encompassing a total score and five subscales: emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. Higher scores indicate greater levels of reported childhood trauma.

Statistical plan

The statistical analysis involved a comprehensive examination of the sample, including descriptive statistics such as means and standard deviations for continuous variables, and rates for the prevalence of traumatic experiences based on the CTQ. Mediation analysis was conducted using the SPSS PROCESS macro-extension (version 3.5), specifically Model 4 (36). In this analysis, the CTQ total score was utilized as the independent variable, with the UCLA Loneliness Scale score as the mediator and the EDE-Q total score as the dependent variable. To assess the mediation effect, bootstrapping with 5,000 samples was performed to estimate the indirect effects, with bias-corrected confidence intervals set at 95%. Bootstrapping involves repeatedly sampling from the data to calculate indirect effects and their confidence intervals, providing a more accurate and reliable estimate by simulating thousands of potential scenarios (37). The mediation model was evaluated including age and BMI as covariates. Additionally, the Sobel test was employed as a confirmatory analysis to validate the overall indirect effect. The Sobel test is a traditional method to check whether a mediator significantly explains the relationship between the independent and dependent variables, offering a straightforward

calculation of statistical significance (38). Statistical significance was determined at an alpha level of $p < 0.05$ for all analyses, executed using IBM SPSS Statistics 25.0 (SPSS, Chicago, IL, United States).

Results

The sample consisted of 206 women (89.4%) and 24 men (10.6%). The mean age was 26.58 ± 11.82 years, with a mean BMI of 22.53 ± 12.02 kg/m², and an average duration of the disorder of 6.90 ± 8.02 years. Diagnoses within the sample included 99 individuals with restrictive anorexia nervosa (42.8%), 34 with binge-purge anorexia nervosa (14.7%), 36 with bulimia nervosa (15.3%), 47 with binge eating disorder (20.0%), and 14 with other specified feeding and eating disorders (6.2%). Most participants lived with their parents ($n = 165$, 71.7%), while fewer lived alone ($n = 35$, 15.2%) or with a partner ($n = 30$, 13.0%). Regarding employment status, the majority reported having a stable occupation ($n = 84$, 36.5%), a significant proportion were unemployed ($n = 84$, 36.5%), and 56 were students (24.3%). EDEQ global score was 4.12 ± 1.31 , CTQ global score was 44.12 ± 17.97 , and UCLA Loneliness score was 49.00 ± 12.16 . See Table 1 for details.

Mediation analyses

The analysis indicated that the CTQ total score significantly predicted UCLA, $b = 0.141$, $p < 0.001$, suggesting that higher levels of childhood trauma are associated with higher UCLA Loneliness scores. UCLA, in turn, significantly predicted EDEQ global score, $b = 0.021$, $p = 0.001$, indicating that greater UCLA Loneliness scores are related to more severe eating disorder symptoms.

The total effect of CTQ total score on EDEQ global score was significant, $b = 0.025$, $p < 0.001$. The direct effect of CTQ total score on EDEQ global score, after accounting for UCLA, was also significant, $b = 0.022$, $p < 0.001$. The indirect effect of CTQ total score on EDEQ global score through UCLA Loneliness was $b = 0.003$, with a 95% bootstrap confidence interval of [0.001, 0.006], which does not include zero, indicating a significant mediation effect. The completely standardized indirect effect was $b = 0.040$ (95% CI [0.009, 0.082]), further confirming that UCLA Loneliness significantly mediates the relationship between total childhood trauma and eating disorder symptoms. These results suggest that the effect of childhood trauma on eating disorders is partially mediated by UCLA. See Figure 1 for the mediation analysis graphical representation and Table 2 for details.

Sobel test corroborated the results of the mediation analysis showing a significant mediation with Sobel test statistic = 2.355 and $p = 0.018$.

Discussion

The present study explored the mediating effect of loneliness on the relationship between traumatic childhood experiences and eating disorder psychopathology. The findings reveal that

TABLE 1 Demographic and clinical characteristics of the sample.

	ED N=	ANr n = 99	ANbp n = 34	BN n = 36	BED n = 47	OSFED n = 14
Gender						
Female	206	97	34	36	31	8
Male	24	2	0	0	16	6
Age, years	26.58	24.56	24.71	23.78	35.23	23.64
	11.82	10.18	8.59	7.57	16.15	8.54
BMI, kg/m ²	22.53	15.05	16.19	21.98	43.81	20.93
	10.02	1.62	1.31	3.88	9.28	1.89
Duration of the disorder, years	6.90	5.50	6.54	8.30	8.68	8.90
	8.02	7.27	7.64	7.44	9.82	8.24
Living condition						
With parents	165	82	25	25	23	10
With partner	30	9	3	4	10	4
Alone	35	8	6	7	14	0
Employment status						
Occupied	84	28	13	8	34	7
Unemployed	84	38	12	21	9	4
Students	56	33	9	7	4	3
EDEQ global score	4.12	4.02	4.34	4.77	3.48	4.82
	1.31	1.35	1.35	1.00	1.18	0.93
CTQ global score	44.12	36.20	44.82	50.86	50.34	60.14
	17.97	11.73	21.07	13.29	20.38	23.66
UCLA loneliness scale	49.00	48.79	49.82	48.67	48.79	50.00
	12.16	12.00	10.97	14.08	12.71	10.21

The table reports the mean and standard deviation for continuous variables and raw counts for categorical variables. ED, eating disorder; AN, anorexia nervosa; r, restrictive; bp, binge-purge; BN, bulimia nervosa; BED, binge eating disorder; OSFED, other specified feeding and eating disorder; BMI, body mass index; EDEQ, eating disorder examination questionnaire; CTQ, childhood trauma questionnaire.

loneliness significantly mediates the relationship between childhood trauma and the severity of eating disorder symptoms. This has profound clinical implications, as it provides insights into the underlying mechanisms that contribute to the development and persistence of eating disorders and suggests avenues for targeted therapeutic interventions. Previous research has established a link between childhood trauma and eating disorders (4, 12), but the

mediating role of loneliness has been underexplored. Our findings extend this understanding by demonstrating that loneliness significantly mediates this relationship.

This study addresses a critical gap in the literature by examining the mediating role of loneliness, providing a more nuanced understanding of how early adverse experiences can lead to disordered eating behaviors through the intermediary of social

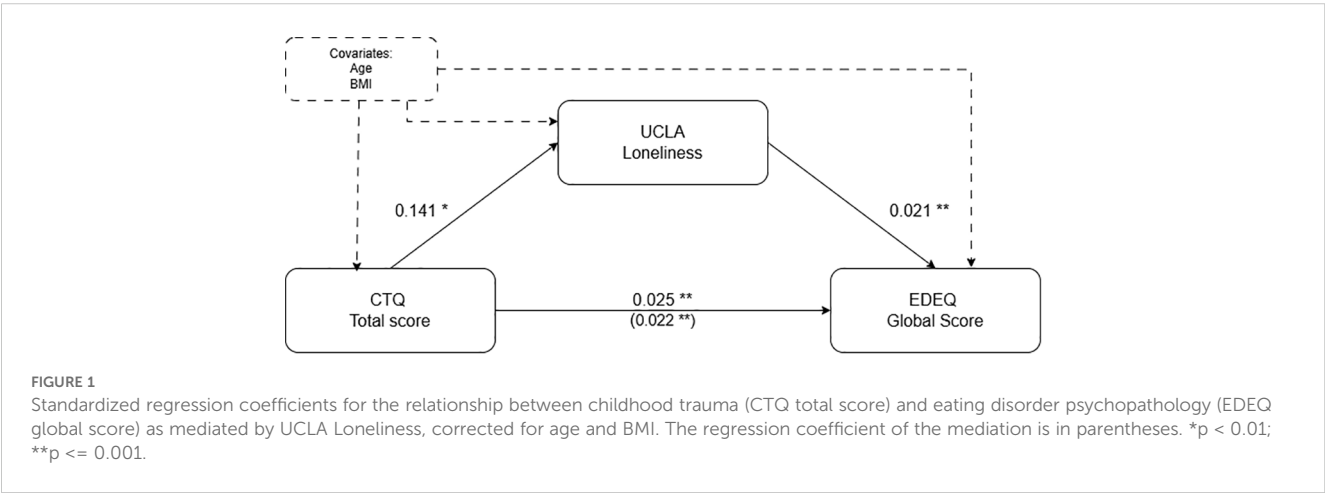


TABLE 2 Regression analysis of eating disorders on childhood trauma and loneliness.

Predictors	B	SE	p	95% CI	R ²
Model 1					
CTQ total score	0.025	0.044	< 0.001	0.016, 0.034	0.235
Age	-0.038	0.007	< 0.001	-0.051, -0.024	
BMI	-0.016	0.007	0.019	-0.029, -0.003	
Model 2					
CTQ total score	0.022	0.004	< 0.001	0.013, 0.031	0.275
UCLA loneliness	0.021	0.006	0.001	0.008, 0.033	
Age	-0.036	0.007	< 0.001	-0.049, -0.023	
BMI	-0.015	0.007	0.031	-0.028, -0.001	
	Effect	SE	p	95% CI	
Total effect	0.025	0.004	< 0.001	0.016, 0.034	
Direct Effect	0.022	0.004	< 0.001	0.013, 0.031	
Indirect Effect	0.003	0.001		0.001, 0.006	

Model 1 includes CTQ total score as the predictor variable, with EDE-Q total score as the dependent variable. Model 2 includes CTQ total score and UCLA Loneliness as predictor variables. This model tests the effect of childhood trauma on eating disorder symptoms, while also accounting for the mediating role of loneliness (UCLA), which significantly predicts eating disorder severity. The increase in R² from Model 1 to Model 2 indicates a stronger model fit when UCLA loneliness is included. The table reports Models corrected for age and BMI.
EDEQ, eating disorder examination questionnaire; CTQ, childhood trauma questionnaire.

isolation. Indeed, loneliness is pointed out as a crucial element in the pathway from childhood trauma to eating disorder symptoms. This finding aligns with the theoretical framework that traumatic childhood experiences disrupt normal developmental trajectories, leading to maladaptive coping mechanisms and alterations in neurobiological stress response systems (39, 40). From a clinical perspective, this underscores the importance of addressing loneliness in therapeutic settings to disrupt this pathway. Otherwise, interventions might be not useful for the improvement of patients' health.

Moreover, the mediating role of loneliness suggests that interventions aimed at reducing feelings of isolation and enhancing social connections could be effective in treating individuals with eating disorders who have a history of childhood trauma. In this perspective, Cognitive Behavioral Therapy (CBT) and Interpersonal Therapy (IPT), which focus on improving social skills and building meaningful relationships, may be particularly beneficial (41–44). Also, specific remediation therapy interventions like Cognitive Remediation and Emotional Skills Training (CREST) might be considered an effective add-on treatment with these specific goals due to their efficacy in implementing specific interpersonal features (45).

The results corroborate recent studies that have identified loneliness as a significant factor in the worsening of physical and psychological conditions, including eating disorders (24, 31, 46). By empirically demonstrating the mediating role of loneliness, this study reinforces the importance of social connections in mental health and eating disorder psychopathology specifically (47, 48).

We found evidence of partial mediation, supporting the idea that childhood maltreatment and loneliness have both combined and independent effects. However, the partial nature of these relationships suggests opportunities for future research to explore additional mediators and moderators. Factors such as resilience, social support, and coping strategies could be examined to provide a more comprehensive understanding of the complex interplay between childhood trauma, loneliness, and eating disorders. Longitudinal studies could also investigate the temporal dynamics of these relationships, offering further insights into causality and optimal intervention timing.

Finally, the findings emphasize the need for personalized treatment plans that take into account the patient's history of childhood trauma and current levels of loneliness (49). Clinicians should consider incorporating assessments for loneliness and trauma history into their diagnostic process to identify patients who may benefit from targeted interventions aimed at improving social connections. This tailored approach can lead to more effective treatment outcomes. Indeed, there is growing evidence that both loneliness and traumatic events have specific disruptive effects on life trajectories, increasing both psychological and physical symptoms (50). From a preventive perspective, early interventions targeting loneliness in children who have experienced trauma have been reported to be effective in reducing the long-lasting negative effects on physical and mental health (51–53). This approach could also reduce the risk of developing eating disorders later in life (54, 55). School-based programs and family interventions that promote healthy attachment and social support could play a crucial role in preventing the onset of eating disorders among at-risk populations (55–57).

This study prioritized mediation analysis to explore the mechanisms underlying the relationships between childhood trauma, loneliness, and ED symptoms. The decision not to examine moderation was guided by our aim to identify potential indirect pathways rather than the interaction effects or conditions that might influence these relationships (58). However, investigating moderation could offer valuable insights into how individual differences or contextual factors, such as gender, cultural background, or severity of symptoms, might shape these associations (59)-all aspects that ED research needs (60). Future research should consider incorporating moderation analyses to provide a more comprehensive understanding of the complexity of these interactions.

Limitations

Several limitations of this study should be acknowledged. First, the cross-sectional design precludes any definitive conclusions about the causal relationships between childhood trauma, loneliness, and eating disorder symptoms. Longitudinal studies are needed to establish the temporal sequence of these variables. Second, the reliance on self-report measures may introduce response biases, such as social desirability or recall biases, which could affect the accuracy of the data. Third, the sample predominantly consisted of individuals identifying as cisgender and white, limiting the generalizability of the findings to more

diverse populations. Additionally, the mixed sample, which includes individuals with various eating disorder diagnoses, may represent a limitation, as these disorders differ significantly in their phenotypic expression and in their associations with childhood trauma—particularly as bulimic variants are more frequently associated with histories of physical and sexual abuse. Moreover, the higher representation of individuals with anorexia nervosa in our sample, likely due to the enrollment criteria of inpatient facilities, may limit the generalizability of the findings to those with other eating disorder diagnoses, as inpatient settings tend to prioritize patients with more severe forms of AN. Furthermore, the inclusion of male participants could introduce a confounding variable, as gender may affect the presentation and correlates of eating disorder symptoms. Moreover, while loneliness was a central variable in our study, we did not assess depressive symptoms, which may be associated with loneliness and could provide a broader understanding of its role in eating disorders; this is a key limitation and an area for further exploration in future studies. Finally, the study did not account for other potential mediators or moderators that could influence the relationship between childhood trauma and eating disorders, such as genetic factors, personality traits, or other environmental influences.

Conclusion

This study underscores the significant mediating role of loneliness in the relationship between traumatic childhood experiences and eating disorder psychopathology. These findings highlight the importance of addressing loneliness in therapeutic interventions to mitigate the impact of childhood trauma on eating disorder symptoms. By advancing the understanding of the underlying mechanisms and suggesting targeted therapeutic approaches, this study contributes to the development of more effective and personalized treatment strategies. Additionally, it fills a critical gap in the literature and sets the stage for future research to further elucidate the complex relationships between childhood trauma, loneliness, and eating disorders.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Ethics statement

The studies involving humans were approved by Vicenza Ethics Committee for Clinical Practice. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

PM: Conceptualization, Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – original draft. AM: Data curation, Investigation, Writing – original draft. BM: Conceptualization, Investigation, Methodology, Resources, Writing – review & editing. FC: Conceptualization, Investigation, Methodology, Resources, Writing – review & editing. LM: Conceptualization, Investigation, Methodology, Resources, Writing – review & editing. PT: Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – review & editing.

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Mediating effects of social detachment in young and middle-aged stroke patients between stigma and ability to return to work

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Objective: To investigate the mediating effect of social isolation on the relationship between stigma and work ability in young and middle-aged stroke patients.

Methods: From May 2022 to May 2024, a survey was conducted on young and middle-aged stroke patients visiting the neurology department of a tertiary hospital in Weifang. The survey utilized the General Information Questionnaire, the Rankin Scale, the General Isolation Scale, the Stigma Scale for Stroke Patients, and the Work Ability Scale.

Results: The scores for work ability, social isolation, and stigma among young and middle-aged stroke patients were 44.23 ± 12.72 , 46.27 ± 5.17 , and 43.37 ± 4.48 , respectively. There was a positive correlation between stigma and social isolation scores ($r = 0.550$, $P < 0.01$), and a negative correlation between stigma and work ability scores ($r = -0.371$, $P < 0.01$). Social isolation was negatively correlated with work ability ($r = -0.418$, $P < 0.01$). Multiple linear stepwise regression analysis indicated that stroke type, duration of illness, mRS score, stigma, and social isolation are significant factors affecting work ability in young and middle-aged stroke patients. Social isolation significantly mediated the relationship between stigma and work ability, accounting for 21.66% of the total effect.

Conclusion: Stigma and social isolation can directly predict the level of work ability in young and middle-aged stroke patients. Additionally, stigma can indirectly influence work ability through social isolation.

KEYWORDS

young and middle-aged, stroke, work ability, social Isolation, mediation model

Introduction

Stroke is a group of acute cerebrovascular diseases caused by various factors. It is characterized by high incidence, high disability, and high mortality rates. Research indicates that the incidence rate of stroke in China is as high as 1.4%, and it is increasing at an annual rate of 8.3% (1). In recent years, with the improvement in treatment levels, the mortality rate of stroke patients has decreased. However, due to the high disability rate,

survivors often have to endure a prolonged recovery period, suffering from irreversible bodily damage such as cognitive impairments, functional disabilities, and poor prognoses (2). Moreover, due to the sequelae of stroke, patients in the recovery phase often experience changes in behavioral abilities, social and familial roles, and interpersonal relationships. These changes can lead to psychological and emotional disorders, such as anxiety and depression, resulting in social avoidance, withdrawal, and anxiety—manifestations collectively described as social isolation (3). Patients with stronger stigma perceptions during the stroke recovery period tend to exhibit more negative self-concepts. As the self-concept represents the core of personality functioning, a more negative self-concept indicates poorer role adaptation and social adjustment, which further exacerbates social isolation (4). Studies have shown that stigma, as an emotional response of shame associated with having suffered a stroke, fundamentally reflects a negative coping strategy toward the condition. The stronger the stigma, the greater the impact on the patient's ability to return to work and reintegrate into society (5).

Research conducted in Sweden, the United States, the United Kingdom, and Japan has extensively explored the return-to-work outcomes of stroke patients, with increasing attention paid to related intervention studies. However, a search of the China National Knowledge Infrastructure (CNKI), Wanfang, and VIP databases revealed that domestic studies on the return-to-work outcomes of stroke patients began around 2,000, with limited publications to date (6). Most existing research in China focuses on the isolated effects of stigma and social isolation on the return-to-work abilities of young and middle-aged stroke patients. However, the mechanisms underlying the interactions among stigma, social isolation, and return-to-work ability remain unclear. The theory of unpleasant symptoms provides a framework for describing the influencing factors of symptom experiences and clarifies the relationships among these factors. This study adopts the theory of unpleasant symptoms to hypothesize that social isolation may act as a key mediator between stigma and return-to-work ability in young and middle-aged stroke patients (7). The findings aim to inform the development of vocational rehabilitation strategies tailored to the needs of Chinese stroke patients in the recovery phase, facilitating their successful reintroduction into the workforce.

Materials and methods

Study subjects

The study selected stroke recovery patients who underwent follow-up examinations at Weifang City Affiliated Hospital from May 2022 to May 2024. Inclusion criteria were: (1) The young and middle-aged stroke population refers to patients clinically diagnosed with stroke who meet the World Health Organization (WHO) age criteria for young and middle-aged individuals, as well as the labor law's definition of working-age. This includes males aged 18–59 years and females aged 18–54 years, age between 18 and 60 (8); (2) meeting stroke diagnostic criteria; (3) regularly attending follow-up appointments as per medical advice after discharge; (4) having a certain level of education and ability to communicate; and (5) being informed and agreeing to participate in the study. Exclusion criteria were: (1) Severe motor aphasia, sensory aphasia,

or mixed aphasia; (2) Being in the acute phase or having an unstable condition; (3) Having other severe systemic diseases; (4) Having psychiatric or psychological disorders.

The sample size was estimated using the cross-sectional study method, with the sample size being 10–20 times the number of study variables. This study included 11 variables and accounted for a 10% invalid questionnaire rate. The calculated sample size range was 130–240, and 234 patients were ultimately included in the study. General information is detailed in Table 1.

Research tools

General information questionnaire

Designed by the researchers and team members based on a literature review and research objectives. It includes questions on gender, age, educational level, marital status, employment status, household income, type of stroke, duration of illness, number of stroke occurrences, method of medical payment, current employment status, and mRS score.

Modified Rankin Scale (mRS) The Modified Rankin Scale (mRS) is used to evaluate neurological recovery after a stroke. The total score ranges from 0 to 6, with higher scores indicating more severe disability: 0 represents no disability, 5 represents severe disability, and 6 represents death. The mRS (disability level) is a commonly used scale for assessing functional outcomes after a stroke. It has a Cronbach's alpha coefficient of 0.78 and a test-retest reliability of 0.81 (9).

General alienation scale (GAS)

This scale was developed by Jessor et al. (10) and translated into Chinese by Wu Shuang et al. (11) to assess the social isolation of participants. The scale includes 15 items across four dimensions: self-alienation (3 items), alienation from others (5 items), mistrust (4 items), and meaninglessness (3 items). It uses a 4-point Likert scale, ranging from “strongly disagree” to “strongly agree,” scoring from 1 to 4 points, respectively. The total score ranges from 15 to 60 points, with higher scores indicating a greater degree of social isolation. The scale has good reliability with a Cronbach's alpha coefficient of 0.770. It has been used by scholars to measure social isolation in middle-aged and young stroke patients, with a Cronbach's alpha coefficient of 0.807. In this study, the Cronbach's alpha coefficient of the scale is 0.829.

Stroke patient stigma scale

This scale was developed by Zhu Minfang et al. (12) to assess stigma in stroke patients. It includes 16 items across four dimensions: physical disability (4 items), self-perception (5 items), experiences of discrimination (4 items), and social interaction (3 items). The scale uses a 5-point Likert scale, ranging from “never” to “always,” scored from 1 to 5 points, respectively. The total score ranges from 16 to 80 points, with higher scores indicating stronger stigma. The scale has a Cronbach's alpha coefficient of 0.916. It has been evaluated in stroke patients, with a Cronbach's alpha coefficient of 0.924. In this study, the Cronbach's alpha coefficient of the scale is 0.918.

TABLE 1 Comparison of total scores for return to work ability among patients with different demographic and disease characteristics ($n = 234$).

Variable	Classification	Sample size	Score ($M \pm SD$)	t/F	P
Sex					
	Male	128	40.25 ± 10.73	0.357	0.536
	Female	106	39.25 ± 7.32		
Age					
	<30	46	34.00 ± 9.41	3.102	<0.05
	35~45	110	44.06 ± 7.31		
	46~59	78	33.23 ± 7.42		
Education					
	Primary school	47	39.13 ± 6.23	2.377	0.058
	Junior high school	88	40.06 ± 11.72		
	High school or technical school	63	39.42 ± 10.78		
	College or higher	36	44.58 ± 7.98		
Marital status					
	Married	192	44.23 ± 8.97	2.023	0.087
	Unmarried	33	44.58 ± 12.15		
	Divorced	7	39.00 ± 10.10		
	Widowed	2	20.50 ± 8.90		
Family income					
	<1,000	16	39.84 ± 7.63	2.278	0.082
	1,000~3,000	21	39.45 ± 11.13		
	3,000~5,000	105	40.05 ± 13.45		
	>5,000	92	44.91 ± 12.07		
Stroke type					
	Ischemic stroke	122	43.21 ± 14.87	6.723	<0.01
	Hemorrhagic stroke	74	39.65 ± 14.08		
	Mixed type	38	36.73 ± 13.24		
Duration of illness (months)					
	1~3	176	40.24 ± 10.91	5.617	<0.01
	3~6	24	34.78 ± 10.23		
	6~12	16	37.23 ± 7.59		
	>12	18	44.11 ± 4.72		
Number of stroke occurrences					
	1	167	44.22 ± 4.73	3.460	<0.05
	2	46	41.27 ± 18.32		
	≥ 3	21	38.69 ± 22.72		
Medical payment method					
	Urban employee basic medical insurance	125	40.29 ± 11.64	1.098	0.351
	Urban and rural resident basic medical insurance	83	40.17 ± 12.75		
	Commercial medical insurance	24	33.40 ± 12.45		
	Other	2	40.12 ± 7.44		

(Continued)

TABLE 1 (Continued)

Variable	Classification	Sample size	Score (M ± SD)	t/F	P
mRS score					
	1	37	36.62 ± 13.73	15.725	<0.001
	2	81	36.69 ± 13.96		
	3	85	46.25 ± 15.2		
	4	31	33.74 ± 10.94		

Work-ability support scale (WSS)

This scale was developed by Turner-Stokes et al. (13) and translated into Chinese by Guo Yawen et al. (14) to assess the level of work-ability support in patients. The scale includes 16 items across three dimensions: physical (5 items), cognitive and communication (5 items), and social (6 items). It uses a 7-point Likert scale, ranging from “continuous support” to “independent work without improvement,” scored from 1 to 7 points, respectively. The total score ranges from 16 to 112 points, with higher scores indicating a stronger ability to return to work. The scale has a Cronbach’s alpha coefficient of 0.932. In this study, the Cronbach’s alpha coefficient of the scale is 0.856.

Data collection method

This study employed a questionnaire survey method. Trained investigators distributed paper-based questionnaires. Initially, the investigators explained the research purpose and significance to the participants using standardized instructions and obtained informed consent before distributing the questionnaires. Participants completed the questionnaires independently. For patients lacking writing or reading abilities, investigators read each item aloud and objectively recorded the responses on the spot. After completion, the investigators collected and immediately checked the questionnaires. If any items were missed or errors were found, the investigators clarified with the participants, made corrections, and confirmed accuracy before final collection. A total of 250 questionnaires were distributed, resulting in 234 valid responses, yielding an effective response rate of 93.6%.

Statistical methods

Data were entered into Excel by two individuals to ensure accuracy and logical consistency. After verification, SPSS 22.0 and AMOS 21.0 software were used for data analysis. Measurement data conforming to a normal distribution were described using mean ± standard deviation. Count data were described using frequencies and percentages. Data were analyzed using independent sample *t*-tests, one-way ANOVA, Pearson correlation analysis, and multiple linear regression analysis. Based on the results of the Pearson correlation analysis, a path relationship model was established and fitted using the maximum likelihood method, with subsequent model modifications. The significance level was set at $\alpha = 0.05$.

Results

Comparison of Total Work-ability Scores Among Patients with Different Demographic and Disease Characteristics. There were statistically significant differences ($P < 0.05$) in the total work-ability scores among middle-aged and young stroke patients when comparing different ages, stroke types, illness durations, stroke occurrences, and mRS scores. Differences in other factors were not statistically significant. For detailed information, see Table 1.

Scores of Stigma, Social Isolation, and Work-ability Among Middle-aged and Young Stroke Patients. In this study, the average score for social isolation among middle-aged and young stroke patients was 46.27 ± 5.17 , indicating a relatively high level, with 66.3% of patients scoring above the average. The average stigma score was 43.37 ± 4.48 , with 46.16% of participants exhibiting moderately high levels. The average score for work-ability was 44.23 ± 12.72 , indicating a moderately low level. For detailed information, see Table 2.

Correlation Analysis of Stigma, Social Isolation, and Work-ability Among Middle-aged and Young Stroke Patients. Stigma was positively correlated with social isolation scores ($r = 0.5496$, $P < 0.01$) and negatively correlated with work-ability scores ($r = -0.371$, $P < 0.01$). Social isolation was negatively correlated with work-ability scores ($r = -0.418$, $P < 0.01$).

Regression Analysis of Return-to-Work Ability Among Middle-aged and Young Stroke Patients. Multiple linear stepwise regression analysis was conducted with return-to-work ability of middle-aged and young stroke patients as the dependent variable. Independent variables included age, stroke type, stroke occurrences, duration of illness, mRS score, stigma, and social isolation scores. Categorical variable assignments are detailed in Table 3. The results indicated that stroke type, duration of illness, mRS score, stigma, and social isolation all entered the regression equation ($P < 0.05$), as shown in Table 4.

Structural Equation Model of Return-to-Work Ability Among Middle-aged and Young Stroke Patients. A structural equation model was constructed with stigma as the independent variable, return-to-work ability as the dependent variable, and social isolation as the mediating variable. The model was fitted using the maximum likelihood method, and the parameters indicated good model fit. Based on the correlation analysis and multiple linear stepwise regression results, AMOS 21.0 was used to establish the hypothetical model and conduct path analysis. The model was tested and modified according to modification indices, resulting in a structural equation model where emotional expression conflict is the independent variable and fear of disease progression acts

as the mediating variable, collectively influencing social isolation. The detailed model is shown in [Figure 1](#). The fit indices for the structural equation model were as follows: $\chi^2/df = 1.685$, RMSEA = 0.054 (<0.08), CFI = 0.965, NFI = 0.920, IFI = 0.966, GFI = 0.946, AGFI = 0.914.

We employed bias-corrected non-parametric percentile Bootstrap analysis, with 5,000 iterations of resampling and a 95% confidence interval, to test the significance of the mediating

effect. The results indicated the following: (1) Stigma significantly positively predicts social isolation ($B = 0.591$, $P < 0.001$); (2) Stigma negatively predicts return-to-work ability ($B = -0.431$, $P < 0.001$); (3) Social isolation directly negatively predicts return-to-work ability ($B = -0.382$, $P < 0.001$); (4) Stigma indirectly affects return-to-work ability through social isolation ($B = 0.165$, $P < 0.001$), suggesting that social isolation partially mediates the relationship between stigma and return-to-work ability, accounting for 21.66% of the total effect ($0.165/0.762$). Detailed results are presented in [Table 5](#).

TABLE 2 Scores of disease shame, social isolation, and return to work ability among young and middle-aged stroke patients ($n = 234$).

Item	Dimension score	Item average score
Disease shame	43.37 ± 4.48	2.71 ± 0.28
Physical disabilities (4)	8.84 ± 2.35	2.21 ± 0.59
Self-perception (5)	14.43 ± 4.21	2.89 ± 0.84
Discrimination experience (4)	11.68 ± 2.57	2.92 ± 0.64
Social interaction (3)	8.62 ± 2.72	2.87 ± 0.91
Social isolation	46.27 ± 5.17	3.08 ± 0.27
Others' alienation (5)	16.72 ± 2.32	3.34 ± 0.46
Self-alienation (3)	9.43 ± 1.19	3.14 ± 0.40
Sense of meaninglessness (3)	10.16 ± 1.92	3.38 ± 0.64
Suspicion (4)	13.71 ± 1.82	3.42 ± 0.46
Return to work ability	44.23 ± 12.72	2.76 ± 0.80
Physiology (5)	11.32 ± 6.08	2.26 ± 1.22
Thinking and communication (5)	10.53 ± 7.75	2.10 ± 1.55
Social behavior (6)	12.34 ± 8.94	2.05 ± 1.49

TABLE 3 Independent variable assignments.

Independent variable	Assignment
Age (years)	$<30 = 1$; $30-45 = 2$; $46-59 = 3$
Number of strokes	$1 = 1$; $2 = 2$; $\geq 3 = 3$
Type of stroke	Ischemic stroke = 1; Hemorrhagic stroke = 2; Mixed type = 3
Duration of illness	$1-3$ months = 1; $3-6$ months = 2; $6-12$ months = 3; >12 months = 4
mRS score	$1 = 1$; $2 = 2$; $3 = 3$; $4 = 4$

Discussion

The results of this study show that the return-to-work ability level of stroke patients in the recovery period scores at (44.23 ± 12.72), which is below average. This finding is consistent with the research results of G. Yawen, indicating that the issue of return-to-work ability in young and middle-aged stroke patients needs to be a focus for healthcare professionals (14). Possible reasons include that young and middle-aged individuals often shoulder multiple family and social roles. However, due to the diagnosis of the disease and the associated stigma of stroke, their enthusiasm for participating in social activities diminishes. Additionally, postoperative physical disabilities and changes in appearance cause psychological distress and a decrease in self-esteem among these patients. Consequently, they lack confidence in social interactions and are reluctant to actively engage in activities (15). The results of multiple linear regression analysis indicate that stroke type, duration of illness, and disability severity (mRS score) are the primary influencing factors on the return-to-work ability. Rooman et al. study results indicate that patients with an mRS score of 0–1 (indicating mild disability) have the ability to return to work, thereby suggesting a higher likelihood of returning to work (16). Physical function is just one component of work ability, but remains an important factor to consider when assessing return-to-work capabilities, particularly in ensuring individuals can meet job requirements safely. Additionally, stroke type can also impact a patient's ability to return to work, possibly due to the severity of the condition and prognosis. A study from Japan noted that patients leaving work due to hemorrhagic stroke may require longer periods to fully return to their job compared to those with ischemic stroke, aligning with findings in this study (17). This study also indicated that the differences in return-to-work ability scores among young and middle-aged

TABLE 4 Multiple linear regression analysis of factors influencing return to work ability among young and middle-aged stroke patients ($n = 234$).

Item	Regression coefficient	Standard error	Standardized coefficient	t-value	p-value
(Constant)	41.45	2.178	-	13.63	0.001
Stroke type	2.006	0.854	0.132	2.179	0.017
Duration of illness	2.236	1.178	0.097	1.927	0.026
mRS score	-1.476	0.235	-0.186	-5.802	0.001
Disease shame	-0.269	0.041	-0.289	-7.341	0.001
Social isolation	-0.478	0.039	-0.443	-10.782	<0.001

$R^2 = 0.612$, Adjusted $R^2 = 0.601$, $F = 135.703$, $p \leq 0.001$.

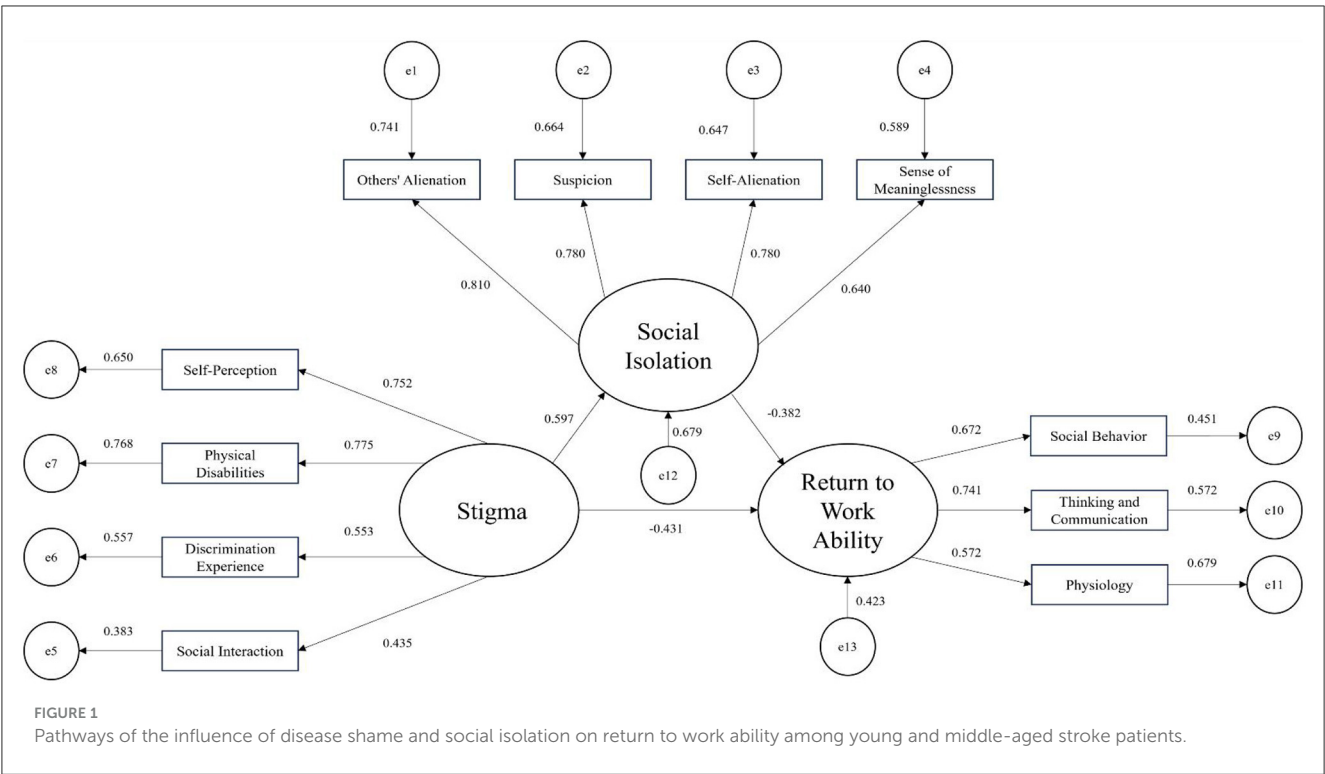


TABLE 5 Effect scores of fear of disease progression as a mediating variable influencing social isolation through emotional expression conflict ($n = 282$).

Effect	Coefficient B	SE	t-value	p-value	95% CI
Total effect	0.762	0.065	10.063	0.001	0.435–0.641
Direct effect	0.597	0.088	4.215	0.001	0.170–0.472
Indirect effect	0.165	0.047	2.156	0.001	0.130–0.391

stroke patients with varying lengths of illness were statistically significant. This may be related to patients experiencing a prolonged rehabilitation period leading to better physical recovery and higher return-to-work ability levels. Healthcare providers can plan vocational rehabilitation assessments and interventions early in the patient's recovery based on their condition and progress. Providing relevant work-related information in a timely manner can enhance their confidence in recovery and ability to return to work.

The results of this study indicate a negative correlation between stigma and return-to-work ability in young and middle-aged stroke patients ($r = -0.371$, $P < 0.01$). Specifically, higher levels of stigma were associated with lower return-to-work scores. In this study, 46.16% of patients exhibited high levels of stigma, with a mean return-to-work score of 49.41 ± 7.17 . These findings align with previous research, confirming that higher stigma levels result in diminished return-to-work ability (18). The study also revealed a positive correlation between stigma and social isolation ($r = 0.5496$, $P < 0.01$), consistent with findings from related research. Young and middle-aged stroke patients with lower levels of physical activity reported higher social

isolation and stigma, suggesting that elevated stigma is a major barrier to mobility. Furthermore, this study identified a negative correlation between social isolation and return-to-work ability ($r = -0.418$, $P < 0.01$), indicating that higher levels of social isolation were associated with lower return-to-work scores. Among the participants, 66.3% experienced social isolation, with a mean return-to-work score of 56.78 ± 12.02 , highlighting significant limitations in return-to-work ability. The strong association between social isolation and reduced return-to-work capacity aligns with findings from prior studies (19). The underlying reason may be that social isolation leads to discomfort in social interactions, thereby reducing patients' willingness and capacity to engage in work environments. Additionally, a lack of social support may exacerbate this isolation, as patients often lack the encouragement and assistance necessary to re-enter the workforce. Other studies have also reported a significant relationship between social isolation and physical activity limitations, which may further restrict workplace participation (20). Therefore, providing increased social support and psychological interventions for young and middle-aged stroke patients could help alleviate social isolation, ultimately improving their ability to return to work.

The results of this study demonstrate that social isolation partially mediates the relationship between stigma and return-to-work ability in young and middle-aged stroke patients, with an effect value of 0.165, accounting for 21.66% of the total effect. This finding indicates that stigma can indirectly influence return-to-work ability through social isolation. Consistent with this result, Yandi et al. (21) found that lower stigma levels predict reduced social isolation in stroke patients. The possible explanation is that after experiencing a stroke, patients may feel shame and embarrassment due to communication difficulties,

such as language impairments (22). This may lead to social withdrawal and a reluctance to engage with others. The lack of effective communication can result in behaviors characterized by social isolation, which in turn reduces motivation for productive activities and daily living, ultimately limiting return-to-work ability (23). Research has shown that as age increases and physical function declines, social isolation and stigma intensify in young and middle-aged stroke patients. This exacerbates functional limitations in daily activities, further reducing their likelihood of re-entering the workforce and negatively affecting their productive capacity and quality of life (24). Nafei highlighted that young and middle-aged patients often express a strong desire to return to work (25). However, concerns about potential threats to their self-esteem significantly hinder their recovery of work capacity, leading to a higher prevalence of social isolation. These findings suggest that frontline healthcare providers could target social isolation as a key intervention point. Strategies may include reducing stigma, minimizing sedentary behavior, and encouraging participation in social activities and outdoor exercise (26). Such interventions could enhance patients' return-to-work ability and improve their overall recovery outcomes.

Limitation

The limitations of this study include the selection of a single research center, the use of convenience sampling, and a cross-sectional study design, which may restrict the generalizability of the findings. The external validity of the mediation model requires further confirmation. Future studies should involve multi-center, large-sample, and prospective designs, extending research settings to include elder care facilities and diverse regions. Additionally, further exploration of other potential variables and their underlying mechanisms is warranted.

Conclusion

Stigma and social isolation are independent influencing factors on return-to-work ability in young and middle-aged stroke patients. Stigma can negatively predict return-to-work ability both directly and indirectly through social isolation. Social isolation plays a partial mediating role in the relationship between stigma and return-to-work ability. Healthcare providers and managers should prioritize interventions aimed at reducing stigma and modifying habitual social isolation behaviors. It is recommended to implement intervention strategies based on pathways influencing social isolation. Nursing managers can adopt various approaches, including supportive-expressive group therapy, enhanced health education, personalized care plans, narrative therapy, mindfulness-based interventions, progressive focused interviews, and peer support interventions, to reduce social isolation among stroke patients in the recovery phase. These measures aim to enhance return-to-work ability and improve physical activity and quality of life in young and middle-aged stroke patients.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by Weifang People's Hospital Ethics Review Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JD: Writing – original draft. XD: Conceptualization, Writing – original draft. YW: Data curation, Writing – review & editing. SS: Data curation, Writing – original draft. JWu: Supervision, Writing – original draft. JWa: Methodology, Writing – original draft. YF: Investigation, Writing – original draft. GH: Investigation, Writing – original draft. ZX: Investigation, Writing – original draft. JL: Investigation, Writing – original draft. XS: Supervision, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2025.1474345/full#supplementary-material>

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Square dance, loneliness, quality of life, and attitude toward aging in middle-aged and older women in China

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Background: With the ongoing advancement of society and the economy, population aging has emerged as an unavoidable global trend, leading to various social issues and exerting a profound impact on the physical and mental well-being of middle-aged and older adults. While women often face greater challenges than men during the aging process, particularly in terms of physical health vulnerabilities, mental health disparities and socioeconomic disadvantages. These factors underscore the importance of studying middle-aged and older women to better address their unique needs and promote healthy aging. Much attention has been paid to how middle-aged and older women can improve healthy aging, positive emotions and subjective well-being through regular physical activity.

Methods: Using 4,819 middle-aged and older women who participated in square dance exercise, structural equation modeling was used to explore the relationship between square dance exercise and attitude toward aging, as well as the chain-mediated effects of loneliness and quality of life.

Results: (a) Square dance exercise is a positive predictor of attitude toward aging in middle-aged and older women. (b) Loneliness and quality of life moderated the relationship between square dance exercise and attitude toward aging, and their mediating effects included three pathways. (c) The single mediating effect of quality of life was the largest compared to the chain mediating effects of loneliness and loneliness-quality of life.

Conclusion: This study aimed to reveal the reduction of loneliness and improvement of quality of life as potential mechanisms in the relationship between square dance exercise and attitude toward aging, and to emphasize that square dance exercise can be effective in promoting positive attitude toward aging and enhancing subjective well-being in middle-aged and older women.

KEYWORDS

square dance, middle-aged and older women, quality of life, loneliness, attitude toward aging

1 Introduction

As population aging leads to an increase in the number of older persons in all societies, the promotion of healthy or successful aging has become an issue of considerable importance (1). China stands out, however, as it already has the world's largest older population (2). According to the World Health Organization (WHO), healthy aging is more than just the absence of disease, it is the process of developing and maintaining the functional ability that

enables well-being in older individuals (3). A lack of physical activity in middle-aged and older adults may lead to deterioration in mental health as they age, as well as a decline in the body's overall functional capacity (4). At the same time, the lack of perceived physical abilities and the complex health problems associated with gradual aging can also trigger a sense of loneliness in middle-aged and older adults, thus interfering with their quality of life (5). Participation in leisure-time physical activity can serve as a means for middle-aged and older adults to effectively cope with aging, reduce negative psychological symptoms, including depression and anxiety, and improve their mental health and quality of life (6).

Physical activity is globally recognized as a vital health asset for all ages and serves as a non-pharmacological intervention to prevent and treat numerous diseases. In China, square dancing, also known as square fitness dance, has become an increasingly popular form of exercise. It involves unified group dances performed spontaneously to music in public spaces such as squares, parks, streets and open areas near buildings (7). Compared to traditional sports like running or swimming, square dancing is simple, beginner-friendly and flexible, as it is not restricted by time, theme or rhythm. This group-based, music-guided outdoor activity has been found to better promote mental health than indoor or individual sports like yoga or tennis (8).

Square dancing is widely practiced across the country, with participants primarily consisting of middle-aged and older women aged 40–65. Role theory indicates that women in this age group often experience emotional and physical challenges stemming from role transitions. As they adapt to changing social roles, square dancing provides them with a platform to assert their individuality, express themselves and remain active participants in urbanized society. As such, it has become a meaningful way for women to reconstruct social relationships and rebuild their sense of identity (9).

Emerging alongside China's rapid urbanization following its reform and opening-up, square dancing has evolved into a significant cultural phenomenon. Ecosystem theory (EST) suggests (10) that individuals are shaped by various interconnected social systems directly or indirectly, and has been applied to studies in recent years on successful aging. Many researchers attribute the rise and popularity of square dancing to broader social changes. As a cultural activity, square dancing incorporates elements of urban, rural, community, fitness, leisure and national cultures, enriching the fabric of contemporary Chinese social culture.

In summary, the focus on middle-aged and older women arises how they often face challenges such as role transitions, changes in health status and weakened social support systems. Square dancing not only helps them address these issues but also fosters social connections, enhances life satisfaction and improves mental health.

According to the World Social Report 2023, women are becoming the mainstay of middle-aged and older adults, especially older adults (11). Square dance exercise has become the first choice for Chinese middle-aged and older women to participate in physical activity (12). Regular square dance exercise can improve numerous psychological indicators in middle-aged and older women, effectively reduce loneliness, increase life satisfaction, and generate an optimistic and positive attitude toward aging (13). Therefore, based on previous

studies, square dancing can be an important means to improve the quality of life, reduce loneliness and promote active aging among middle-aged and older adults. However, as a unique form of exercise for middle-aged and older adults in China, the relationship between square dancing and aging attitudes in this population has not been fully confirmed. However, the direct effects of square dancing on the aging attitudes of middle-aged and older adults, as well as the role of loneliness and quality of life as mediating variables, have not been fully investigated in the middle-aged and older population.

Therefore, in order to fill this research gap, this study selected loneliness and quality of life as mediator variables from the perspective of psychology to explore the relationship between square dance and the aging attitudes of middle-aged and older adults. It is hoped that through a large-sample cross-sectional study, the chain-mediated effects of loneliness and quality of life will be verified, the relationship between square dancing and aging attitudes of middle-aged and older people and its internal mechanism will be elucidated, so as to provide research bases and theoretical references for the promotion of healthy aging.

1.1 Square dance and attitude toward aging

Attitude toward aging are expectations about one's experience and evaluations of the process of aging and of growing old (14). Attitude toward aging are divided into positive and negative attitudes based on middle-aged and older adults' feelings. Positive attitude toward aging are positive experiences and feelings that are related to health and well-being. Negative attitude toward aging stem from declines in physical, mental, and social capabilities (15). When middle-aged and older women engage in physical activities, they make relatively positive evaluations of their own life events, and their sense of efficacy and positive thoughts become the basis of their attitudes toward life (16).

Attitudes toward physical functioning and emotional well-being can have long-term effects on one's own aging (17). Social-emotional choice theory suggests that as middle-aged and older women grow older, the accumulation of knowledge and experience encourages them to better regulate their emotions and to find things in their living environment that are conducive to regulating their emotions to release them (18). Physical activity can help middle-aged and older adults achieve good physical function and positive emotional experiences, prevent disease, promote mental health, and effectively improve attitude toward aging (19). When middle-aged and older women perceive stressors in their bodies, they can focus on upbeat music to release the tension and pressure, effectively transferring and dispersing their negative emotions (20). First, in a study comparing dance, listening to music, and cycling in non-clinical populations, both dancing and passive listening to music were shown to enhance positive emotions, reduce negative emotions and fatigue. Meanwhile, regular voluntary participation in exercise can reduce emotional inertia (21). Second, compared with the square dance practitioners, Tai Chi practitioners have better physical health and immune function (22). Third, square dancing has a greater positive impact on mental health and illness than walking exercise, table tennis and running (23). As can be seen from the above that square dance exercise effectively reduced the dimension of psychosocial loss, improved the dimension of physical change,

Abbreviations: WHO, World health organization; AAQ, Attitudes to aging questionnaire; SF-12, 12-Item short-form health survey; SF-36, 36-Item short-form health survey; COVID-19, Corona virus disease 2019.

enhanced the sense of psychological gain and further improved the mental health of middle-aged and older individuals. Lastly, square dance exercise has a positive impact on all aspects of their physical fitness. Square dance exercise can effectively regulate the body composition of middle-aged and older women, improve their physical fitness and prevent physical function problems that occur as they grow older (24). The muscle strength of the lower limbs increases during exercise, the dynamic balance of the body improves, osteoporosis is prevented, and the health of the shoulder joints is protected (25).

In summary, physical activity can foster a positive outlook on aging, which in turn significantly impacts their mental health (26). Square dance exercise, in particular, helps improve attitude toward aging and contributes to participants' psychological well-being.

1.2 Loneliness and attitude toward aging

Loneliness is the gap between one's expectations of social relationships and actual social relationships, including both emotional loneliness due to loss or lack of close emotional attachments and social loneliness due to infrequent contact or lack of engagement (27). Loneliness is considered an adaptation that can facilitate interpersonal and social relationships (28). Among those aged ≥ 55 years, 22% of the female population experiences loneliness, and this proportion rises with increasing age (29). At the same time, aging-related physical incapacity and complex health problems are more likely to trigger loneliness in middle-aged and older women (5). Loneliness is a key factor affecting active aging. Physical activity can provide enriching opportunities for middle-aged and older women experiencing loneliness to develop positive and meaningful social relationships with other participants, leading to positive emotions in old age (30). However, poor health or the need to care for an ill spouse or other relative can limit physical activity and social interaction, thereby increasing the risk of loneliness. Instead, it can have a negative impact on the survival and overall well-being of older persons (31).

Square dance exercise is a group physical activity that is essential for experiencing a sense of belonging and social identity, and helps to improve the well-being of middle-aged and older women (32). Meanwhile, social interaction theory suggests that social activities are important for improving the psychological and social adaptability as well as enhancing the physical and mental health of middle-aged and older adults (33). High-quality participation in social activities expands the range of social activities of older persons, increases social interactions, maintains and strengthens intimate relationships, thereby reducing loneliness and improving the quality of life in old age (34). Square dancing, as a recreational physical activity, is believed to create a rich social interaction environment for participants, and the better the social interaction environment, the more it helps middle-aged and older women achieve successful aging (35). Square dancing also promotes their social interactions with peers, maintains social engagement, eliminates loneliness, and ultimately promotes psychosocial health experiences (36).

In conclusion, the more middle-aged and older women interact with their peers and groups through square dance exercise, the more connected they become to others and society. Therefore, loneliness is improved.

1.3 Quality of life and attitude toward aging

The WHO recommends that the goal of achieving an "active aging" policy framework should be to improve the quality of life of older persons (37). Quality of life is a multidimensional and multilayered concept that measures "an individual's perception of his or her place in life" (38). Quality of life potentially consists of four basic dimensions, the two dimensions of health and economic status are objective, and the two dimensions of social relationships and emotions reflect individual judgments (39). Specific aspects of attitude toward aging (e.g., physical changes and psychological growth) are strongly associated with the quality of life of middle-aged and older adults (40). As Low argues, "the four dimensions of quality of life can influence mental health and thus change subjective perceptions of physical, cognitive and social aging" (41). Appropriate physical activity can help middle-aged and older women achieve good physical functioning, promote psychological well-being, and effectively improve attitude toward aging (42). A correlation between aerobic exercise and quality of life exists. For example, interventions such as square dancing, yoga and Tai Chi have shown small to moderate improvements in both physiological and psychological health for individuals aged 60 and above (43). Additionally, square dance helps enhance quality of life to some extent by providing social opportunities, which in turn boosts self-esteem and life satisfaction (44). However, yoga is more effective than square dance in improving menopausal symptoms, depression, and anxiety in middle-aged and older women (45).

The main characteristics of quality of life are health and well-being, which are key indicators of successful aging (46). Socioemotional choice theory reveals that as people age, they prioritize goals that are more emotionally meaningful and are motivated to fulfill their social preferences (47). In China, middle-aged and older women prioritize psychological values such as social relationships and emotions, while being motivated to persist in activities that are appropriate for them to meet their emotional needs (48). Square dancing creates a social environment that meets needs through interpersonal communication and significantly improves mood, promotes psychological adaptation, and enhances well-being (49).

In conclusion, square dance exercise improves middle-aged and older women's perspectives on their overall mental health, including their attitude toward aging and their perceptions of quality of life.

1.4 The serial multiple mediation mechanism of loneliness and quality of life

The main theory of loneliness, the "Cognitive Discrepancy Model," posits that loneliness arises when the ideal social relationships fail to match the actual social relationships in both quality and quantity (50). Greater participation in group-based leisure activities is associated with better health perceptions and closer social relationships among middle-aged and older adults (51). The sense of belonging generated by participation in group activities can be seen as a motivation to connect with society and others (52). It can also improve the collective well-being of middle-aged and older adults, allowing them to fully experience social relationships, reduce loneliness, and improve subjective well-being (53). Adequate social relationships can determine personal success related to happiness and

quality of life (54). Reducing loneliness leads to a better self-perception of mental health, which in turn results in greater happiness, self-esteem and quality of life (55).

Loneliness correlates with the quality of life: the stronger the feelings of loneliness, the poorer the quality of life (56). Loneliness affects quality of life in two ways. Participation in group, recreational and social square dance exercises for people aged 45 and above has a more obvious effect on improving the loneliness of middle-aged and older adults, especially in the areas of social isolation and self-enclosure, which can further improve the overall quality of life (57). Square dancing is effective as a protective and accepting intervention after experiencing empty nesting and retirement, effectively linking social support to improved quality of life and positive attitude toward aging (21).

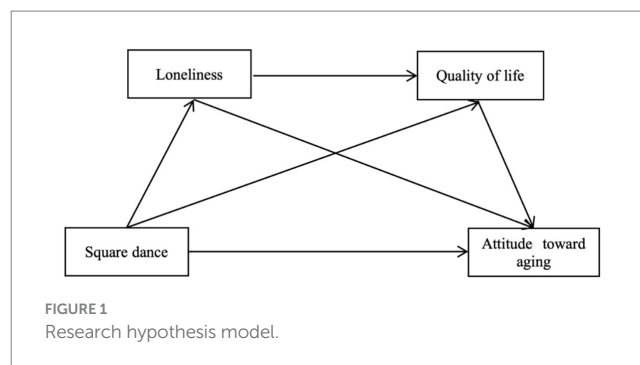
Active aging is a process of optimizing health, participation and security opportunities, aiming to improve quality of life as people age and create a favorable social environment that encourages middle-aged and older adults to engage in meaningful social activities (3). Additionally, the theory of aging activity suggests that when middle-aged and older adults remain active and maintain social interactions, they successfully transition into old age, reducing loneliness, delaying the aging process, and enhancing quality of life (58). Square dance has a strong predictive effect on increasing social interaction, improving physical function, establishing positive and optimistic psychological emotions, and fostering a positive attitude toward aging in middle-aged and older women. Therefore, we should actively pay attention to the attitude toward aging of middle-aged and older adults, and improving loneliness and quality of life may help reduce depression and anxiety and produce positive emotions (59).

In conclusion, loneliness and quality of life may serve as significant mediating variables between square dance exercise and attitude toward aging. However, this relationship needs further verification, especially in middle-aged and older female populations.

1.5 The present study

In recent years, physical and psychological problems have become a major global concern related to ensuring quality of life for a growing number of middle-aged and older women (60). Previous research related to square dance exercise has focused on its effects on the physical and mental health of older adults (61, 62). However, it is unclear whether square dance exercise improves attitude toward aging, and studies using loneliness and quality of life as mediating variables are relatively limited. Few cross-sectional surveys have been conducted on large samples of square dance participants. Therefore, the purpose of this study was to examine the relationship between square dance exercise and attitude toward aging among middle-aged and older adults, using loneliness and quality of life as the underlying mechanisms. The aim was to identify aspirations for active aging and to examine the relationship between attitudes in later life and loneliness and quality of life in the sport of square dancing. Based on the results, a foundation of information and recommendations will be provided for future square dance interventions and practices for middle-aged and older adults. The following research hypotheses were formulated (Figure 1):

H1. Square dance exercise predicts attitude toward aging in middle-aged and older women.



H2. Loneliness mediates the relationship between square dance exercise and attitude toward aging.

H3. Quality of life mediates the association between square dance exercise and attitude toward aging.

H4. Loneliness and quality of life chain-mediate the relationship between square dance and attitude toward aging.

1.6 Theoretical framework

This study employs 6 key theoretical perspectives to explore the relationship between square dance exercise and attitude toward aging, with a focus on the mediating roles of loneliness and quality of life. These theories collectively highlight the positive impact of square dancing on middle-aged and older women. Role theory suggests that square dance helps women redefine their social roles and identity during the aging process. Ecosystem theory emphasizes square dance as a cultural phenomenon that promotes personal well-being and enriches urban and community culture. Social-emotional choice theory posits that square dance provides emotional support, helping women focus on positive emotions and reduce stress. Social interaction theory highlights how square dance fosters social connections, improving psychological and social adaptability. The cognitive discrepancy model of loneliness suggests that square dance provides opportunities for women to form meaningful social relationships, reducing loneliness. Lastly, aging activity theory suggests that square dance, as a low-barrier activity, promotes physical health, social interaction, and psychological well-being, helping delay aging, improving quality of life, and fostering a positive attitude toward aging.

2 Materials and methods

2.1 Participants

The data were collected in 2023 through a web-based survey¹ between August 9 and September 2, 2023, through the Questionnaire Star platform. We monitored the IP addresses of the respondents to avoid multiple repetitions. The questionnaires were distributed in 32

¹ <https://www.wjx.cn/>

TABLE 1 Demographic information of the participants ($N = 4,819$).

	Contents	$N = 4,819$	Percent (%)
Sex	Female	4,819	100
Age (in years)	45 ~ 59	2,516	52.2
	≥ 60	2,303	47.8
Living condition	Live with children	784	16.27
	Live with spouse and children	1,600	33.2
	Live with spouse	2,112	43.83
	Other	136	2.82
	Live alone	187	3.88
Place of residence	Countryside	1,008	20.92
	City	3,811	79.08
Education level and degree	Primary and below	308	6.39
	Junior high school	1,749	36.29
	Senior high school includes technical secondary school	1,822	37.81
	Bachelor degree or above (including Junior college)	940	19.51
Pension or medical insurance	Both	4,218	87.53
	Pension	353	7.32
	Medical	248	5.15
Marital status	Married	4,580	95.04
	Unmarried	24	0.5
	Divorce	215	4.46

provinces, autonomous regions, and municipalities directly under the central government, including Beijing, Jiangsu, Guangdong, Fujian, Inner Mongolia, Shanghai, Qinghai, Shandong, Yunnan, and 32 other provinces, with a wide geographical distribution.

Since the data were self-reported by the participants, outliers may exist due to input errors or recall bias. To minimize the impact of outliers on data accuracy, SPSS 26.0 software was used to clean the data against the scale. The initial data set consisted of 5,068 respondents. After screening, 249 invalid questionnaires were excluded. Among these, 240 were from male respondents, including one who reported their age incorrectly. Additionally, 5 female respondents were excluded due to incorrect age reporting. Furthermore, 4 incomplete questionnaires were removed, along with those that showed repeated answers for given scales or displayed obvious response patterns. This process resulted in a final sample of 4,819 valid questionnaires, achieving a valid return rate of 95.08%. The age range of the sample for this study was 52.2% 45–59 years and 47.8% over 60 years.

2.2 Measures

- Demographic Information – The demographic information obtained by the questionnaire included the participants' sex, age, residency status, place of residence, education level, whether they were enrolled in health insurance or pension insurance, and marital status, as detailed in [Table 1](#).
- The Physical Activity Rating Scale-3 (PARS-3) assesses square dance movement to determine how extensively individuals are

participating in the square dance movement. This scale was revised by Liang Deqing, who concluded that the scale has high reliability and validity (63). The scale has only three items, which are scored on a five-point scale ranging from 1 to 5, examining the amount of exercise in terms of intensity, time and frequency of participation in physical activity. The scoring method was as follows: physical activity = intensity $\times$ (time-1) frequency, with the highest score being 100 and the lowest score being 0. The scale evaluates exercise level as follows: low exercise level ≤ 19 points, moderate exercise level = 20–42 points, and high exercise level ≥ 43 points. In this study, the Cronbach coefficient was 0.645.

- Attitudes to Aging Scale – The Attitudes to Aging Questionnaire (AAQ) was developed by Laidlaw et al. in 2007 to measure older people's evaluations and perceptions of themselves in the aging process using a self-report format (14). The questionnaire was introduced and adopted to the Chinese context by Huang Yifan in 2010 to create the Chinese version of the AAQ. The questionnaire includes three dimensions, i.e., psychosocial loss, coping with physical changes, and psychological gain, with 8 entries for each dimension and a total of 24 entries. The questionnaire was scored on a 5-point Likert scale ranging from 1 to 5, indicating “totally disagree” to “totally agree,” with the psychosocial loss dimension reverse scored. The total score of the questionnaire ranged from 24 to 120, with higher scores indicating more positive attitude toward aging. The Cronbach's α coefficient of the questionnaire is 0.840, which indicates that the questionnaire has good reliability and validity and is suitable for the older population in China. In this study, the

Chinese version of the AAQ measured the attitudes of older adults in the community, and the Cronbach's α of the AAQ was 0.926.

- d. Emotional and Social Loneliness Scale – The Emotional and Social Loneliness Scale is based on the theory of R. S. Weiss and was developed by Wittenberg et al. in 1986. The scale consists of 10 items, with 5 items each for social and emotional loneliness (64). Each entry is scored on a 5-point scale ranging from 1 (none) to 5 (often), with higher scores indicating greater loneliness. This scale has been shown to have good reliability and validity. In this study, the Cronbach's α coefficient for the total scale was 0.854.
- e. Quality of Life Scale SF-12 (12-items Short Form Health Survey) is a 12-item short-form health survey of the 36-item short-form health survey (SF-36) commonly used internationally (65). The SF-12, is a universal scale and has the advantages of simple responses and less operation time than the SF-36, and the correlation between the SF-12 and SF-36 has been confirmed in the literature (66). There are 12 items with in 8 dimensions: general health, physical functioning, physical functioning, somatic pain, energy, social functioning, emotional functioning, and mental health. Each item is scored according to the corresponding option, with questions 1, 8, 9, and 10 reverse scored. The SF-12 calculates two total scores, the total physical score and the total psychological score; higher scores indicate better quality of life.

Since the 12 questions of the quality of life scale have different value ranges, neither Cronbach's α coefficients nor factor analysis are suitable for analysis, and the only way to test the reliability of the questionnaire is through retest reliability. However, due to the large number of people in this survey and considering the high cost of evaluating retest reliability, we did not evaluate retest reliability; however, a retest reliability analysis has been conducted for this scale, and the result was 0.864 (67). Therefore, it is reasonable to assume that the results of this scale are reliable and can be used for further analysis.

2.3 Statistical analysis

The predictor variable in this study was square dance exercise, the mediator variables were loneliness and quality of life, and the outcome variable was attitude toward aging. SPSS 26.0 and Process 4.0 were used to analyze the data statistically, with $\alpha = 0.05$ indicating statistical significance. SPSS 26.0 statistical software was used to calculate and describe the distribution of the variables and their correlations; 95% confidence intervals for the mediating paths were tested using the bootstrap method, with 5,000 repetitions of the sample, and if the interval did not contain zero, the mediating paths were considered significant.

3 Results

3.1 Preliminary results

A total of 4,819 older women were evaluated in this study. Table 1 shows the demographic information, means and standard deviations

of the participants' sex, age, living condition, place of residents, highest level of education, pension or medical insurance, marital status. As shown in Table 1, the age of the 4,819 study participants was mainly over 45 years old. Among them, the number of females who ages 45 ~ 59 accounted for 52.2% of the total number, and who ages above 60 years old accounted for 47.8% of the total number. In terms of living condition, 784 people live with their children, accounting for 16.27% of the sample; 1,600 people live with spouse and children, accounting for 33.2%; 2,112 people live with spouse, accounting for 43.83%; 136 live with others, accounting for 2.82%; and 187 live alone, accounting for 3.88%. So, it can be seen that most women who participate in the activity prefer to live with others, like children, spouse and so on. Only a very small number of people choose to live alone.

As regards the place of residence, 3,811 participants live in the city, accounting for 79.08%; only 1,008 people live in the countryside, accounting for 20.92%. We can infer that most square dancing participants live in the city.

As to the education level and degree, 308 women only have primary education level even below, accounting for 6.39%; 1,749 have junior high school level, accounting for 36.29%; 1,822 women have senior high school includes technical secondary school level, accounting for 37.81%; 940 women have bachelor degree or above (including Junior college) level, accounting for 19.51%. So, it is clear that most participants only have below bachelor degree or above (including Junior college) education level.

In terms of the pension or medical insurance, 4,218 both have two, accounting for 87.53%; 353 only have pension, accounting for 7.32%; 248 only have medical, accounting for 5.15%. The number of having both is the most, and is much more than only have pension or medical.

As for marital status, the married group consists of 4,580 individuals, accounting for 95.04%, while the Unmarried group includes only 24 individuals, making up 0.5%. Additionally, the divorced group consists of 215 individuals, representing 4.46% of the total population.

3.2 Common method bias test

When self-reported methods are used to collect data, the issue of common method bias may arise. Common method bias was tested using the Harman one-factor test. The results showed that there was a total of one factor with an eigenroot greater than 1. The total variance explained by the first common factor was 39.867%, which is less than the critical value of 40%. Therefore, there was no common method bias in the data of this study.

Since the data were self-reported by the participants, outliers may exist due to input errors or recall bias. To minimize the biases typically associated with self-reported data, several methods were implemented. First, we used SPSS 26.0 software for data cleaning, identifying and reviewing outliers and inconsistent data to ensure the dataset's reliability. Outliers and unlikely responses were excluded, enhancing the overall quality of the data. We also employed standardized, validated questionnaires to reduce response biases and ensure consistency across participants' answers. This approach helped minimize interpretation errors and made the data more comparable and reliable. To address recall bias, we limited the recall period for

TABLE 2 Correlations between variables ($N = 4,819$).

Variables	M	SD	1	2	3	4	5	6	7	8
Square dance exercise	25.888	17.87	1							
Physical health	37.023	5.294	0.127**	1						
Mental health	61.141	8.264	0.103**	−0.267**	1					
Psychosocial loss	28.318	8.952	0.096**	0.095**	0.238**	1				
Body change	32.244	6.711	0.169**	0.142**	0.241**	0.233**	1			
Psychological acquisition	25.713	8.572	0.105**	0.114**	0.112**	0.439**	0.599**	1		
Social loneliness	10.13	4.086	−0.069**	−0.056**	−0.301**	−0.189**	−0.076**	−0.039**	1	
Emotional loneliness	11.822	4.139	−0.013	−0.083**	−0.121**	−0.139**	−0.026	−0.006	0.413**	1

* $p < 0.05$, ** $p < 0.01$.

certain questions, focusing on recent experiences and encouraging participants to report based on their current feelings or actions, thus reducing inaccuracies due to distant memories. Additionally, to mitigate social desirability bias, we assured participants of their anonymity and confidentiality, promoting honest and unbiased responses, particularly in sensitive areas. These combined strategies helped ensure the accuracy and integrity of the self-reported data.

3.3 Related analysis

The mean value, standard deviation and Pearson correlation analysis of each variable are shown in Table 2. Square dance exercise and quality of life ($r = -0.267$ – 0.127 , $p < 0.01$) and attitude toward aging ($r = 0.105$ – 0.599 , $p < 0.01$) were significantly negatively correlated with loneliness ($r = -0.069$ – 0.413 , $p < 0.01$). The above results show that this approach is suitable for further analysis of intermediary effects.

3.4 Testing the mediating effect

The mediation analysis was performed using the PROCESS plug-in in SPSS software, and the regression analysis in SPSS software was used to generate Model 1 (regression model of the independent variable on the dependent variable), Model 2 (regression model of the independent variable on the mediator variable 1), and Model 3 (regression model of the independent variable on the mediator variable 2) at the same time. The above hierarchical regression table is composed of Model 1, Model 2, Model 3, and PROCESS—generated Model 4 (multivariate regression model of the independent variable and the mediator variable on the dependent variable at the same time), and we can see the specific information of the individual models, as well as path coefficients a and path coefficients b in the mediator model, which are analyzed as follows.

In Model 1, a significant positive effect of square dance exercise on attitude toward aging ($\beta = 0.162$, $p < 0.05$), which means that c (total effect) in the mediation model is significant; that is, it is significantly different from 0 (not equal to 0).

In Model 2, square dance exercise had a significant negative effect on loneliness ($\beta = -0.019$, $p < 0.05$); in Model 3, square dance exercise had a significant positive effect on quality of life ($\beta = 0.079$, $p < 0.05$); and square dance exercise had a significant negative effect on loneliness ($\beta = -0.353$, $p < 0.05$).

Model 4 adds mediating variables based on Model 1. At this time, square dance exercise has a notable positive impact on attitude toward aging ($\beta = 0.103$, $p < 0.05$); that is, c' (direct effect) in the mediating model is significant, as it is significantly different from 0 (not equal to 0); loneliness has a significant negative effect on attitude toward aging ($\beta = -0.086$, $p < 0.05$); and quality of life has a significant negative impact on attitude toward aging ($\beta = -0.676$, $p < 0.05$).

The 95% confidence interval for the mediating path was tested using the bootstrap method; if the interval did not contain 0, the mediating path was considered significant. The details of results of sequential mediation model of square dance and attitude toward aging were summarized in Table 3.

The bootstrap test further indicated that the direct effect was 63.46%, the mediating effect consisted of the indirect effect generated by the 3 paths (36.54% of the total effect), and the 95% confidence intervals of the three paths did not include 0, indicating that all three indirect effects reached a significant level. Path 1, square dance exercise $\rightarrow$ loneliness $\rightarrow$ attitude toward aging was composed of mediating effect 2 (0.0016); path 2, square dance exercise $\rightarrow$ quality of life $\rightarrow$ attitude toward aging was composed of mediating effect 3 (0.0533); and path 3, square dance exercise $\rightarrow$ loneliness $\rightarrow$ quality of life $\rightarrow$ attitude toward aging was composed of mediating effect 4 (0.0044). Accordingly, square dance exercise not only directly predicted attitude toward aging but also indirectly predicted attitude toward aging through the independent mediating effects of loneliness and quality of life, as well as through the chain mediating effect between loneliness and quality of life.

Finally, comparing the variability of the mediating effects of the 3 paths revealed that the mediating effect of path 1 was greater than those of path 2 and path 3. This suggests that quality of life plays a more important role in the relationship between square dance exercise and attitude toward aging. The details of results of effect values of the mediation effect tested by bootstrapping were summarized in Table 4.

TABLE 3 Regression analysis of square dance, loneliness, quality of life and attitude toward aging in middle-aged and older women in China ($N = 4,819$).

	Attitude toward aging			Loneliness			Quality of life			Attitude toward aging		
	β	SE	t	β	SE	t	β	SE	t	β	SE	t
Constant	82.082**	0.478	171.88	22.434**	0.175	128.093	103.868**	0.428	242.533	19.189**	3.463	5.542
Square dance	0.162**	0.015	10.667	-0.019**	0.006	-3.346	0.079**	0.006	12.148	0.103**	0.015	6.998
Loneliness							-0.353**	0.017	-21.026	-0.086*	0.039	-2.204
Quality of life										0.676**	0.032	21.078
R^2	0.023			0.002			0.113			0.118		
F	113.79			11.199			307.847			215.275		

* $p < 0.05$, ** $p < 0.01$.TABLE 4 Analysis of mediation effects between square dance, loneliness, quality of life and attitude toward aging in middle-aged and older women in China ($N = 4,819$).

Intermediary process	Effect value	Bootstrapped LLCI ^a	Bootstrapped ULCI ^a	Effect size (%)
Square dance $\Rightarrow$ Loneliness $\Rightarrow$ Attitude toward aging	0.0016	0.0001	0.0041	0.99
Square dance $\Rightarrow$ Quality of life $\Rightarrow$ Attitude toward aging	0.0533	0.0429	0.0642	32.84
Square dance $\Rightarrow$ Loneliness $\Rightarrow$ Quality of life $\Rightarrow$ Attitude toward aging	0.0044	0.0017	0.0073	2.71
Direct effect	0.103	0.074	0.131	63.46
Indirect effect	0.0593	0.044	0.067	36.54
Total effect	0.1623	0.132	0.192	100.00

^aBoot LLCI and Boot ULCI refer to the 95% confidence intervals of the indirect effect estimated via the bias-corrected bootstrap method and refer to the upper and lower limits of the intervals, respectively. CI, confidence interval. Total effect = indirect effect + direct effect.

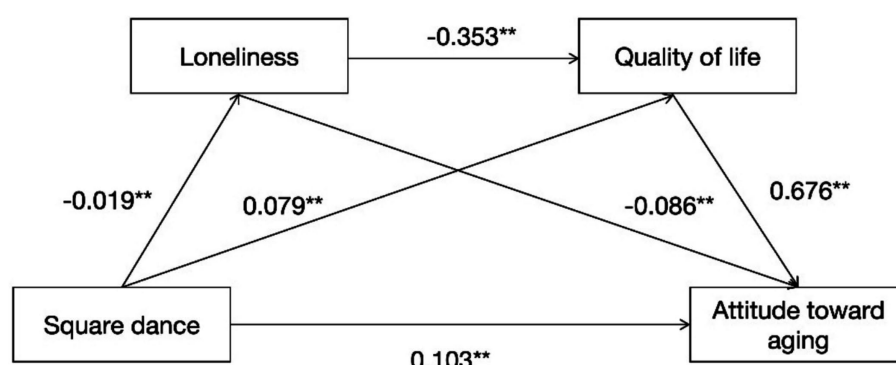


FIGURE 2

Chain mediating effect model of loneliness and quality of life between square dance exercise and attitude toward aging ($N = 4,819$). * $p < 0.05$, ** $p < 0.01$.

The path diagram in Figure 2 shows that (1) square dance exercise ($\beta = 0.103^{**}$, $p < 0.001$) significantly and positively predicts attitude toward aging, indicating that the greater the level of square dance exercise is, the more positive the attitudes of older adults toward aging. (2) square dance exercise ($\beta = -0.019^{**}$, $p < 0.001$) significantly and negatively predicts loneliness, indicating that the greater the level of square dance exercise is, the lower the loneliness felt by older people. (3) square dance exercise ($\beta = 0.079^{**}$, $p < 0.001$)

significantly and positively predicts quality of life, indicating that the greater the level of square dance exercise is, the greater the quality of life. (4) loneliness ($\beta = -0.086^{**}$, $p < 0.001$) and quality of life ($\beta = 0.676^{**}$, $p < 0.001$) significantly negatively and positively predict attitude toward aging, respectively. (5) loneliness ($\beta = -0.353^{**}$, $p < 0.001$) significantly and negatively predicted quality of life, indicating that the lower the loneliness was, the greater the quality of life of the older participants.

The corrected bias bootstrap method with 5,000 replicated samples was used to test each path of the serial mediation model, and the mediation effect of loneliness was 0.0016, 95% CI [0.0001, 0.0041], with an effect size of 0.99%, and the mediation effect of quality of life was 0.0533, 95% confidence interval [0.0429, 0.0642], with an effect size of 32.84%; its series mediated effect was 0.0044, 95% confidence interval [0.0017, 0.0073], and its effect size was 2.71%.

In conclusion, loneliness and quality of life play a serial-mediated role in the relationship between square dance exercise and attitude toward aging. The details of each path case of the model are shown in Table 4.

4 Discussion

In a cross-sectional survey of 4,819 middle-aged and older women in China, this study aimed to explore the relationship between square dance exercise and attitude toward aging and to reveal the mediating roles of loneliness and quality of life in the relationship between square dance exercise and attitude toward aging. Interventions that increase opportunities for social interaction versus improving social skills are more effective in reducing overall loneliness (68). At the same time, quality of life is closely related to physical, psychological and social adaptation. Therefore, square dance exercise is characterized by a wide range of groups, rich socialization, and diverse movements that comprehensively regulate the physical and mental functions of middle-aged and older women, thus improving their attitude toward aging. This study supports the significant positive predictive effect of square dance exercise on attitude toward aging, as well as the formation of a chained mediation model, validating H1, H2, H3, and H4.

4.1 The direct relationship between square dance and attitude toward aging

Physical activity (PA) is a major component of maintaining health and well-being (69). PA is a positive predictor of attitude toward aging, which is consistent with previous research findings (70). PA is considered to be a part of active lifestyle and necessary condition for active aging. It promotes healthy aging by facilitating the maintenance and improvement of personal fitness (71), enhancing the general self-efficacy of middle-aged and older adults, and improving the quality of life of middle-aged and older adults so that they can live healthier, more fulfilling lives (72).

Square dance exercise significantly positively predicts attitude toward aging, which confirms the hypothesis of this study. The social choice emotion theory further explains the perception of survival time in middle-aged and old adults, who are more inclined to emotion management, obtain intimate emotional experience, and pursue positive emotions (18). With the gradual increase of age, the middle-aged and older population will have a negative attitude toward aging along with the loss of physical, psychological, and social fields (73). In the city, because in the context of sports power and national fitness, residents have more access to cutting-edge policies, so they are more affected by policies and have higher enthusiasm to participate in sports activities. In addition, cities have more funds than rural areas, so they are more likely to have access to high-quality sports resources

and have a stronger incentive to participate in sports activities. In summary, it can be seen that urban residents are more aware of individual health. Middle-aged and older adults' awareness of the importance of recreational and cultural activities, and the support of family and friends enhancing their eagerness, attitude, and motivation to participate in PA. What underpins their practice is the increased awareness of their own health and their awareness of the value of "aging well" (74).

Square dance exercises can enable middle-aged and older adults to establish stable and intimate relationships with team members in the process of long-term participation, so as to produce a more positive emotional experience in the team. This increased social interaction, coupled with positive personal emotional experiences, is a key factor in shaping positive attitude toward aging and promoting mechanisms for successful aging (19). Because of its low cost and easy participation, square dancing attracts middle-aged and older adults with low socioeconomic status. In this study, most of the participants in square dancing have only a secondary education level. This reflects the generally lower educational attainment of the generation born around the 1950s, and the less educated middle-aged and older adults may be more inclined to choose square dancing as a low-barrier way to socialize and exercise (75). Meanwhile, the percentage of those who participated in square dance exercise with a time intensity of 30 min or more was close to 90%. By increasing the duration of square dance exercises, the cardiopulmonary function can be enhanced, muscle strength and endurance can be improved, and the overall level of physical health can be improved (76). Furthermore, the musical rhythm of square dancing has a unique charm. As the rhythm of the music changes, middle-aged and older adults are immersed in the music melody, which can effectively promote the activity of the cerebral cortex and improve their cognitive function (77). At the same time, rhythmic exercise can trigger positive emotional experiences, such as happiness and pleasure, which is conducive to middle-aged and older adults to show greater energy and vitality, and achieve a positive aging attitude, and promote successful aging (78).

In summary, a strong correlation between square dance exercise and attitude toward aging. Attitude toward aging usually become more positive and result in a stable emotional experience, that promotes a positive attitude toward life in the middle-aged and older adults.

4.2 The intermediary role of loneliness

Loneliness plays an important role in the health and well-being of middle-aged and older adults (74). Square dance exercise was negatively correlated with both types of loneliness, and square dance exercise can contribute to attitude toward aging through both dimensions of loneliness (social loneliness and emotional loneliness). This confirms hypothesis 2 of this study. A lack of close relationships with spouses, children, and even grandchildren are associated with emotional loneliness. Thus, social loneliness is more general in nature, whereas emotional loneliness is more specific and varies with specific intimate connections with significant others. Physical activity was significantly negatively correlated with loneliness, with higher physical activity participation being associated with lower loneliness, which is consistent with previous research findings (79).

According to the effect analysis table of this study, the mediating effect size of loneliness in the relationship between

square dance exercise and attitude toward aging was 0.99%. Square dance exercise enlarges the social circle of participants, satisfies the social needs of middle-aged and older women, and helps them overcome loneliness (80). However, the mediating effect of loneliness was weaker. First, 96.12% of this study's sample living with their spouses and children. Adult children can provide support to their aging parents during their aging and retirement transitions, thereby reducing their parents' fear and emotional distress about their future lives. At the same time, China is a society with a traditional culture of respecting the older and a country where the two-way support relationship between parents and children is very close (81). Family intergenerational support provided by children to the older, such as financial and emotional support, is regarded as an act of respecting the older and aligns with traditional Chinese filial piety norms (82). China's close intergenerational support system, rooted in its tradition of respecting the older, allows adult children to alleviate their parents' aging-related anxieties through financial and emotional support. This reflects a strict adherence to the norms of filial piety. Moreover, the degree of depression among the older adults varies significantly depending on their marital status. Married older adults have the lowest level of depression, followed by those who are divorced or widowed, while unmarried older adults have the highest level of depression (83). On the one hand, spouses can provide emotional support and comfort, whereas unmarried or widowed individuals lack such support and are more prone to feelings of loneliness and loss. On the other hand, couples can support each other and share burdens and stress, thereby reducing depression (84).

First, middle-aged and older women emphasize family support, and support from family members (e.g., spouses and adult children) plays an important role in maintaining their mental health (85). Women who are square dance exercisers are more likely to have relationships with their families and are less likely to feel lonely. Second, according to the data, the middle-aged and older adults who participate in square dance exercise are mostly urban residents, accounting for 79.1% of the total population. The middle-aged and older adults living in urban areas have rich daily lives, better public facilities and richer urbanization resources. The healthful role played by urban and community design that promotes physical activity may moderate declines in physical function. Loneliness is lower in urban-dwelling middle-aged and older adults. Third, social interaction theory suggests that social ties and interpersonal contact are the main reasons for participation in group movements. Physical activity can facilitate social relationships, thereby improving an individual's mental health. Square dance is a form of daily group exercise, providing middle-aged and older women with a relaxing and enjoyable exercise atmosphere and the opportunity to expand their social interactions during group exercise (15). Square dance can effectively compensate for the social isolation and negative emotional problems caused by socialization deficits (86).

In this study, emotional loneliness is not significantly associated with square dance exercise, changes in attitude toward aging, or loss of psychological identity. Because this study focused on a group of middle-aged and older women, there were fewer effects on emotional loneliness, which led to a weaker mediating effect on loneliness. Loneliness has a low impact as a mediator.

4.3 The intermediary role of quality of life

Quality of life is a conscious cognitive judgment of life satisfaction that accounts for the physical, psychological and social aspects of life (87). Square dance exercise is positively correlated with two dimensions of quality of life (physical health, mental health) and three dimensions of attitude toward aging (psychosocial loss, physical change, and psychological gain). This confirms H3 of this study. Higher levels of physical activity are independently associated with long-term quality of life, according to previous research (88). Regular physical exercise not only improves physical condition but also adjusts the process of self-adaptation to the social environment and helps middle-aged and older women competently regulate their psychology and cultivate good psychological quality by strengthening their communication with the outside world.

Inequalities in health are exacerbated by unequal socioeconomic status, which reflects a range of key social determinants of people's health and is a root cause of health disparities (89). China is a vast country with large differences in economic development across the country, and differences exist in the factors affecting quality of life in different places and at different stages of development (90). The impact of economic development on mind and body shows different patterns in urban and rural areas. The impact of economic conditions on the quality of life of the older adults in urban areas is relatively weak due to the higher level of urban economy, superior urban planning, better medical conditions and supporting facilities. From the perspective of demand theory, non-material needs become important when economic resources mainly satisfy the material needs of the population (91).

According to the decomposition of the mediating effects in this paper, 32.84% of the effects were mediated through quality of life, which was more significant than the effect of loneliness. In the domain of physical health, square dance exercise can significantly improve the physical health of middle-aged and older women. Long-term adherence to participate in square dance exercise can affect the body's joints, increase core strength, coordination of the upper and lower limbs, increase cardiorespiratory endurance, effectively reduce muscle and bone loss, improve body shape and strengthen the immune system (61). However, as square dancing is a spontaneous sport, the lack of professional risk awareness and supervision of participants may lead to varying degrees of injuries among middle-aged and older adults, affecting their quality of life (92).

First, from the perspective of mental health, square dance exercise is accompanied by music, which allows middle-aged and older women to promote the secretion of dopamine neurotransmitters. A pleasant and relaxing atmosphere enables them to experience the joyful experience of "reliving," reduce anxiety and tension in life (93). As a result, they actively choose to spend their time on square dance workouts. Second, square dance exercise can promote communication and exchange between middle-aged and older women, promote the development of interpersonal relationships and help middle-aged and older women actively integrate into society and regain their own self-worth. Social-emotional selection theory also suggests that the socially meaningful attributes of this activity appeal to middle-aged and older women (18). However, it is verifiable that Tai Chi, yoga, and other forms of exercise are significantly better than square dancing for cognitive function and mood in middle-aged and older adults (22).

Attitude toward aging are an important predictor of quality of life and one of the most important factors that enables middle-aged and older women to age positively (15). The quality of life of middle-aged and older women can be improved through long-term adherence to square dance exercise, thereby increasing the likelihood of successful individual aging. As the cycle begins, behavior → quality of life → attitude toward aging form a closed loop (86). Participation in square dance exercise can be transformed into a positive experience of the physical, psychological and social environment. Improving middle-aged and older women's perceptions and experiences of their aging and helping them face aging with a more positive and optimistic attitude is important for promoting successful aging.

4.4 The serial multiple mediation mechanism of loneliness and quality of life

This study also examined whether the relationship between square dance exercise and attitude toward aging was influenced by levels of loneliness and quality of life. However, the mediating roles of loneliness and quality of life in the relationship between square dance exercise and attitude toward aging have been rarely discussed in related studies. In this study, a negative correlation between loneliness and quality of life, indicating that the lower the sense of loneliness among middle-aged and older adults, the higher their quality of life. Quality of life, a good indicator of overall health, is more significantly affected by loneliness among older adults, which is consistent with H4 of this study. Participation in physical activity helps middle-aged and older women become more socially engaged and better integrated into society, which in turn produces psychological benefits, improves the quality of life of middle-aged and older women and reduces loneliness (94).

According to social identity theory, an individual's sense of belonging to a group influences their perceptions of aging (95). Square dance provides middle-aged and older adults with opportunities to engage in group activities and experience social connections, fostering positive emotional experiences within the group. This increased social interaction and a strong sense of belonging are closely linked. Overall, square dance exercise positively impacts the quality of life of middle-aged and older adults by reducing feelings of loneliness, enhancing social closeness and promoting positive emotional experiences. This further proves the potential value of square dancing in promoting people's positive attitude toward aging.

According to the mediating effect analysis in this paper, the mediating effect size of square dance exercise → loneliness → quality of life → attitude toward aging is 2.71%, which is not high. This may be because 79% of the middle-aged and older women in the sample in this study lived in the city. In 2011 China Longitudinal Healthy Longevity Survey (CLHLS), the mental health of urban older people is better than that of rural older people. This is essentially related to the fact that healthcare, social welfare, cultural and recreational facilities are better in urban areas. The standard of living and social status of the urban older adults is relatively high (96). Adequate health-care services, modern facilities, a sense of personal security and opportunities for active participation in social groups or organizations are the main reasons for the high quality of life of older adults in urban areas (97). In addition, the effect size of loneliness in this study was 0.99%. This may be related to the fact that the survey was conducted

during the COVID-19 pandemic, a period when the virus inevitably impacted individuals' psychological and emotional well-being, possibly leading to a decrease in social engagement (98). However, the social environment of the time, while hindering face-to-face social interactions, increased time spent with family. Over time, square dance workouts have been adapted to online home workout formats.

In conclusion, square dance as a group physical activity, not only helps reduce loneliness and improve the quality of life for middle-aged and older adults but also generates positive emotions that promotes a positive attitude toward aging. Additionally, loneliness and quality of life in middle-aged and older adults are influenced by various factors, including economic and cultural aspects (99). The sample in this study had relatively low levels of loneliness. This may explain why square dancing is not as effective in improving loneliness, which further affects the impact of square dancing on quality of life and attitude toward aging. Therefore, future research could conduct comparative analyses in areas with different levels of urbanization to explore the varying effects of square dance in different social environments.

4.5 Limitations and future research directions

This study also has some limitations. First, this study utilized a cross-sectional design, so interpretation of results should be considered with caution. To deepen the understanding of causality, researchers could use a longitudinal design to track changes between square dance exercise, loneliness, quality of life, and attitude toward aging. Second, the sample of this study was mainly focused on the middle-aged and older female population, which may have affected the overall understanding of the exercise effects of square dancing. Whether the results of future research can be generalized to other genders or age groups needs to be confirmed by further interventions and surveys to more accurately assess the impact of square dancing on the physical and mental effects of different populations. In addition, the samples included in this study are from China, and the effects of square dancing have not been studied abroad. Therefore, the results of this study can only be generalized to China, and for the time being, they are not applicable to foreign countries with different economic conditions and cultural backgrounds. Finally, in addition to the indicators in this study, other sociodemographic variables, such as level of education, presence of children or grandchildren, race and ethnicity, history of chronic disease, and other important psychological variables, such as anxiety, depression, motivation to exercise, and personality traits should be included in future related studies. The selection of variables and the construction of models, especially the influence of complex multidimensional concepts and potential factors on the relationships between variables, remain to be tested experimentally.

4.6 Implications

Theoretical implications: this study analyses how square dance exercise affects middle-aged and older women's attitude toward aging with the help of social-emotional choice theory, social interaction theory, and aging activity theory and explores the chain-mediated model of loneliness and quality of life to further elucidate the intrinsic and extrinsic mechanisms involved. By giving middle-aged and older

women specific social roles, it is possible, in a certain sense, to alleviate anxiety or stress caused by various factors such as retirement and aging, and to grow in physical and mental health. In summary, this study examined the effects of square dance exercise on middle-aged and older women's attitude toward aging, providing a rich theoretical reference for empirical research on square dance exercise interventions for middle-aged and older women.

Practical implications: against the multifaceted and complex background of population aging, some middle-aged and older women experienced a certain degree of decline in their physical and mental health during the coronavirus epidemic. Spontaneous participation in group-type social activities, such as square dance exercise, can raise older people's awareness of fitness and health, help them find a sense of belonging to a group, enhance their self-worth, and change their attitude toward aging. For this reason, the present intervention study on reducing loneliness and improving the quality of life of the middle-aged and older female population is of profound practical significance and is in line with the current background and trend of coping with population aging, providing a new intervention idea for achieving the goal of active aging.

5 Conclusion

Based on a cross-sectional design and utilizing a large sample empirical research methodology. This study provides an in-depth examination of the relationship between square dance exercise and attitude toward aging, with a particular focus on the intrinsic mediating role of the variables of loneliness and quality of life. First, square dance exercise is a positive predictor of attitude toward aging in middle-aged and older adults. Second, loneliness and quality of life significantly moderate the relationship between square dance exercise and attitude toward aging and mediate the effect through all three pathways together. Moreover, further analysis revealed that the mediating effect of quality of life is more significant than that of loneliness. In conclusion, this study aimed to reveal the reduction in loneliness and improvement in quality of life as potential mechanisms underlying the relationship between square dance exercise and attitude toward aging and to emphasize that positive attitude toward aging can be effectively promoted among middle-aged and older adults through square dance exercise. The positive effects of square dance exercise are worthy of further in-depth research and application promotion to make an important contribution to improving the quality of life and happiness of middle-aged and older adults and realizing the strategy of positive aging.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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Ethics statement

The studies involving humans were approved by Sports Science Experiment Ethics Committee of Beijing Sport University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

RL: Writing – original draft, Data curation, Formal analysis, Investigation, Visualization. QY: Data curation, Formal analysis, Investigation, Writing – original draft. YQ: Investigation, Writing – review & editing. YW: Data curation, Supervision, Writing – review & editing, Investigation, Project administration.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Identifying major depressive disorder among US adults living alone using stacked ensemble machine learning algorithms

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Background: It has been increasingly recognized that adults living alone have a higher likelihood of developing Major Depressive Disorder (MDD) than those living with others. However, there is still no prediction model for MDD specifically designed for adults who live alone.

Objective: This study aims to investigate the effectiveness of utilizing personal health data in combination with a stacked ensemble machine learning (SEML) technique to detect MDD among adults living alone, seeking to gain insights into the interaction between personal health data and MDD.

Methods: Our data originated from the US National Health and Nutrition Examination Survey (NHANES) spanning 2007 to 2018. We finally selected a set of 30 easily accessible variables encompassing demographic profiles, lifestyle factors, and baseline health conditions. We constructed a SEML model for MDD detection, incorporating three conventional machine learning algorithms as base models and a Neural Network (NN) as the meta-model. Furthermore, SHapley Additive exPlanations (SHAP) analysis was used to explain the impact of each predictor on MDD.

Results: The study included 2,642 adult participants who lived alone, of whom 10.6% (279 out of 2,642) had a PHQ-9 score of 10 or above, indicating the presence of MDD. The performance of our SEML model was robust, with an area under the curve (AUC) of 0.85. Further analysis using SHAP revealed positive correlations between the occurrence of MDD and factors such as sleep disorders, number of prescription medications, need for specific walking aids, leak urine during nonphysical activities, chronic bronchitis, and Healthy Eating Index (HEI) scores for sodium. Conversely, age, the Family Monthly Poverty Level Index (FMMPI), and HEI scores for added sugar showed negative correlations with MDD occurrence. Additionally, a U-shaped relationship was noted between the occurrence of MDD and both sleep duration and Body Mass Index (BMI), as well as HEI scores for dairy.

Conclusion: The study has successfully developed a predictive model for MDD, specifically tailored for adults living alone using a stacked ensemble technique, enhancing the identification of MDD and its risk factors among adults living alone.

KEYWORDS

major depressive disorder, adults living alone, stacked ensemble technique, machine learning, US NHANES

1 Introduction

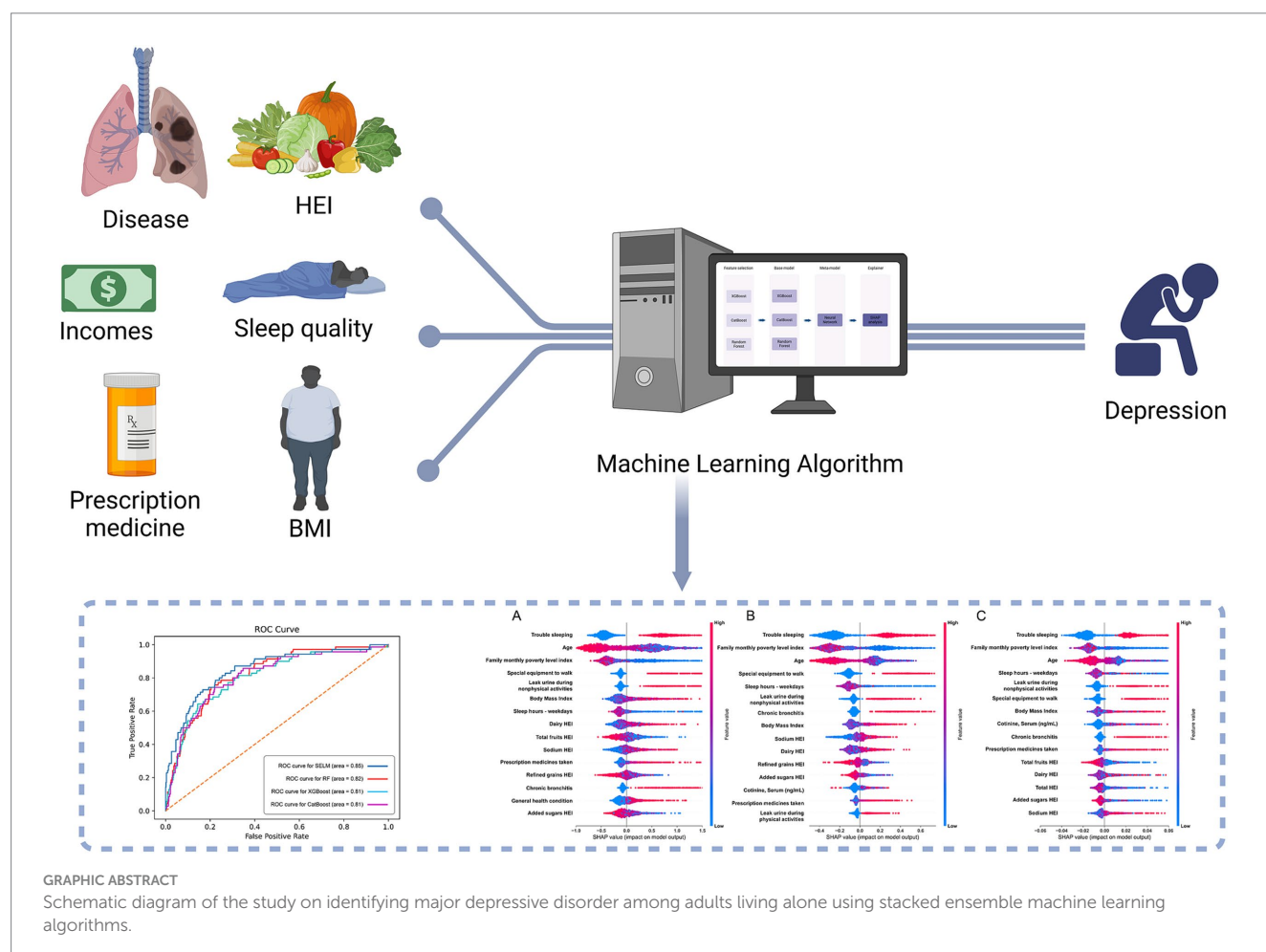
The past decade has witnessed a surge in the number of individuals living alone in the United States (U.S.), with a significant increase of 4.7 million to a total of 37.9 million from 2012 to 2022. This shift has garnered considerable attention due to the well-established link between living arrangements and mental health outcomes, particularly concerning Major Depressive Disorder (MDD). Recent research findings indicate a higher prevalence of MDD among adults living alone in the U.S. (6.4%) compared to those residing with others (4.1%) (1).

Major Depressive Disorder (MDD) is a prevalent mental health conditions marked by persistent mood lows, diminished interest, and a variety of affective, cognitive, somatic, and behavioral symptoms. These symptoms can profoundly impair psychosocial functioning and greatly diminish quality of life (2). The global prevalence of MDD has steadily risen over the past three decades, affecting approximately 5% of the adult population (3). It ranks as one of the leading causes of disability worldwide, contributing significantly to the overall burden of disease (4).

The therapy of MDD poses a challenge due to its heterogeneous nature (5). Key to improving patient prognosis is early detection and

intervention. Unfortunately, stigma surrounding mental health assessments, inadequate mental health resources, and the common practice of concealing symptoms complicate the timely recognition and prediction of MDD (6). Although numerous studies have developed predictive models for MDD (6–10) to enhancing the likelihood of detection, there is currently a dearth of MDD predictive models specifically tailored for adults living alone.

Machine learning has demonstrated remarkable effectiveness in medical prediction (11), and is increasingly used in medical diagnostics (12). Machine learning models can adaptively learn from data to identify complex, nonlinear patterns (13). Furthermore, these models offer high interpretability, allowing researchers to understand model behavior and how decisions are made through various visualization and explanatory techniques (14, 15). Ensemble learning is a machine learning paradigm that enhances prediction accuracy by aggregating the predictions from several base models. It reduces the risk associated with individual models by combining their opinions, typically resulting in more accurate and robust predictions (16). The most common ensemble strategies include voting, averaging, stacking, and boosting. Among them, stacking has demonstrated strong predictive ability in tackling complex problems



(17, 18). Nevertheless, to date, there is a dearth of research on the application of stacking in predicting the presence of MDD among adults living alone.

Therefore, we propose a stacked ensemble machine learning (SEML) model, utilizing data from the US National Health and Nutrition Examination Survey (NHANES), to predict MDD in adults living alone. We compared the performance of our SEML model with single machine learning models. Furthermore, we explored the interaction between predictors and the presence of MDD via the application of SHapley Additive exPlanations (SHAP) analysis. We aim to make a contribution to the field of MDD prediction in adults living alone and provide valuable insights for potential interventions and treatments.

2 Methods

2.1 Study design and participants

This cross-sectional study utilizes publicly available data from the US NHANES, an ongoing health-related initiative conducted periodically by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC). The NCHS Ethics Review Board (ERB) approved the protocol for US NHANES, and all participants provided written informed consent (19).

Our study included data from respondents surveyed between 2007 and 2018. Living arrangements were evaluated by the number of people in the household, with only one person defined as living alone. Respondents under 18 years old, living with others, or with incomplete data were excluded.

2.2 Definition of MDD

MDD was evaluated using the Patient Health Questionnaire-9 (PHQ-9), which is based on the diagnostic criteria for MDD illustrated in the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). The PHQ-9 has been widely recognized for its accuracy in screening for MDD (20), with a score of 10 or higher indicating clinically significant symptoms (21). Therefore, in this study, we utilized a PHQ-9 score of 10 as the threshold for defining MDD.

2.3 Selection of predictors

The initial phase of the study included 72 feature variables related to demographic profiles, lifestyle factors, and baseline health conditions. Subsequently, a rigorous feature selection process was conducted, resulting in the identification of a subset of 30 variables for constructing the final predictive model. Within the initial pool of 72 variables, demographic characteristics encompassed participants' age, gender, race, marital status, citizenship status, educational level, employment status, and income level. Lifestyle factors encompassed dietary quality, physical activity level, sleep patterns, and smoking habits. Dietary quality was assessed using the Healthy Eating Index-2020 (HEI-2020) (22), following the methodology proposed by Zhan et al. (23). Physical activity level was quantified by calculating

participants' weekly metabolic equivalent task (MET) minutes, derived from multiplying the MET values of specific physical activities by their respective weekly frequency and duration. The determination of the remaining variables relied on participants' detailed responses to interview questions. Baseline health status was assessed based on participants' medication usage and the presence of various diseases.

2.4 Statistical analysis

In our study, the raw data from the US NHANES database was used to construct machine learning models. Continuous variables were presented as means with standard deviations (SD), while categorical variables were displayed as counts and percentages. The statistical significance of differences in continuous and categorical variables was evaluated using independent t-tests and Chi-square tests, respectively, with a significance threshold set at a two-sided *p*-value of less than 0.05.

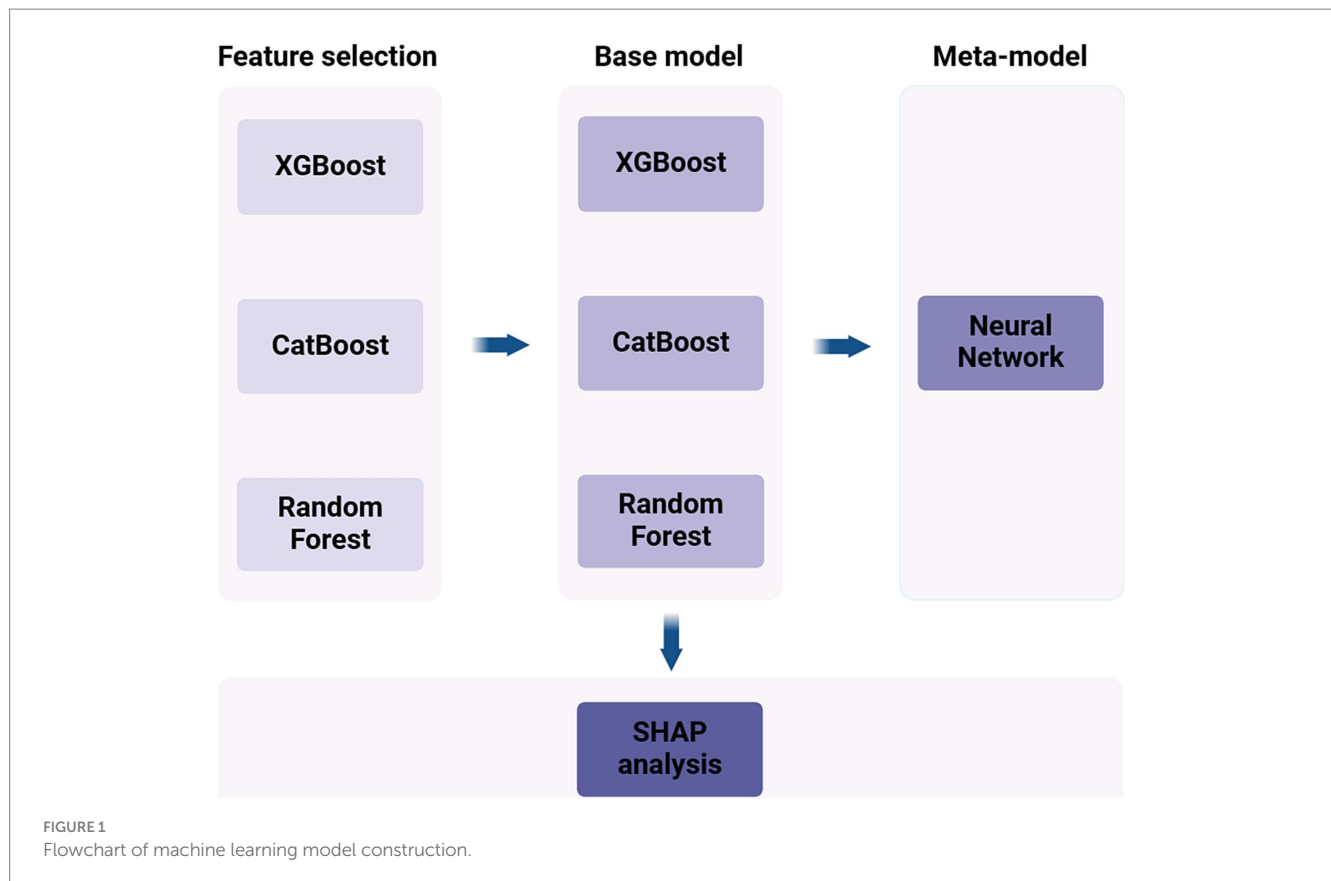
2.5 Model construction

In our study, a stratified sampling method was adopted to ensure an even distribution of MDD cases across different groups. The dataset was split into a training set, comprising 80% of the participants, and a test set, comprising the remaining 20%. To create the SEML model, we incorporated three algorithms as base models, including eXtreme Gradient Boosting (XGBoost), Categorical Boosting (CatBoost), and Random Forest (RF). Additionally, a Neural Network (NN) was designated as the meta-model (Figure 1). Both XGBoost and CatBoost belong to the Gradient Boosting Decision Trees (GBDT) algorithm, which employs ensemble learning to combine multiple decision trees using an additive model for predictions. RF represents another ensemble learning approach that enhances predictive power through voting or averaging the results of several decision trees. NN, a deep learning technique, process data by simulating the connections between biological neurons, making them adept at capturing complex nonlinear relationships. In this study, we integrated the aforementioned methods through SEML technique to fully leverage the strengths of each model and improve overall predictive performance.

Firstly, we employed the base models to select the top 30 variables in terms of importance out of the initial set of 72 variables. The feature importance was calculated by normalizing and summing the importance values from three different models. Both 10-fold cross-validation and Bayesian optimization were utilized by us for hyperparameter tuning and model evaluation (Details of the model hyperparameter settings are provided in the [Supplementary materials](#)). To enhance the predictive accuracy of the models, we performed normalization on the dataset. Additionally, the technique of Synthetic Minority Over-sampling Technique (SMOTE) was employed to mitigate class imbalance between MDD and non-MDD instances in the training data.

During the training phase, we utilized the predictions generated by each base model as input features for training the meta-model. When it came to the testing phase, the base models that had been trained were used to predict the test set. These predictions were then incorporated as input features to make the final prediction using the meta-model.

The assessment of model performance in this study employed the area under the Receiver Operating Characteristic (ROC) curve as the



primary metric. Sensitivity, specificity, Youden index, and F1-score were also calculated at the optimal threshold to provide a comprehensive assessment. Furthermore, to elucidate the individual variables' contributions and their importance in the model's predictions, SHapley Additive exPlanations (SHAP) analysis was conducted.

All procedures were implemented in Python version 3.12.4.¹

3 Study results and findings

3.1 Participant inclusion

38,788 respondents were initially selected from the 2007–2018 US NHANES data. 9,429 participants under the age of 18 were excluded from the study. A further 26,717 participants were excluded due to incomplete data or residing with others. Finally, a total of 2,642 participants were included in the study (Figure 2).

3.2 General characteristics

Among these participants, 10.6% (279/2,642) of them had a PHQ-9 score of 10 or higher. No significant differences were observed in age ($p = 0.2$), marital status ($p = 0.287$), race ($p = 0.644$) and citizenship status ($p = 0.315$) between participants with and without MDD. Notable

differences were found in gender ($p < 0.001$), education level ($p < 0.001$), employment status ($p < 0.001$) and family monthly poverty level index ($p < 0.001$; Table 1).

3.3 Included predictors

The final set of 30 feature variables integrated into the predictive model could be categorized as follows: demographic characteristics, including DMDMARTL, RIDAGEYR, IND235, and INDFMMPI; lifestyle factors, including HEI2020_ALL, HEI2020_DAIRY, HEI2020_ADDEDSUGAR, HEI2020_FATTYACID, HEI2020_FRT, HEI2020_GREENNBEAN, HEI2020_SODIUM, HEI2020_REFINEDGRAIN, HEI2020_SATFAT, HEI2020_SEAPLANTPRO, HEI2020_TOTALFRT, HEI2020_TOTALPRO, HEI2020_VEG and HEI2020_WHOLEGRAIN, LBXCOT, PAD680, TPA, SLD012, and SLQ050; Baseline health status, which encompassed BMXBMI, RXDDAYS, RXDCOUNT, PFQ054, MCQ160k, KIQ046, and HSD010. For more detailed information on each feature, please refer to Table 2.

3.4 Performance of machine learning models

The ROC curve analysis revealed that SEML model performed the best among the evaluated models, as evidenced by an AUC value of 0.85 (95% CI 0.84–0.88), Followed by the RF model, which achieved an AUC of 0.82 (95% CI 0.80–0.83), while the AUC values for the CatBoost and XGBoost models were 0.81 (95% CI 0.78–0.84) and 0.81 (95% CI 0.77–0.85), respectively (Figure 3). Moreover, when considering the optimal

¹ <https://www.python.org/downloads/release/python-3124/>

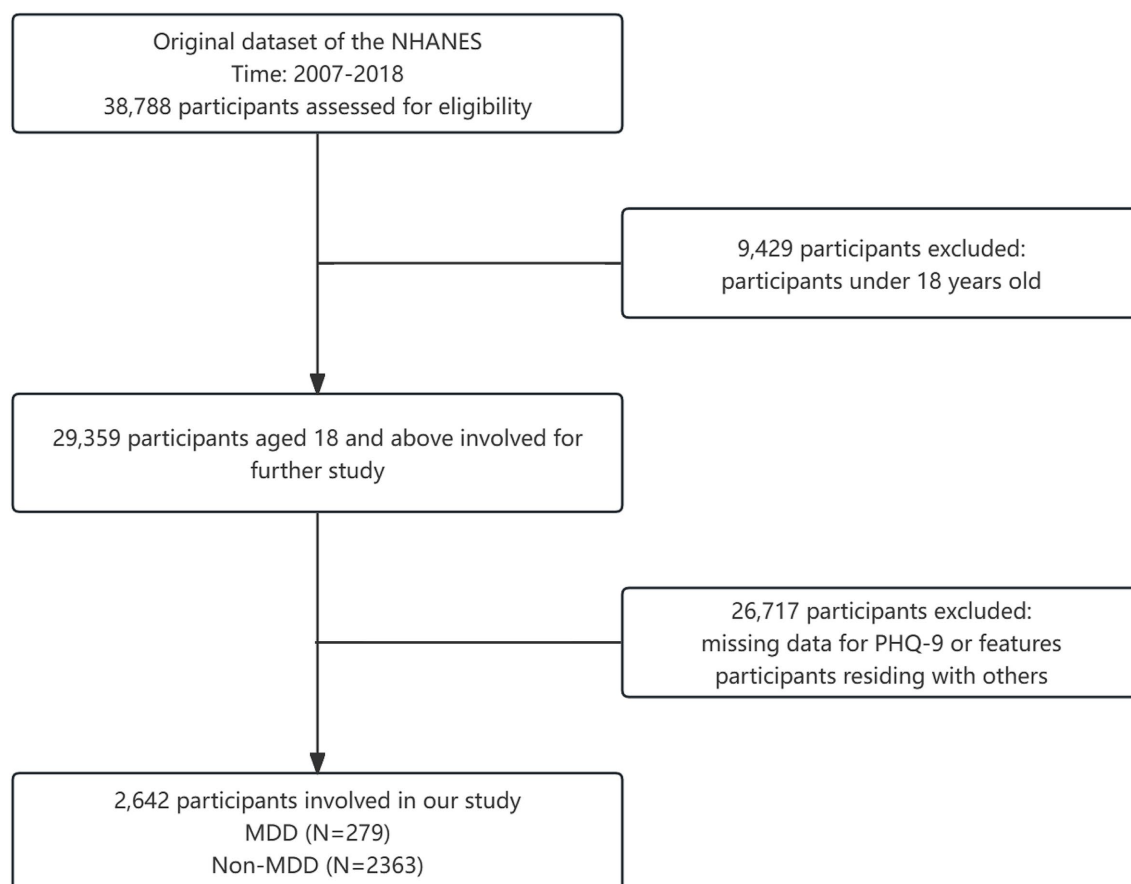


FIGURE 2
Flowchart of participants inclusion.

threshold, the SEML model exhibited superior performance in terms of sensitivity, Youden index, and F1 score, with values of 0.79, 0.57, and 0.50, respectively. Furthermore, the SEML model demonstrated a specificity of 0.78, which was marginally lower than the specificity of the XGBoost model, recorded at 0.86. Detailed results were recorded in Table 3.

3.5 Importance of predictive features

In this study, we utilized SHAP analysis to determine the importance ranking of the features included in the base models. We summarized the top 15 features in terms of importance in the base models, and the detailed analysis results are presented in Figure 4. Across all three base models, the top 15 features consistently included SLQ050, SLD012, RIDAGEYR, INDFMMPI, BMXBMI, PFQ054, KIQ046, MCQ160K, HEI2020_SODIUM, HEI2020_DAIRY, and HEI2020_ADDSUGAR, amounting to a total of 12 features. Please refer to Table 3 for detailed interpretation regarding the code.

3.6 Features impact on MDD

By conducting SHAP analysis, we had effectively delineated the positive and negative impacts exerted by each feature on the

occurrence of MDD. As illustrated in Figure 4, a set of features, namely SLQ050, PFQ054, KIQ046, BMXBMI, RXDCOUNT, HEI2020_DAIRY, HEI2020_SODIUM, MCQ160K, and HSD010 exhibited a positive correlation with the occurrence of MDD, whereas features such as RIDAGEYR, INDFMMPI, and HEI2020_ADDSUGAR manifested a negative correlation. Subsequent SHAP dependency analysis further corroborated these findings, as depicted in Figures 5, 6. Specifically, an augmentation in the values of features such as RXDCOUNT and HEI2020_SODIUM was concomitant with an escalated risk of developing MDD. Conversely, an escalation in the values of RIDAGEYR, INDFMMPI, and HEI2020_ADDSUGAR was linked to a diminished risk of MDD. Additionally, the dependence plot of SLQ012, BMXBMI, and HEI2020_DAIRY revealed a U-shaped relationship between their feature values and the occurrence of MDD. These findings aligned with the data presented in the SHAP summary plots, which depicted the influence of these features on MDD occurrence as a relatively complex interplay of both positive and negative impacts.

4 Discussion

Despite the existence of numerous studies utilizing machine learning methods to predict the occurrence of MDD (24–26), there

TABLE 1 Baseline characteristics according to depression or not.

	Non-depression (N = 2,363)	Depression (N = 279)	Total (N = 2,642)	p-value
Gender				
Male	1,057 (44.7%)	113 (40.5%)	1,170 (44.3%)	<0.001
Female	1,306 (55.3%)	166 (59.5%)	1,472 (55.7%)	
Age (year)				
Mean (SD)	60.2 (16.5)	56.4 (14.9)	59.8 (16.4)	0.2
Median [Min, Max]	63.0 [20.0, 80.0]	59.0 [20.0, 80.0]	63.0 [20.0, 80.0]	
Education level				
Less than 9th grade	133 (5.6%)	26 (9.3%)	159 (6.0%)	<0.001
9-11th grade	268 (11.3%)	50 (17.9%)	318 (12.0%)	
High school graduate/GED or equivalent	572 (24.2%)	59 (21.1%)	631 (23.9%)	
Some college or AA degree	735 (31.1%)	95 (34.1%)	830 (31.4%)	
College graduate or above	655 (27.7%)	49 (17.6%)	704 (26.6%)	
Marital status				
Married or Living with partner	75 (3.2%)	8 (2.9%)	83 (3.1%)	0.287
Widowed, divorced or separated	1,619 (68.5%)	204 (73.1%)	1823 (69.0%)	
Never married	669 (28.3%)	67 (24.0%)	736 (27.9%)	
Race				
Mexican American	209 (8.8%)	28 (10.0%)	237 (9.0%)	0.644
Other Hispanic	189 (8.0%)	27 (9.7%)	216 (8.2%)	
Non-Hispanic White	1,192 (50.4%)	135 (48.4%)	1,327 (50.2%)	
Non-Hispanic Black	598 (25.3%)	73 (26.2%)	671 (25.4%)	
Other Race - Including Multi-Racial	175 (7.4%)	16 (5.7%)	191 (7.2%)	
Citizenship status				
Citizen by birth or naturalization	145 (6.1%)	22 (7.9%)	167 (6.3%)	0.315
Not a citizen of the US	2,218 (93.9%)	257 (92.1%)	2,475 (93.7%)	
Employment status				
Employed	1,027 (43.5%)	81 (29.0%)	1,108 (41.9%)	<0.001
Unemployed	1,336 (56.5%)	198 (71.0%)	1,534 (58.1%)	
Family monthly poverty level index				
Mean (SD)	2.27 (1.51)	1.58 (1.34)	2.20 (1.51)	<0.001
Median [Min, Max]	1.81 [0, 5.00]	1.11 [0, 5.00]	1.69 [0, 5.00]	

remains a lack of research specifically focused on predicting MDD among adults living alone. Furthermore, many prediction models rely heavily on comprehensive clinical evaluations and laboratory data (9, 27), which limits their applicability. To address these limitations, this study is the first to focus on the population of adults living alone, utilizing easily accessible predictive variables from the US NHANES database to construct an MDD prediction model. This model incorporates 30 features related to demographic characteristics, lifestyle factors, and baseline health conditions. By

employing a stacked ensemble technique, the model achieved an AUC value of 0.85, providing a new tool for predicting MDD in adults living alone.

To elucidate the contribution of each variable in the model's predictions, we conducted SHAP analysis, a method based on game theory. The core idea is to calculate Shapley values to quantify each feature's contribution to the prediction outcome, thereby enhancing the model's transparency and interpretability. This helps researchers and decision-makers better understand the impact of

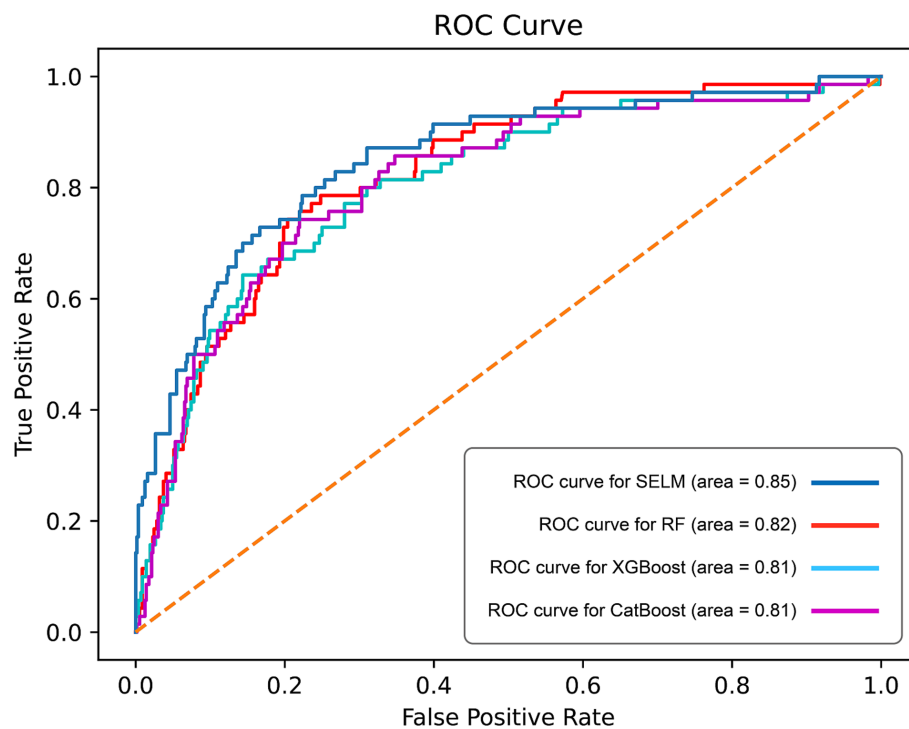


FIGURE 3

Curves of receiver operating characteristic (ROC) of different algorithms in test set. ROC, receiver operating characteristic; AUC, Area Under the Curve.

different factors on the prediction results. Provides valuable insights for potential intervention and treatment strategies for MDD in adults living alone (28).

Compared to previous studies focused on the general adult population, our research identifies that, in addition to common influencing factors such as age, sleep, and income, daily sodium intake, added sugars, and dairy consumption are also significant factors affecting MDD in adults living alone. Furthermore, physical health factors such as mobility issues, urinary incontinence during non-physical activities, and chronic bronchitis also have important impacts on MDD (2, 27).

Firstly, within the demographic variables incorporated into our final predictive model, a significant correlation was observed between age and MDD occurrence. The SHAP dependence curve demonstrated a progressive decline in MDD risk with advancing age as participants aged 50 and above. Subsequently, as participants reached the age range of 60 to 65, we observed a shift in SHAP values from positive to negative, suggesting a potential protective effect of advanced age on the occurrence of MDD. This observation aligns with previous research by Villamil et al., who reported a significant reduction in MDD prevalence among women over 60 and men over 65 (29). Based on these findings, we can infer that individuals under 60 living alone face a higher risk of MDD compared to their older counterparts. Moreover, the Family Monthly Mean Poverty Index (FMMPI) of the participants emerged as a significant predictive feature. The SHAP dependence curve revealed a progressive decline in MDD risk as FMMPI increased within the range of 0 to 2. Previous studies have consistently demonstrated that lower income levels are typically

associated with a heightened risk of MDD (30–32). Our findings further support this perspective, underscoring that adults living alone with a FMMPI below 2 are more vulnerable to MDD.

Regarding lifestyle characteristics, our findings underscore that both sleep quality and dietary quality are pivotal predictors of the occurrence of MDD. Prior study by Zhang et al. has identified sleep disorders as risk factors for secondary depression (33). Additionally, research by Baglioni et al. has shown that individuals with insomnia face a doubled risk of developing depression compared to those without sleep problems (34). Our current analysis employing SHAP reveals a positive correlation between sleep disorders and MDD occurrence, highlighting sleep disorders as significant risk factors for MDD among adults living alone. Another feature reflecting participants' sleep status is sleep duration. In this study, the SHAP dependence curves displayed a U-shaped relationship between sleep duration and MDD occurrence. Notably, the lowest SHAP values are observed within a sleep duration of 7–8 h. This finding aligns with the conclusions drawn by Zhang et al., that individuals with an 8-h sleep duration exhibit the lowest risk of depression (35). Consequently, modifying sleep duration among adults living alone may potentially yield a substantial reduction in the risk of MDD occurrence. Regarding dietary quality, we employed the HEI scores to quantify the intake of various components. Through SHAP analysis, significant correlations were identified between the HEI scores for added sugar, dairy, and sodium components and the occurrence of MDD among adults living alone. Firstly, an inverse association was observed with the occurrence of MDD when HEI scores for added sugar exceeded 5. This finding aligns

TABLE 2 Explanation of the predictors used in this study.

Code	Variable type	Label	Involvement/Exclusion
BMXBMI	Continuous variables	Body Mass Index (kg/m**2)	Involvement
BPQ020	Categorical variables	Ever told you had high blood pressure	Exclusion
DIQ010	Categorical variables	Doctor told you have diabetes	Exclusion
DMDCITZN	Categorical variables	Citizenship status	Exclusion
DMDEDUC2	Categorical variables	Education level - Adults 20+	Exclusion
DMDMARTL	Categorical variables	Marital status	Involvement
HEI2020_ADDEDSUGAR	Continuous variables	Added sugars HEI	Involvement
HEI2020_ALL	Continuous variables	Total Healthy Eating Index (HEI)	Involvement
HEI2020_DAIRY	Continuous variables	Dairy HEI	Involvement
HEI2020_FATTYACID	Continuous variables	Fatty acids HEI	Involvement
HEI2020_FRT	Continuous variables	Whole fruits HEI	Involvement
HEI2020_GREENNBEAN	Continuous variables	Greens and beans HEI	Involvement
HEI2020_REFINEDGRAIN	Continuous variables	Refined grains HEI	Involvement
HEI2020_SATFAT	Continuous variables	Saturated fats HEI	Involvement
HEI2020_SEAPLANTPRO	Continuous variables	Seafood and plant proteins HEI	Involvement
HEI2020_SODIUM	Continuous variables	Sodium HEI	Involvement
HEI2020_TOTALFRT	Continuous variables	Total fruits HEI	Involvement
HEI2020_TOTALPRO	Continuous variables	Total protein foods HEI	Involvement
HEI2020_VEG	Continuous variables	Total vegetables HEI	Involvement
HEI2020_WHOLEGRAIN	Continuous variables	Whole grains HEI	Involvement
HSD010	Categorical variables	General health condition	Involvement
HSQ500	Categorical variables	SP have head cold or chest cold	Exclusion
HSQ510	Categorical variables	SP have stomach or intestinal illness?	Exclusion
HSQ520	Categorical variables	SP have flu, pneumonia, ear infection?	Exclusion
HSQ571	Categorical variables	SP donated blood in past 12 months?	Exclusion
IND235	Categorical variables	Monthly family income	Involvement
INDFMMP	Categorical variables	Family monthly poverty level category	Exclusion
INDFMMP	Continuous variables	Family monthly poverty level index	Involvement
INQ012	Categorical variables	Income from self-employment	Exclusion
INQ020	Categorical variables	Income from wages/salaries	Exclusion
INQ030	Categorical variables	Income from Social Security or RR	Exclusion
INQ060	Categorical variables	Income from other disability pension	Exclusion
INQ080	Categorical variables	Income from retirement/survivor pension	Exclusion
INQ090	Categorical variables	Income from Supplemental Security Income	Exclusion
INQ132	Categorical variables	Income from state/county cash assistance	Exclusion
INQ140	Categorical variables	Income from interest/dividends or rental	Exclusion

(Continued)

TABLE 2 (Continued)

Code	Variable type	Label	Involvement/Exclusion
INQ150	Categorical variables	Income from other sources	Exclusion
KIQ022	Categorical variables	Ever told you had weak/failing kidneys	Exclusion
KIQ042	Categorical variables	Leak urine during physical activities	Exclusion
KIQ046	Categorical variables	Leak urine during nonphysical activities	Involvement
LBXCOT	Continuous variables	Cotinine, Serum (ng/mL)	Involvement
MCQ010	Categorical variables	Ever been told you have asthma	Exclusion
MCQ160a	Categorical variables	Doctor ever said you had arthritis	Exclusion
MCQ160b	Categorical variables	Ever told had congestive heart failure	Exclusion
MCQ160c	Categorical variables	Ever told you had coronary heart disease	Exclusion
MCQ160d	Categorical variables	Ever told you had angina/angina pectoris	Exclusion
MCQ160e	Categorical variables	Ever told you had heart attack	Exclusion
MCQ160f	Categorical variables	Ever told you had a stroke	Exclusion
MCQ160g	Categorical variables	Ever told you had emphysema	Exclusion
MCQ160k	Categorical variables	Ever told you had chronic bronchitis	Involvement
MCQ160l	Categorical variables	Ever told you had any liver condition	Exclusion
MCQ160m	Categorical variables	Ever told you had thyroid problem	Exclusion
MCQ220	Categorical variables	Ever told you had cancer or malignancy	Exclusion
MCQ300A	Categorical variables	Close relative had heart attack?	Exclusion
MCQ300B	Categorical variables	Close relative had asthma?	Exclusion
MCQ300C	Categorical variables	Close relative had diabetes?	Exclusion
OCQ150	Categorical variables	Type of work done last week	Exclusion
PAD680	Continuous variables	Minutes sedentary activity	Involvement
PFQ049	Categorical variables	Limitations keeping you from working	Exclusion
PFQ054	Categorical variables	Need special equipment to walk	Involvement
RIAGENDR	Categorical variables	Gender	Exclusion
RIDAGEYR	Continuous variables	Age in years at screening	Involvement
RIDRETH1	Categorical variables	Race/Hispanic origin	Exclusion
RPA	Continuous variables	Recreational physical activities	Exclusion
RXDCOUNT	Categorical variables	Number of prescription medicines taken	Involvement
RXDDAYS	Categorical variables	Number of days taken medicine	Involvement
RXDUSE	Categorical variables	Taken prescription medicine, past month	Exclusion
SLD012	Continuous variables	Sleep hours - weekdays or workdays	Involvement
SLQ050	Categorical variables	Ever told doctor had trouble sleeping?	Involvement

(Continued)

TABLE 2 (Continued)

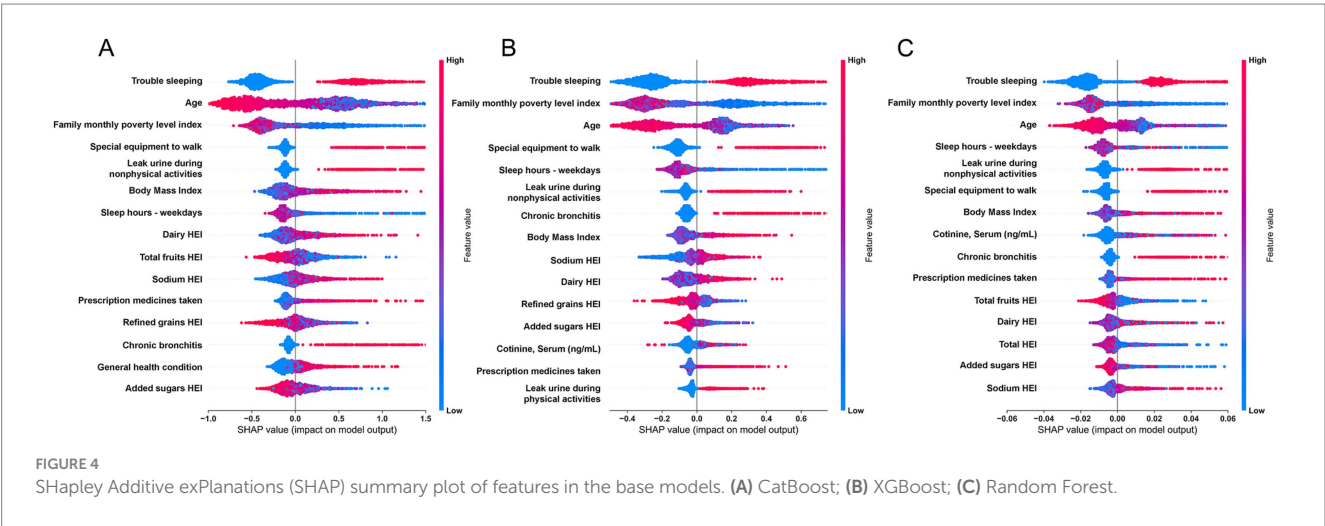
Code	Variable type	Label	Involvement/Exclusion
SMQ680	Categorical variables	Used tobacco/nicotine last 5 days?	Exclusion
SMS	Categorical variables	Smoking status	Exclusion
TPA	Continuous variables	Total physical activity	Involvement
WPA	Continuous variables	Work-related physical activity	Exclusion

HEI, Health Eating Index.

TABLE 3 Performance evaluation of machine learning algorithms.

	AUC	Sensitivity	Specificity	Youden index	F1-score
SEML	0.85	0.79	0.78	0.57	0.50
CatBoost	0.81	0.74	0.78	0.52	0.47
XGBoost	0.81	0.64	0.86	0.50	0.46
RF	0.82	0.74	0.80	0.54	0.45

AUC, Area Under the Curve; SEML, Stacking Ensemble Machine Learning; CatBoost, Categorical Boosting; XGBoost, eXtreme Gradient Boosting; RF, Random Forest.



with prior research, which indicates that excessive intake of added sugars can have adverse effects on mental health and increase the risk of developing MDD (36, 37). Secondly, for sodium intake, a positive correlation was observed with the occurrence of MDD when HEI scores exceeded 2, indicating a potential link between low sodium diets and increased risk of MDD in adults living alone. This finding is consistent with findings from animal studies, which suggest that insufficient sodium intake may induce depressive symptoms, alleviated by sodium supplementation (38, 39). However, it is noteworthy that while these results from animal experiments exist, current limited human studies only support this inverse relationship between sodium intake and depression among females (40). Thus, the present findings still require further validation through larger, more rigorously designed studies. Lastly, regarding dairy intake, a U-shaped relationship was found between dairy intake and MDD occurrence. Specifically, the lowest contribution to MDD risk was observed when HEI scores reached 5, emphasizing that both excessive and insufficient dairy intake are closely associated with the occurrence of MDD in adults living alone. Given the

current insufficiency of research on the relationship between dairy products and depression, particularly lacking longitudinal studies targeting the US population, we cannot yet determine a causal relationship between the two. These findings underscore the necessity for future research.

Moreover, this study has confirmed a series of baseline health conditions as key predictors for MDD. we systematically identified multiple health indicators closely associated with MDD occurrence. Firstly, body mass index (BMI), a common measure assessing whether an individual's weight falls within a healthy range, shows a significant correlation with MDD risk. SHAP dependence curves indicate that elevated BMI ($\text{BMI} > 25 \text{ kg/m}^2$) is positively correlated with an increased risk of MDD, aligning with findings from previous epidemiological and clinical studies, which have shown that individuals who are overweight or obese have a higher risk of MDD (41–43). Conversely, a moderate BMI ($18\text{--}25 \text{ kg/m}^2$) appears to have a protective effect. This highlights the critical role of weight management in preventing MDD among adults living alone. Secondly, the number of prescription medications has also been identified as an important predictive

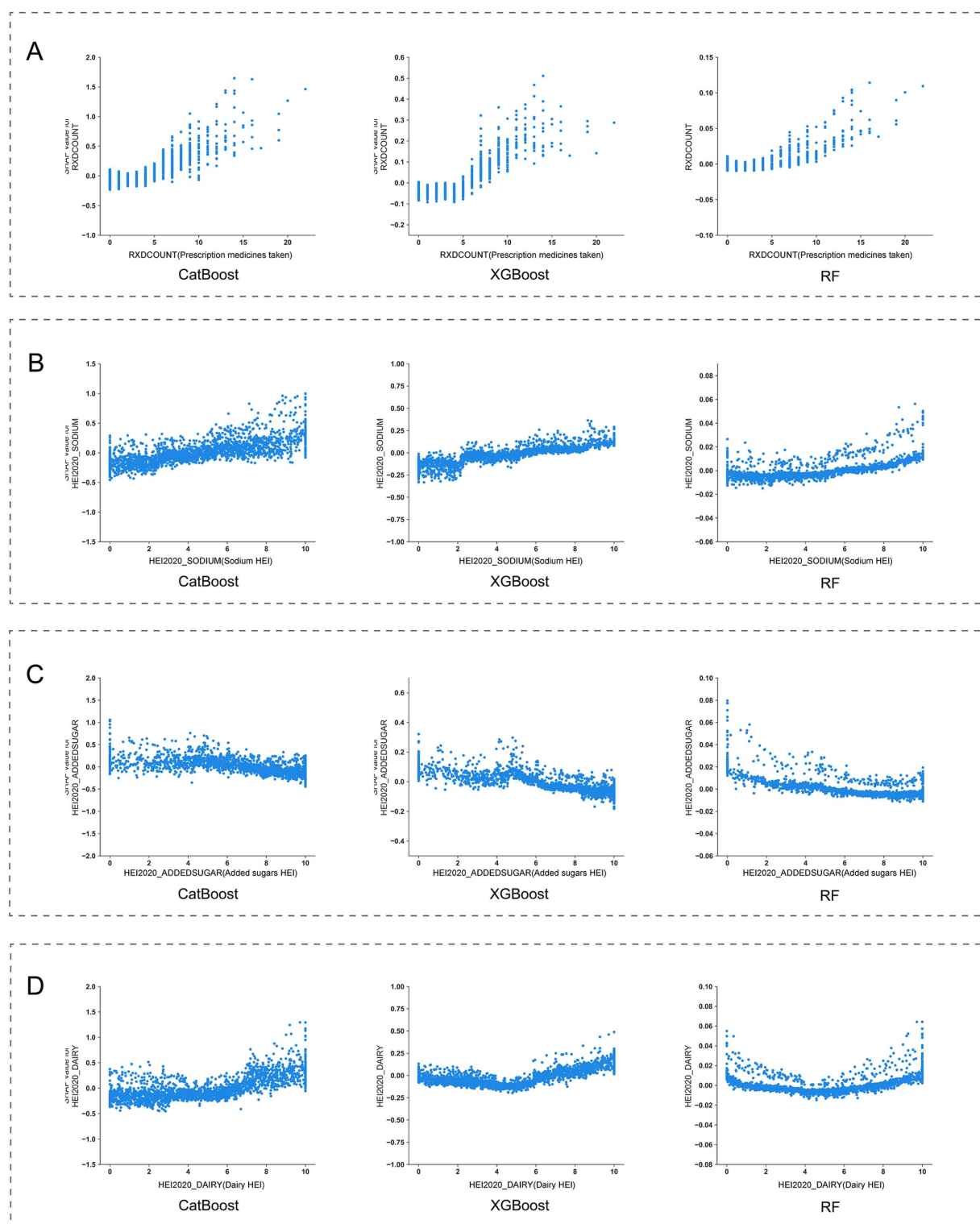


FIGURE 5
SHapley Additive exPlanations (SHAP) dependence plot of features in the base models. (A) RIDAGEYR; (B) BMXBMI; (C) SLD012; (D) INDFMMP1.

feature. Generally, an increase in the number of prescription medications indicates potentially more complex health conditions among participants. In this study, we observed that the risk of MDD significantly rises when the number of prescription medications reaches five or more, indicating the need for special

attention to mental health issues among adults living alone who require multiple medications. Additionally, the study found significant associations between the risk of MDD and the need for specific walking aids, symptoms of leak urine during nonphysical activities, and chronic bronchitis conditions.

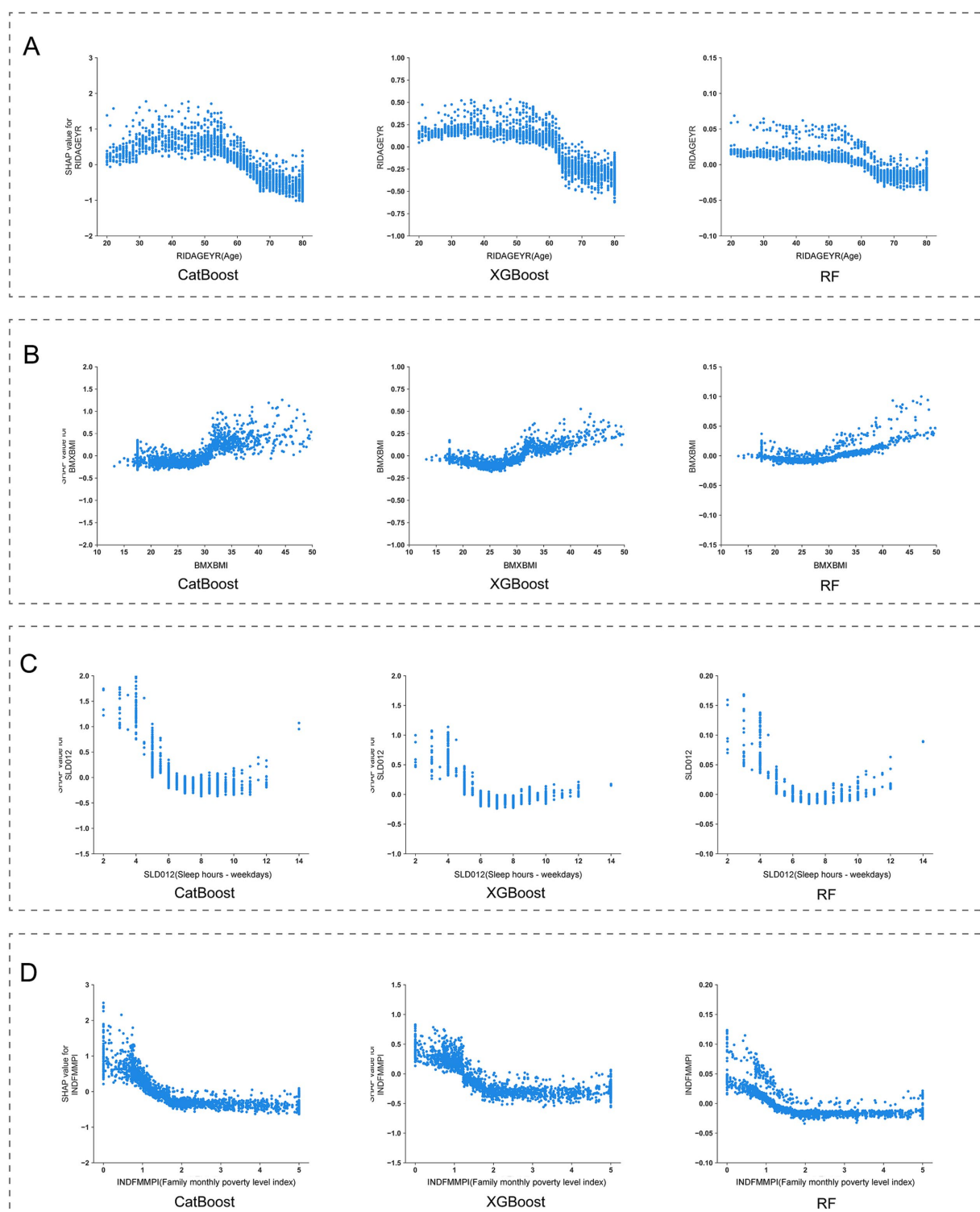


FIGURE 6
SHapley Additive exPlanations (SHAP) dependence plot of features in the base models. (A) RXDCOUNT; (B) HEI2020_SODIUM; (C) HEI2020_ADDEDSUGAR; (D) HEI2020_DAIRY.

Changes in these participants' physiological functions may indirectly increase the risk of MDD by affecting their quality of life. However, the causal relationships between these factors and MDD require further longitudinal research to be confirmed.

In summary, the findings presented above demonstrate that our model's results are interpretable and meaningful. These outcomes not

only corroborate the algorithm's efficacy in predicting MDD but also offer a reference for the development of public health policies.

There are several limitations found in the current study. Firstly, the data utilized in this research was sourced exclusively from the US NHANES database, which contains information on the US population only. Therefore, caution ought to be applied when generalizing the

predictive model to other countries. Secondly, the cross-sectional design of the study necessitates a high-quality prospective research to delve into the causal relationship between the identified predictors and the occurrence of MDD.

In conclusion, this study has successfully constructed a predictive model for MDD specifically tailored for adults living alone by applying stacked ensemble technique. Through SHAP analysis, the research thoroughly dissected the complex interplay among various predictors and MDD, providing a scientific reference for the development of personalized and effective intervention strategies.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: <https://www.cdc.gov/nchs/nhanes>.

Ethics statement

Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/ participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

ZC: Conceptualization, Writing – original draft, Writing – review & editing. HL: Writing – original draft, Writing – review & editing. YZ: Methodology, Software, Writing – review & editing. FX: Formal analysis, Methodology, Writing – review & editing. JJ: Formal analysis, Methodology, Writing – review & editing. ZX: Funding acquisition, Supervision, Writing – review & editing. XD: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2025.1472050/full#supplementary-material>

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Do interpersonal trust and social avoidance mediate the association between psychotic symptoms and social functioning in chronic schizophrenia patients?

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Objective: Schizophrenia is a complex mental disorder that significantly impacts social functioning. The present study aimed to investigate the relationship between psychotic symptoms and social functioning in individuals with chronic schizophrenia. Specifically, we examined the mediating roles of social avoidance and impaired interpersonal trust in this relationship, as these factors are most worrisome in individuals with schizophrenia.

Methods: A total of 223 outpatients with chronic schizophrenia and 201 unrelated healthy controls were included. The Positive and Negative Syndrome Scale (PANSS), the Interpersonal Trust Scale (ITS), the Social Avoidance and Distress Scale (SAD), and the simplified Chinese version of the Social Disability Screening Schedule (SDSS) were used for evaluation. Mediation analysis was performed using the PROCESS macro in SPSS23.0.

Results: Our results showed that individuals with chronic schizophrenia scored significantly lower on the ITS total and two index scores but higher on the SAD total and two index scores than healthy controls. The ITS score was significantly associated with the psychotic symptoms (both PANSS total score and subscale score) and social functioning in those patients. Interestingly, we further found that interpersonal trust had a significantly mediating effect on the relationship between psychotic symptoms (including positive, negative, cognitive, excited, and depressed symptoms) and social functioning in individuals with schizophrenia.

Conclusion: Our preliminary findings suggest that improving interpersonal trust may be a promising approach to enhance social functioning and improve prognosis in individuals with schizophrenia. This insight underscores the importance of incorporating trust-building interventions into clinical practice, which could potentially lead to better social outcomes for patients.

KEYWORDS

schizophrenia, psychotic symptoms, interpersonal trust, social avoidance, social functioning

1 Introduction

Schizophrenia is a severe mental illness that mainly characterized by positive symptoms (e.g., hallucinations, delusions, disorganized speech, and abnormal movements), negative symptoms (such as flattened affect, asociality, anhedonia, apathy, and lack of emotions), general pathology symptoms (e.g., depressive and anxious mood) and cognitive impairment (including attention, processing speed, memory, executive functioning, and social cognition) (1–3). It affects 1% of the world population and places huge economic burdens on patients, their families, and society as a whole (4). Currently, antipsychotic drugs are the main treatment for schizophrenia, which often have a good effect on improving positive symptoms but have little effect on negative symptoms and cognitive impairment (5). Moreover, negative symptoms and cognitive impairment are usually associated with poor social performance and personal functions, thus leading to a poor prognosis in these patients. Additionally, existing literature has demonstrated that positive and negative symptom severity or the lack of symptom improvement are crucial risk factors related to poor treatment compliance in individuals with schizophrenia (6). Given the adverse effects of psychiatric symptoms on functional outcomes in patients with schizophrenia, it is essential to identify and intervene in potential mediating factors that may influence this relationship and thus provide benefits to individuals with schizophrenia.

Building on this understanding, interpersonal trust emerges as a critical factor that could mediate the relationship between psychiatric symptoms and functional outcomes. Interpersonal trust has been described as a core dimension of cooperative, mutually beneficial interpersonal relationships and the basis for the development of a concept of fairness and moral identity among children and adolescents (7). It plays an essential role in almost all human relationships and is an essential behavior for developing and maintaining supportive social relationships and social interaction with others (8). The lack of interpersonal trust is significantly associated with poor social interaction and social avoidance (9), and such social avoidance can further reduce the potential benefits of social situations and result in problematic behavior and difficulty adapting to changes (10). Given the importance of interpersonal trust for adaptive psychosocial functioning, deficits in interpersonal trust have also been regarded as

a risk factor for psychopathology in adolescence (11). Prior studies have observed significant associations between interpersonal trust and conduct disorder, suicide, externalizing problems, and delinquency (12, 13). Moreover, ample evidence has demonstrated that interpersonal trust beliefs are strongly associated with mental illness, including depression (14), borderline personality disorder (11, 15), autism spectrum disorder (16), and schizophrenia (17). Previous studies employing the trust game have demonstrated reduced trust in individuals with schizophrenia (8, 18). Moreover, existing evidence has shown that interpersonal trust is also reduced in individuals at clinical high risk for psychosis and in healthy first-degree relatives of those with schizophrenia who have increased genetic risk for schizophrenia (19, 20). The above findings suggest that reduced trust is related to the risk for psychosis and may be an endophenotype of schizophrenia (20). Hence, more studies should be conducted to understand interpersonal trust in schizophrenia and explore its relationship to psychotic symptoms and their impact on functional outcomes in those patients.

To date, there are surprisingly few studies that have examined the link between interpersonal trust and psychotic symptoms in individuals with schizophrenia, especially in chronic patients. An early study included 39 adolescents with early psychosis and found that higher negative symptoms were significantly associated with lower interpersonal trust in the trust game, but there was no significant association between interpersonal trust and positive symptoms in those patients (21). Interestingly, another study with 24 schizophrenia patients suggested that the lack of interpersonal trust is attributable to their positive symptoms (17). Since there are limited and contradictory results, more research involving larger samples of patients with schizophrenia is warranted to further examine and clarify these relationships. In addition, whether reduced interpersonal trust presents in individuals with chronic schizophrenia should also be investigated.

Additionally, the relationships between interpersonal trust and social avoidance and social function in individuals with schizophrenia deserve considerable attention. Social avoidance is commonly seen in individuals with schizophrenia (22), and it was hypothesized that social avoidance may be a consequence of a diminished anticipatory pleasure or distress in response to psychotic experiences (23, 24). A recent study conducted among college students documented that interpersonal trust

closely interacted with social avoidance (9). Although substantial evidence supports that both interpersonal trust and social avoidance are predictors of adverse functional outcomes in schizophrenia (25–27), no study to date has explored the relationship between interpersonal trust and social avoidance in individuals with schizophrenia. Given the prevalence of interpersonal trust and social withdrawal in individuals with schizophrenia, clarifying the complex relationship between psychotic symptoms, interpersonal trust, social withdrawal, and social functioning in individuals with schizophrenia may help improve their prognosis.

Therefore, the purpose of the present study aimed to investigate: (1) whether patients with chronic schizophrenia experienced difficulties in interpersonal trust and social avoidance compared to healthy controls; (2) whether interpersonal trust is significantly correlated with psychotic symptoms, social avoidance and social functioning in these patients; and (3) whether interpersonal trust and social avoidance affect the relationship between psychotic symptoms and social functioning in these patients. It was hypothesized that individuals with chronic schizophrenia have reduced interpersonal trust and increased social avoidance compared to healthy controls and that interpersonal trust and social avoidance could mediate the role of psychotic symptoms on social functioning in individuals with schizophrenia.

2 Methods

2.1 Subjects

We recruited 223 chronic outpatients with schizophrenia from psychiatric hospitals (Wenzhou Kangning Hospital and the Second People's Hospital of Jiangning District, Nanjing). The criteria for selecting the participants were as follows: (1) meeting the diagnosis of schizophrenia based on the Structured Clinical Interview for DSM-5 (SCID) by two psychiatrists; (2) Han Chinese, aged 20–65 years; (3) had a disease duration of ≥ 36 months (28) and received fixed-dose antipsychotic treatment for at least 6 months prior to this study. The exclusion criteria were as follows: (1) had physical comorbidities, such as head trauma or intellectual disability; (2) had comorbid substance abuse or dependence; (3) refusal to participate in the study. A total of 201 unrelated healthy controls who were age and sex matched were recruited from the local community and underwent the SCID to exclude the presence of a current/past mental disorder. Each participant signed a written informed consent form, which was approved by the Institutional Ethical Committee for Clinical Research of Wenzhou Kangning Hospital. All procedures were conducted in strict accordance with the Declaration of Helsinki.

2.2 Clinical assessment

The Positive and Negative Syndrome Scale (PANSS) is a 30-item clinician-rated scale to measure the severity of the psychotic symptoms of individuals with schizophrenia. The five-factor model, including the

positive (items P1, P3, P5, G9), negative (items N1, N2, N3, N4, N6), cognitive/disorganized (items P2, N5, G11), excited (items P4, P7, G8, G14), and depressed (items G2, G3, and G6) factors, was used in the present study based on the previous literature and guidance from the European Psychiatry Association (29, 30). Two psychiatrists who received training sessions conducted the face-to-face interviews and maintained an inter-rater correlation coefficient greater than 0.8.

Interpersonal trust was assessed using the Interpersonal Trust Scale (ITS), which was developed by Rotter in 1967. It is a self-reporting tool consisting of 25 items on a 5-point scale (ranging from 1 = totally agree to 5 = totally disagree). Higher scores indicate higher amounts of trust, and factor analysis found two factors in the Chinese version of the ITS: trust in relatives and friends (special trust factor) and trust of indirectly related people (general trust factor) (31).

Social avoidance was evaluated using the Social Avoidance and Distress Scale (SAD) (Watson and Friend, 1969). It consists of 28 items, of which 14 are used to rate social avoidance and 14 are used to rate social distress. Items are self-rated on a “Yes–No” scale, with total scores ranging from 0 to 28. The total score reflects the tendency to avoid social interaction and the distress experienced as a result of social interaction, with higher scores indicating greater social discomfort and avoidance tendencies. The α -coefficient in this study was greater than 0.75, which indicated high reliability and validity.

The simplified Chinese version of the Social Disability Screening Schedule (SDSS) was used to measure the social, occupational, and psychological functioning of the patients. Each item was rated from 0 to 2, with a total score ranging from 0 to 20. Higher scores reflect worse social functioning. It works well in social functioning evaluations of individuals with schizophrenia and has been administered with good validity and reliability among Chinese samples (32).

2.3 Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences, version 23.0 (SPSS 23.0). The significance value was set at $P < 0.05$ in all two-tailed tests. We divided individuals with schizophrenia into a high interpersonal trust group and a low interpersonal trust group according to the mean score of the ITS of all patients. For the between-group comparison of demographic and clinical characteristics, the chi-squared test for categorical variables and the independent-sample t-test for continuous variables were applied. An analysis of covariance (ANCOVA) was used to control for confounding variables. Further, the Pearson correlation was performed to examine the correlation between clinical variables in the patients with schizophrenia and healthy controls. Bonferroni corrections were used for multiple tests. Finally, we tested whether interpersonal trust mediated the relationship between psychotic symptoms and social functioning in individuals with schizophrenia using the PROCESS macro in SPSS23.0. A standard procedure was followed using bootstrap sampling with 5,000 iterations, which produced 95% bias-corrected confidence intervals (CIs). The mediation effect was statistically significant if the bias-corrected CI did not include 0.

3 Results

3.1 Comparisons between chronic schizophrenia and healthy controls

Table 1 shows the demographic and clinical characteristics of the patients with chronic schizophrenia and healthy controls. There were no significant differences in age, sex, and height between the patients and controls (all $P > 0.05$). We found that individuals with schizophrenia had higher weights ($t = 4.356$, $P < 0.001$) but lower marriage rates ($X^2 = 36.924$, $P < 0.001$) compared to the healthy controls, thus, the weight and marital status were controlled for in the following analysis. Our results showed that the individuals with schizophrenia scored significantly lower on the ITS total and two index scores but higher on the SAD total and two index scores than the healthy controls (all $P < 0.001$). After controlling for age, sex, weight, and marital status, all these significant differences still remained in the multivariate analysis of covariance (all $P < 0.001$).

3.2 Comparisons between high interpersonal trust and low interpersonal trust patients

Table 2 shows the demographic and clinical characteristics of the high interpersonal trust and low interpersonal trust patients (107 vs. 116). There were no significant differences in age, sex, height, weight, marital status, family history, and age of onset

between these two groups (all $P > 0.05$). Compared to the low interpersonal trust patients, we found that the patients with high interpersonal trust had lower total score ($t = 6.185$, $P < 0.001$), and lower scores for the positive symptom subscale ($t = 2.809$, $P = 0.005$), negative symptom subscale ($t = 5.126$, $P < 0.001$), and general psychopathology subscale ($t = 5.829$, $P < 0.001$) of the PANSS. In addition, the high interpersonal trust patients had better social functioning ($t = 10.698$, $P < 0.001$) compared to the low interpersonal trust patients. After controlling for age, sex, and marital status, the differences in PANSS total and subscale scores, the ITS total and subscale score, and SDSS between these two patient groups remained significant (all $P < 0.05$). Curiously, our results found no significant differences in SAD total score and the social distress subscale and social avoidance subscale scores between these two patient groups (all $P > 0.05$).

3.3 Correlation analysis

Our results showed that ITS total score was negatively associated with the PANSS positive factor score ($r = -0.199$, $P = 0.003$), negative factor score ($r = -0.270$, $P < 0.001$), cognitive factor score ($r = -0.245$, $P < 0.001$), excited factor score ($r = -0.152$, $P < 0.023$) and total score ($r = -0.414$, $P < 0.001$), and SDSS score ($r = -0.653$, $P < 0.001$) in all patients. All the correlations remained significant ($P_{\text{Bonferroni}} < 0.05$) after the Bonferroni correction was performed except for the correlation between the ITS total score and PANSS excited factor score in the patients ($P_{\text{Bonferroni}} > 0.05$).

TABLE 1 Comparisons between schizophrenia patients and healthy controls.

	Healthy controls (N = 201)	Schizophrenia (N = 223)	t/ X^2	P
Age (year)	37.30 $\pm$ 9.75	37.98 $\pm$ 9.91	0.714	0.475
Sex			0.335	0.563
Male	98	115		
Female	103	108		
Height (cm)	167.02 $\pm$ 22.22	166.56 $\pm$ 7.63	0.290	0.772
Weight (Kg)	61.80 $\pm$ 12.38	67.11 $\pm$ 12.69	4.356	<0.001
Marital status			36.924	<0.001
Unmarried	75	149		
Married	126	74		
SAD total score	5.04 $\pm$ 1.89	12.52 $\pm$ 3.39	28.434	<0.001
Social distress	2.61 $\pm$ 1.41	6.33 $\pm$ 2.47	19.245	<0.001
Social avoidance	2.43 $\pm$ 1.19	6.18 $\pm$ 1.89	24.727	<0.001
ITS total score	99.55 $\pm$ 7.17	60.52 $\pm$ 15.10	34.515	<0.001
Special trust factor	51.08 $\pm$ 4.51	29.11 $\pm$ 9.73	30.309	<0.001
General trust factor	48.47 $\pm$ 4.44	31.41 $\pm$ 8.26	26.830	<0.001

Data are presented as Mean $\pm$ Standard deviation or Number.

ITS, the Interpersonal Trust Scale; SDSS, the Social Disability Screening Schedule.

TABLE 2 Comparisons between high interpersonal trust and low interpersonal trust patients.

	Low trust group (N = 116)	High trust group (N = 107)	t/X ²	P
Age (year)	37.18 ± 9.27	38.85 ± 10.54	1.258	0.210
Sex			2.437	0.118
Male	54	61		
Female	62	46		
Height (cm)	166.93 ± 8.41	166.15 ± 6.69	0.770	0.442
Weight (Kg)	68.02 ± 13.40	66.13 ± 11.85	1.116	0.266
Marital status			0.021	0.885
Unmarried	77	72		
married	39	35		
Family history			2.352	0.125
No	88	90		
Yes	28	17		
Age of onset (year)	24.22 ± 6.87	24.64 ± 7.91	0.424	0.672
PANSS	59.08 ± 12.07	48.24 ± 14.07	6.185	<0.001
Positive factor	7.84 ± 3.99	6.45 ± 3.21	2.870	0.005
Negative factor	12.04 ± 5.30	9.50 ± 4.34	3.939	<0.001
Cognitive/disorganized factor	6.05 ± 2.68	4.94 ± 2.33	3.282	0.001
Excited factor	5.89 ± 1.95	5.41 ± 1.89	1.852	0.065
Depressed factor	6.07 ± 2.43	4.38 ± 1.93	5.762	<0.001
SDSS	18.47 ± 4.23	11.86 ± 4.98	10.698	<0.001
SAD total score	12.55 ± 3.17	12.48 ± 3.62	0.165	0.869
Social distress	6.24 ± 2.34	6.43 ± 2.62	0.568	0.571
Social avoidance	6.31 ± 1.67	6.05 ± 2.10	1.040	0.299
ITS total score	48.46 ± 8.28	73.60 ± 8.44	22.443	<0.001
Special trust factor	22.10 ± 4.15	36.70 ± 8.22	16.526	<0.001
General trust factor	26.35 ± 7.30	36.90 ± 5.16	12.526	<0.001

Data are presented as Mean ± Standard deviation or Number.

PANSS, the Positive and Negative Syndrome Scale; ITS, the Interpersonal Trust Scale; SDSS, the Social Disability Screening Schedule.

There was no significant correlation between interpersonal trust and social avoidance in both the patients and healthy controls (all $P > 0.05$). Additionally, our results showed that PANSS total score, and positive factor, negative factor, cognitive factor, and excited factor subscale scores were all positively correlated with SDSS score (PANSS: $r = 0.417$, $P < 0.001$; positive factor: $r = 0.291$, $P < 0.001$; negative factor: $r = 0.256$, $P < 0.001$; cognitive factor: $r = 0.282$, $P < 0.001$; excited factor: $r = 0.161$, $P = 0.016$; depressed factor: $r = 0.386$, $P < 0.001$) in the patients. The correlations between PANSS total and subscale score and SDSS score remained significant after the Bonferroni correction was performed (All $P_{\text{Bonferroni}} < 0.05$). There were no significant correlations between social avoidance and either psychotic symptoms or social functioning in the patients with schizophrenia (All $P > 0.05$).

3.4 Mediating model

According to the principle of mediation effect, both the PANSS subscale score and ITS total score were significantly associated with SDSS. Hence, we performed a medication analysis to test whether interpersonal trust could mediate the effect of psychotic symptoms on social functioning in individuals with chronic schizophrenia (Figure 1). However, since the correlation analyses did not reveal any significant correlations between social avoidance and either psychotic symptoms or social functioning, this suggested that social avoidance cannot mediate the impact of psychotic symptoms on social functioning in schizophrenia, so we did not proceed with the mediation model involving psychotic symptoms, social avoidance and social functioning.

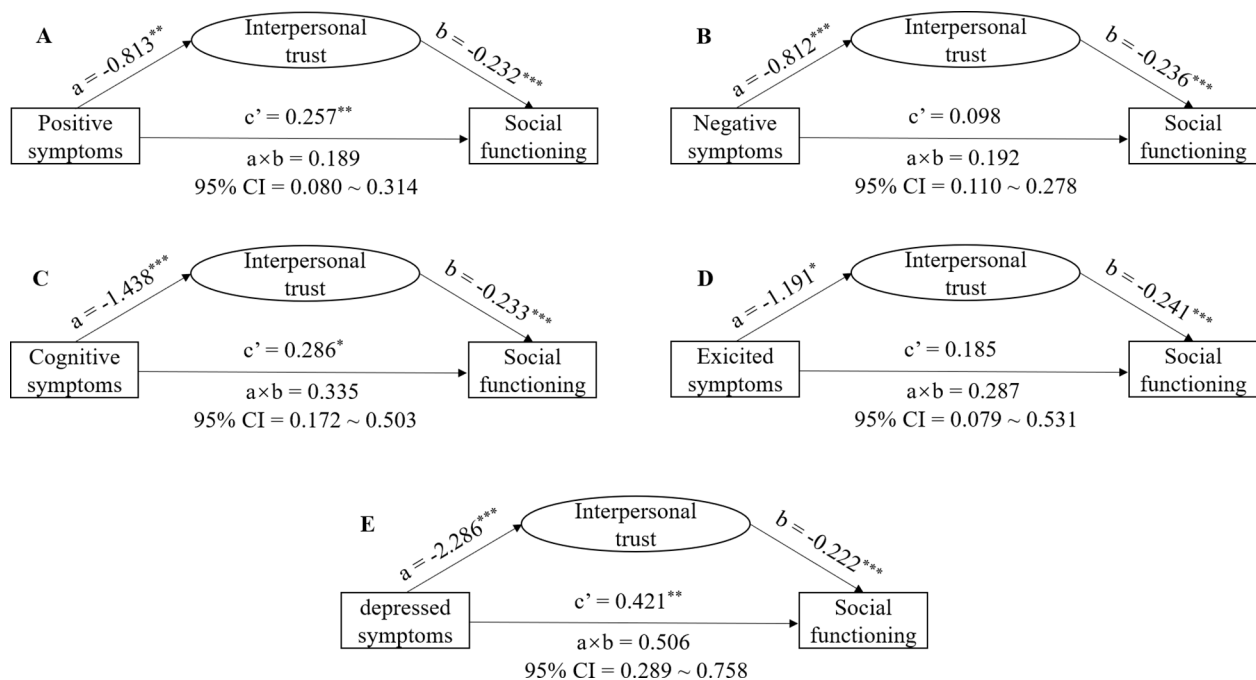


FIGURE 1

Hypothesized mediation model: indirect effect of interpersonal trust on the relationship between psychotic symptoms and social functioning in individuals with chronic schizophrenia. (A) PANSS positive factor-ITS-SDSS model; (B) PANSS negative factor-ITS-SDSS model; (C) PANSS cognitive factor-ITS-SDSS model; (D) PANSS excited factor-ITS-SDSS model; (E) PANSS depressed factor-ITS-SDSS model. * $P < 0.05$, ** $P < 0.001$. Path a is independent variable (X) → mediator (M). Path b is mediator (M) → dependent variable (Y), adjusted for X. Path c' is X → dependent variable (Y), adjusted for M. Path a × b is X → Y through M. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In the PANSS positive factor-ITS-SDSS model, we found significant direct effects of the PANSS positive factor on SDSS [$c' = 0.257$, $P = 0.001$, 95% CI (0.103, 0.410)], the PANSS positive factor on ITS [$a = -0.813$, $P = 0.003$, 95% CI (-1.344, -0.283)], and ITS on SDSS ($b = -0.232$, $P < 0.001$, 95% CI = -0.270, -0.195). The total effect of the PANSS positive factor on SDSS was 0.446 [$P < 0.001$, 95% CI (0.251, 0.640)]. The indirect effect of the PANSS positive factor through ITS on SDSS was 0.189 [95% CI (0.080, 0.313)]. The results indicated that interpersonal trust partially mediates the effect of the PANSS positive factor on social functioning in schizophrenia (with a 57.6% direct effect and a 42.4% indirect effect). In the PANSS negative factor-ITS-SDSS model, the direct effect of the PANSS negative factor on SDSS was 0.098 [$P = 0.102$, 95% CI (-0.019, 0.215)], the PANSS negative factor on ITS was -0.812 [$P < 0.001$, 95% CI (-1.196, -0.427)], and ITS on SDSS was -0.236 ($P < 0.001$, 95% CI = -0.275, -0.197). The total effect of the PANSS negative factor on SDSS was 0.289 [$P = 0.001$, 95% CI (0.145, 0.434)]. The indirect effect of the PANSS negative factor through ITS on SDSS was 0.192 [95% CI (0.110, 0.278)]. The results indicated that interpersonal trust partially mediates the effect of the PANSS negative factor on social functioning in schizophrenia (with a 33.8% direct effect and a 66.2% indirect effect). In the PANSS cognitive factor-ITS-SDSS model, we found significant direct effects of the PANSS cognitive factor on SDSS [$c' = 0.286$, $P = 0.013$, 95% CI (0.068, 0.511)], the PANSS cognitive factor on ITS [$a = -1.438$, $P = 0.001$, 95% CI (-2.192, -0.684)], and ITS on SDSS ($b = -0.233$, $P < 0.001$, 95% CI = -0.271, -0.195). The total effect of the PANSS cognitive factor on SDSS was 0.621 [$P < 0.001$,

95% CI (0.341, 0.901)]. The indirect effect of the PANSS cognitive factor through ITS on SDSS was 0.335 [95% CI (0.172, 0.503)]. The results indicated that interpersonal trust partially mediates the effect of the PANSS cognitive factor on social functioning in schizophrenia (with a 46.1% direct effect and a 53.9% indirect effect). In the PANSS excited factor-ITS-SDSS model, the direct effect of the PANSS excited factor on SDSS was 0.185 [$P = 0.221$, 95% CI (-0.112, 0.483)], the PANSS excited factor on ITS was -1.191 [$P = 0.023$, 95% CI (-2.216, -0.167)], and ITS on SDSS was -0.241 ($P < 0.001$, 95% CI = -0.279, -0.203). The total effect of the PANSS excited factor on SDSS was 0.473 [$P = 0.016$, 95% CI (0.089, 0.856)]. The indirect effect of the PANSS excited factor through ITS on SDSS was 0.287 [95% CI (0.079, 0.531)]. The results indicated that interpersonal trust partially mediates the effect of the PANSS excited factor on social functioning in schizophrenia (with a 39.2% direct effect and a 60.8% indirect effect). In the PANSS depressed factor-ITS-SDSS model, we found significant direct effects of the PANSS depressed factor on SDSS [$c' = 0.421$, $P = 0.001$, 95% CI (0.168, 0.674)], the PANSS depressed factor on ITS [$a = -2.286$, $P < 0.001$, 95% CI (-3.081, -1.492)], and ITS on SDSS ($b = -0.222$, $P < 0.001$, 95% CI = -0.261, -0.182). The total effect of the PANSS depressed factor on SDSS was 0.928 [$P < 0.001$, 95% CI (0.634, 1.222)]. The indirect effect of the PANSS depressed factor through ITS on SDSS was 0.506 [95% CI (0.289, 0.758)]. The results indicated that interpersonal trust partially mediates the effect of the PANSS depressed factor on social functioning in schizophrenia (with a 45.4% direct effect and a 54.6% indirect effect).

4 Discussion

To the best of our knowledge, this is the first study that aimed to compare interpersonal trust and social avoidance between individuals with chronic schizophrenia and healthy controls and to examine the relationship between interpersonal trust, social avoidance, psychotic symptoms, and social functioning in these patients. The main findings of the present study include: (1) Individuals with chronic schizophrenia had reduced interpersonal trust but increased social avoidance compared to healthy controls. (2) Interpersonal trust was significantly associated with the PANSS positive and negative factors, general psychopathology, and social functioning in all individuals with schizophrenia. (3) Interpersonal trust had a partial mediating effect on the relationship between psychotic symptoms (including positive, negative, cognitive, excited, and depressed symptoms) and social functioning in these patients.

In the present study, our results showed that patients with chronic schizophrenia had reduced interpersonal trust compared to healthy controls, which was also reported in patients with first-episode psychosis, individuals at clinical high risk for psychosis, and first-degree relatives of patients with schizophrenia (20, 33). Impaired interpersonal trust in different stages of schizophrenia suggests that it may be an endophenotype of schizophrenia. However, other studies reported the absence of a difference in interpersonal trust between patients with psychosis and controls (34). Since the previous studies had small sample sizes, a recent meta-analysis included 183 patients with psychosis and 272 controls and further demonstrated significant trust deficits in patients with psychosis (35). It is supposed that several social cognitive processes, especially mentalizing processes (referring to the ability to infer, implicitly or explicitly, the intentions, dispositions, and beliefs of others) (36), might result in altered interpersonal trust in patients with psychosis, since evidence supports that intact social cognition is crucial in decision-making and modification of trust behavior (37). Interestingly, impairments in social cognition were widely reported in individuals with schizophrenia (38), and a recent experiment demonstrated that altered oxytocin levels in the lateral parietal cortex and amygdala play an important role in regulating interpersonal trust among individuals with schizophrenia, as measured through a social cognition task (39). Despite some preliminary findings, the exact mechanisms of how social cognition affects interpersonal trust in schizophrenia remain unclear, and further studies are warranted to unravel this issue.

Psychotic symptoms in patients with schizophrenia were also correlated with interpersonal trust, but with mixed results. One study reported that higher PANSS positive and negative symptoms were associated with lower interpersonal trust in early psychosis (34), but another research only indicated a significant correlation between negative symptoms and interpersonal trust in patients with psychosis (21). Moreover, a recent study demonstrated that only positive symptoms are significantly associated with reduced trust in individuals with schizophrenia (17). In another study, researchers failed to reveal any association between psychotic symptoms and interpersonal trust in individuals with schizophrenia (40). In the current study, we recruited a relatively large sample of individuals with schizophrenia and utilized the five-factor PANSS. Our results indicated that reduced interpersonal trust

was significantly associated with the severity of positive, negative, cognitive, excited, and depressed symptoms in individuals with chronic schizophrenia. The discrepancies in findings regarding the relationship between different dimensions of psychotic symptoms and interpersonal trust can be attributed to a combination of factors, including sample characteristics, disease state, measurement tools, and study design. Future research should aim to address these factors to provide more consistent and reliable findings. Despite the discrepancies, there is still considerable evidence supporting the relationship between the different dimensions of psychotic symptoms and interpersonal trust in schizophrenia. Paranoia and delusions of being persecuted are the most commonly observed positive symptoms in individuals suffering from schizophrenia. Thinking that others intend to harm them might lead to defensive aggressive behaviors as self-protection or avoiding normal interaction with others, and this weakens the ability to develop interpersonal trust in individuals with schizophrenia (19, 41). The relationship between negative symptoms, depressed symptoms, and reduced interpersonal trust may be reflected by the lack of social motivation. Individuals with schizophrenia with negative symptoms rarely engage in normal social interaction and usually evaluate other persons in a more negative way and lack interpersonal trust (42). However, no study has explored the relationship between cognitive and excited factors and interpersonal trust in schizophrenia since most existing studies did not use the five-factor PANSS (17, 34).

Unsurprisingly, we found that positive, negative, cognitive, excited, and depressed symptoms were significantly associated with social functioning in individuals with schizophrenia, which was also observed in many previous studies (43–45). We know that the social function deficits in schizophrenia significantly impact their daily life, rehabilitation work, and return to society (46). Although the negative symptoms are among the strongest independent predictors of social functioning in individuals with schizophrenia (44), some studies have indicated that negative symptoms influence real-world functioning while also correlating with positive symptoms in schizophrenia (45). Moreover, an early study demonstrated that the negative symptoms of blunted affect and passive-apathetic social withdrawal and the positive symptoms of hallucinatory behavior and suspiciousness predicted social functioning in individuals with schizophrenia, but the total scores on these clinical rating scales include other variables that actually dilute the prediction of functional outcomes in the patients (43). In the current study, our goal was not to split the items of these scales but to explore the effect of interpersonal trust on the relationship between psychotic symptoms and social functioning in individuals with chronic schizophrenia, and we tested our hypothesis. It is supposed that trusting others and returning the trust placed in oneself with trustworthy actions are important aspects of everyday interactions, and the impairment in this fundamental ability can lead to poor social functioning in individuals (35). In the present study, our results further revealed that interpersonal trust could aggravate the influence of psychotic symptoms on social functioning in individuals with chronic schizophrenia. As such, it is important that we develop interventions to improve interpersonal trust in individuals with schizophrenia to promote their social functioning.

In the present study, our results showed that individuals with chronic schizophrenia had significant social avoidance compared to

healthy controls. Social avoidance in young patients is always a clinically worrisome phenomenon and often readily contributes to the onset of schizophrenia. Both retrospective studies of first episode patients and prospective studies of patients at risk for psychosis supported that social decline occurred up to several years before the first episode of schizophrenia (47, 48). In addition, ample evidence indicates that individuals with chronic schizophrenia also have significant social withdrawal (22, 49), and the current study further supports this point.

Although a recent study revealed a significant correlation between social withdrawal and interpersonal trust in the general population (50), we failed to find this relationship in individuals with schizophrenia. Since few researchers have explored this issue, further studies are warranted to investigate the relationship between interpersonal trust and social avoidance in individuals with schizophrenia and to better understand their effects on function and prognosis in those patients.

Therefore, treatment of psychotic symptoms through antipsychotic drugs and non-pharmacological treatments is the first step toward improvement of social functioning in individuals with schizophrenia. Meanwhile, our findings suggest that enhancing interpersonal trust in these patients can further improve their social functioning and assist in their successful reintegration into society. Hence, future studies should focus on exploring effective approaches to enhance interpersonal trust among individuals with schizophrenia.

There are some limitations in the present study. First, the cross-sectional nature of the research precludes us from identifying causal relationships among psychotic symptoms, interpersonal trust, and social functioning in individuals with schizophrenia. Second, the ITS and SAD are both self-report evaluations, and individuals with schizophrenia tend to exhibit severe cognitive impairment and lack of judgement and insight (51, 52), potentially affecting the accuracy of their self-reported interpersonal trust and social avoidance. Additionally, the Interpersonal Trust Scale may yield different results compared to behavioral tools such as the trust game. Thus, our results should be further validated using behavioral measures to ensure their robustness. Third, PANSS may not be the most suitable tool for evaluating negative symptoms in schizophrenia since it includes some aspects that are not conceptualized as negative symptoms and only focuses on the patient's behavior but fails to assess the subject's internal experience. Fourth, the study sample was outpatients and thus may not extend to inpatients. Finally, some other factors that are commonly associated with social functioning, such as neurocognition and side effects of drugs, were not collected in the current study. Therefore, the findings in the current study should be considered preliminary, and future studies with a comprehensive longitudinal design and objective measures should be carried out to replicate our findings.

To conclude, the results indicated that individuals with schizophrenia had reduced interpersonal trust and increased social avoidance compared to healthy controls, and interpersonal trust had a mediating role between psychotic symptoms and social functioning in individuals with schizophrenia. It provides a new perspective for the clinical promotion of social functioning and

prognosis in individuals with schizophrenia, that is, from the perspective of improving their interpersonal trust. The preliminary findings warrant further exploration and verification.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Each participant signed a written informed consent form, which was approved by the Institutional Ethical Committee for clinical Research of Wenzhou Kangning Hospital. All procedures were conducted in strict accordance with the Declaration of Helsinki.

Author contributions

HL: Writing – original draft, Formal Analysis, Data curation. XP: Data curation, Methodology, Writing – review & editing. XH: Writing – review & editing, Investigation. HT: Investigation, Writing – review & editing. XS: Writing – review & editing, Project administration, Software, Supervision. DW: Writing – review & editing, Formal Analysis, Investigation. LW: Writing – review & editing, Supervision, Validation. CB: Validation, Writing – review & editing, Project administration. XF: Writing – review & editing, Formal Analysis, Writing – original draft. ZY: Formal Analysis, Supervision, Validation, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Loneliness among dementia caregivers: evaluation of the psychometric properties and cutoff score of the Three-item UCLA Loneliness Scale

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Introduction: Dementia is a chronic progressive syndrome, with an entire loss of function in the late stages. The care of this demanding condition is primarily provided by family members, who often suffer from chronic burnout, distress, and loneliness. This instrumental study aimed to examine the factor structure, reliability, convergent validity, criterion validity, and cutoff scores of a short loneliness measure: the Three-Item version of the University of California, Los Angeles, Loneliness Scale (UCLALS3) in a convenience sample of dementia family caregivers (N = 571, mean age = 53 ± 12 years, 81.6% females).

Methods: Exploratory and confirmatory factor analyses were used to examine the structure of the UCLALS3 while receiver-operating characteristic (ROC) curve, including caregiving burden and emotional distress as outcomes, was used to examine its cutoff.

Results: One factor accounted for 79.0% of the variance in the UCLALS3; it was perfectly invariant across genders but variant at the metric level across countries. The scale had adequate internal consistency (alpha = 0.87), high item-total correlations (0.69 – 0.79), reduced alpha if item deleted (0.77 – 0.86), and strong positive correlations with caregiving burden and psychological distress scores (r = 0.57 & 0.74, p values = 0.01). Percentile scores and the ROC curve

suggested two cutoffs (≥ 6 and ≥ 6.5), which classified 59.3 and 59.4% of the participants as having higher levels of loneliness—comparable to global levels of loneliness among informal caregivers. The Mann-Whitney test revealed significantly high levels of caregiving burden and distress in caregivers scoring ≥ 6.5 on the UCLALS3.

Conclusion: The UCLALS3 is a valid short scale; its cutoff ≥ 6.5 may flag major clinically relevant symptoms in dementia caregivers, highlighting the need for tailored interventions that boost caregivers' individual perception of social relationships. More investigations are needed to confirm UCLALS3 invariance across countries.

KEYWORDS

Three-item version of the University of California Los Angeles Loneliness Scale (UCLALS3)/loneliness, caregiving burden/burnout/the Zarit Burden Interview (ZBI), psychological distress/depression anxiety stress scale 8-items, factor structure/psychometric, older adults/old age/elders/elderly, informal/family caregivers, cutoff score/receiver-operating characteristic curve (ROC) analysis

1 Introduction

Loneliness is a feeling of insurmountable distance between self and others (1). Lonely individuals develop unpleasant experiences as a result of deficiencies in their network of social relations, which may be of quantitative (e.g., network size, number of friends) and/or qualitative aspects (e.g., relationship closeness, trust, intimacy) (2, 3). Loneliness has also been classified as social deficit in the amount and quality of relations as well as an emotional deficit in relationship closeness (4). Loneliness represents a core public issue worldwide, with a stable prevalence of 15–30% in the general population (5, 6). However, its prevalence varies over regions of the world and lifetime, with peaks among adolescents (14.4%) and older adults (24.2%) while lower rates are reported in middle adulthood (2, 6). Although loneliness represents a stable trait, the set point for the loneliness feeling vacillates according to specific social circumstances (7).

Loneliness may result from the symptoms and maladaptive behaviors that develop in certain pathological conditions such as withdrawing and not confiding in depressive disorders (1, 8). It also increases in response to situational threats to a cherished interpersonal relationship such as social exclusion, ostracism, rejection, separation, divorce, and bereavement (7). Loneliness has increased in the last few decades due to the spread of activities, which limit the chances of social interactions such as digital gaming as well as excessive use of the internet and smartphones (9–12). Social distancing measures have been extensive during the long-lasting COVID-19 pandemic, which has been associated with accelerated internet use for gaming, and social media interactions, and receiving information on the pandemic, leading to reduced life satisfaction, depressed mood, and increased chance for social connections (10,

13–18). Lonely people may retreat to social media to meet their needs for inclusion in a social group (19, 20). Unfortunately, creating virtual relations through social media does not mitigate loneliness, and it may evoke a range of physical and mental adverse effects such as nomophobia (fear of being disconnected from smartphones), body dissatisfaction, and disordered eating, among others (12, 21). Even more, a recent meta-analysis reports a very low quality of evidence for the effect of digital interventions on loneliness among the elderly (5).

Loneliness at moderate to severe levels is widely reported among dementia family caregivers (up to 61.4) (4, 22–24). The time and effort exerted in caregiving may be a source of distancing and relational deprivation in this population (24). Among dementia caregivers, loneliness is aggravated by increased social isolation and caregiving stress. On the other hand, loneliness levels are lower among those expressing good quality of relationship with the care recipient, as well as those with increased levels of well-being and life satisfaction (4, 24, 25). The adverse effects of loneliness on the health and well-being of caregivers can be devastating. Loss of self-esteem has been reported by dementia spouse caregivers (22, 24). Loneliness may also worsen mood and perpetuate depression (26, 27). Indeed, loneliness was the only predictor of depression among family caregivers (accounting for up to 49% of the variance) (22, 24). Longitudinal data reveals an increase in the physical and mental symptoms (e.g., concurrent pain, depression, and fatigue) and larger increases in symptom cluster levels from one year to the next in lonelier than less lonely caregivers (23). The effects of loneliness, along with the caregiving burden and possible physical and mental problems, which older caregivers (e.g., spouses) may suffer as a function of their advanced age, may put the well-being of those caregivers in jeopardy (14).

Loneliness can be mitigated through a variety of cognitive interventions, which focus on interrupting maladaptive cognitions about the social world (1). Such manipulations may interfere with the psychophysiological mechanisms underlying loneliness-related biopsychosocial morbidity (28). Therefore, it is important to screen for and treat loneliness, particularly in groups vulnerable to stress.

Because the literature is mixed on whether loneliness is a unidimensional or a multidimensional construct, different instruments were designed to measure global loneliness as well as different dimensions of loneliness (3). The University of California, Los Angeles, Loneliness Scale (UCLALS) is a widely used 20-item measure of global loneliness. Although several studies replicated the unidimensional structure of the UCLALS, some studies reported two (29, 30) or three dimensions (31, 32). The scale has been revised several times resulting in many shortened versions, which comprise fewer items ranging from 10 to three (33). The three-item UCLALS3 is widely used because of its brevity; however, it has been tested in a few studies. Until the current moment, no cutoff score has been identified to distinguish victims of loneliness who may require special help. The present study aimed to evaluate the psychometrics of the UCLALS3 in a European sample of dementia family caregivers during the peak of the COVID-19 pandemic. We hypothesized that the UCLALS3 will 1) demonstrate a single factor structure, 2) express adequate internal consistency and convergent validity, and 3) correlate strongly with caregiving burden and psychological distress. A secondary aim of this study was to determine an optimal cutoff score for the UCLALS3.

2 Materials and methods

2.1 Design, participants and procedure

This instrumental study is a secondary analysis that was based on data obtained from a convenience sample of 571 Italian (74.4%) and Swiss (25.6%) dementia family caregivers (mean age = 53 ± 12 , range = 24–89 years) (34). The sample was recruited through an online survey conducted in the Italian language through RedCap over one month from May 25 to June 25, 2020. The study included those aged 18 years or older who could speak Italian and stated being family caregivers of non-institutionalized individuals who are formally diagnosed with dementia. Not consenting to participate or not meeting the inclusion criteria disqualified inclusion in the study. Swiss participants were recruited from a border region in southern Switzerland where more Swiss people can speak Italian (34).

Most participants were females ($n = 466$, 81.6%); adult children of the dementia patients ($n = 410$, 71.8%); full or part-time employees ($n = 283$, 49.6%); and with a higher or secondary education ($n = 322$, 56.4%). The average duration of dementia caregiving was 6.1 ± 4.0 years. Care recipients were primarily affected with Alzheimer's type dementia ($n = 316$, 55.3%) and unable to perform activities of daily living (ADL) ($n = 455$, 79.7%). The characteristics of the respondents and procedure are described in detail elsewhere (14, 34, 35). The dataset generated and analyzed during the current study is available in the Zenodo open repository, DOI: 10.5281/zenodo.4748651 (36).

2.2 Measures

Data were collected through a self-administered online survey, which comprised a set of questions eliciting information on the sociodemographic characteristics of the participants (e.g., age, gender, education, etc.), as well as the condition of dementia care recipients (e.g., dementia type and level of ability to perform ADL independently), duration of care provision, and if they received help with care from someone else. The survey also comprised a test battery, which consisted of three symptom measures:

1. The Italian version of the Three-Item version of the University of California, Los Angeles, Loneliness Scale (UCLALS3) (7, 37). This scale has been developed as a refinement of the 20-item UCLALS for easier screening of loneliness through interviews on the phone. It consists of three items, which measure three interrelated dimensions of isolation, relational connectedness, and trait loneliness: how often do you feel that you lack companionship, how often do you feel left out, and how often do you feel isolated from others. The respondents rate the scale on three response categories (1 = hardly ever, 2 = some of the time, and 3 = often). The minimum and maximum total scores of the UCLALS3 range between 3 and 9. Higher scores indicate higher levels of loneliness (7). Its reliability in the current study is very good (see the results section).
2. The Italian version of the Zarit Burden Interview (ZBI) (37) consists of 22 items, which capture burnout: the adverse effects of caring for a patient with dementia on physical and mental health, quality of life, relationships, and finance (38). Example items include feeling strained, feeling angry, social life suffering, financial stress, health affected, and lack of privacy. Respondents rate the frequency of endorsing the items of the ZBI on a five-point Likert scale (0 = never, 1 = rarely, 2 = sometimes, 3 = quite frequently, 4 = nearly always). The response categories of only item 22 are different (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, and 4 = extremely). The minimum and maximum total scores of the ZBI range between 0 and 88. Burnout or higher burden are flagged by higher ZBI scores (37, 39). Its reliability in the current study is excellent (coefficient alpha = 0.94).
3. The Depression Anxiety Stress Scale-8 (DASS-8) was nested within the Italian version of the DASS-21 (40). In other words, the respondents rated the 21 items of the DASS-1, but we used in the analysis only eight items, which comprise the DASS-8. This is because this short version of the DASS-21 demonstrates adequate psychometric qualities relative to the full scale (9, 41). Like the DASS-21, the DASS-8 comprises three subscales, which measure the symptoms of depression, anxiety, and stress, respectively. The scale itself measures overall distress. The depression subscale comprises three items (e.g., felt that I had nothing to look forward), the anxiety subscale also comprises three items (e.g., felt close to panic), while the

stress subscale comprises only two items (e.g., was using a lot of my mental energy) (9, 41). The respondents rate the scale on four response categories (0 = did not apply to me at all, 1 = applied to me to some degree, or some of the time, 2 = applied to me to a considerable degree or a good part of the time, and 3 = applied to me very much or most of the time). Accordingly, the minimum score of the DASS-8 and its subscales is 0 while their maximum scores are 24, 9, 9, and 6, respectively. Its reliability in the current study is excellent (coefficient alpha = 0.93).

2.3 Statistical analysis

Mean and standard deviation (SD) were used to describe continuous variables while frequency and percentage were used to describe categorical variables. To examine the factor structure of the UCLALS3, we conducted exploratory factor analysis (EFA) with maximum-likelihood extraction, direct Oblimin rotation, Kaiser-Meyer-Olkin (KMO), and Bartlett's test of sphericity. EFA permits the items of a measure to load freely on the corresponding factors without enforcing any constraints.

In a next stage, confirmatory factor analysis (CFA) was conducted to examine the theory-based structure of the UCLALS3. Because of its limited number of items, examination of the UCLALS3 through CFA produces a saturated model ($\chi^2 = 0$, $DF = 0$), which has no explanatory power because the absence of degrees of freedom denotes equity of the number of estimated parameters to the number of data points (42). To escape this problem, CFA is conducted by anchoring the ultra-short scale to another measure in a structural equation model (SEM) (27). Therefore, the UCLALS3 was anchored to the DASS-8. In addition to non-significant chi square index (χ^2), two pairs of indices were considered as criteria for judging model fit as acceptable or good: 1) Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) >0.90 or >0.95 , and 2) root mean square error of approximation (RMSEA) and standardized root-mean-square residual (SRMR) <0.08 or <0.06 , respectively (43, 44).

Measurement invariance of the UCLALS3 across gender and country was evaluated through multi-group analysis, which evaluated four nested models that address configural, metric, scalar, and strict invariance. Because χ^2 is sensitive to sample size, variant models were determined based on ΔCFI and ΔTLI exceeding 0.020, along with $\Delta RMSEA$ above 0.015 (35, 45).

To identify the internal consistency of the UCLALS3, alpha coefficient was estimated. Convergent validity testing was mirrored by item-total correlations and alpha if an item was deleted. The criterion validity of the UCLALS3 was evaluated through Pearson correlations with the scores of the ZBI and the DASS-8.

To identify a suitable cutoff point for the UCLALS3, we examined its percentile scores. We also used the receiver-operating characteristic (ROC) method. In this technique, the UCLALS3 was used as a continuous variable to differentiate caregivers with remarkable caregiving burden based on a ZBI cutoff score of 48

(46), as well as those with a significant level of distress based on a DASS-8 score of 13 (35, 47). The effectiveness of the UCLALS3 as a diagnostic marker can be considered according to the value of the Area Under Curve (AUC), sensitivity, specificity, and the Youden index. The latter is calculated as the sum of sensitivity and specificity minus one. In ideal tests, the values of all these fit indices should be close to 1 (48, 49).

The Mann Whitney U test and Kruskal Wallis test were used to examine differences in the levels of caregiving burden and distress across the examined levels of loneliness as determined by the percentiles and the ROC analysis. The analyses were conducted in SPSS (version 28), and the significance of the results was considered at a probability level less than 0.05 in two-tailed tests.

2.4 Ethics

Electronic consent was obtained from all subjects involved in the study. Before answering the main questionnaire, all participants provided informed consent for participation, data collection, and analysis by clicking the "Yes, I agree and give my informed consent" box on the digital form. Responses to the electronic questionnaire were anonymous; no personal data were requested to identify the participant. The current research followed the ethical guidelines of the Helsinki Declaration, ensuring that all participants received the same information while completing the questionnaire. The research was in accordance with the European Data Protection Law (34).

3 Results

The values of KMO = 0.721 and Bartlett's test ($\chi^2(3) = 857.50$, $p < 0.001$) indicate adequate sample size and participant-to-item ratio for the EFA. A single factor with an eigenvalue greater than one (2.37) was produced (Figure 1). It explained 78.97% of the variance in the UCLALS3. The loadings of all three items on this factor were strong, as shown in Table 1.

The fit of the SEM was acceptable (χ^2 (DF) = 255.33 (43), $p = 0.001$, CFI = 0.955, TLI = 0.942, RMSEA = .093 RMSEA 95% CI = 0.082-0.108, SRMR = 0.034), albeit RMSEA was a bit on the high side. A slight improvement in the fit was done after correlating few items on the DASS-8 (χ^2 (DF) = 156.34 (40), $p = 0.001$, CFI = 0.975, TLI = 0.966, RMSEA = .071 RMSEA 95% CI = 0.060-0.083, SRMR = 0.027). In both models, the items of the UCLALS3 had strong significant loadings (>0.7) on their domain-specific factors, in the absence of error correlation of these items with each other or with the items of the DASS-8 (Figure 2).

Multigroup CFA analysis revealed invariance of the UCLALS3 at the configural, metric, scalar, and strict levels across gender. Although the UCLALS3 demonstrated configural invariance across countries, it did not hold scalar invariance (Table 2). Accordingly, we have examined the UCLALS3 in each group separately. As shown in Figure 3, the fit of the crude model did not vary much from the fit noticed in the whole sample. However, all item loadings (DASS-8 and UCLALS3) decreased in the Swiss sample, and UCLALS3 items

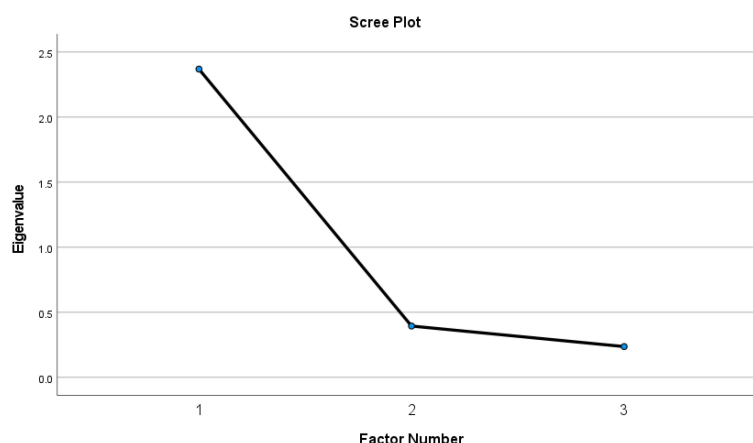


FIGURE 1

Factor structure of the Three-Item University of California, Los Angeles, Loneliness Scale-version (UCLALS3) among dementia caregivers as determined by exploratory factor analysis.

expressed an obvious reduction in their loadings, albeit they loaded significantly (p values <0.01). The correlation between the DASS-8 and UCLALS3 in this sample was out of the logical range. Strangely, the fit in this sample was corrected by correlating the error terms of item 3 on the UCLALS3 with item 8 on the DASS-8, which was associated with a greater increase in the association between the DASS-8 and the UCLALS3 (Supplementary Figure 1).

Strong correlations of the UCLALS3 with the ZBI and the DASS-8 (Table 3) signify its usefulness as a criterion variable in distressed and burdened groups. The internal consistency of the scale was very good ($\alpha = 0.87$). Moreover, the reduction in the UCLALS3's reliability upon item deletion (Table 1) indicates a strong contribution of each item to the latent structure covered by this measure. High values of item-total correlations reflect adequate convergent validity.

Based on percentile scores, five cutoff scores were suggested for the UCLALS3. They may reflect various levels of loneliness (Table 4).

Most participants (59.3%) had high to severe loneliness (UCLALS3 scores greater than 6). An optimal cutoff score of 6.5 on the UCLALS3 was indicated by the ROC-curve criteria prediction of ZBI and DASS-8 scores ($AUC = 0.75$ and 0.87 , $SE = 0.02$, p values <0.001 , 95% CI: 0.71 to 0.80 and 0.84 to 0.90, sensitivity = 0.79 and 0.87, specificity = 0.69 and 0.78, Youden index = 0.48 and 0.65, respectively) (Figure 4). Based on the cutoff score obtained from ROC analysis, 232 (40.6%) respondents had

UCLALS3 scores below and equal to 6.5, and 339 (59.4%) had scores greater than 6.5.

The Kruskal-Wallis's test revealed significant differences in caregiving burden and psychological distress across percentile categories ($H(4) = 191.29$ and 313.40 , respectively, p values <0.001), with the highest levels reported in participants with a UCLALS3 score of 7 and above. Likewise, the Mann-Whitney U test revealed significant differences in caregiving burden and distress between low- and high-loneliness groups as defined by the cutoff score produced by the ROC analysis ($U = 13318.5$ and 6996.0 , $z = -13.43$ and -16.72 , p values <0.001).

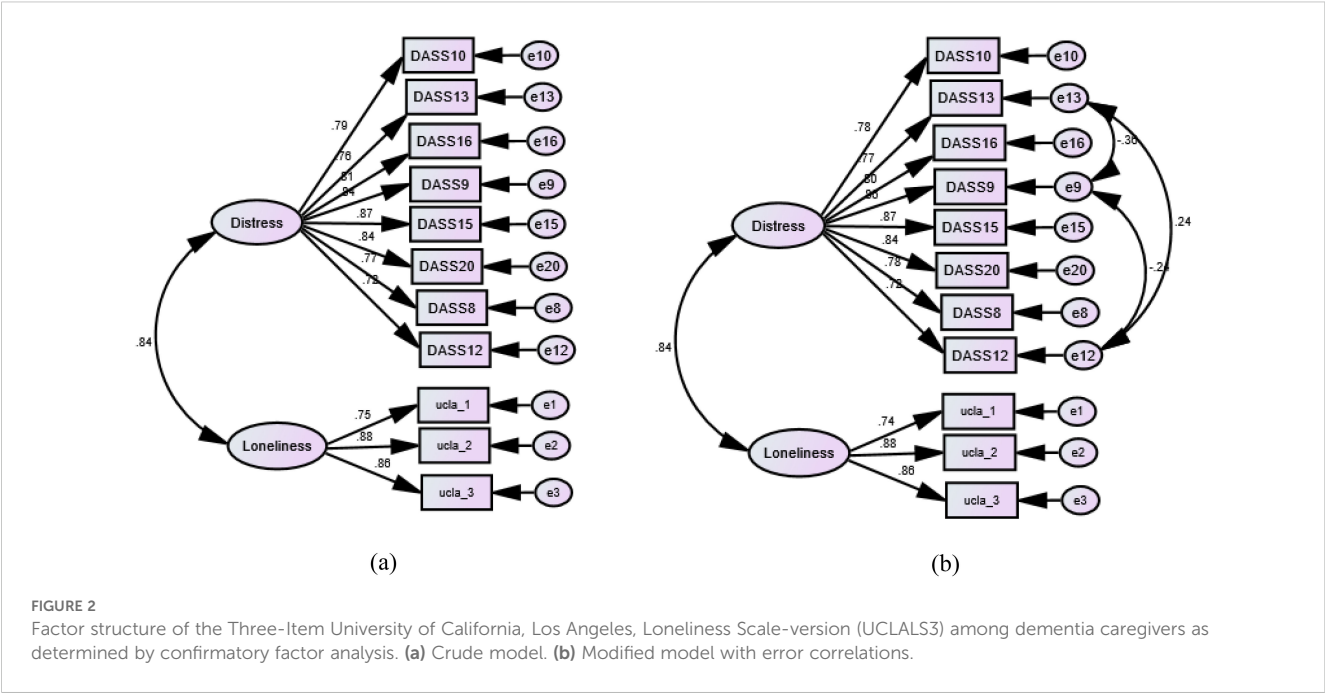
4 Discussion

Poor physical health, psychological distress, and emotional negativity are documented correlates of loneliness, which is evident in a considerable proportion of dementia caregivers (1, 4, 28). Aiming to improve the detection of loneliness in this population, this study examined the psychometric characteristics and the cutoff score of the UCLALS3, the briefest version of the UCLALS, in a sample of Italian and Swiss family caregivers. Our findings indicate the usefulness of the UCLALS3 as a unidimensional measure of loneliness, with an optimal cutoff score of 6.5 for detecting noxious psychological experiences such as caregiving burden and emotional distress.

TABLE 1 Descriptive statistics, item loadings, and internal consistency indicators of the Three-Item University of California, Los Angeles, Loneliness Scale-version (UCLALS3) among dementia caregivers ($N = 571$).

	Mean	SD	Item loadings from EFA	Alpha if item deleted	Item total correlations
UCLALS -1	2.37	0.72	0.74	0.865	0.687
UCLALS -2	2.16	0.81	0.89	0.773	0.788
UCLALS -3	2.24	0.79	0.86	0.790	0.769

EFA, exploratory factor analysis.



Limited studies have examined the psychometrics of the UCLALS3. In our study, EFA and CFA showed strong loadings of all the items on a single factor, which explained most of the variance. The scale expressed perfect invariance across gender and invariance only at the configural level across countries. Similarly, the UCLALS3 expressed a good fit for a single factor in the general population and older adults from the USA (7, 50), German older adults (50), Italian and Spanish samples of healthy adults (42, 51), Portuguese community-dwelling adults (52), as well as Japanese mothers of little children (2). The structure of the scale in these studies was primarily examined by EFA or principal component analysis; one factor explained above 70% of the variance (51, 52). All these results support the construct validity of the unifactorial UCLALS3. This finding supports its usability for quick screening for loneliness in epidemiological surveys, given that the literature reports extensive misfit and non-invariance of the UCLALS and most of its shorter versions, with the shortest versions expressing the least non-invariance and highest reliability (33).

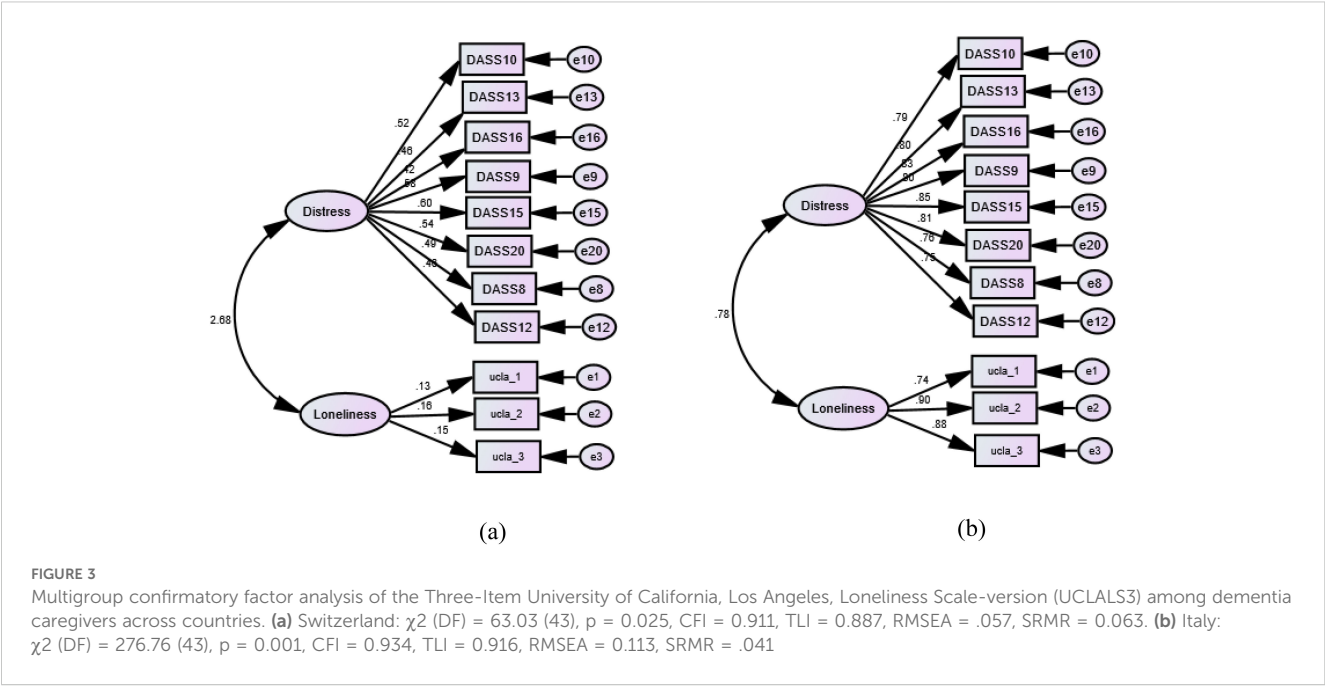
Although invariance of the UCLALS3 across gender ensures rigorous comparisons of the levels of loneliness between men and

women, more attention should be paid to comparing loneliness at the global level when the UCLALS3 is used due to variance at the metric level across countries, with the Swiss sample displaying extremely low item loadings (<0.2), extraordinary correlation between the DASS-8 and the UCLALS3, as well as correlations of the error terms of item 8 of the former “I felt that I was using a lot of nervous energy” with item 3 of the latter “How often do you feel isolated from others” (Supplementary Figure 1). It seems that studies on the invariance of various UCLA scales across countries are quite lacking. However, we located a single study examining invariance of the UCLA-20 and the UCLA-8 across three countries: USA, Germany, and Indonesia. In that study, both measures failed to hold invariance at all levels except for the UCLA-8, which was invariant only at the configural, and the authors had to omit two items to improve the fit of the UCLA-8. Interestingly, the items removed were exclusively related to social isolation—same as item 3 in our study (53). In a Chinese evaluation of the UCLA-8 in older adults through CFA and Rasch analysis, the scale was not unidimensional, item 3 was misfitting, and the response categories were combined. The level of loneliness determined in that study was

TABLE 2 Invariance of the Three-Item University of California, Los Angeles, Loneliness Scale-version (UCLALS3) among dementia caregivers (N = 571).

Groups	Invariance levels	χ^2	DF	<i>p</i>	$\Delta\chi^2$	Δ DF	<i>p</i> ($\Delta\chi^2$)	CFI	Δ CFI	TLI	Δ TLI	RMSEA	Δ RMSEA	SRMR
Gender	Configural	310.575	86	0.001				.951		.937		.068		0.044
	Metric	319.179	95	0.001	8.61	9	0.475	.951	0.000	.943	-0.006	.064	0.004	0.049
	Scalar	328.902	98	0.001	9.72	3	0.021	.950	0.001	.943	0.000	.064	0.000	0.082
	Strict	339.155	109	0.001	10.25	11	0.508	.950	0.000	.949	-0.006	.061	0.003	0.081
Country	Configural	339.683	86	0.001				.933		.914		.072		0.041
	Metric	340.827	95	0.001	1.14	9	0.999	.935	-0.002	.925	0.011	.067	0.005	0.041
	Scalar	552.548	98	0.001	211.72	3	0.001	.880	0.055	.865	0.060	.090	-0.023	0.064
	Strict	581.941	109	0.001	29.39	11	0.002	.875	0.005	.874	-0.009	.087	0.003	0.060

χ^2 , chi-square; DF, degrees of freedom; CFI, comparative fit index; TLI, Tucker–Lewis index; RMSEA, root mean square error of approximation; CI, confidence interval; SRMR, standardized root mean residual; F, factor, values in boldface indicate partial non-variance.



much lower than those generally reported in that population (54). Moreover, an evaluation of the UCLALS3 in 337 young adults from South Africa suggested that the scale is best conceptualized as comprising three subscales (isolation, relational connectedness, collective connectedness), in addition to the total scale score (55). These findings indicate that despite of the general perception of loneliness, individuals from different countries may vary on how they conceptualize their loneliness experience. Further investigations of this phenomenon across many countries are warranted.

Despite its small number of items, the reliability of the UCLALS3 noticed in our study is high: similar to or greater than that reported in other studies ($\alpha = 0.89$) (2) ($\omega = 0.78$ & $\alpha = 0.72$) (3, 7, 56). The dataset used in our analysis did not comprise the UCLALS or longer shortened versions, which may be used for known tests of convergent/predictive validity. However, the scale displayed adequate convergent validity through strong correlations of all the items with each other and with the total score of the scale (Table 1), same as the original UCLALS3 (7). The UCLALS3 also expressed adequate convergent validity in former studies; it had strong positive

correlations with the UCLALS10 (2) and the UCLALS20 (2, 7, 33). These results show that the affiliative aspects covered by the UCLALS3 (isolation, relational connectedness, and trait loneliness) are strongly related in a pattern that may reliably reflect significant loneliness.

In the exploration of its criterion validity, we found strong positive correlations of the single factor covered by the UCLALS3 with caregiving burden and distress scores. Similarly, previous studies express strong correlations of the UCLALS3 with depressive symptoms (e.g., feeling lonely, couldn't get going, and not enjoying life) (7), measures of self-esteem (3), childcare burden, and limited social networks (2). Accordingly, the UCLALS3 may be a useful criterion variable that may indirectly flag numerous negative emotional experiences in distressed groups (e.g., caregivers of chronic conditions, mothers of little children, and older adults).

We used scale percentile scores to distinguish those with high-from low-loneliness at a score above 6. ROC analysis examining the

TABLE 3 Criterion validity of the Three-Item University of California, Los Angeles, Loneliness Scale-version (UCLALS3) among dementia caregivers (N = 571).

	1.	2.	3.
1. UCLALS3	–		
2. ZBI	0.569**	–	
3. DASS-8	0.736**	0.727**	–
Alpha coefficient	0.87	0.94	0.93
Mean (SD)	6.8 ± 2.1	13.6 ± 6.9	54.3 ± 18.3

UCLALS3, Three-Item University of California, Los Angeles, Loneliness Scale-version, ZBI, Zarit Burden Interview, DASS-8, Depression Anxiety Stress Scale-8, SD, standard deviation, ** Correlation is significant at the 0.01 level (2-tailed).

TABLE 4 Percentile distribution of the Three-item University of California, Los Angeles, Loneliness Scale-version (UCLALS3) scores among dementia caregivers (N = 571).

	Percentiles	UCLALS3 scores	No (%)
Low	10 th	3.0	63 (11.0)
Mild	20 th 25 th	5.0 5.0	95 (16.6)
Moderate	30 th 40 th	6.0 6.0	74 (13.0)
High	50 th 60 th 70 th	7.0 8.0 8.0	183 (32.0)
Severe	75 th 80 th 90 th	9.0 9.0 9.0	156 (27.3)

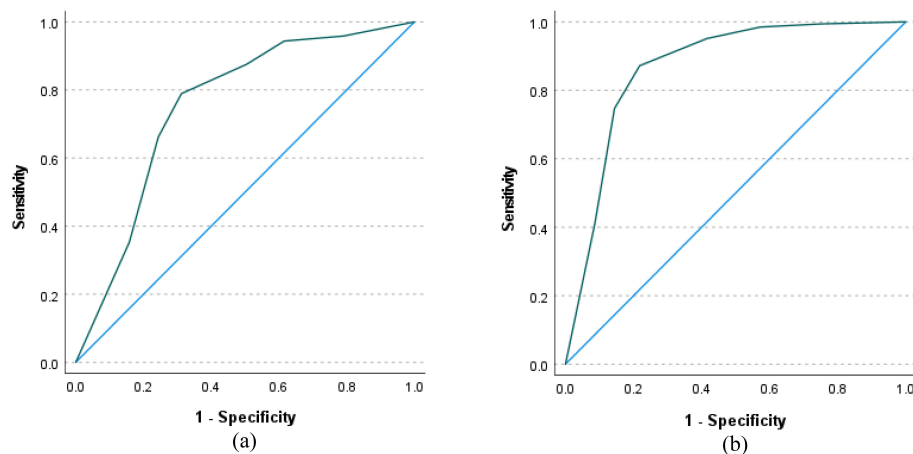


FIGURE 4

Receiver-operating characteristic (ROC) curve using scores of the Three-Item University of California, Los Angeles, Loneliness Scale-version (UCLALS3) to classify dementia family caregivers according to caregiving burden (a) and their level of distress (b).

cutoff score of the UCLALS3 in relevance to reported cutoff points of the ZBI and the DASS-8 indicated that a UCLALS3 score of 6.5 and above may effectively reflect caregivers with higher levels of caregiving burden and emotional distress—this score is relatively closer to the suggested percentile score. AUC values in both models (0.75 & 0.87) show that the discriminative potential of the UCLALS3 ranges from good to very good. Furthermore, we examined the differences in caregiving burden and psychological distress across groups defined by cutoff scores produced in both methods. The scores of caregiving burden and psychological distress were significantly greater among those scoring 6 and above, which lends further credibility to the defined cutoff scores. Interestingly, the levels of discrimination between high and low loneliness were greater when a single optimal cutoff was used compared with multiple cutoff scores, which describe different levels of loneliness (low, mild, moderate, high, and severe: Table 4). Therefore, a UCLALS3 score of 6.5 may be reliably used to discriminate caregivers with high caregiving burden and emotional distress, who may be subjected to further screening for mental morbidities and be targeted by interventional strategies.

Reports on the prevalence of loneliness among dementia caregivers are scarce. As reported above, loneliness levels observed in the present study (moderate and high) are, somewhat, comparable to those reported in other countries. For example, moderate and severe loneliness are reported in 43.7 and 17.7% of 1283 dementia family caregivers in the United Kingdom (4). However, more participants in our study expressed severe loneliness. This finding can be interpreted with reference to the time of data collection, 2020 when the COVID-19 pandemic was peaking in all countries of the world. Lockdown measures, along with the related unavailability of an alternative caregiver may be possible reasons (14, 15). Indeed, lonely people feel unsafe likely due to activation of an anachronistic survival mechanism that intensifies sensitivity to different threats, including minor ones (32). Other factors may include variations in the loneliness measures used in those studies as well as cultural orientations in different countries—

individuals from individualistic cultures (such as the current sample) experience greater levels of loneliness (57).

This study has the advantage of employing already available data to examine the psychometrics of the UCLALS3 and the prevalence of loneliness among dementia caregivers. To our knowledge, this study is the first to statistically determine a cutoff score of the UCLALS3, and this cutoff score seems to efficiently identify individuals with high burnout and distress. Given that only three items could statistically predict caregiving burden and distress, the UCLALS3 may be a cost-effective measure, which may indirectly detect other mental problems in distressed individuals. This may have implications for assessing loneliness-related mental consequences in research and practice. This study; however, comes with many limitations: 1) risk for selection bias because of convenience sampling and online surveying, possibly targeting those with special internet use skills and tendencies, 2) females constituted most of the participants, 3) the status of being a dementia caregiver, as well as the duration of caregiving, and the type of dementia were self-reported, 4) cross-sectional data do not allow a chance to evaluate the stability of symptoms over time, 5) data are limited to a specific geographical area and time period during the peak of the COVID-19 pandemic, 6) it was not possible to assess the concurrent validity of this measure in relevance to commonly used measures of loneliness (the gold standard), and 7) the number of participants in Swiss group was relatively small, which may influence the results (58). Replication of the study may be necessary to ensure the suitability of the scale to various cultural contexts as well as the credibility of the determined cutoff score.

5 Conclusions

The findings of the present study provide further evidence for the single-factor structure of the UCLALS3, as well as its measurement invariance across gender, adequate internal consistency, convergent validity, and criterion validity. The scale at a cutoff score of 6.5 may

efficiently identify clinical targets: lonely people with considerable levels of burnout and mental distress. According to this optimal cutoff, the prevalence of clinically relevant loneliness in this sample was high (59.4%). The results note that loneliness may at these scores be a likely aspect of intervention to reduce caregivers' mental suffering. Scale invariance across Swiss and Italian caregivers observed in our study calls for future studies that evaluate invariance of the UCLALS3 across different countries.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found in the Zenodo open repository: <https://zenodo.org/records/4748652>.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was required from the participants in accordance with the national legislation and the institutional requirements.

Author contributions

AMA: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing. SA: Data curation, Formal analysis, Writing – review & editing. CL: Software, Validation, Writing – review & editing. AS: Methodology, Validation, Writing – review & editing. SH: Formal analysis, Writing – review & editing. AAA: Conceptualization, Funding acquisition, Writing – original draft. AFA: Resources, Writing – original draft. MAA: Resources, Writing – original draft. EAA: Resources, Writing – original draft. AP: Methodology, Visualization, Writing – review & editing. HK: Conceptualization, Data curation, Resources, Software, Visualization, Writing – review & editing.

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Community-level determinants of loneliness and social isolation: a population-based cohort study across younger and older adults

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Introduction: Loneliness and social isolation (SI) are critical public health issues with well-documented effects on health and well-being. However, much of existing observational and intervention research has focused predominantly on individual- and interpersonal-level factors. This longitudinal study addresses significant knowledge gaps by comprehensively examining the independent influence of multiple community-level determinants on loneliness and SI and uniquely comparing these effects across younger (18–30 year) and older (60 + years) adults within an Australian population cohort over a 12-year period.

Methods: Using longitudinal data from the Household, Income and Labour Dynamics in Australia (HILDA) survey, we analysed data from four wave pairs (2006/07, 2010/11, 2014/15, 2018/19) to investigate associations between loneliness and SI and nine community and neighbourhood-level variables. We employed lagged mixed-effects Poisson regression models to calculate risk ratios (RR) adjusted for individual- and interpersonal-level factors.

Results: Our findings reveal that low community engagement is the strongest risk factor for loneliness and SI in both younger (Loneliness, RR = 1.34; SI, RR = 1.58) and older populations (Loneliness, RR = 1.35; SI = 2.02). Low neighbourhood social cohesion was found to significantly increase loneliness and SI in older adults (Loneliness, RR = 1.15; SI, RR = 1.36) and to increase SI in younger adults (RR = 1.54). We also observed distinct age-specific effects, with cultural practices, altruism, and perceived neighbourhood safety having differential impacts across age groups.

Discussion: Our findings highlight the critical need for community-level interventions to address loneliness and SI, suggesting that focusing solely on individual-related factors is insufficient. Tailoring public health strategies to enhance community dynamics may be essential in reducing loneliness and SI among vulnerable populations, particularly in areas with low social cohesion and community engagement offerings.

KEYWORDS

loneliness, social isolation, public health, community-level, longitudinal

1 Introduction

The effect of loneliness and social isolation (SI) on the population's health are well established. Clear links have been found between loneliness and an increased risk of cardiovascular disease, dementia, and mental ill-health (1–3). Similarly, SI can lead to poorer mental health, lower self-perception of health and the adoption of unhealthy behaviours such as a sedentary lifestyle (2, 4). Additionally, there is evidence for considerable economic costs associated with loneliness and SI, although this research is still in its infancy (5).

Given these significant health impacts, there is a need for clear definitions and frameworks to guide the research that we conduct, also helping to reduce the currently siloed nature of the research into loneliness and SI (6). Loneliness is defined for the purposes of this study as 'the subjective unpleasant or distressing feeling of a lack of connection to other people, along with a desire for more, or more satisfying, social relationships' while SI refers to having 'objectively few social relationships, social roles, group memberships, and infrequent social interaction' (7). The two may be viewed as a matrix, whereby people may be lonely but not socially isolated, or conversely isolated but not lonely, both or neither. It has been argued that the two experiences, while distinct, are closely entwined and therefore should be investigated in tandem (8).

Typically, loneliness and SI have been investigated and intervened upon primarily at the individual and interpersonal level, overlooking the benefits of a population approach and resulting in interventions with mixed efficacy (9). Therefore, in line with previous research, we propose that an appropriate framework for the investigation of loneliness and SI is the social ecological model (6). This model represents a diversion from the typical individualistic approach to health, to a more holistic view of health determinants (10). While there are numerous versions of the social ecological model, the one that we have used to conceptualise this study consists of four nested circles representing the four levels of influence on peoples' experiences of loneliness and SI, namely the individual, interpersonal, community and societal levels (11). This model is particularly relevant for a public health approach to loneliness and SI, as it contextualises how community and societal factors influence social connection beyond individual choices (12).

Community-level interventions are commonplace in public health and have the potential to influence behaviour at the population level with greater exposure (13). The majority of studies which have investigated the broader community-level determinants of loneliness and SI have only focused on one or two factors at a time, and commonly used cross-sectional designs, hence a more comprehensive approach is needed (6, 14). This would support more comprehensive policies and help to guide the development of more effective interventions.

While younger and older adults are the two groups found to be most at risk of experiencing loneliness and SI (4, 15), there is little research exploring the similarities and differences of the various community-level determinants within these cohorts (6, 14). This limits the ability to identify the common factors for intervening at the community-level, and those more idiosyncratic for a particular age group. Understanding the differential effects of community-level factors on the experience of loneliness and SI in younger and older people would help to create targeted interventions addressing the unique contexts of each population. Therefore, we aim to use a

longitudinal study design to identify community-level determinants of loneliness and SI and compare their effects among younger and older adults within a population cohort in Australia.

2 Methods

2.1 Data source

We used data from the Household, Income and Labour Dynamics in Australia (HILDA) survey, a nationally representative longitudinal panel survey. A detailed description of the HILDA survey design has been published previously by Wooden and Watson (16). In short, the HILDA sample is a multi-stage stratified random sample of Australian private dwellings ($n = 7,682$ households in 2001, the Wave 1-baseline sample), in which household members over the age of 15 were recruited into a panel (17). The household response rate to the baseline survey was 66%. Panel members have been subsequently reinterviewed annually and in 2011, a top-up sample of 2,153 households was added to ensure the survey remained nationally representative (17). A range of household, economic and labour questions are asked in interviews with participants. A self-completion questionnaire with more sensitive questions is then offered to participants and could be completed online or on paper and mailed back to the researchers (18).

Due to the rotating nature of the questions used in the HILDA surveys, the data required to address our research question were collected only every 4 years. Consequently, we use data from Waves 6–19 (2006–2019), where Wave 6, 10, 14 & 18 are used for covariates, and Waves 7, 11, 15 & 19 are used for loneliness and SI data. We have reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (19), with the checklist available in [Supplementary File 4](#).

2.2 Study sample

The study sample included only participants who are aged 18–30 (younger adults) or 60 + (older adults). Participants were included if they responded to the survey in Waves 6, 10, 14 and/or 18 and they answered all the questions included in the loneliness and/or the SI measure in the subsequent lagged wave. Consequently, if someone responded to Wave 6, they would also have needed to respond to the loneliness or SI questions in Wave 7 to be included.

2.3 Study measures

2.3.1 Outcome variables

The loneliness and SI measures and scoring methods use those from a previous cross-sectional analysis of the HILDA data (20), and as detailed below. Additionally, these measures have been psychometrically tested using this data and these populations (21).

Loneliness: Three questions assessed loneliness by asking participants to their level of agreement with the statements 'People do not come to visit me as often as I would like', 'I often need help from other people but cannot get it' and 'I often feel very lonely' on a seven-point Likert scale (increasing scores denote increasing agreement). We dichotomised this variable into a lonely and not lonely group,

TABLE 1 Community participation and neighbourhood variables.

Factor	Description
Community participation variables	
Civic engagement	The extent to which participants engage in activities that aim to influence the community and society at large.
Community engagement	How often participants engage in social activities.
Altruism	The extent to which participants actively contribute to the community and/or non-profit organisations.
Cultural practices	The participants participation in events and spiritual practices that are characteristic of their community.
Neighbourhood variables	
Neighbourhood safety	The participants perception of safety in their local neighbourhood.
Neighbourhood social cohesion	The participants perception of cohesion in their local neighbourhoods including shared values in the local area, as devised by Sampson et al. (43)
Neighbourhood atmosphere	The participants perception of the neighbourhood noise levels and the aesthetics.
Remoteness	Determined using the 2011 Australian Statistical Geography Standard Remoteness Areas (44) based on the postcode of a participant's primary address, into three categories; major cities, inner regional and outer regional-very remote.
SEIFA quintiles	Determined from the Australian Bureau of Statistics 2011 Socioeconomic Index for Area (SEIFA) index of relative socio-economic advantage/disadvantage using the participant's primary address (45). This variable was categorised as quintiles where higher scores indicate lower disadvantage.

using a median score of ≥ 4 across the three questions to denote loneliness as done previously (20).

Social isolation (SI): The statements used to assess SI were 'there is someone who can always cheer me up when I'm down', 'I enjoy the time I spend with the people who are important to me', 'when somethings on my mind, just talking with the people I know can make me feel better' and 'when I need someone to help me out, I can usually find someone'. The questions were scored on a seven-point Likert scale, where a higher score denotes increasing agreement. Consistent with the construction of the loneliness variable, the SI variable was dichotomised, using a median score of ≤ 4 across the four questions to indicate the participant was experiencing SI (20).

2.3.2 Independent variables

Community participation variables included in analyses comprise civic engagement, community engagement, altruism, and cultural practices. Neighbourhood variables were neighbourhood safety, neighbourhood social cohesion, neighbourhood atmosphere, remoteness, and Socioeconomic Index for Area (SEIFA) quintiles. All independent variables were treated as time-variant in our analysis which is further detailed in the Statistical Analysis section below. Descriptions of each variable are provided in Table 1. These community participation and neighbourhood variables were selected based on a previous review identifying the potential role of community factors in social connection outcomes (6), and represent different dimensions of community life that may affect opportunities for meaningful social interaction. The combination of these variables allows for a comprehensive assessment of the community environment while minimising collinearity between related concepts. Further details about the question wording and measure construction are detailed in the Supplementary File 1.

2.3.3 Covariates

Wave of survey was used as a continuous time variable to account for change in loneliness and SI over the four time points, whereby each wave represents a four-year interval between 2006 and 2018.

Individual-and interpersonal-level variables included in analyses were age, gender, ethnicity, marital status, level of educational attainment, self-assessed health, number of people in dwelling, working status, and gross annual household income. The operationalisation of each variable, can be found in Supplementary File 1.

2.4 Statistical analysis

We report unweighted descriptive statistics for each study population across each wave of interest, using raw numbers and percentages.

We conducted a series of mixed effects modified Poisson regression models to investigate the relationship between loneliness, SI, and the independent variables of interest over time, stratified by the two age groups: younger (18–30) and older adults (60+). Our models included both fixed effects (all independent variables and covariates) and random effects (person ID) regressed on the outcome variables, respectively. Results are reported as risk ratios and their 95% confidence intervals. We used these modified Poisson regressions as an alternative to log binomial regression (22). This has been found to be an appropriate method to account for the intra-person correlations that occur when measurements are repeated on the same subject over time, while maintaining binary outcomes (22, 23). The use of mixed effects modelling also allows for an unbalanced panel (24), meaning that participants do not need to have answered the included questions at all four time points to have their data included in the analysis which accounts for case-level missingness. Independent variables and covariates were included as fixed effects in the models, with the person ID as a random intercept.

We carried out all analyses using 'lagged' models, whereby loneliness and SI were regressed on all independent variables and covariates from the previous wave. For example, loneliness and SI from Wave 7 were regressed on variables from Wave 6, while loneliness and SI from Wave 11 were regressed on the variables from Wave 10. By using a lagged model, we control for temporary experiences of

loneliness and SI (which are less likely to affect health) while still allowing the direction of the relationship between variables to be detected. Additionally, we treated loneliness and SI as independent variables within the other's model. That is, when loneliness is the outcome variable, SI from the preceding wave was used as an independent variable and vice versa which allows for us to estimate the influence of each of these experiences on the other within the lagged analysis. We carried out all statistical analysis in Stata v.18.5 (25).

Categorical data analysis was chosen to improve the interpretation of the results, where we could predict the outcome (lonely vs. not lonely, SI vs. not SI), using more meaningful increases and decreases in covariates than those that can be achieved using continuous variables thereby improving the interpretability of the results. We conducted sensitivity analyses on the suitability of the operationalisation of the variables to verify this method. We compared models with continuous/binary outcomes variables and with continuous/categorical covariates using the Bayesian Information Criterion (BIC) and determined that using categorical outcome variables was a better fit than using continuous outcome variables. Using categorical covariates, despite having a larger BIC, was acceptable when balanced with the benefits of interpretation. Further information can be found in [Supplementary File 3](#). Additional analyses were conducted to determine the effect of missing values, with investigations of which variables were most affected and patterns of missingness. Missing data were handled through pairwise deletion, where participants were only included if they had valid data for loneliness and SI in each analysis, and data for at least one of the independent variables. For household income, we used the imputed values provided by HILDA data custodians, however no additional imputation was performed for other variables. As shown in our supplementary analyses ([Supplementary File 2](#)), missing data were minimal for most variables (<5%), with only neighbourhood safety having substantial missingness (11.4%) primarily due to 'do not know' responses. Sensitivity analyses indicated that patterns of missingness did not substantially influence our main findings. Further information about the missing values can be found in [Supplementary File 2](#).

3 Results

3.1 Sample characteristics

There were 16,163 participants within scope for this study between the ages of 18–30 ($n = 9,414$) or aged 60+ ($n = 6,749$) who responded to the survey in Waves 6, 10, 14 and/or 18 with an average of two wave pairs per participant. The final analytical sample included 13,799 participants, comprising 7,802 younger people (18–30) and 5,997 older people (60+). There was a sample population of 2,984 younger people in Wave 6, with this number growing to 4,406 by Wave 18. In Wave 6 there were 2,873 older people included in the sample, while the sample population of older adults in Wave 18 was 4,816.

Further sample characteristics are presented in [Tables 2, 3](#) for each wave.

3.2 Regression analysis

3.2.1 Community participation determinants

Low altruism was not significantly associated with either outcome in either population, while civic engagement was only significantly

associated with loneliness in the older population (RR:1.09, 95% CI:1.01–1.18). Low participation in cultural practices was significantly associated with an increased risk of loneliness in younger people (RR: 1.11, 95% CI:1.02–1.20) and older people (RR:1.13, 95% CI 1.04–1.21), and with a significantly increased risk of SI in older people (RR:1.19, 95% CI:1.03–1.36), but not in younger people. Low community engagement was strongly and significantly associated with an increased risk of loneliness and SI in both populations, where older people were more than twice as likely to experience SI if they had low community engagement scores (RR: 2.02, 95% CI: 1.75–2.32) and younger people were 1.5 times more likely to experience SI (RR:1.58, 95% CI: 1.38–1.81) ([Table 4](#), [Figures 1, 2](#)).

3.2.2 Neighbourhood determinants

SEIFA quintile was associated with the risk of SI in the older population where being in the second-most affluent SEIFA quintile was significantly associated with a 21% decrease in SI. Low perceived neighbourhood safety significantly increased the risk of loneliness (RR: 1.21, 95% CI: 1.12–1.30) and SI (RR: 1.17, 95% CI 1.02–1.35) in younger adults, however no association was found for either outcome variable in older people. Low neighbourhood social cohesion was significantly associated with SI in younger (RR: 1.54, 95% CI: 1.34–1.76) and older people (RR: 1.36, 95% CI: 1.19–1.56). There was a significant effect for loneliness in older people (RR: 1.15, 95% CI: 1.06–1.24), however, no significant effect was seen in the younger population for loneliness ([Table 4](#), [Figures 1, 2](#)).

3.2.3 Individual and interpersonal determinants

In the regression models, among both younger and older participants, being socially isolated strongly predicted loneliness and vice versa; being lonely was strongly and significantly prospectively associated with SI ([Table 4](#)).

Adjusted for all other variables, being female was significantly associated with a higher risk of loneliness and a lower risk of SI in both populations. Poorer self-assessed health was strongly and significantly associated with an increased risk of loneliness and SI in both populations. Being employed was associated with a decreased risk of loneliness and SI in younger people. Living in a lone person household was associated with an increased risk of loneliness in older people but was not significant in younger people. Further details may be found in [Supplementary File 5](#).

4 Discussion

This is the first study to longitudinally identify such an extensive range of community-level determinants of loneliness and SI, comparing their effects among younger and older adults in the Australian context. Our findings support the utility of the social ecological model, demonstrating community level factors which affect the way that younger and older adults experience loneliness and SI. Community engagement emerged as the most influential community-level factor for both outcomes in younger and older adults, while social cohesion was also shown to reduce loneliness and SI in both populations. Additionally, there were several factors which were age specific, such as neighbourhood safety, neighbourhood atmosphere and cultural practices, highlighting important nuances in outcomes across generations. Our findings also confirm a strong relationship between loneliness and SI.

TABLE 2 Unweighted descriptive statistics for the younger population (18–30) stratified by wave.

Factors	Wave			
	Wave 6	Wave 10	Wave 14	Wave 18
	<i>n</i> (%) (<i>N</i> = 2,984)	<i>n</i> (%) (<i>N</i> = 3,494)	<i>n</i> (%) (<i>N</i> = 4,623)	<i>n</i> (%) (<i>N</i> = 4,406)
Age				
18–21	1,028 (34.45%)	1,211 (34.66%)	1,352 (29.25%)	1,218 (27.64%)
22–24	719 (24.10%)	823 (23.55%)	1,138 (24.62%)	961 (21.81%)
25–27	649 (21.75%)	764 (21.87%)	1,080 (23.36%)	1,140 (25.87%)
28–30	588 (19.71%)	696 (19.92%)	1,053 (22.78%)	1,087 (24.67%)
Gender				
Male	1,456 (48.79%)	1,769 (50.63%)	2,301 (49.77%)	2,174 (49.34%)
Female	1,528 (51.21%)	1,725 (49.37%)	2,322 (50.23%)	2,232 (50.66%)
Ethnicity				
Australian, non-indigenous	2,339 (83.48%)	2,823 (85.96%)	3,623 (83.02%)	3,464 (83.89%)
Australian, indigenous	106 (3.78%)	143 (4.35%)	226 (5.18%)	252 (6.10%)
Main English-speaking country born	113 (4.03%)	112 (3.41%)	173 (3.96%)	155 (3.75%)
Others	244 (8.71%)	206 (6.27%)	342 (7.84%)	258 (6.25%)
Marital status				
Legally married or de facto	1,212 (43.24%)	1,538 (46.83%)	1,995 (45.71%)	1,912 (46.31%)
Separated or divorced	35 (1.25%)	32 (0.97%)	52 (1.19%)	41 (0.99%)
Widowed	1 (0.04%)	1 (0.03%)	1 (0.02%)	1 (0.02%)
Never married and not de facto	1,555 (55.48%)	1,713 (52.16%)	2,316 (53.07%)	2,175 (52.68%)
Level of educational attainment				
Tertiary level educated	569 (20.30%)	582 (17.72%)	922 (21.13%)	953 (23.08%)
Trade certificate	700 (24.97%)	815 (24.82%)	1,251 (28.67%)	1,185 (28.70%)
High school certificate	927 (33.07%)	1,196 (36.42%)	1,421 (32.56%)	1,354 (32.79%)
Did not finish high school	569 (20.30%)	664 (20.22%)	712 (16.32%)	581 (14.07%)
Still in school	38 (1.36%)	27 (0.82%)	58 (1.33%)	56 (1.36%)
Self-assessed health				
Excellent	404 (17.38%)	465 (17.16%)	616 (17.01%)	563 (16.01%)
Very good	975 (41.95%)	1,137 (41.96%)	1,521 (42.00%)	1,412 (40.15%)
Good	721 (31.02%)	882 (32.55%)	1,145 (31.62%)	1,184 (33.67%)
Fair	193 (8.30%)	206 (7.60%)	299 (8.26%)	299 (8.50%)
Poor	31 (1.33%)	20 (0.74%)	40 (1.10%)	59 (1.68%)
Number of people in dwelling				
Multi-person household	2,524 (84.58%)	3,051 (87.32%)	3,946 (85.36%)	3,794 (86.11%)
Lone person household	460 (15.42%)	443 (12.68%)	677 (14.64%)	612 (13.89%)
Working status				
Employed	2,250 (80.27%)	2,538 (77.26%)	3,263 (74.75%)	3,234 (78.32%)
Unemployed, looking for work	159 (5.67%)	224 (6.82%)	345 (7.90%)	272 (6.59%)
Unemployed, not looking for work	394 (14.06%)	523 (15.92%)	757 (17.34%)	623 (15.09%)

(Continued)

TABLE 2 (Continued)

Factors	Wave			
	Wave 6	Wave 10	Wave 14	Wave 18
	<i>n</i> (%) (<i>N</i> = 2,984)	<i>n</i> (%) (<i>N</i> = 3,494)	<i>n</i> (%) (<i>N</i> = 4,623)	<i>n</i> (%) (<i>N</i> = 4,406)
Gross annual household income				
Below median	1,884 (63.14%)	1,788 (51.17%)	2,156 (46.64%)	1,775 (40.29%)
Above median	1,100 (36.86%)	1,706 (48.83%)	2,467 (53.36%)	2,631 (59.71%)
Civic engagement				
Average-High	927 (39.33%)	1,176 (43.73%)	1,577 (43.73%)	1,368 (38.61%)
Low (Bottom quartile)	1,430 (60.67%)	1,513 (56.27%)	2,029 (56.27%)	2,175 (61.39%)
Community engagement				
Average-High	1,683 (72.17%)	1,926 (72.27%)	2,401 (67.05%)	2,225 (62.91%)
Low (Bottom Quartile)	649 (27.83%)	739 (27.73%)	1,180 (32.95%)	1,312 (37.09%)
Altruism				
Average-High	1,351 (56.93%)	1,455 (53.93%)	1,872 (51.83%)	1,512 (42.48%)
Low (Bottom quartile)	1,022 (43.07%)	1,243 (46.07%)	1,740 (48.17%)	2,047 (57.52%)
Cultural practices				
Average-High	1,202 (50.74%)	1,480 (54.92%)	1,910 (52.86%)	1,817 (51.04%)
Low (Bottom quartile)	1,167 (49.26%)	1,215 (45.08%)	1,703 (47.14%)	1,743 (48.96%)
Neighbourhood safety				
Average-High	1,114 (53.76%)	1,303 (55.47%)	1,934 (60.93%)	1,971 (62.89%)
Low (Bottom quartile)	958 (46.24%)	1,046 (44.53%)	1,240 (39.07%)	1,163 (37.11%)
Neighbourhood social cohesion				
Average-High	1,362 (57.81%)	1,629 (60.74%)	2,153 (59.91%)	2,188 (61.53%)
Low (Bottom quartile)	994 (42.19%)	1,053 (39.26%)	1,441 (40.09%)	1,368 (38.47%)
Neighbourhood atmosphere				
Average-High	1,161 (50.92%)	1,291 (50.37%)	1,753 (50.81%)	1,696 (49.53%)
Low (Bottom quartile)	1,119 (49.08%)	1,272 (49.63%)	1,697 (49.19%)	1,728 (50.47%)
Remoteness				
Major cities	2,125 (71.21%)	2,375 (67.99%)	3,247 (70.24%)	3,016 (68.48%)
Inner regional	505 (16.92%)	684 (19.58%)	864 (18.69%)	894 (20.30%)
Outer regional- very remote	354 (11.86%)	434 (12.42%)	512 (11.08%)	494 (11.22%)
SEIFA quintiles				
Low 1	595 (19.94%)	706 (20.21%)	961 (20.79%)	835 (18.95%)
2	575 (19.27%)	738 (21.12%)	931 (20.14%)	973 (22.08%)
3	567 (19.00%)	728 (20.84%)	993 (21.48%)	875 (19.86%)
4	613 (20.54%)	693 (19.83%)	901 (19.49%)	908 (20.61%)
High 5	634 (21.25%)	629 (18.00%)	837 (18.11%)	815 (18.50%)

Percentages may not equal 100 due to missing values. Further information about missing values included in [Supplementary File 2](#).

The importance of community engagement provides a strong rationale for community-level interventions to prevent and reduce loneliness and SI. This importance was particularly pronounced for the older adults' experience of SI when compared to younger adults (RR: 2.02 vs. 1.58). This differential impact may be attributed to younger adults' access to institutionalised pathways for social connection such as those found through employment and educational settings, a finding supported by our individual-level results where employment demonstrated

protective effects against loneliness and SI in the younger cohort. For older adults, specific interventions to increase community engagement may be effective. Previous volunteer befriending interventions have been found to be beneficial in older populations, perhaps because they operationalise community engagement (26, 27). Interventions which allow older people to volunteer as well as be recipients of the programs may be even more beneficial for community loneliness reduction because of an additional effect of altruism (28).

TABLE 3 Unweighted descriptive statistics for the older population (60+) stratified by wave.

Factors	Wave			
	Wave 6	Wave 10	Wave 14	Wave 18
	<i>n</i> (%) (<i>N</i> = 2,873)	<i>n</i> (%) (<i>N</i> = 3,181)	<i>n</i> (%) (<i>N</i> = 4,424)	<i>n</i> (%) (<i>N</i> = 4,816)
Age				
60–64	753 (26.21%)	929 (29.20%)	1,218 (27.53%)	1,289 (26.76%)
65–69	651 (22.66%)	725 (22.79%)	1,091 (24.66%)	1,079 (22.40%)
70–74	518 (18.03%)	537 (16.88%)	778 (17.59%)	976 (20.27%)
75–79	472 (16.43%)	439 (13.80%)	572 (12.93%)	661 (13.73%)
80–84	308 (10.72%)	348 (10.94%)	425 (9.61%)	406 (8.43%)
85–89	126 (4.39%)	160 (5.03%)	242 (5.47%)	282 (5.86%)
90+	45 (1.57%)	43 (1.35%)	98 (2.22%)	123 (2.55%)
Gender				
Male	1,317 (45.84%)	1,485 (46.68%)	2,065 (46.68%)	2,231 (46.32%)
Female	1,556 (54.16%)	1,696 (53.32%)	2,359 (53.32%)	2,585 (53.68%)
Ethnicity				
Australian, non-indigenous	1,949 (70.92%)	2,077 (68.46%)	2,883 (68.20%)	3,168 (69.08%)
Australian, indigenous	26 (0.95%)	32 (1.05%)	38 (0.90%)	51 (1.11%)
Main English-speaking country born	391 (14.23%)	463 (15.26%)	649 (15.35%)	663 (14.46%)
Others	382 (13.90%)	462 (15.23%)	657 (15.54%)	704 (15.35%)
Marital status				
Legally married or de facto	1,739 (63.26%)	1,939 (63.87%)	2,756 (65.18%)	2,978 (64.95%)
Separated or divorced	290 (10.55%)	372 (12.25%)	542 (12.82%)	647 (14.11%)
Widowed	613 (22.30%)	602 (19.83%)	748 (17.69%)	744 (16.23%)
Never married and not de facto	107 (3.89%)	123 (4.05%)	182 (4.30%)	216 (4.71%)
Level of educational attainment				
Tertiary level educated	332 (12.09%)	466 (15.37%)	778 (18.44%)	980 (21.40%)
Trade certificate	698 (25.42%)	807 (26.62%)	1,247 (29.55%)	1,468 (32.05%)
High school certificate	185 (6.74%)	237 (7.82%)	319 (7.56%)	364 (7.95%)
Did not finish high school	1,531 (55.75%)	1,522 (50.20%)	1,876 (44.45%)	1,768 (38.60%)
Self-assessed health				
Excellent	98 (4.00%)	104 (3.74%)	156 (4.02%)	165 (3.90%)
Very good	603 (24.62%)	714 (25.69%)	1,043 (26.89%)	1,122 (26.49%)
Good	956 (39.04%)	1,097 (39.47%)	1,502 (38.72%)	1,701 (40.17%)
Fair	634 (25.89%)	699 (25.15%)	928 (23.92%)	986 (23.28%)
Poor	158 (6.45%)	165 (5.94%)	250 (6.44%)	261 (6.16%)
Number of people in dwelling				
Multi-person household	2,038 (70.94%)	2,308 (72.56%)	3,246 (73.37%)	3,561 (73.94%)
Lone person household	835 (29.06%)	873 (27.44%)	1,178 (26.63%)	1,255 (26.06%)
Working status				
Employed	505 (18.37%)	666 (21.94%)	1,013 (23.95%)	1,115 (24.31%)
Unemployed, looking for work	14 (0.51%)	15 (0.49%)	30 (0.71%)	36 (0.78%)

(Continued)

TABLE 3 (Continued)

Factors	Wave			
	Wave 6	Wave 10	Wave 14	Wave 18
	<i>n</i> (%) (<i>N</i> = 2,873)	<i>n</i> (%) (<i>N</i> = 3,181)	<i>n</i> (%) (<i>N</i> = 4,424)	<i>n</i> (%) (<i>N</i> = 4,816)
Unemployed, not looking for work	2,230 (81.12%)	2,355 (77.57%)	3,186 (75.34%)	3,436 (74.91%)
Gross annual household income				
Below median	2,551 (88.79%)	2,608 (81.99%)	3,310 (74.82%)	3,406 (70.72%)
Above median	322 (11.21%)	573 (18.01%)	1,114 (25.18%)	1,410 (29.28%)
Civic engagement				
Average-High	1,300 (52.80%)	1,598 (58.32%)	2,171 (56.83%)	2,230 (53.10%)
Low (Bottom quartile)	1,162 (47.20%)	1,142 (41.68%)	1,649 (43.17%)	1,970 (46.90%)
Community engagement				
Average-High	1,764 (73.68%)	2,021 (75.92%)	2,776 (75.13%)	3,007 (73.36%)
Low (Bottom quartile)	630 (26.32%)	641 (24.08%)	919 (24.87%)	1,092 (26.64%)
Altruism				
Average-High	1,944 (78.14%)	2,187 (79.10%)	2,937 (76.17%)	3,025 (71.58%)
Low (Bottom quartile)	544 (21.86%)	578 (20.90%)	919 (23.83%)	1,201 (28.42%)
Cultural practices				
Average-High	1,645 (66.12%)	1,855 (67.14%)	2,458 (63.94%)	2,577 (61.05%)
Low (Bottom quartile)	843 (33.88%)	908 (32.86%)	1,386 (36.06%)	1,644 (38.95%)
Neighbourhood safety				
Average-High	1,662 (71.12%)	1,842 (72.18%)	2,713 (76.14%)	2,990 (77.62%)
Low (Bottom quartile)	675 (28.88%)	710 (27.82%)	850 (23.86%)	862 (22.38%)
Neighbourhood social cohesion				
Average-High	1,810 (75.39%)	2,074 (76.31%)	2,966 (78.13%)	3,280 (78.41%)
Low (Bottom quartile)	591 (24.61%)	644 (23.69%)	830 (21.87%)	903 (21.59%)
Neighbourhood atmosphere				
Average-High	1,565 (65.54%)	1,715 (64.62%)	2,350 (63.79%)	2,610 (63.72%)
Low (Bottom quartile)	823 (34.46%)	939 (35.38%)	1,334 (36.21%)	1,486 (36.28%)
Remoteness				
Major cities	1,716 (59.73%)	1,934 (60.80%)	2,702 (61.08%)	2,944 (61.13%)
Inner regional	750 (26.11%)	806 (25.34%)	1,120 (25.32%)	1,231 (25.56%)
Outer regional- very remote	407 (14.17%)	441 (13.86%)	602 (13.61%)	641 (13.31%)
SEIFA quintiles				
Low 1	734 (25.55%)	757 (23.80%)	1,055 (23.85%)	1,108 (23.01%)
2	592 (20.61%)	642 (20.18%)	923 (20.86%)	994 (20.64%)
3	581 (20.22%)	647 (20.34%)	829 (18.74%)	894 (18.56%)
4	476 (16.57%)	572 (17.98%)	805 (18.20%)	880 (18.27%)
High 5	490 (17.06%)	563 (17.70%)	812 (18.35%)	940 (19.52%)

Percentages may not equal 100 due to missing values. Further information about missing values included in [Supplementary File 2](#).

Our results provide robust evidence for investigating loneliness and SI jointly due to their mutual influence, supporting previous work (2, 8). At the individual level, our results are also in agreement with previously published literature, whereby gender was shown to have universal relevance in determining loneliness and SI (29). We also replicate results showing that marriage and

household size are not consistent predictors across both age groups (29). Despite some individual-level factors, such as gender or self-assessed, health having a stronger effect on loneliness and SI, they are less amendable to change, highlighting the need for action on every level of the social ecological model to appropriately address loneliness and SI.

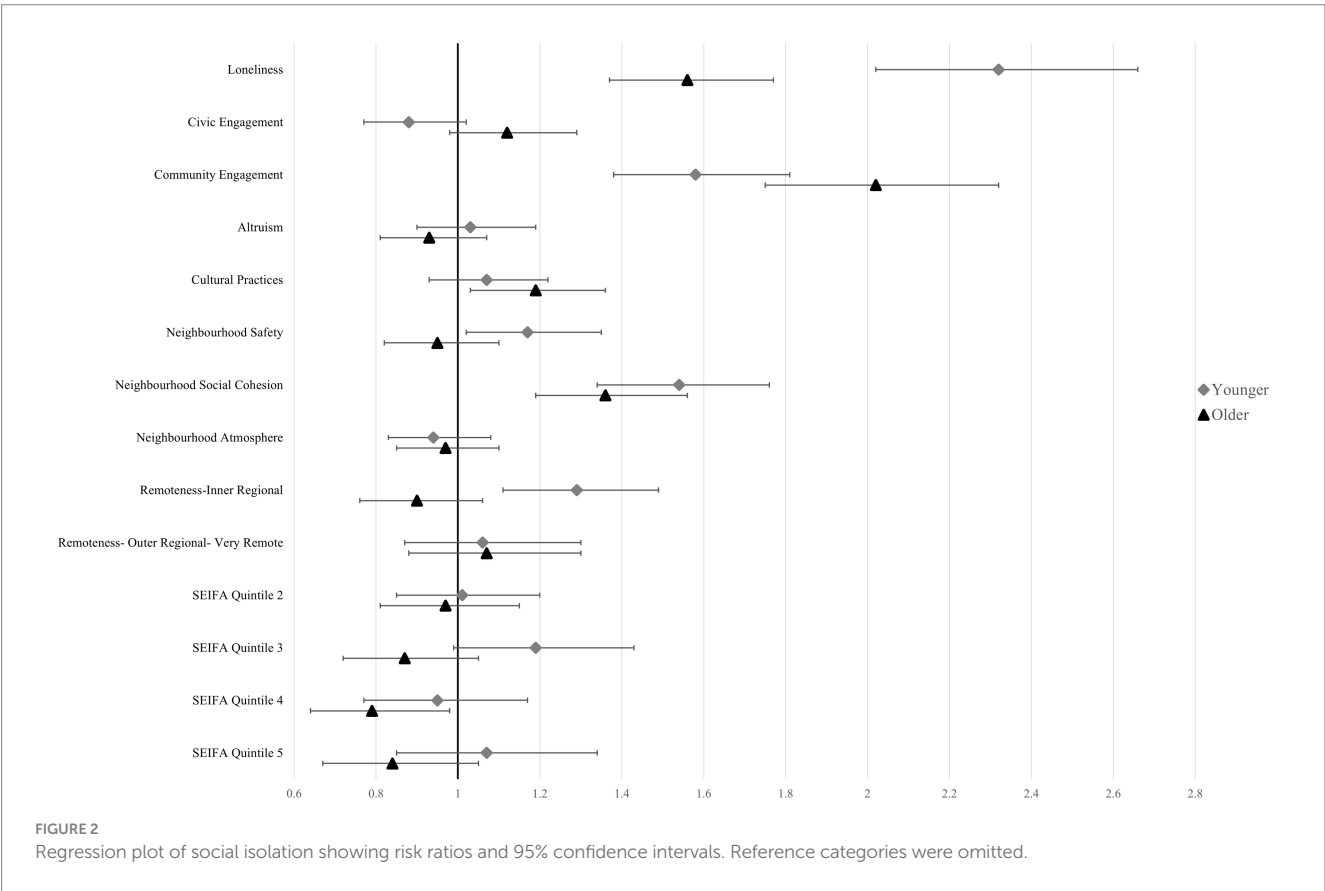
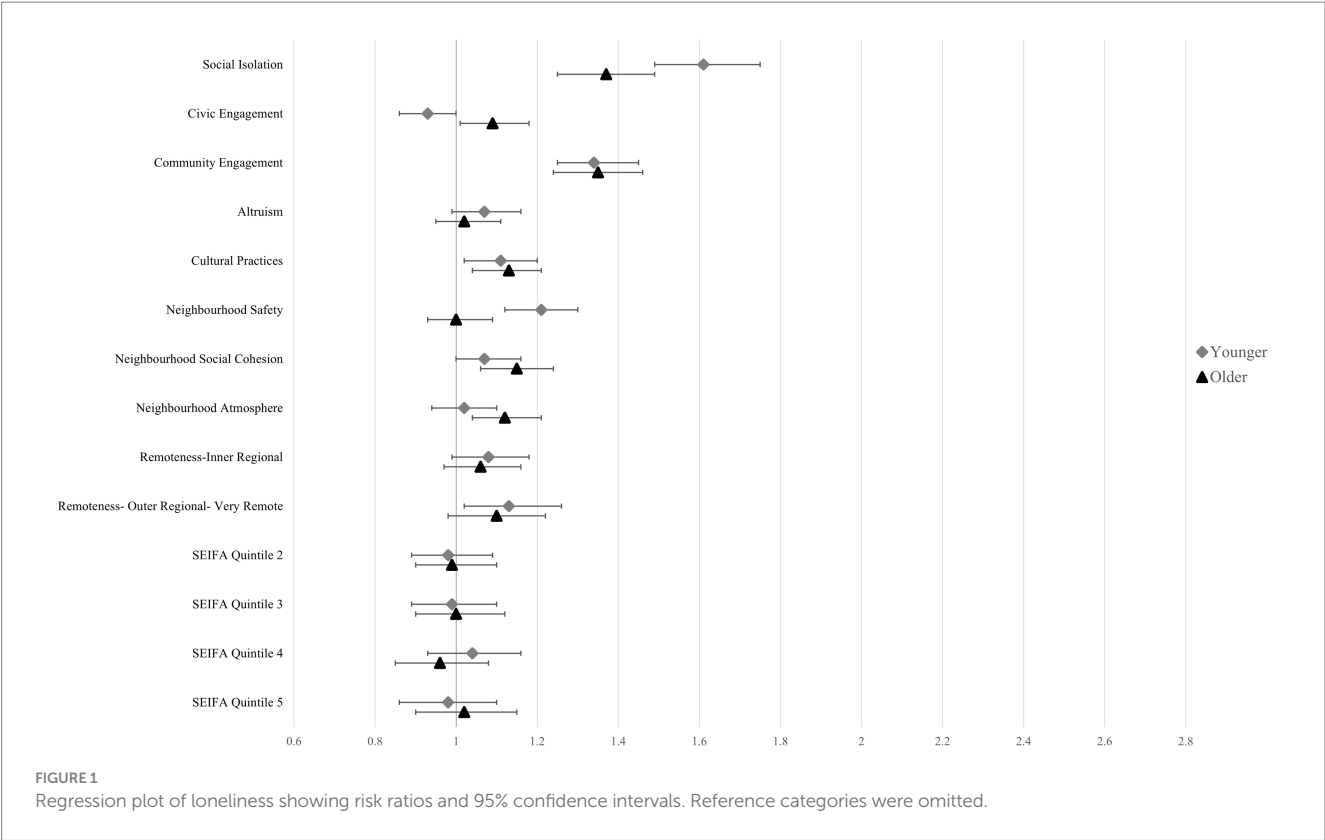
TABLE 4 Poisson regression of loneliness and social isolation displaying risk ratios.

Variables	Loneliness		Social isolation	
Population	Younger (18–30)	Older (60+)	Younger (18–30)	Older (60+)
	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
Number of observations	8,215	9,876	8,220	9,875
Intercept	0.07 (0.06–0.09)***	0.07 (0.05–0.10)***	0.02 (0.01–0.03)***	0.05 (0.03–0.09)***
Loneliness				
Not lonely	-	-	Ref	Ref
Lonely	-	-	2.32 (2.02–2.66)***	1.56 (1.37–1.77)***
Social isolation				
Not isolated	Ref	Ref	-	-
Isolated	1.61 (1.49–1.75)***	1.37 (1.25–1.49)***	-	-
Time (Wave)	1.01 (1.00–1.02)	1.00 (0.99–1.01)	1.01 (1.00–1.03)	1.00 (0.98–1.01)
Community participation variables				
Civic engagement				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	0.93 (0.86–1.00)	1.09 (1.01–1.18)*	0.88 (0.77–1.02)	1.12 (0.98–1.29)
Community engagement				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	1.34 (1.25–1.45)***	1.35 (1.24–1.46)***	1.58 (1.38–1.81)***	2.02 (1.75–2.32)***
Altruism				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	1.07 (0.99–1.16)	1.02 (0.95–1.11)	1.03 (0.90–1.19)	0.93 (0.81–1.07)
Cultural practices				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	1.11 (1.02–1.20)*	1.13 (1.04–1.21)**	1.07 (0.93–1.22)	1.19 (1.03–1.36)*
Neighbourhood variables				
Neighbourhood safety				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	1.21 (1.12–1.30)***	1.00 (0.93–1.09)	1.17 (1.02–1.35)*	0.95 (0.82–1.10)
Neighbourhood social cohesion				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	1.07 (1.00–1.16)	1.15 (1.06–1.24)***	1.54 (1.34–1.76)***	1.36 (1.19–1.56)***
Neighbourhood atmosphere				
Average-High	Ref	Ref	Ref	Ref
Low (Bottom quartile)	1.02 (0.94–1.10)	1.12 (1.04–1.21)**	0.94 (0.83–1.08)	0.97 (0.85–1.10)
Remoteness				
Major cities	Ref	Ref	Ref	Ref
Inner regional	1.08 (0.99–1.18)	1.06 (0.97–1.16)	1.29 (1.11–1.49)***	0.90 (0.76–1.06)
Outer regional-very remote	1.13 (1.02–1.26)*	1.10 (0.98–1.22)	1.06 (0.87–1.30)	1.07 (0.88–1.30)
SEIFA quintiles				
Low 1	Ref	Ref	Ref	Ref
2	0.98 (0.89–1.09)	0.99 (0.90–1.10)	1.01 (0.85–1.20)	0.97 (0.81–1.15)
3	0.99 (0.89–1.10)	1.00 (0.90–1.12)	1.19 (0.99–1.43)	0.87 (0.72–1.05)
4	1.04 (0.93–1.16)	0.96 (0.85–1.08)	0.95 (0.77–1.17)	0.79 (0.64–0.98)*
High 5	0.98 (0.86–1.10)	1.02 (0.90–1.15)	1.07 (0.85–1.34)	0.84 (0.67–1.05)

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

All models adjusted for the following individual and interpersonal level factors: age, gender, ethnicity, marital status, level of educational attainment, self-assessed health, number of people in dwelling, working status, and gross annual household income.

Significant results are bolded.



Our findings underscore the complex interplay between individual, interpersonal, community and societal-level factors in shaping experiences of loneliness and SI, further demonstrating how factors at different ecological levels may interact dynamically, creating both vulnerabilities and opportunities for intervention that would be missed by single-level analyses. Similarly, Holt-Lunstad (30) emphasises that social disconnection emerges from interactions between personal vulnerabilities and environmental contexts, with neither alone fully explaining outcomes. This multi-level interaction may explain why certain community factors, such as neighbourhood safety, have differential impacts across age groups, reflecting not just varying environmental needs but also age-related psychological resources and coping mechanisms. These interactions highlight the need for interventions that simultaneously address multiple levels of the social ecological model, bridging individual characteristics with community resources in ways that create meaningful connections.

The literature supporting the effect of neighbourhood social cohesion among older people is well developed (6, 31), but is less robust among younger people (32). Our study demonstrates that social cohesion can also impact loneliness and SI in younger people, albeit a weaker association than for community engagement. Our results indicate that increasing social cohesion in the community would benefit both the younger and older populations. Previous research suggests that this may be achieved through countering social stereotypes and providing opportunities for positive interactions (33).

Neighbourhood safety, neighbourhood atmosphere and cultural practices affected each age group differently. The cultural practice variable elicited an effect on younger adults' loneliness but not SI, and older adults' loneliness and SI, suggesting different causal pathways which may require different intervention approaches. Younger people are less likely to identify as religious than older people, and therefore, unlike older people, are less inclined to experience going to religious places as a social practice (34). Therefore, attending religious services has differential effects for each age cohort. Younger people who do engage in religious services however, draw a much stronger sense of identity from these practices, lowering their potential for loneliness when compared to those who do not engage in religious services (35).

Low perceived neighbourhood safety was seen to predict loneliness in younger and older people in our study, consistent with previous research (36). Approaches that improve the neighbourhood safety in communities with a high proportion of younger or older adults may help reduce loneliness. Previous studies have shown a relationship between social cohesion and neighbourhood safety, allowing for considerations of neighbourhood safety to be incorporated into population approaches for improving neighbourhood social cohesion, rather than as standalone interventions (37).

Contrary to previous studies (20), we did not find an association between SEIFA and loneliness and SI, except for a weak protective effect over SI in older adults in the second-highest SEIFA quintile. We hypothesise that community-level factors may mitigate the effect that SEIFA has on the outcomes, demonstrating that SEIFA may not be a good indicator of the risk of loneliness or SI in a population. Lower socio-economic areas typically have lower offerings of activities, which may hinder peoples' ability to connect (38).

A strength of this study is our longitudinal design, using the HILDA dataset. HILDA has a robust study design and covers a wide range of variables across the individual, interpersonal and community

levels allowing investigation of factors at the community-level, while controlling for factors from the other levels, addressing a research gap identified in a previous review (6). However, the HILDA data does not assess other community-level factors and potential confounders, such as the effect of personality, open green space and transport availability, which have also been found to influence loneliness and SI. While our longitudinal design helps reduce the impact of time-invariant unmeasured confounders, time-varying unmeasured factors could still influence our findings, therefore further investigation through data linkage studies would be beneficial (39).

A limitation of this study is the reliance on self-reported responses as an indirect proxy for determining community-level variables, which may introduce differential measurement bias where those who are lonely or isolated may overstate or understate the effects of community variables (40). However, self-reported data can be a reliable measurement tool in neighbourhood settings particularly those that are answered on a large-scale, which have been shown to have high internal-consistency and re-test reliability (41). Further, we constructed covariates by collapsing several questions under one concept category (e.g., cultural practice, neighbourhood atmosphere) to minimise the number of factors, limiting our ability to identify which aspect is more influential.

Our sample was drawn from a nationally representative sample in the Australian context; however, some caution should be employed when generalising our findings. The HILDA sample only includes private dwellings, therefore those who are in unstable housing and those who reside in institutions, including those living in defence force dwellings and aged-care homes are not captured in this study, representing a limitation, particularly in the younger and older adults who are more likely to be in these populations. Additionally, when generalising these findings outside of the Australian context, specific cultural considerations and context specific factors must be considered. Further research is needed to elucidate the extent of these limitations.

4.1 Implications for research, policy and practice

Given this study used research-led quantitative conceptualisation of community-level determinants, it will be important to further examine how Australian younger and older people understand loneliness and SI in their lives and how community-level factors may influence their experiences using qualitative methods. In addition, leaders in the fields of loneliness and SI research have called for a systems approach as a priority for future research (42), as is exemplified by our results. Evaluations of future interventions which account for all levels of influence should be undertaken to examine whether there is added benefit of using the social ecological framework when compared to an individualised approach. Future research should adopt a life-course approach ensuring prevention can occur at the primordial level rather than targeting only those at most risk or those already suffering from loneliness and/or SI. Interventions that prioritise creating healthy connections and cultural identity within a community, through formation of community interest groups and clubs; or evaluations of social policy changes, such the implementation of free community events and park upgrades, are

necessary. Specific policy recommendations include ensuring the continuity of community groups through targeted and sustainable funding, investing in spaces with community-led design which would include parks, community centres and other public third places. Additionally, implementing free or low-cost inter-generational events may help to improve social cohesion across younger and older populations.

5 Conclusion

By identifying and comparing the effects of an extensive range of community-level determinants of loneliness and SI among younger and older adults in the Australian context, our findings demonstrate community level factors which affect the way that these populations experience loneliness and SI. The findings highlight age-specific nuances, such as those for neighbourhood safety, neighbourhood atmosphere and cultural practices, which provide evidence for the need to account for all levels of the social ecological model in determining appropriate interventions and solutions. Our study highlights the importance of using a social ecological framework when designing public health programs to address loneliness and SI in younger and older people as there needs to be consideration of the individual, interpersonal, community and societal factors in tandem to effectively prevent and reduce loneliness and SI.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: this paper uses unit record data from Household, Income and Labour Dynamics in Australia Survey [HILDA] conducted by the Australian Government Department of Social Services (DSS). The findings and views reported in this paper, however, are those of the author[s] and should not be attributed to the Australian Government, DSS, or any of DSS' contractors or partners, doi: [10.26193/PI5LPJ](https://doi.org/10.26193/PI5LPJ). Requests to access these datasets should be directed to Australian Government Department of Social Services (DSS), doi: [10.26193/PI5LPJ](https://doi.org/10.26193/PI5LPJ).

Ethics statement

The HILDA study was approved by the Human Research Ethics Committee of the University of Melbourne. The study used only de-identified existing unit record data from the HILDA survey. The authors completed and signed a confidentiality agreement with NCLD (nclresearch@dss.gov.au) and obtained database access from the Australian Data Archive (ada@anu.edu.au) following application acceptance. Additional approval was sought from the Human Research Ethics Committee of Western Sydney University: HREC Approval Number: H15196.

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DEM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. PC: Formal analysis, Methodology, Supervision, Writing – review & editing. AG: Supervision, Writing – review & editing. DM: Conceptualization, Formal analysis, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2025.1526166/full#supplementary-material>

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Study on the mechanism of family resilience on loneliness in older adults with stroke

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Objective: This study examines loneliness in stroke patients who were ≥ 60 years of age, identifying key factors such as family resilience, social support, family function, and psychological capital.

Methods: We sampled 234 stroke patients who were ≥ 60 years of age. These patients were diagnosed with stroke (ischemic stroke, hemorrhagic stroke) by the hospital and their condition is stable in the recovery period. Data were collected using the UCLA Loneliness Scale, Family Resilience Assessment scale, Positive Psychological Capital scale, Family APGAR Index, and Social Support Rating Scale. Using one-way analysis of variance and multiple linear regression equation to analyze the influencing factors of loneliness in older adults with stroke; Construct a structural equation model to explore the pathways of social support, family function and psychological capital in the relationship between family resilience and loneliness.

Results: The average loneliness score among older adults with stroke was (35.07 ± 15.24). Factors affecting loneliness included income, activity level, community resources, social participation, and illness duration. Pearson analysis showed significant negative correlations between loneliness and family resilience ($r = -0.738$, $P < 0.01$), social support ($r = -0.715$, $P < 0.01$), family function ($r = -0.745$, $P < 0.01$), and psychological capital ($r = -0.684$, $P < 0.01$). Family resilience has a direct negative predictive effect on loneliness ($\beta = -0.342$, $P < 0.001$). Social support, family functioning, and psychological capital play a chain mediating effect between family resilience and loneliness, with a mediating effect value of -0.436 , accounting for 56.04% of the total effect.

Conclusion: Loneliness in elderly stroke patients is moderate. Strengthening family resilience and support systems can effectively reduce loneliness.

KEYWORDS

older adults with stroke, loneliness, family resilience, social support, family function, psychological capital

1 Introduction

Stroke is an acute neurological disorder resulting from either the blockage or rupture of cerebral blood vessels. As population aging intensifies, stroke has emerged as a leading factor contributing to the global disease burden (Li X. Y. et al., 2024). Research suggests that the likelihood of experiencing a stroke rises with age, particularly among individuals over 60, who are at increased risk, while those over 70 are even more susceptible to severe disability or death. This places substantial economic and caregiving pressures on both families and society (Collaborators GBDS, 2021).

Studies have shown that stroke patients are highly prone to suffering from varying degrees of physical, language, and cognitive impairments (VanGilder et al., 2020; Elendu et al., 2023; Nakawah and Lai, 2016). These issues can lead to feelings of stigma and self blame among patients, who then actively or passively reduce their interactions with family and society, thereby experiencing higher levels of loneliness (Guo et al., 2024; Zhu et al., 2019; Fan et al., 2023; Huang et al., 2024; Hughes and Cummings, 2020). Loneliness, defined as a subjective emotional distress caused by the gap between expected and actual social connections (Seemann, 2022), can hasten physical decline in the elderly and is linked to moderate to severe depression, cognitive decline, and poor self-perceived health (Odaci Comertoglu et al., 2024). In severe cases, loneliness can directly affect the nervous system, increasing the risk of stroke recurrence by 40% (Cené et al., 2022), which significantly worsens their rehabilitation outcomes.

According to the theory of social ecosystem, psychological capital, family functioning, and social support are the influencing factors of loneliness in stroke patients (Yang et al., 2025). Psychological capital, family function, and social support are closely related to the three elements of family belief system, family communication process, and family organizational model in Walsh's family resilience framework model (Walsh, 2016). It can be inferred that there is a certain correlation between family resilience and loneliness, which can indirectly affect the loneliness of stroke patients through the effects of psychological capital, family function, and social support.

Family resilience refers to a family's ability to adapt positively when confronted with adversity, characterized by constructive behavior patterns that are strongly linked to individual psychological resources, family functioning, and the availability of social support (Walsh, 2003; Li et al., 2019; Wong et al., 2019; Zhang et al., 2022). Strong psychological capital, healthy family dynamics, and high levels of social support are crucial for reducing patients' psychological distress and promoting their reintegration

into society. Research has found that strong psychological capital can help patients maintain a relatively stable mentality when facing pressure and difficulties caused by illness (Parviniannasab et al., 2022). Family functioning can help patients enhance their psychological resilience and subjective wellbeing, and high-level social support can significantly improve their mental health (Coty and Wallston, 2010; Zhou and Kulick, 2023). These can effectively enhance their positive coping strategies for illness, and reduce loneliness. It is therefore suggested that family resilience could play a vital role in alleviating loneliness among older adults with stroke. However, the specific mechanisms through which it achieves this outcome is still mostly unclear. According to the theory of social ecosystem and the theory of family elasticity, combined with the literature review, we proposed the following assumptions and developed the model (Figure 1).

This study mainly discusses the current situation and influencing factors of loneliness in older adults with stroke, and constructs a Structural Equation Model (SEM) using psychological capital, family function, and social support as a mediating factor to explore the relationship between family resilience and loneliness. Provide new research insights and theoretical guidance for alleviating loneliness in older adults with stroke from the perspective of improving family resilience.

2 Object and method

2.1 Research subjects

We used convenience sampling to select 234 older adults with stroke discharged from the Rizhao Stroke Diagnosis and Treatment Center between December 2023 and June 2024. The study was approved by the Medical Ethics Committee of Rizhao People's Hospital (Ethical Approval Number: 2024-MR-40-01). The study was performed in accordance with the STROBE guidelines. Trial

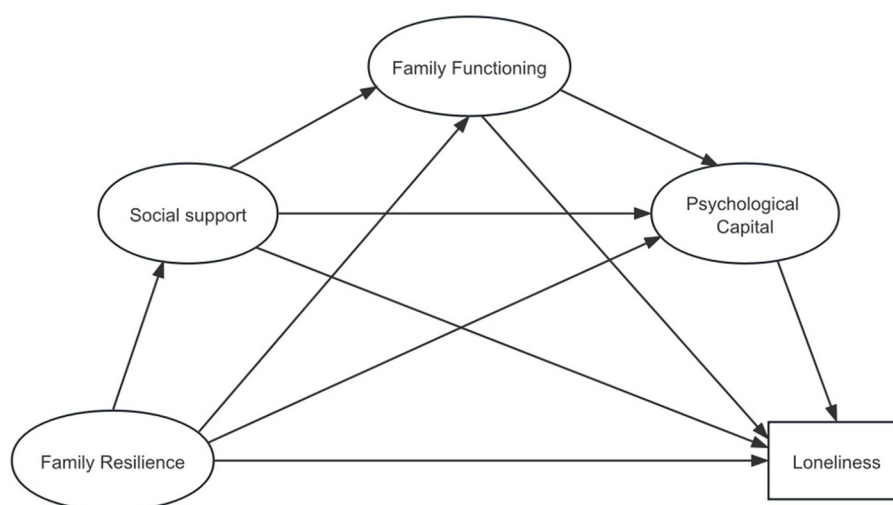


FIGURE 1
Hypothetical model.

registration: Chinese Clinical Trial Registry Identifier: MR 37-24-043662.

Included were: (1) Patients diagnosed with stroke (both hemorrhagic and ischemic stroke) confirmed by cranial CT or MRI, in accordance with the diagnostic criteria of the Chinese Clinical Management Guidelines for Cerebrovascular Disease (Lou et al., 2020). (2) Patients with stroke aged 60 years or older. (3) Patients with stable stroke conditions and in the recovery phase. Excluded were: (1) Patients with mental illness, severe cognitive or memory impairment. (2) Patients with a history of significant traumatic events (such as bereavement, severe accidents, or cancer diagnosis) in the past 6 months.

2.2 Sample size

This cross-sectional survey investigates the prevalence of loneliness among older adults with stroke in a specific region, employing a two-tailed test with a significance level of $\alpha = 0.05$. Based on multiple studies, ~40–66% of older adults with stroke experience feelings of loneliness (Liu X. et al., 2021; Byrne et al., 2022; Hollands et al., 2024; Zhang M. Y. et al., 2023). Structural equation modeling (SEM) requires large samples for computation because large samples can provide more stable parameter estimates, enhance the power of statistical tests, and better meet the assumptions of data distribution, thereby ensuring the reliability and accuracy of the model. Consequently, the anticipated prevalence (P) was set at 40%, with an allowable error (δ) of $1/6$ of P . Utilizing the sample size calculation formula for proportions (Verma et al., 2024), the required sample size was determined to be 210 participants. To account for an estimated 10% rate of invalid questionnaires, the study aimed to include at least 234 participants.

2.3 Survey instruments

2.3.1 General information questionnaire

We developed a questionnaire divided into two sections. The first section collected general demographic data, including gender, age, residence, marital status, living arrangements, educational level, occupation, per capita monthly household income, type of health insurance, social media engagement, participation in social activities, and community resource availability. The second section addressed disease-related information, encompassing the type of stroke, frequency of stroke incidents, dependency in activities of daily living (ADL), the number of combined diseases, and the duration of the illness. The self-designed questionnaire is based on multiple literatures regarding the influencing factors of loneliness, aiming to comprehensively assess the current status of loneliness among older adults with stroke and its related factors (Zuo et al., 2023; Meehan et al., 2023; Guo et al., 2023).

2.3.2 Shortened Chinese Version of the Family Resilience Assessment Scale (FRAS-C)

We then utilized the Shortened Chinese Version of the Family Resilience Assessment Scale (FRAS-C), translated and introduced

by Li et al. (2016), to assess family resilience among older adults with stroke. This scale comprises three dimensions: family belief system, family communication process, and family organizational model, featuring a total of 32 items. It employs a 4-point Likert scoring system, with overall scores ranging from 32 to 128, where higher scores indicate greater family resilience. The FRAS-C has been extensively applied in stroke research; previous studies reported a Cronbach's alpha coefficient of 0.97 (Yan et al., 2021), while this study found it to be 0.919. Additionally, the Construct Reliability (CR) was 0.846, and the Average Variance Extracted (AVE) was 0.6475.

2.3.3 University of California, Los Angeles Loneliness Scale (UCLA)

In this study, we used the third edition of the University of California, Los Angeles Loneliness Scale (UCLA) (Russell, 1996), developed by Russell et al., to assess loneliness among older adults with stroke. This scale comprises 20 items and utilizes a 4-point Likert scoring system, with total scores ranging from 20 to 80 points. Specifically, scores below 28 signify a low level of loneliness, scores between 28 and 33 indicate a below-average level, scores from 34 to 38 represent an average level, scores from 39 to 44 reflect an above-average level, and scores exceeding 44 denote a high level of loneliness. Previous studies reported a Cronbach's alpha coefficient of 0.96 for this scale (Bottaro et al., 2023), while the current study achieved a significantly higher coefficient of 0.972, indicating excellent internal consistency.

2.3.4 Social support rating scale (SSRS)

We utilized the Social Support Rating Scale (SSRS) developed by Xiao Shuiyuan et al. to evaluate the level of social support among older adults with stroke. The SSRS is widely recognized and used in China (Huang et al., 2020; Fang et al., 2022; Li et al., 2021). The scale comprises three dimensions: objective support, subjective support, and the utilization of social support, with a total of 10 items. Total scores range from 12 to 66, where higher scores indicate more favorable social support conditions. Specifically, scores below 35 signify low social support, scores between 35 and 45 indicate moderate support, and scores above 45 reflect high social support. Previous research indicated a Cronbach's alpha coefficient of 0.81 for this scale (Shen et al., 2022), while this study recorded a coefficient of 0.835. Additionally, the Construct Reliability (CR) was found to be 0.838, and the Average Variance Extracted (AVE) was 0.636.

2.3.5 Family caregiving APGAR index (APGAR)

The APGAR index was used to assess older adults with stroke' subjective satisfaction with their family functioning. Developed by American scholar Smilkstein in 1978 (Smilkstein, 1978), the Family Caregiving APGAR Index Scale consists of five items: adaptation, partnership, growth, affection, and resolve. This scale utilizes a 3-point Likert scoring system, yielding total scores that range from 0 to 10, with higher scores reflecting more effective family functioning. Specifically, scores between 7 and 10 indicate good family function and high levels of care; scores ranging from 4 to 6 suggest moderate impairment and partial loss of family care;

scores from 0 to 3 signify severe family function impairment and significant loss of care. Previous research reported a Cronbach's alpha coefficient of 0.88 for this scale (Liu T. L. et al., 2021), while the current study recorded a coefficient of 0.866. Additionally, the Construct Reliability (CR) was 0.867, and the Average Variance Extracted (AVE) was 0.567.

2.3.6 Positive psychological capital questionnaire (PPQ)

To assess the psychological capital of older adults with stroke, we used the Positive Psychological Capital Questionnaire (PPQ) (Kuo et al., 2010; Wang and Xue, 2021). Developed by Zhang Kuo and colleagues, the PPQ was formulated after reviewing domestic and international literature and measurement tools. The questionnaire consists of 26 items across four dimensions: self-efficacy, resilience, optimism, and hope. Each item is rated on a 7-point Likert scale, with total scores ranging from 26 to 182, where higher scores reflect a more positive psychological state. Scores above 154 indicate a superior psychological state, 109 to 154 suggest a moderate level, and scores below 109 indicate a poor psychological state. Previous studies reported a Cronbach's alpha of 0.94 (Jeong and Kim, 2022), while this study achieved an alpha of 0.938. Additionally, the Construct Reliability (CR) was 0.917, and the Average Variance Extracted (AVE) was 0.733.

2.4 Survey methodology

The questionnaire survey method was used to gather data. Surveyors were trained to use uniform instructional language to introduce the requirements for completing the questionnaire, informing participants of the purpose of the study and the right not to participate or to withdraw from the survey at any time. Before conducting the survey, patients were informed of the study's purpose and significance, and their informed consent was obtained. Instructions for completing the questionnaire were explained, and patients filled it out according to their actual circumstances. For those unable to complete it independently, the Surveyors asked the questions and recorded the responses. To minimize bias, the Surveyors personally distributed and supervised the completion of all questionnaires, offering standardized explanations without leading questions or subjective input. Completed questionnaires were reviewed on-site, and any missing or illogical responses were addressed by the Surveyors before final collection. Before data entry, the questionnaires were rechecked for completeness, and those with more than 20% missing data were excluded. Two individuals were responsible for data entry and coding, and a random sample of entered data was cross-verified against the original responses to ensure accuracy.

2.5 Statistical methods

SPSS 25.0 and AMOS 24.0 were applied for data analysis after double checking. The data were expressed as frequencies, percentages, means and standard deviations. Using one-way

analysis of variance to compare the differences in loneliness among older adults with stroke with different demographic and disease characteristics groups. Construct a multiple linear regression equation with statistically significant factors in one-way ANOVA as independent variables and loneliness score as dependent variable for analysis. Using Pearson correlation analysis to explore the correlation between family resilience, social support, family functioning, psychological capital and loneliness in older adults with stroke. The structural equation model was constructed using AMOS 24.0 software. The mediating effects were tested by the Bootstrap bias-corrected percentile method with 5,000 resamples. $P < 0.05$ indicated statistical significance.

3 Results

3.1 Demographic and disease characteristics of older adults with stroke

A total of 234 older adults with stroke were ultimately included in the study, with ages ranging from 60 to 86 years, and a mean age of 71.56 ± 6.88 years. In terms of demographic characteristics, there were 130 male patients, accounting for 55.6%, which was slightly higher than the number of females. Regarding marital status, the highest proportion was married patients, at 85.9% (201 cases). In terms of occupation, the largest proportion was farmers, at 72.2% (169 cases). Regarding educational level, 60.3% of patients had an elementary school education or lower. In terms of family economic status, 54.3% of patients had a per capita monthly family income of less than 2,000 yuan. Regarding the payment method for medical expenses, urban resident insurance was the primary method, accounting for 75.2% (176 cases). In terms of disease characteristics, 73.9% of patients had mild dependence in activities of daily living. The proportion of ischemic stroke patients was 96.2% (225 cases), and the majority of patients had their first stroke (175 cases, 74.8%). Detailed data are shown in Table 1.

3.2 Total scores of family resilience, social support, family functioning, psychological capital, and Loneliness in older adults with stroke

The family resilience score of the older adults with stroke averaged (97.80 ± 16.88), while the social support score was (38.31 ± 8.74). The family functioning score averaged (7.06 ± 2.97), the psychological capital score was (119.85 ± 29.26), and the loneliness score averaged (35.07 ± 15.24).

3.3 Analysis of factors influencing loneliness in older adults with stroke

Univariate analysis was performed to examine the loneliness scores of older adults with stroke across various demographic and disease-related characteristics. The findings revealed statistically significant differences in loneliness based on factors such as place

TABLE 1 Demographic and disease characteristics.

Item	Category	N	Rate (%)	Item	Category	N	Rate (%)
Gender	Male	130	55.6	Type of health insurance	Urban Resident Insurance	176	75.2
	Female	104	44.4		Urban Employee Insurance	58	24.8
Age	60–70	103	44.0	Social media usage	None	0	0.0
	71–80	110	47.0		Yes	105	44.9
	>80	21	9.0		No	129	55.1
Place of residence	Urban	98	41.9	Community resource availability	Good	101	43.2
	Rural	136	58.1		Moderate	81	34.6
Marital status	Unmarried	0	0.0		Poor	52	22.2
	Married	201	85.9	Participation in social activities	Yes	90	38.5
	Divorced	1	0.4		No	144	61.5
	Widowed	32	13.7	Stroke type	Ischemic	225	96.2
Living arrangements	Living Alone	20	8.5		Hemorrhagic	9	3.8
	Living with Spouse	176	75.2	Frequency of stroke incidents	First episode	175	74.8
	Living with Children	22	9.4		Multiple episodes	59	25.2
	Living with Spouse and Children	13	5.6	Activities of daily living (ADL)	Mild dependence	173	73.9
	Other	3	1.3		Moderate dependency	44	18.8
Educational level	Elementary school	141	60.3		Severe dependency	17	7.3
	Junior High School	58	24.8	The number of combined diseases	0	13	5.6
	High School	32	13.7		1	48	20.5
	University or above	3	1.3		2	63	26.9
Occupation	Retired	59	25.2		≥3	110	47.0
	Farmer	169	72.2	The duration of the illness	Within 1 Month	65	27.8
	Self-employed	4	1.7		2–3 Months	58	24.8
	Other	2	0.9		4–5 Months	48	20.5
Per capita monthly household income	< 2,000 Yuan/Month	127	54.3		Over 6 Months	63	26.9
	2,000–5,000 Yuan/Month	65	27.8				
	> 5,000 Yuan/Month	42	17.9				

of residence, marital status, education level, per capita monthly household income, social media usage, Community resource availability, participation in social activities, stroke type, ADL, number of comorbidities, and illness duration ($P < 0.05$).

A multiple linear regression analysis was performed using the total loneliness score of older adults with stroke as the dependent variable and the statistically significant items from the univariate analysis as independent variables. The independent variables were coded as outlined in Table 2. The analysis revealed that key factors influencing loneliness among older adults with stroke included Per capita monthly household income, ADL, community resource availability, participation in social activities, and illness duration ($P < 0.05$). Detailed results are provided in Table 3.

3.4 Correlation between family resilience, social support, family functioning, psychological capital, and loneliness in older adults with stroke

Pearson correlation analysis showed a significant negative correlation between loneliness and family resilience, social support, family functioning, and psychological capital in older adults with stroke ($P < 0.01$). Furthermore, family resilience, social support, family functioning, and psychological capital were positively correlated with one another ($P < 0.01$). Detailed correlation coefficients are presented in Table 4.

TABLE 2 Assignment table for independent variables.

Independent variable	Assignment method
Duration of illness	<1 month = 1, 2 month–3 month = 2, 4 month–5 month = 3, more than 6 months = 4
Place of residence	Urban = 1, rural = 2
Marital status	Unmarried = 1, Married = 2, Divorced = 3, Widowed = 4
Educational level	Elementary school = 1, Junior high school = 2, High school = 3, University or above = 4
Per capita monthly household income	<2,000 yuan per month = 1, 2,000–5000 yuan per month = 2, > 5,000 yuan per month = 3
Social media usage	Yes = 1, No = 2
Community resource availability	Good = 1, Average = 2, Poor = 3
Participation in social activities	Yes = 1, No = 2
Type of stroke	Ischemic stroke = 1, Hemorrhagic stroke = 2
ADL	Mild dependency = 1, Moderate dependency = 2, Severe dependency = 3
The number of combined diseases	0 case = 1, 1 case = 2, 2 case = 3, more than 3 case = 4

TABLE 3 Results of multiple linear regression analysis of loneliness ($N = 234$).

Item	Regression coefficient	t/F value	P	VIF
Place of residence	−0.918	−0.594	0.553	1.308
Marital status	0.396	0.385	0.7	1.120
Educational level	1.245	1.184	0.238	1.477
Per capita monthly household income	−2.58	−2.236	0.026	1.767
ADL	5.031	3.843	<0.001	1.615
Social media usage	1.769	1.044	0.298	1.793
Community resource availability	6.691	5.862	<0.001	1.638
Participation in social activities	4.918	2.793	0.006	1.082
Type of stroke	2.283	0.632	0.528	1.408
The number of combined diseases	0.294	0.391	0.696	1.146
Duration of illness	−3.45	−5.858	<0.001	1.195

$F = 33.779$, $P < 0.001$, $R^2 = 0.626$, adjusted $R^2 = 0.607$; VIF, variance inflation factor.

3.5 Construction of a structural equation model for loneliness

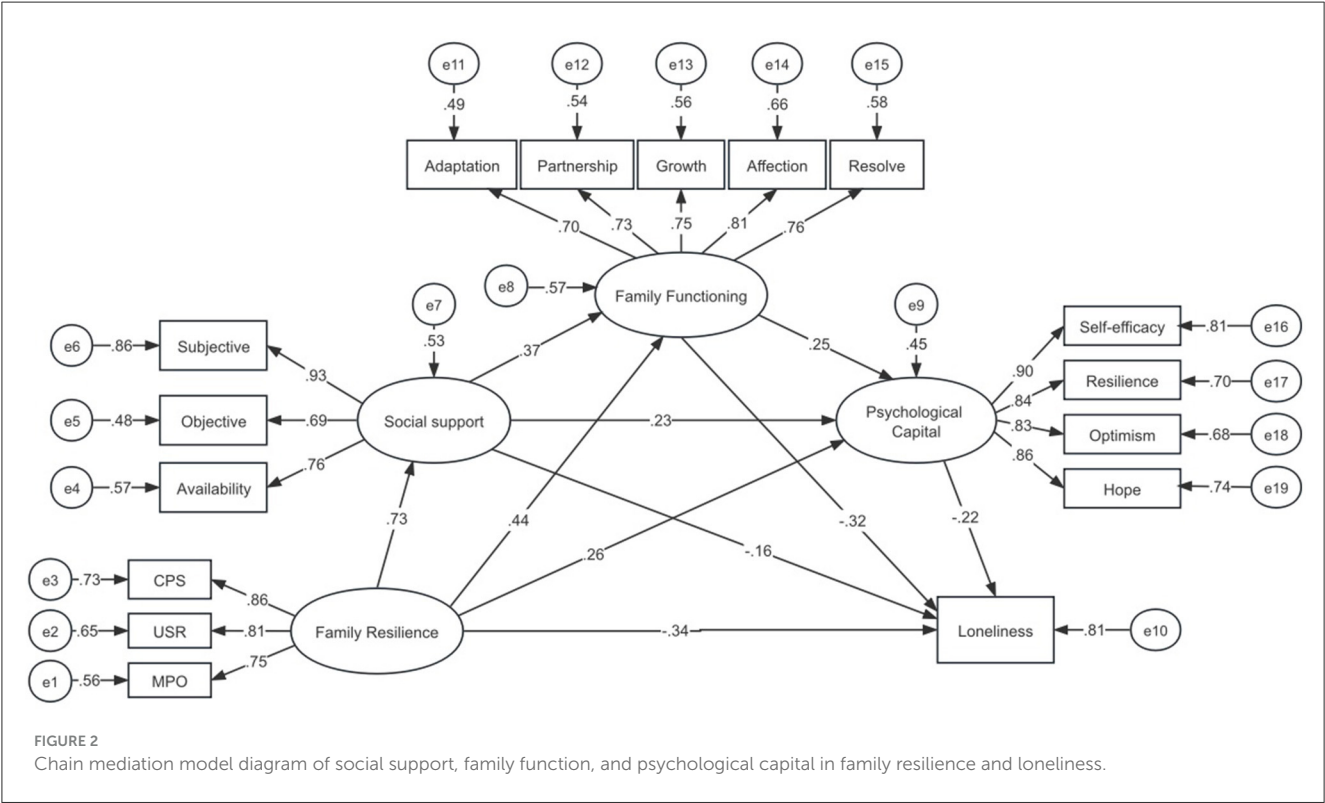
With family resilience as the independent variable and loneliness as the dependent variable, a structural equation model was constructed with social support, family functioning, and psychological capital as mediating variables. Data analysis was conducted using Amos 24.0. Its main fit indices are: $\chi^2/df = 1.148 < 3$; RMSEA = 0.025 < 0.05; GFI = 0.946 > 0.9; AGFI = 0.923 > 0.9; CFI = 0.994 > 0.9, indicating a good model fit (Figure 2). We constructed a conceptual diagram to summarize the Structural Equation Model (SEM) and the mediating pathways (Figure 3). The Bootstrap method was used to repeatedly sample 5,000 times to calculate the 95% confidence interval for mediating effect tests. The results showed that family resilience has a direct negative predictive effect on loneliness ($\beta = -0.342$, $P < 0.001$); social support has a negative predictive effect on loneliness ($\beta = -0.157$, $P < 0.001$), and it plays a partial mediating role between family resilience and loneliness, with a mediating effect value of -0.114 ,

accounting for 14.65% of the total effect; family functioning has a negative predictive effect on loneliness ($\beta = -0.319$, $P < 0.001$), and it plays a partial mediating role between family resilience and loneliness, with a mediating effect value of -0.140 , accounting for 17.99% of the total effect; psychological capital has a negative predictive effect on loneliness ($\beta = -0.216$, $P < 0.001$), and it plays a partial mediating role between family resilience and loneliness, with a mediating effect value of -0.057 , accounting for 7.33% of the total effect; social support and family functioning have a chain mediating effect between family resilience and loneliness, with a mediating effect value of -0.086 , accounting for 11.05% of the total effect; family functioning and psychological capital have a chain mediating effect between family resilience and loneliness, with a mediating effect value of -0.024 , accounting for 3.08% of the total effect; social support, family functioning, and psychological capital have a chain mediating effect between family resilience and loneliness, with a mediating effect value of -0.015 , accounting for 1.93% of the total effect. The confidence intervals corresponding to the model tests all did not include 0, indicating the existence

TABLE 4 Correlation analysis of family resilience, social support, family functioning, psychological capital, and loneliness (*r*).

Project	Loneliness	Family resilience	Social support	Family functioning	Psychological capital
Loneliness	1				
Family resilience	−0.738**	1			
Social support	−0.715**	0.618**	1		
Family functioning	−0.745**	0.604**	0.614**	1	
Psychological capital	−0.684**	0.520**	0.542**	0.533**	1

***P* < 0.01.



of mediating effects and the establishment of chain mediation (Tables 5, 6).

4 Discussion

4.1 Analysis of the current situation of older adults with stroke

The findings of this study reveal that the overall loneliness score for older adults with stroke was (35.07 ± 15.24), indicating a moderate level of loneliness. Notably, 117 patients (50%) reported experiencing moderate to severe loneliness, a figure that surpasses the incidence of moderate to severe loneliness among the general elderly population as reported by Ying et al. (2021). This suggests that loneliness among older adults with stroke may be more pronounced than in the broader elderly demographic. Studies have shown that loneliness has adverse effects on the health of the elderly. It has been identified as a risk factor for suicide,

cardiovascular and cerebrovascular diseases, all-cause morbidity and mortality in the elderly, and can also lead to mental health issues such as dementia and depression (McClelland et al., 2020; Prince et al., 2015; Hakulinen et al., 2018; Isik et al., 2021). Therefore, healthcare professionals should pay attention to the loneliness of older adults with stroke.

This study found that all older adults with stroke experienced varying degrees of loneliness, but the severity was lower than that reported in Hollands Ls cross-sectional survey (Hollands et al., 2024). The reason for this difference may be that his study included a large number of patients with aphasia, whose impaired language function may lead to a loss of connection with a broader social network, thereby increasing their sense of loneliness (Hilari et al., 2010). Additionally, his survey was conducted during the COVID-19 pandemic, and the visiting restrictions during the pandemic, as an external factor, further weakened the social connections of the patients, exacerbating their loneliness (Su et al., 2023). In contrast, in this study, 73.9% of the patients undergoing home-based rehabilitation had mild dependency in their self-care abilities. They

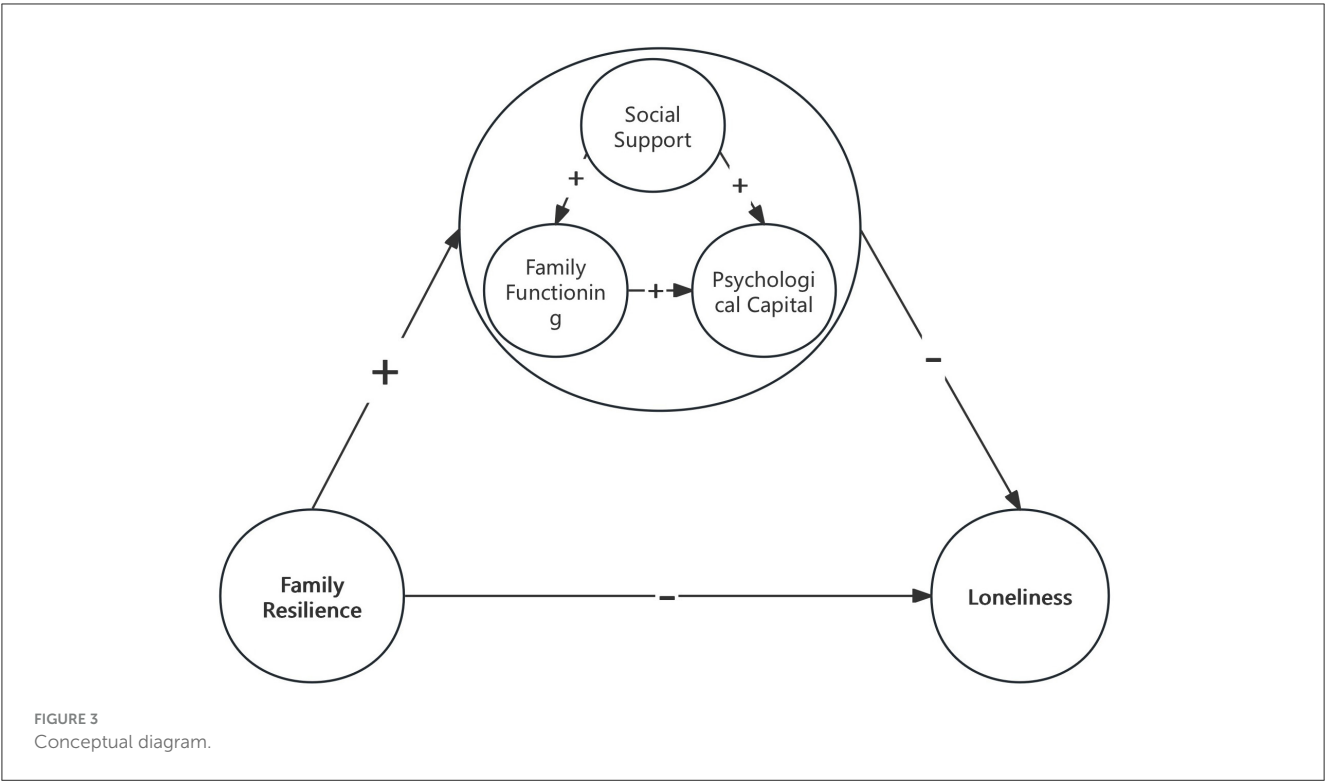


TABLE 5 Regression analysis of family resilience, social support, family functioning, psychological capital, and loneliness.

Dependent variable	Predictor variable	r^2	β	SEs	t	P	LLCI	ULCI
Social support	Family resilience	0.535	0.731	0.057	8.783	$P < 0.001$	0.64	0.806
	Social support							
Family functioning	Family resilience	0.569	0.440	0.016	4.289	$P < 0.001$	0.235	0.626
	Social support		0.371	0.023	3.703	$P < 0.001$	0.163	0.554
Psychological capital	Family resilience	0.453	0.264	0.289	2.395	0.017	0.017	0.471
	Social support		0.234	0.392	2.285	0.022	0.032	0.466
	Family functioning		0.250	1.689	2.485	0.013	0.053	0.476
Loneliness	Family resilience	0.806	-0.342	0.368	-4.934	$P < 0.001$	-0.506	-0.188
	Social support		-0.157	0.485	-2.501	0.012	-0.302	-0.031
	Family functioning		-0.319	2.183	-4.962	$P < 0.001$	-0.467	-0.182
	Psychological capital		-0.216	0.098	-4.485	$P < 0.001$	-0.312	-0.125

may have been more independent in their daily lives. Although they also had certain physical functional impairments, they were recovering in a familiar environment with more interaction with their family members and a relatively intact social support network, which may have alleviated their loneliness to some extent (Bergersen et al., 2024). Therefore, the loneliness of older adults with stroke is closely related to their family environment. While healthcare professionals are committed to the physical rehabilitation of patients, they should also pay close attention to their mental health status. By building communication bridges to enhance the interaction between patients and their families, and encouraging family members to provide more emotional and practical support, the loneliness of patients can be reduced, their mental health status can be improved.

4.2 Analysis of the current status and influencing factors of loneliness in older adults with stroke

This study identified several factors influencing loneliness in older adults with stroke through multivariate analysis, including ADL, Per capita monthly household income, participation in social activities, community resource availability, and duration of illness. The findings suggest that older stroke patients with limited daily activity capacity tend to experience higher levels of loneliness, aligning with research by Pan et al. (2022). This may be attributed to a decline in daily activity capacity, which restricts patients' ability to engage in social activities such as shopping and dining, thereby diminishing their interactions with the outside world and

TABLE 6 Path and effect analysis among variables in the model (N = 234).

Project	Effect size	Standard error	Bootstrap 95% CI		Proportion of total effect (%)
Total effect	−0.778	0.029	−0.866	−0.751	100
Direct effect	−0.342	0.081	−0.506	−0.188	43.96
Total indirect effect	−0.436	0.065	−0.606	−0.345	56.04
X-M1-Y	−0.114	0.049	−0.222	−0.024	14.65
X-M2-Y	−0.140	0.049	−0.263	−0.062	17.99
X-M3-Y	−0.057	0.027	−0.117	−0.01	7.33
X-M1-M2-Y	−0.086	0.031	−0.161	−0.036	11.05
X-M2-M3-Y	−0.024	0.013	−0.061	−0.006	3.08
X-M1-M2-M3-Y	−0.015	0.008	−0.036	−0.004	1.93

X, family resilience; M1, social support; M2, family functioning; M3, psychological capital; Y, loneliness.

increasing the risk of social loneliness. Most stroke patients are accompanied by a certain degree of disability after onset, which leads to loss of self-identity and physical dysfunction, resulting in a sense of shame (Huang et al., 2024; Kariasa et al., 2024). Due to the decline in daily activity ability, stroke patients often require the care and assistance of multiple family members, leading to feelings of stigma and self blame (Hughes and Cummings, 2020; Zhang Y. et al., 2023). The shame and guilt of stroke patients exacerbate their sense of loneliness by weakening their social motivation, reducing their sense of self-worth, and decreasing social interaction.

Family economic status plays a crucial role in providing material security post-illness and significantly affects patients' treatment decisions and rehabilitation attitudes (Rajacic et al., 2019). Stroke patients with lower per capita family income often worry about treatment costs, and this financial strain can lead to a passive approach toward recovery and social engagement. Additionally, economic stress may precipitate psychological issues such as anxiety, depression, and low self-esteem, which are closely linked to loneliness (Peltzer and Pengpid, 2019). Social participation is vital for the elderly to maintain a positive outlook on life and a sense of self-worth. However, limited social activities and inadequate community resources can hinder social interaction among older adults with stroke, diminishing their sense of participation and leading to a regression in social roles and self-worth, ultimately contributing to loneliness (Elayoubi et al., 2023).

Moreover, this study observed a significant negative correlation between the duration of illness and loneliness in older adults with stroke, which slightly contrasts with Guo et al. (2024) longitudinal findings on first-time stroke patients. This discrepancy may stem from better functional outcomes in patients whose illness has lasted over 6 months in this survey. Following the traumatic event of a stroke, patients often experience intense loneliness initially due to the shock and unfamiliarity of their circumstances. However, as recovery progresses and patients adapt to their condition and regain physical function, they may develop greater confidence, facilitating a gradual return to normal social interactions. This improvement in social participation may, in turn, help alleviate feelings of loneliness.

4.3 The impact of family resilience on loneliness in older adults with stroke

Family resilience influences depressive moods through two primary mechanisms: enhancing individual resilience and bolstering social support, highlighting its significant role in promoting and safeguarding mental health (Walsh, 2003). The family resilience theory posits that families function as dynamic systems capable of integrating both internal and external resources to adapt to stressors and adversity. Externally, a well-structured family environment is essential for alleviating loneliness among older adults with stroke. It offers consistent material support, emotional comfort, and opportunities for social interaction, which collectively enhance the patient's sense of belonging and self-worth, thereby effectively mitigating the detrimental effects of loneliness. Internally, the family's belief system acts as a motivational force, encouraging patients to adopt a positive outlook, which can alleviate stress arising from negative emotions and help maintain psychological wellbeing. Furthermore, a robust family communication framework enhances the level of care provided to the patient and fosters the mobilization of positive psychological resources within the individual. Together, these elements create a strong psychological support network that helps combat feelings of loneliness (Li K. et al., 2024; Lima et al., 2023; Lou and Ng, 2012).

The findings of this study reveal that older adults with stroke scored an average of 97.80 ± 16.88 on the FRAS-C, indicating a moderate level of family resilience. A closer examination of the dimension scores shows that both family belief system and family organizational model received lower average ratings. This suggests that older adults with stroke and their families may struggle with sustaining a positive attitude and seeking external social support effectively. Medical professionals should focus on enhancing interactions between patients and their families, employing various intervention strategies to bolster family resilience. First, communication skills training for medical staff can improve the effectiveness of dialogue between patients and their families, facilitating better information exchange. Second, guiding families toward a problem-solving approach, such as through family meetings, can encourage collective discussions to address challenges, thereby fostering the patient's intrinsic motivation and

promoting positive outlook. Additionally, healthcare providers should actively work to expand the social resources available to families of older adults with stroke, educating them on how to access these resources. This approach can enhance families' awareness and utilization of social support, ultimately aiding in the psychosocial recovery of the patients.

4.4 The mediating role of social support between family resilience and loneliness

Family resilience is a strong positive predictor of social support levels ($\beta = 0.73, P < 0.001$). The mediating effect of social support in the relationship between family resilience and loneliness is measured at 0.1147, which corroborates the findings of Zhao et al. (2018). Families exhibiting high resilience, particularly when confronting challenges posed by illnesses such as stroke, tend to demonstrate keen awareness and effective engagement with their social support networks. They systematically mobilize resources from relatives and friends, thoroughly explore community services, and leverage medical resources to establish a robust social network for the patient. This proactive approach not only enhances the patient's social integration but also provides a solid foundation for effective disease management.

Social support is a significant negative predictor of loneliness ($\beta = -0.16, P < 0.05$), aligning with findings from several studies (Farhang et al., 2024; Yu et al., 2024; Wen et al., 2024). Research indicates that patients who experience a sudden stroke are often susceptible to acute stress disorder (Unal et al., 2017). Access to community support resources can assist these patients in establishing a stable social network, thereby alleviating feelings of loneliness and self-isolation. The emotional comfort and practical aid offered by relatives and friends in daily life can mitigate the stress associated with the illness, enabling patients to maintain a positive emotional outlook throughout their recovery. This support enhances their self-identity and self-efficacy, ultimately reducing the risk of experiencing loneliness.

4.5 The mediating role of family function between family resilience and loneliness

Family resilience positively influences the family functioning of older adults with stroke ($\beta = 0.44, P < 0.001$), with a mediating effect value of 0.1408 observed between family resilience and loneliness. Enhancements in family resilience are typically accompanied by improved communication and support among family members, fostering a positive family environment. This supportive atmosphere allows family members to collaborate in overcoming difficulties, effectively addressing life's challenges. Consequently, family cohesion and functionality are strengthened (Chen et al., 2018). Additionally, family functioning serves as a negative predictor of loneliness ($\beta = -0.32, P < 0.001$), a correlation corroborated by multiple studies (Qiu et al., 2024; Qian et al., 2022). Within a nurturing family setting, older adults with stroke often feel a heightened sense of psychological security and social belonging—critical psychological resources that combat loneliness. Conversely, when family care is inadequate, patients

may perceive themselves as neglected and isolated, struggling to attain emotional fulfillment and support. This emotional shortfall can exacerbate their feelings of psychological alienation.

4.6 The mediating role of psychological capital between family resilience and loneliness

Family resilience is a positive predictor of the psychological capital of older adults with stroke ($\beta = 0.26, P < 0.05$), with a mediating effect value of 0.0572 identified between family resilience and loneliness. Families characterized by strong resilience not only enhance the patient's self-efficacy, instilling greater confidence in their ability to tackle rehabilitation challenges, but also cultivate an environment imbued with hope and optimism. Such an atmosphere is essential for alleviating anxiety and depression, thereby increasing the likelihood that patients will adopt a resilient mindset, adapt swiftly to adversity, and seek solutions to their problems, which in turn reinforces their psychological capital (Li et al., 2019, 2018). The enhancement of psychological capital not only promotes the patient's mental wellbeing but also translates into positive social behaviors. This study indicates that psychological capital negatively predicts loneliness in older adults with stroke ($\beta = -0.22, P < 0.001$). Prior research has shown that individuals with high psychological capital are more likely to engage in social activities and cultivate healthy social relationships, significantly reducing feelings of loneliness (Ren and Ji, 2019). Consequently, family resilience can indirectly diminish loneliness in older adults with stroke by fostering their psychological capital, which is crucial for their long-term rehabilitation.

4.7 The chain mediating role of social support, family function, and psychological capital between family resilience and loneliness

This study explores the intricate relationship between family resilience and the loneliness experienced by older adults with stroke, revealing a distinct pathway of influence: family resilience $\rightarrow$ social support $\rightarrow$ family functioning $\rightarrow$ psychological capital $\rightarrow$ loneliness. It demonstrates that family resilience can indirectly impact the loneliness of older adults with stroke through this interconnected mechanism. Specifically, older stroke patients with strong family resilience have a more solid social support network, enabling them to receive more assistance from friends, relatives, the community, and professional institutions. The intervention of this support helps to alleviate family conflicts and tension caused by the illness. Family members reposition their roles, coordinate internal relationships, and jointly confront challenges, thereby maintaining family functions (Acoba, 2024). The positive interactions among family members play a crucial role in enhancing the patient's psychological capital. Studies have shown that encouragement and support from family members can significantly increase the patient's level of hope (Yang et al., 2022), which is of great importance for reducing loneliness.

In conclusion, this study elucidates the specific pathways and mechanisms through which family resilience influences loneliness. Compared to prior research, it offers deeper insights into the interactive relationships among various components within the family system and their synergistic effects on the mental health of patients. Additionally, it presents a fresh perspective for family interventions, indicating that bolstering family resilience and enhancing family functioning can facilitate the development of patients' social support networks and the growth of psychological capital, effectively preventing and alleviating loneliness in older adults with stroke.

4.8 Importance of family reliance

Based on the theory of family resilience, the family, as a dynamic system, has the capacity to integrate internal and external resources to adapt to stress and adversity (Walsh, 2016, 2003). In terms of external resources, a well-organized family structure can expand the patient's social support network and enhance their sense of belonging and self-worth by providing material support, emotional comfort, and opportunities for social interaction (An et al., 2024; Nshimyumuremyi et al., 2023). In terms of internal resources, the family belief system, as an internal force guiding the patient to live positively, can alleviate negative emotions and maintain a positive psychological state (Zhu et al., 2024). A good family communication system can further enhance family care by promoting understanding and trust among family members through open and sincere communication, creating a warmer and more supportive family environment, which helps to mitigate the negative impact of loneliness (Favotto et al., 2019; Chiao et al., 2021).

Therefore, to address the issue of loneliness in older adults with stroke, a family systems perspective should be adopted. On the one hand, intrinsic resilience can be enhanced through methods such as family belief reconstruction and communication skills training. On the other hand, external support acquisition can be optimized through resource linking and caregiving guidance. Clinical healthcare providers should offer family-participatory nursing interventions to help patients better cope with the challenges of illness, thereby reducing their sense of loneliness.

4.9 Innovation in research

Currently, there is limited research on the sense of loneliness among older adults with stroke, and the analysis of its influencing factors is not comprehensive. Meanwhile, the role of family in improving loneliness is often overlooked. This study innovatively incorporates the well-researched influencing factors of loneliness, delving into the factors that contribute to loneliness among stroke patients. Based on the social ecosystem theory and family resilience theory, this study constructs a theoretical framework, recognizing loneliness as a result of the combined effects of individual, family, and social environmental factors. It analyzes the direct relationships and mediating effects between family resilience, psychological capital, family functioning, and social support on loneliness among older adults with stroke, highlighting

the importance of family in preventing and improving loneliness among older adults with stroke.

5 Conclusion

This study highlights that loneliness is an issue that cannot be ignored in the rehabilitation process of older adults with stroke and requires high attention from healthcare professionals and society. The power of the family plays an important role in alleviating loneliness. When healthcare professionals develop rehabilitation and care plans for older adults with stroke, they should place greater emphasis on the role of the family. By enhancing family resilience, they can improve communication efficiency among family members, strengthen their ability to collaborate in problem-solving, and expand access to social resources. These measures are crucial for alleviating the patients' loneliness, and promoting their mental health.

This study has several limitations. First, the reliance on convenience sampling from a single geographic area may compromise generalizability due to potential regional biases, such as socioeconomic or cultural homogeneity. Second, although structural equation modeling was applied, the cross-sectional design precludes establishing causality between family resilience and loneliness. Third, unmeasured confounding factors, such as cognitive function, sleep quality, and healthcare accessibility, may influence the observed associations. Fourth, the general questionnaire did not directly include content related to family resilience. This has led to a lack of close and intuitive connection between family resilience and other variables in the overall structure of the questionnaire.

Future studies should prioritize multicenter probability sampling to enhance representativeness and longitudinal designs to establish causality. Additionally, incorporating neuropsychological and healthcare variables into the analytical models will elucidate potential mechanisms. Finally, intervention studies targeting mediating pathways, such as family resilience programs, are needed to translate research findings into strategies for alleviating loneliness among older adults with stroke. Addressing these gaps will advance the theoretical framework and evidence-based care for this vulnerable population.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of Rizhao People's Hospital, Shandong Province, China. It belongs to the People's Hospital of Rizhao City. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

HJ: Methodology, Project administration, Writing – review & editing, Data curation, Investigation, Writing – original draft. YD: Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing, Funding acquisition, Resources, Supervision. JL: Data curation, Investigation, Resources, Writing – original draft, Software. JM: Data curation, Investigation, Software, Writing – original draft, Project administration. LG: Data curation, Investigation, Project administration, Software, Writing – original draft. JC: Project administration, Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review & editing.

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Social-ecological factors associated with loneliness in university students: results from the German cross-sectional StudiBiFra study

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Aims: Using a social-ecological perspective, this study aims to understand loneliness in university students by (1) assessing its prevalence, and (2) identifying inter-personal and organizational factors associated with loneliness during studies.

Methods: Data from the StudiBiFra study, a cross-sectional survey among university students in Germany, were used. The sample consisted of 12,874 students from 7 universities, surveyed between May 2022 and March 2023 using the Bielefeld Questionnaire on Study Conditions and Mental Health. Hierarchical logistic regression was employed to examine the associations of individual, inter-personal, and organizational variables with loneliness.

Results: A total of 28.2% of students experienced loneliness during their studies. Gender-diverse students (OR = 1.69; 95% CI: 1.04 – 2.73) and males (OR = 1.43; 95% CI: 1.26 – 1.63), as well as those with poor subjective overall health (OR = 2.62; 95% CI: 2.26 – 3.05), were at high risk of feeling lonely. At the inter-personal level, positive social relationships among students acted as a protective factor against loneliness (OR = 0.31; 95% CI: 0.29 – 0.34). At the organizational level, weak connectedness to the university was positively associated with loneliness (OR = 1.43; 95% CI: 1.23 – 1.67), while high university engagement was negatively associated with loneliness (OR = 0.90; 95% CI: 0.83 – 0.97). Students enrolled in universities of applied sciences were less likely to experience loneliness compared to those at universities (OR = 0.76; 95% CI: 0.63 – 0.91).

Conclusions: The findings underscore the importance of both individual and institutional efforts to address loneliness at German universities, a demand that was accelerated during and after the pandemic. Promoting social connections and strengthening students' ties to their university are important strategies for combating loneliness, highlighting the importance of community-building health promotion.

KEYWORDS

loneliness, mental health, university students, social-ecological factors, social support, health promotion

1 Introduction

University students are at high risk of mental health problems such as depression, anxiety (1–3), and loneliness (3–6). In addition to the negative health effects of loneliness (7, 8), loneliness and mental health problems are also associated with poor academic outcomes for university students (9, 10). From a social-ecological perspective, loneliness is caused by a number of interrelated factors, including individual, inter-personal and environmental aspects (11). While it is crucial to identify predictors of loneliness, it is equally important to understand the variation in these risk factors across different contexts (12). In general, Bronfenbrenner's social-ecological model of health is used to better understand and address health determinants on multiple interrelated levels (13). In this study, we refer to the social-ecological model framework for prevention (SEM) by the World Health Organization (WHO), originally proposed by Dahlberg et al. (14), with the Holt-Lundstad extension regarding social connectedness (11). Dahlberg et al. (14) distinguish four different levels: the individual level focuses on personal factors like age, education and several sociodemographic factors, with prevention strategies targeting attitudes and behaviors. At the inter-personal level, close social circles such as family and peers play a role, and prevention includes programs to improve communication and promote healthy relationships. At the community level, attention shifts to settings including schools and neighborhoods, with the aim of improving safety and addressing underlying conditions such as poverty. Finally, the societal level examines broader factors like cultural norms and societal inequalities, with prevention efforts targeting systemic issues, for instance economic inequality, and promoting norms (14). For the purposes of our study, we will only consider the first three levels of the SEM. We suggest that loneliness in university students is influenced by various factors at the individual, inter-personal, and organizational level. While previous research has focused on the individual contributions within these single domains, there has been minimal consideration of their combined impact.

Individual-level factors related to loneliness in university students have been well studied and are related to several sociodemographic characteristics: Previous research has shown that loneliness is associated with being single (4, 5, 15), living alone (4, 5, 16), or studying abroad (4, 5). Younger and older students are reported to feel more lonely than middle-aged students (4), and loneliness is linked to gender. Female (17, 18) and gender-diverse students (19) seemed to be particularly vulnerable to loneliness. Furthermore, loneliness among university students has been linked to mental health issues, depressive symptoms (5, 20, 21) and anxiety (5, 20), as well as a poor subjective health status (22).

The second level of the SEM examines inter-personal relationships, e.g., peer groups, partners, friends, or family, which

may influence the experience of loneliness (14) and may also be stressors in academia (23). Social connection (or, conversely, social disconnection) is an umbrella term with components related to the structural aspects of social life (e.g., size of social network, living situation), the functional aspects of social life (e.g., received or perceived availability of social support), and the quality of social relationships (e.g., perceived satisfaction) (24). Together, these categories are associated with several (mental) health risks (25), and social connection is a significant protective factor for morbidity and mortality (24). In the university context, low levels of student cooperation, in terms of social support (22), deficits in friendships, and not feeling connected to peers were associated with loneliness among university students (26). However, university-based research is still limited. Prior studies of adolescents in schools showed that several social relationships were associated with loneliness: strong bonds with peers and face-to-face contact with friends (e.g., going out with friends) were protective factors against loneliness (12). Further, higher levels of peer victimization at school were associated with poorer mental health outcomes and increased loneliness (27, 28). In addition, previous research has highlighted perceived teacher behavior and peer cooperation as important determinants of loneliness. Higher levels of loneliness were associated with both lower levels of teacher support and lower levels of students' cooperation (29).

The third level of the SEM explores the community or settings, such as schools and universities, in which social relationships take place, and attempts to identify the characteristics of these environments that contribute to people's loneliness (14). However, university-based research on loneliness and organizational factors is also scarce. In general, previous research has shown that organizational factors, such as study conditions, may also be associated with mental health problems in students (30, 31). Similarly, socially supportive academic environments, feelings of belongingness regarding the sense of connectedness to learning environments, and inter-personal resilience are associated with better mental health outcomes and academic persistence (32). Previous school-based research has shown that social inclusion at school is a significant protective factor of adolescent loneliness, and that loneliness partially mediates the association of social inclusion with subjective well-being and mental health problems (33). Adolescents who had experienced social exclusion at school reported higher levels of loneliness (33). Some evidence also suggests that participating in school extracurricular activities and demonstrating high levels of school engagement can lead to higher levels of perceived social support and lower levels of perceived loneliness (34). In addition, loneliness at school is associated with poor academic performance and can lead to absenteeism due to health effects (35, 36).

Although research has examined geographical or regional characteristics associated with loneliness (37), or referred to the school context (27, 29), few studies have examined the prevalence of

loneliness in the university context. However, there is an urgent need to develop effective methods and interventions that go beyond individual-level strategies (13). Using a social-ecological perspective, this study seeks to better understand the factors associated with loneliness in the university context. The aims of this study were [1] to assess the prevalence of loneliness in university students and, [2] to identify individual, inter-personal and organizational factors associated with loneliness.

Based on the current literature, we hypothesized that female and diverse gender as well as younger age and poor health state are associated with loneliness. Moreover, we assume that both student cooperation and lecturer support are positively associated with loneliness. We further suggest that positive experiences of the university culture, higher levels of university engagement, and a sense of connectedness to the university act as protective factors against loneliness.

2 Materials and methods

2.1 Study design and procedures

For the present study, we used data from the StudiBiFra project, a cross-sectional study aimed at assessing the study conditions and (mental) health status of students across thirteen German universities. The survey questionnaire (Bielefeld Questionnaire on Study Conditions and Mental Health) included questions on a range of topics including study conditions, academic outcomes, sociodemographic characteristics, and health-related outcomes. Further information on the survey questionnaire can be found elsewhere (38). Participants were able to complete it in either English or German. University students enrolled in undergraduate and postgraduate programs were invited by email. Data collection was conducted via LimeSurvey (LimeSurvey GmbH, Hamburg, Germany) and took place between June 2021 and March 2023. The StudiBiFra study has received ethical approval from the ethics committee of Charité - Universitätsmedizin Berlin (EA1/055/21). Written informed consent was obtained from all respondents prior to participation.

This analysis comprises data of seven universities. These institutions were selected because data collection occurred during a period devoid of strict COVID-19 protective measures. Data collection at the selected institutions took place between May 2022 and March 2023, and the average response rate obtained across these universities was 11.5%.

2.2 Measures

A more detailed description of the variables and their response options can be found in Table 1. For all items analyzed in this paper, students had the opportunity to choose the option 'no answer'.

2.2.1 Dependent variable: loneliness during studies

Consistent with other studies in this area (28, 39), our research objective focuses on 'loneliness during studies' rather than general loneliness. To examine the subjective perceptions of loneliness at university, participants were asked about their level of agreement with the statement: 'I am lonely in my studies' with five answering options: (1) 'strongly disagree' (2) 'disagree', (3) 'neither disagree, nor agree', (4) 'agree' (5) 'strongly agree'. Those who strongly agreed or agreed with this statement (4 – 5) were grouped as 'perceived loneliness during studies' (reference group) and distinguished from those expressing neutrality or who (strongly) disagreed 'no perceived loneliness during studies' (1 – 3).

2.2.2 Independent variables: individual level

At the individual level, we considered self-identification with gender, age, and overall self-perceived health state. The self-perceived health state was measured using the item: 'In the last two months of my studies, my overall state of health was'. To facilitate comparative analysis among respondents, the responses were encoded into three distinct representations: those reporting being 'severely' or 'rather affected', those indicating neutrality ('neither affected nor unaffected'), and those reporting no impact ('rather not affected' or 'not affected at all').

2.2.3 Independent variables: inter-personal level

At the inter-personal level, we distinguish between the quality of students' cooperation and the perceived support from lecturers. To assess social support among students, we used four items. For analysis, the first item was reversed, and sum and mean scores were calculated, ranging from 1 to 5, with a higher score indicating a higher level of perceived social support among students. Perceived lecturers' support was measured by four items, and we used the same response options and mean calculation as for social support among students. The Cronbach's alpha in our sample was $\alpha = 0.80$ for student social support and $\alpha = 0.72$ for lecturer support.

2.2.4 Independent variables: university level (organizational level)

At the university level, we differentiated between university characteristics and students' experience and engagement in university. University culture of open communication was assessed using one item. We grouped those who (strongly) agreed (4 – 5) with the statement, distinguished from those who were neutral (3) and those who (strongly) disagreed (1 – 2). The university connectedness was measured using one item with responses categorized according to the 'university culture of open communication'. To assess university engagement, we used three items. These three items were summed to give an overall score, then the mean was calculated, ranging from 1 to 5, with a higher score indicating a higher level of university engagement. The Cronbach's alpha in our sample was $\alpha = 0.72$ for the university engagement

TABLE 1 Measurement of variables and response options.

Domain	Variables	Assessment	Response options
Dependent variable			
	Loneliness	'I am lonely in my studies'	(1) 'strongly disagree' (2) 'disagree' (3) 'neither disagree, nor agree' (4) 'agree' (5) 'strongly agree'
Independent variables			
Individual level	Gender	'I identify with the following gender'	'female' 'male' 'diverse'
	Age	'I belong to the following age group'	'18–25 years' '26–30 years' '31–40 years' '41 and older'
	Overall health state	'In the last two months of my studies, my overall state of health was'	(1) 'severely affected' (2) 'rather affected' (3) 'neither affected, nor unaffected' (4) 'rather not affected' (5) 'not affected at all'
Inter-personal level	Social support among students	'There are tensions and conflicts among the students'	(1) 'strongly disagree' (2) 'disagree' (3) 'neither disagree, nor agree' (4) 'agree' (5) 'strongly agree'
		'The (personal) relationships among the students in my course of studies are good'	
		'In my course of studies, the students mutually support each other'	
		'In my course of studies, it is easy to connect socially'	
	Lecturers' support	'My lecturers show appreciation for the individual students'	(1) 'strongly disagree' (2) 'disagree' (3) 'neither disagree, nor agree' (4) 'agree' (5) 'strongly agree'
		'My lecturers support cooperation among students (e.g., through group work)'	
		'My lecturers are approachable in case of personal problems'	
		'My lecturers are overall sufficiently available outside of the courses (e.g.,	

(Continued)

TABLE 1 Continued

Domain	Variables	Assessment	Response options
Independent variables			
		office hours, email contact')'	
University level	University culture of open communication	'Overall, people experience a culture of open communication at the university'	(1) 'strongly disagree' (2) 'disagree' (3) 'neither disagree, nor agree' (4) 'agree' (5) 'strongly agree'
	University connectedness	'I feel connected to my faculty'	(1) 'strongly disagree' (2) 'disagree' (3) 'neither disagree, nor agree' (4) 'agree' (5) 'strongly agree'
	University engagement	'I am committed to issues related to my course of studies (e.g., student council, committee work, teaching evaluations)'	(1) 'strongly disagree' (2) 'disagree' (3) 'neither disagree, nor agree' (4) 'agree' (5) 'strongly agree'
		'I make a contribution to the further development of my course of studies'	
		'I am involved at my university (e.g., General Students' Committee, university groups)'	

scale. Further, we considered the type of university. In our study, we included students from universities and from universities of applied sciences as two distinct types of higher education institutions in Germany.

2.3 Data analyses

First, descriptive statistics were calculated for both sociodemographic characteristics and the prevalence of loneliness during studies. The prevalence of loneliness during studies in this sample was estimated based on the extent of agreement with the respective statement, as those who (strongly) agreed to feel lonely during their studies. The varying sample sizes in the descriptive calculations are due to participants having the option to choose 'no answer' for each item, and missing data were excluded. Second, a hierarchical approach was used to sequentially add the social-ecological domains of interest and examine the associations with loneliness as the dependent variable. Thus, the variables were added blockwise. Model 1 tested for associations between individual

factors and loneliness. Inter-personal and university factors were added to models 2 and 3, respectively. Hierarchical regression was used to allow for a theoretically driven process whereby subsequent variables were incorporated into the model based on key research considerations (e.g., adding additional social-ecological domains of influence). Complete case analysis was utilized in the regression models. Prior to including the independent variables into the models, multicollinearity was assessed. The correlations among independent variables were found to be minimal ($r < .70$; VIF coefficients > 1.00 and < 5.00), suggesting that multicollinearity did not significantly impact the analysis. Results from the hierarchical logistic regression analyses were reported as odds ratios (ORs) and 95 percent confidence intervals (CIs). Statistical analyses were conducted using IBM SPSS, version 28.0.

3 Results

The characteristics of the study sample are presented in [Table 2](#). Most participants were female (64.1%), with 1.6% identifying as gender-diverse. The majority of participants were aged between 18 and 25 years (71.5%) and studied at a university (84.7%), rather than a university of applied sciences (15.3%). In relation to their overall health state, 38.8% of students reported being (rather) unaffected, whereas 35.3% indicated being severely or rather affected. The culture of open communication of their university was perceived positively by most students (65.1%). However, almost half of students (43.6%) did not feel connected to their university. The perceived level of social support among students was slightly higher than the level of lecturers' support.

The percentages of students who reported feeling lonely during studies are shown in [Table 3](#). During their time at university, 28.2% of students felt lonely. Prevalences of loneliness during studies according to several sociodemographic and other characteristics are shown in [Table 4](#). We found that the percentage of lonely students was highest among gender-diverse students (45.8%), students aged 26–40 (66.5%) and those with a severely or rather affected overall health state (41.9%). Students who did not perceive culture of open communication at university reported loneliness more often (40.7%) than those with a positive perception (23.6%). In addition, our results revealed that students who felt strongly connected to their university reported lower levels of loneliness during their studies (19.6%) than those who felt only weakly connected (38.1%). Moreover, the proportion of lonely students at universities of applied sciences (20.9%) was slightly lower than at universities (29.6%).

[Table 5](#) shows the results of the hierarchical logistic regression analysis to determine the associations of individual, inter-personal, and university factors with loneliness. The results of the final model are presented in the following. At the individual level, the odds of experiencing loneliness during studies were higher for gender-diverse students (OR = 1.69; 95% CI: 1.04 – 2.73) and for males

(OR = 1.43; 95% CI: 1.26 – 1.63), compared with females. Additionally, students with a neutral or a poor overall health state showed higher odds of loneliness (OR = 1.56; 95% CI: 1.33 – 1.84 and OR = 2.62; 95% CI: 2.26 – 3.05, respectively) than students with a good overall health state. At the inter-personal level, we found students with a higher level of social support by their fellow students being at lower risk of reporting loneliness during their studies (OR = 0.31; 95% CI: 0.29 – 0.34). Support from lecturers was not a significant factor associated with loneliness in our analysis. At university level, we found no association between a university's culture of open communication and loneliness. Our findings revealed that students with weak connectedness to their university were almost one and a half times more likely to report loneliness during their studies (OR = 1.43; 95% CI: 1.23 – 1.67). In addition, university engagement was associated with a lower chance of feeling lonely during studies (OR = 0.90; 95% CI: 0.83 – 0.97). A university culture of open communication was not associated with loneliness. Students who studied at a university of applied sciences were less likely to report loneliness (OR = 0.76; 95% CI: 0.63 – 0.91).

4 Discussion

Our study investigated the factors associated with loneliness among students in the university context based on the social-ecological framework. To the best of our knowledge, this is the first study to examine the prevalence of loneliness and the association of individual and several university characteristics with loneliness among university students, thus comparing the relative importance of individual and socio-environmental predictors.

With respect to the first aim of the study to assess the prevalence of loneliness, we found that 28.2% of students experienced loneliness, not necessarily in their everyday life, but specifically during their studies. This is in line with other research (4, 5). Thus, our study adds to prior evidence that mainly investigated general feelings of loneliness. It appears that even when COVID-19 restrictions were loosened, students were at high risk of experiencing loneliness. During the pandemic, there was a decrease in time spent socializing and a lack of interaction between students (18, 40). Especially in the aftermath of the pandemic, universities should once again be a place of common learning and social interaction.

With respect to the second aim of our study to study factors associated with loneliness we identified diverse gender identity, male gender identity, and a poor overall health state as consistent predictors of loneliness at the individual level. At the inter-personal level, higher levels of social support among students were associated with a lower likelihood of experiencing loneliness. At the organizational, i.e., university, level, students reporting weak connectedness to the university showed higher odds of experiencing loneliness during studies, while a high level of university engagement was negatively associated with loneliness. The type of university was also an associated factor – studying at a

TABLE 2 Characteristics of the sample (n = 12,874).

Variables	n	%	Mean	SD
Gender (n = 8,369)				
Female	5,361	64.1		
Male	2,874	34.3		
Diverse	134	1.6		
Age (n = 8,449)				
18 – 25	6,037	71.5		
26 – 30	1,657	19.6		
31 – 40	604	7.1		
41 and older	151	1.8		
Overall health state (n = 8,329)				
(Rather) not affected	3,230	38.8		
Neither affected nor unaffected	2,162	26.0		
Severely/rather affected	2,937	35.3		
Type of university (n = 12,874)				
University	10,908	84.7		
University of applied sciences	1,966	15.3		
University culture of open communication (n = 7,430)				
Positive perception	4,837	65.1		
Neutral perception	1,807	24.3		
Negative perception	786	10.6		
University connectedness (n = 8,201)				
(Strong) connectedness	2,765	33.7		
Neutral connectedness	1,864	22.7		
Weak connectedness	3,572	43.6		
Social support among students	8,585		3.70	0.82
Lecturers support ^a	8,915		3.47	0.78
University engagement ^a	8,315		2.31	0.89

SD, standard deviation; ^a1 to 5, higher score indicates higher level of satisfaction with variable.

university of applied sciences was associated with a lower likelihood of experiencing loneliness.

While females were shown to be more affected by loneliness in previous works (17, 18, 26), this was not the case in our sample. We found that male and gender-diverse students were more likely to experience loneliness in their studies. However, the gender aspect of loneliness has not been conclusively established, and there are still mixed findings (5, 15, 16). There is indication that women are able to build stronger social networks at university than men (41). As Barthauer et al. (41) also noted, women could benefit from mentoring programs at universities to build their social support networks. Recently, male students showed a higher increase in loneliness than female students (4). Moreover, work by Hajek et al.

(19) found associations between gender-diverse identity and loneliness, with a high prevalence of loneliness among individuals identifying themselves as gender-diverse. Our findings expand on previous research showing that gender-diverse youth is particularly susceptible to mental health issues or problems (42, 43). In our sample, they are also more likely to feel lonely than either male or female students. Further, age was not associated with loneliness. However, research in this area has also been inconsistent (4, 5), suggesting that loneliness interventions are equally important for different age groups.

Furthermore, as demonstrated in several previous studies, we found that a poor subjective health state was associated with loneliness (20, 22). In addition to loneliness interventions,

TABLE 3 Perceived loneliness during studies (n = 8,437).

I am lonely in my studies		
Response options	n	%
(1) strongly disagree	2,095	24.8
(2) disagree	2,236	26.5
(3) neither disagree, nor agree	1,724	20.5
(4) agree	1,335	15.8
(5) strongly agree	1,047	12.4
Loneliness during studies		
Perceived loneliness during studies (4-5)	2,382	28.2
No perceived loneliness during studies (1-3)	6,055	71.8

TABLE 4 Prevalence of perceived loneliness during studies by sociodemographic and other factors.

Loneliness during studies	n	%*
Gender (n = 8,162)		
Female	1,405	26.8
Male	835	30.0
Diverse	60	45.8
Age (n = 8,242)		
18 – 25	1,555	26.4
26 – 30	543	33.6
31 – 40	193	32.9
41 and older	34	24.6
Overall health state (n = 8,227)		
(Rather) not affected	541	16.9
Neither affected nor unaffected	566	26.9
Severely/rather affected	1,214	41.9
University culture of open communication (n = 7,268)		
Positive perception	1,120	23.6
Neutral perception	551	31.6
Negative perception	310	40.7
University connectedness (n = 8,114)		
(Strong) connectedness	535	19.6
Neutral connectedness	424	23.0
Weak connectedness	1,346	38.1
Type of university (n = 8,437)		
University	2,106	29.6
University of applied sciences	226	20.9

*The percentages are calculated based on students who responded both to the loneliness item and to the other corresponding items.

universities should implement student health management programs to address health behaviors, particularly in the university context, and to create a health-promoting environment. There is a need for further qualitative research that delves deeper into the diversity-sensitive organization of universities to identify the specific needs of the individuals concerned.

Our results only partially confirmed our hypothesis that both student social support and lecturer support are negatively associated with loneliness, because a significant association could only be found for student social support. Findings of our study revealed that higher levels of social support among students act as a protective factor against loneliness at university, which is consistent with recent studies in the university context (18, 22, 44). Previous qualitative research has shown that social groups help students to find their place and develop an identity in an unfamiliar context (45), and university friends are the most important social group to protect against mental illness by reducing feelings of loneliness (46). Furthermore, social deficits were identified as a correlate of loneliness in Polish and American college students (26). In general, identifying as a part of a social group creates social connectedness, which is associated with better mental health and a decreased prevalence of depression (47).

However, our results are in contrast with previous research that found that a positive student-teacher relationship may have positive impact on adolescents' mental health (27). Interestingly, recent school-based findings point in the opposite direction. In Scottish schools, support from teachers was associated with better mental health, while support from classmates was not (48). It is possible that the role of lecturers in young adults' mental health changes over the course of their lives and lecturers' roles for mental health may become less important. Our findings suggest that peer support seems to be more important than lecturer support in relation to experienced loneliness in the university context. As recently noted by McIntyre et al. (46) the campus environment provides opportunities for students to make valuable social connections, which can promote mental well-being. Universities should improve mental health support by raising awareness of social groups and organizing events to foster communities of interest.

At university level, we were able to partially confirm our hypothesis. We found that students with a weak connectedness to their university were almost one and a half times more likely to report loneliness than students with a strong connectedness. Similarly, school-based research confirmed that school inclusion had a protective effect on adolescent feelings of loneliness (33). In addition, students' mental health may be positively influenced by a sense of belonging to the university (32, 49). In light of these results, it is noteworthy that higher levels of adjustment to university life and attachment to their university were also found among students who reported strong bonds with their peers (50).

Moreover, our findings suggest that university engagement in terms of engaging in course-related interests and participating in university activities such as general student committees and university groups are linked to a decreased likelihood of experiencing loneliness during university years. Our results confirm the assumptions that extracurricular activities are related with lower levels of perceived

TABLE 5 Results from the hierarchical logistic regression analyses.

Domain	Variables		Loneliness at university					
			Model 1 (n 6,655)		Model 2 (n 6,665)		Model 3 (n 6,665)	
			OR	95% CI	OR	95% CI	OR	95% CI
Individual level	Gender	Female (ref.)	1.00		1.00		1.00	
		Male	1.40	(1.24 – 1.58)	1.42	(1.24 – 1.61)	1.43	(1.26 – 1.63)
		Diverse	1.65	(1.07 – 2.53)	1.60	(1.00 – 2.59)	1.69	(1.04 – 2.73)
	Age	18-25 (ref.)	1.00		1.00		1.00	
		26-30	1.23	(1.07 – 1.41)	1.06	(0.91 – 1.24)	1.07	(0.92 – 1.25)
		31-40	1.21	(0.98 – 1.50)	0.97	(0.77 – 1.23)	1.02	(0.81 – 1.29)
		41 and older	0.82	(0.52 – 1.30)	0.71	(0.43 – 1.19)	0.77	(0.46 – 1.29)
	Overall health state	(Rather) not affected (ref.)	1.00		1.00		1.00	
		Neither affected nor unaffected	1.87	(1.60 – 2.17)	1.55	(1.32 – 1.82)	1.56	(1.33 – 1.84)
		Severely/rather affected	3.62	(3.16 – 4.15)	2.64	(2.27 – 3.06)	2.62	(2.26 – 3.05)
Inter-personal level	Social support among students				0.30	(0.28 – 0.33)	0.31	(0.29 – 0.34)
	Lecturers support				1.03	(0.95 – 1.12)	1.08	(0.99 – 1.18)
University level	University culture of open communication	Positive perception (ref.)					1.00	
		Neutral perception					0.92	(0.80 – 1.07)
		Negative perception					0.99	(0.80 – 1.23)
	University connectedness	(Strong) connectedness (ref.)					1.00	
		Neutral connectedness					0.93	(0.78 – 1.11)
		Weak connectedness					1.43	(1.23 – 1.67)
	University engagement						0.90	(0.83 – 0.97)
	Type of university	University (ref.)					1.00	
		University of applied sciences					0.76	(0.63 – 0.91)

OR, Odds Ratio; CI, Confidence Interval; (ref.), Reference category.

loneliness at university (34). However, there is previous evidence that students’ engagement with the university environment is not a predictor of mental health (32) and that loneliness is associated with mental health (5, 8, 15). Conversely, our results showed that a university culture of open communication was not associated with feelings of loneliness. In terms of mental health outcomes, previous school-based research has shown similar findings (27). Nevertheless, university culture can contribute to students’ sense of belonging (27), so both university communication and culture should be transparent and inclusive. In fact, further research is needed to explore the nuanced associations of students’ university connectedness and extracurricular engagement with loneliness. Longitudinal studies and qualitative research could provide valuable insights into these dynamics. Moreover, examining potential moderating factors such as sociodemographics and coping strategies would enhance our understanding.

Additionally, students at universities of applied sciences were less likely to report loneliness during studies than students at universities. Unlike universities, universities of applied sciences tend to have more practical teaching, smaller learning groups, and more hours on campus. These structural differences between universities and universities of applied sciences may explain the lower level of loneliness in the latter one. As universities of applied sciences tend to have smaller learning groups, our findings are consistent with school-based research suggesting that school size has little effect on pupils’ mental health (51). Nevertheless, universities should seek to provide opportunities for students to learn and interact in smaller, more consistent groups, thereby enhancing the overall campus experience.

Our study is not without limitations. Firstly, no causal claims can be made due to the cross-sectional design. However, by following a hierarchical approach to testing social-ecological

domains, this allows for a detailed analysis of the comparative relevance of different predictors and their interactions, providing a differentiated insight into the relationship between variables. Future research should seek to examine changes in student loneliness over time in relation to both inter-personal and university factors. Secondly, the StudiBiFra study used a convenience sample. Therefore, selection bias cannot be ruled out, and females, those studying health subjects, and those with better health may be over-represented. This may have affected levels of university loneliness and self-rated overall health state, and an under-estimation of the prevalence of loneliness is likely. In addition, due to the stigmatized nature of loneliness, direct measures of loneliness may be prone to under-reporting (52). Furthermore, the measure of loneliness in our study should be interpreted with caution, as we explicitly asked about loneliness during studies. Rather, it represents loneliness in a particular setting. Additionally, it's worth noting that other studies have also adopted a similar approach, focusing on loneliness within specific contexts (28, 39) and using one single item measure for loneliness is common (4, 53). Further to this, as there is no validated measure of youth loneliness (54), a single-item measure focusing on loneliness at university would be preferable to a scale that does not capture all aspects of loneliness experienced by young people. In addition, our sample had a high proportion of female participants, which may have led to gender imbalance. However, the impact of certain types of selection bias on the associations presented can be considered small, as the analysis was adjusted for gender and other factors. In addition, we were able to reach a large number of students, improving the accuracy of our estimates. We also have large geographical coverage in our sample, as we included seven universities from five federal states in Germany. Thirdly, we cannot conclusively ascertain the absence of any remaining COVID-19-related restrictions within the university settings, even though the data collection took place at a time when face-to-face teaching was generally permitted again. However, some of the lighter COVID-19 measures may still have influenced university life (e.g., wearing face masks). Further, some of our variables did not include temporal information. This may have affected factors at the inter-personal and university level because the time frame of the questions was not clearly defined, and thus previous COVID-19 measures may have influenced responses. Our results should therefore be interpreted with some caution.

5 Conclusions

To our knowledge, this is one of the first studies to provide evidence on factors associated with loneliness at individual, inter-personal, and organizational levels among university students at the same time. Our findings underscore the multifaceted nature of loneliness among university students. We found high levels of loneliness at universities that highlight the need for interventions targeting individual, inter-personal, and organizational factors for a supportive social campus environment. Our results reinforce the importance of positive social support among students to reduce and prevent loneliness. Therefore, universities should offer opportunities

for student networking, peer-to-peer and buddy programs, with particular attention given to specific groups (e.g., gender-diverse students) in these initiatives. Findings of the present study also highlight the importance of university connectedness-based prevention measures and interventions aiming at promoting mental health and wellbeing in university settings. Promoting social connections and strengthening students' ties to their university are important strategies for tackling loneliness, highlighting the importance of community-building initiatives. Overall, universities should strive to function as vibrant and supportive communities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by ethics committee of Charité - Universitätsmedizin Berlin (EA1/055/21). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

VW: Conceptualization, Methodology, Visualization, Writing – original draft, Writing – review & editing. KH: Conceptualization, Writing – review & editing. EH: Conceptualization, Writing – review & editing. JL: Conceptualization, Data curation, Writing – review & editing. JB: Conceptualization, Writing – review & editing. ZD: Conceptualization, Writing – review & editing. CS: Conceptualization, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Establishing community partnerships to maintain social connection and healthcare access during an emergency declaration: virtual veterans socials

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This community case study reflects the transition of a community-based social intervention at a Veterans Affairs (VA) Medical Center in the northeastern United States (U.S.) from in-person to virtual gatherings during COVID-19 restrictions. Initially, the Veterans Socials program began in 2014 to address social support challenges of veterans who received care from VA, then evolved into community-based social groups delivered with and for the veteran community. These consist of veteran-led weekly meetups aimed at fostering social connection and reducing isolation. This evaluation explores the challenges and opportunities involved in shifting to a virtual platform, focusing on how community partnerships, including collaboration between private and government organizations, supported the continuity of this inclusive social support initiative. Leveraging these partnerships expanded access to health-related resources and services, while maintaining critical social networks. Findings include program-level data and three individual case studies that underscore the role of social support systems in mitigating loneliness and improving healthcare accessibility in times of crisis. This evaluation highlights how community partnerships were essential for sustaining social support, enhancing access to healthcare information, and disseminating vital information to the community during an emergency declaration.

KEYWORDS

social connection, loneliness, access to care, public-private partnerships, veterans, emergency preparedness, virtual support

1 Introduction

Efforts to limit the spread of the COVID-19 pandemic led to the unfortunate side effect of reducing social connections (1), and in this way, exacerbated another epidemic in the U.S., the ongoing epidemic of loneliness that has been a source of growing concern over the past two decades (2). Loneliness refers to the negative subjective experience of having a social network that is inadequate in quality and/or quantity (3), while social isolation refers to an individual's limited social relationships, group memberships and infrequent social contacts (4). Two meta-analyses, including a combined 160 studies (*N* of 5.6 million), suggest that

social isolation and loneliness increase the risk of early death by 29–32% (5, 6). Loneliness and social isolation can impair mental health and physical functioning (6, 7), predict depression severity and suicidality (8). One of the most prominent predictors of loneliness is the low frequency of high-quality contact with supportive friends and family (9, 10). Interventions that increase social connection, by enhancing the size and diversity of one's social network, the roles and functions of relationships and the positive qualities of the relationships (2) can ameliorate the negative outcomes associated with loneliness (11).

Further, experiences of loneliness can create cognitive distortions whereby individuals perceive social interactions as more threatening and view their environment as fundamentally less safe (12). This altered perception can heighten the sense of personal vulnerability and increase beliefs about potential threat from others (13). Moreover, evidence indicates that increased feelings of being unsafe related to loneliness are significantly associated with unsecured firearm storage practices, which substantially elevates the risk for death by suicide (14, 15).

Interventions thwarting loneliness or social isolation may particularly be necessary for veterans, who may be vulnerable to loneliness across various age groups, due to challenges transitioning from the military and feeling disconnected from community networks (16–19). Among veterans who participated in the National Health and Resilience in Veterans survey 2019–2020 ($N = 4,069$; mean age = 62), 56.9% reported feeling lonely sometimes or more (20).

1.1 Virtual interventions to promote social connection

Historically, interventions that increase social connection have been based on in-person interactions, though a shift to online platforms has accelerated and gained acceptance across age groups (21–23). Healthcare policy changes during the COVID-19 pandemic and patients' increased willingness to use telehealth services have made virtual interventions more acceptable and, at times, even essential to receiving care (24). Further, online social connections during the COVID-19 pandemic may have played an important role in maintaining health through mitigating loneliness (25).

During the COVID-19 pandemic, VA-led several telehealth interventions in the veteran population targeting social support and loneliness among veterans, with mixed results in loneliness. For example, VA CONNECT a telehealth cognitive-behavioral therapy and dialectical-behavioral therapy skills group that integrated peer support did not show significant changes in loneliness over 10-sessions, but significantly reduced perceived stress (26). A 12-session intervention CONNECTED, showed peer-facilitated group sessions were both feasible and preliminarily effective, showing reductions in social isolation and increased perceived social support (27). Another initiative, Compassionate Contact Corps, matched veterans with trained volunteers for weekly supportive phone calls, providing a scalable approach with goals of reducing loneliness and fostering social connection (28).

Naslund et al. (29) proposed a conceptual model for online peer-to-peer social connection with persons experiencing mental health challenges. This model addressed potential benefits, including opportunities to challenge stigma, increase consumer activation, and

access to mental and physical wellbeing interventions while engaging with peers online. It also identified possible risks of using online communities to engage patients, including feeling more uncertain about one's diagnosis or condition. In addition, the online disinhibition effect can further amplify risks by increasing the likelihood of aggressive or derogatory interaction among users (30). To effectively implement online peer-to-peer support interventions, the benefits, risks, and technological barriers must be continually explored, evaluated, and addressed to further understand best practices in virtual platforms for social interventions.

1.2 Public-private partnerships that can support social connection

Leveraging public-private partnerships can capitalize on the shared goals of government and private organizations to better serve veterans and improve the standard of care for veterans and their families (31). Collaborations through public-private partnerships are advancing across multiple areas including suicide prevention (32), support for transitioning service members and coordinating care (33), education (34), employment (35), information access and dissemination (36). As social relationships become more prioritized in public health policy, the urgency to explore social interventions intensifies (37). Non-medical interventions aimed at enhancing social connection for veterans, often supported by community volunteers and private organizations have also gained traction. [TogetherWeServed.com](https://www.togetherweserved.com), a U.S. military and veteran online community, launched a veteran Buddy Link on its platform to help connect veterans seeking camaraderie connect online with others who live nearby, registering over 2,200 users looking for a local buddy within the first month of launch (38). Veteran and military-affiliated gaming communities (e.g., Regiment Gaming, Warrior GMR Foundation, and Stack Up) have grown in popularity (39) and may have the potential to support social connection initiatives and public health goals (40, 41).

1.3 Veterans socials

In 2014, peer specialists (PSs) employed by the U.S. Department of Veterans Affairs developed and co-hosted Veterans Socials (VSs) in communities around VA facilities. These were developed through community partnerships between VA, veteran serving organizations and veteran community leaders over 5.5 years. PSs worked with community leaders to initiate weekly VSs, which evolved based on the interests and preferences of attendees (e.g., coffee meetup, bowling leagues, gaming clubs, volunteer groups). Further, VSs offered an inclusive approach to community building, often incorporating military affiliated family members, caregivers, and supportive others in social activities. This flexible, community-based social intervention was designed to offer a low barrier to entry, with no attendee requirements. Essential elements of the VSs included:

1. VS is held in a community location other than a VA facility.
2. VS is open to all military-affiliated and supportive others who wish to join.
3. Attendance is not entered in the veterans' medical records.

4. VS is held at least once per month (in-person or virtually).
5. The primary objective is to foster social interaction in the community.
6. Attendee preferences drive the format, content, and process of the VS.
7. The host presents opportunities for attendees to socialize outside of the VS.
8. The host has materials (e.g., health and community activity information) available to assist attendees in choosing to pursue VA and/or community resources and services.

VSs were founded on strong partnerships between veterans and their local communities. In collaboration with community leaders, the creation of VSs followed guidance that involved designing, organizing, and implementing events in partnership with attendees and local organizations (42). These efforts employed a multi-channel, community-based approach to recruiting attendees, relying entirely on no-cost recruitment strategies. VA PSs and community leaders advertise in local businesses (e.g., grocery stores, health centers, restaurants, community centers), veteran organizations and in VA hospitals, as well as through social media, and word-of-mouth campaigns. As a result, VSs typically gain attendees progressively over a 4- to 6-month period. Veteran leaders and PSs often collaborated to initiate and co-host VS, with the aim of developing sustainable, regularly scheduled (e.g., weekly or monthly) veteran gatherings in the community (43). A positive social group culture within VSs is demonstrated when hosts and attendees actively discuss community events, share personal stories including stories that highlight the importance of seeking help when needed, and exchange information on community and VA resources. The overarching goal was to build community-based social support systems by harnessing the power of veteran-to-veteran connections.

1.4 Community partnerships

Collaborative community-level interventions are foundational for long-term and sustainable community impact (44). Moreover, in times of crisis social infrastructure bolsters community resilience and drives the collective ability of a population to withstand and recover from crises (45). Community partnerships were initiated and maintained through an active engagement strategy led by peer specialists from the Veteran Community Connection Team, with support from VA hospital leadership. This team regularly participated in community meetings, joined initiatives led by veteran-serving organizations, and collaborated with local collaboratives in surrounding areas. Over time, strong relationships were formed between VA staff, town leaders, state veterans services, non-profit veteran organizations, and local businesses. These partnerships were nurtured and sustained through ongoing contact at in-person VSs, which provided a consistent platform for collaboration and relationship-building. In March of 2020, restrictions associated with the COVID-19 pandemic (46) led to the abrupt cessation of all 28 in-person VSs across two VA medical center catchment areas. Community partnerships between neighborhood organizations, businesses, key leaders, and local government facilitated the rapid development and implementation of Virtual VSs. Through three cases studies, this report explores the process of developing and

implementing Virtual VSs, opportunities for increased accessibility, and benefits of collaborating with community partners.

2 Context

2.1 Process of adapting VS

PSs adapted in-person VS to a virtual format. The PSs advertised the Virtual VS by contacting VS hosts, veterans who subscribed to the monthly VS newsletter, local veteran organizations (e.g., American Legion, The Veterans of Foreign Wars, Disabled American Veterans), state and city veteran services, veterans service officers, local business, the organizations that had provided space for the in-person VS, and the local Veteran Affairs (VA) medical center communication channels. Further, the Virtual VS was advertised on community-run VS Facebook pages, flyers in local VAs, and a word-of-mouth campaign that encouraged veterans to spread information about the Virtual VSs.

The PSs who co-hosted Virtual VSs examined various virtual platforms such as Skype, Zoom, Webex, and Microsoft Teams. They spent time on each platform and considered who the audience would be and what attendees would need. Considerations included: (1) having a virtual platform that would allow veterans to call in with a phone as well as a computer; (2) making the Virtual VSs feel comparable to an in-person VS by employing a platform that used video and a share screen function; and (3) using a platform that was easy to navigate to allow people with varying levels of technical abilities to join.

2.2 Attendance and participation

Unlike in-person VSs, Virtual VSs required more facilitation demands from the host. Virtual platforms also eliminated side conversations, which often occurred during in-person VS. The Virtual VS host would lead the conversation and monitor the chat as another form of communication. The Virtual VS host would also assist attendees if they had challenges using the technology during and before the Virtual VS. They also discussed ways of making it clear when one was done speaking, as social cues were more difficult to interpret.

The Virtual VSs began in late March 2020 and continued for 14 months, during which a single VA facility—working in partnership with the community—co-led 234 virtual events, resulting in 1,226 attendee engagements (non-unique). For program evaluation purposes, anonymous information was collected by hosting PSs during Virtual VSs. Initially, these Virtual VSs were held daily, Monday through Friday, with two hosts typically in attendance. The average number of attendees per Virtual VS from March to July 2020 was seven. However, starting in August 2020, attendance began to decline, with an average of 4.5 attendees per session from August 2020 to March 2021. In response to this decreased attendance, the frequency of Virtual VSs were reduced to 3 days per week beginning in October 2020. The downward trend in participation continued, with attendance further declining to an average of 3.5 attendees per session during the final 2 months (April and May 2021). Consequently, Virtual VSs were mostly discontinued after May 2021, primarily due to veterans'

expressed preferences for attending in-person socials. This shift in format reflects the program's responsiveness to changing attendance patterns and participant preferences throughout the evaluation period.

The content of the initial Virtual VS primarily focused on practical matters, including familiarization with the virtual platform, dissemination of COVID-19-related information, and discussion of available resources for veterans in need. Hosts occasionally prepared specific topics for discussion, such as self-care strategies, locations of food pantries, financial assistance options, and community resources. However, as regular attendance patterns emerged, the nature of these interactions evolved. Conversations transitioned from host-directed discussions to more attendee-driven dialogues, reflecting an organic development of community within the virtual space.

3 Case studies

This manuscript reflects a description of the Virtual VSs from the perspectives of the VS hosts. Three Virtual VS hosts were interviewed to provide three intrinsic case studies that describe phenomena for veteran participants in Virtual VSs during the COVID-19 pandemic. This approach aligns with the intrinsic case study method, which seeks to understand a particular cases due to their unique context or features (47). Three case studies are presented from the viewpoint of the Virtual VS hosts, who were interviewed for this information to allow these VS experts to select and describe case(s) that would provide unique insights into the program and, in doing so, illustrate implementation, impact, and lessons learned. This also allowed for a more naturalistic understanding of veteran experiences within the Virtual VS process and setting, without causing any additional burden of obtaining information directly from veterans during a particularly challenging time. Each case highlights features of veterans' experiences learning about and engaging with the Virtual VS.

3.1 Case 1—Virtual veterans socials: facilitated social support in the absence of in-person options

Betty (name changed), a White female Gulf War veteran in her 60s, had participated in an in-person VS regularly, often assisting the host and bringing snacks for the other attendees. Betty was considered an essential worker, a designation that required her to be present on-site during hours that conflicted with the Virtual VS. As a result, she was unable to attend the Virtual VS regularly throughout the COVID-19 pandemic. As capacity limits on businesses were relaxed, she began attending the few local in-person VSs and gradually decreased her attendance in the Virtual VS.

However, in the fall of 2020, she contracted COVID-19 and was homebound for weeks. At that time, Betty participated in a Virtual VS four times per week and utilized the platform's video conferencing capability to interact. After that experience, she took on more responsibilities in the Virtual VS and conducted buddy checks, which consisted of a brief phone call to veterans with whom she had formed relationships and had not attended the VS recently. Overall, she viewed the Virtual VS as a beneficial "option" when "you need that support." Following this experience, she chose to participate in additional social and health opportunities through virtual platforms,

including a virtual art group and VA group therapy sessions using video conferencing technology—a pattern that suggests reduced isolation.

3.2 Case 2—Virtual veterans socials: facilitated increased engagement

Connor (name changed), a White male Vietnam-era veteran in his mid-70s, was introduced to the VS at his local senior center. He attended a VS for approximately 1 year before the virtual adaptation, typically attending one or two events per month, including a local bowling group that evolved from a VS. The veteran's initial social engagement at the VS was limited. Connor attended infrequently, and when he did attend, he had limited interaction with others and disclosed little about himself, his feelings, or his personal history.

As COVID-19 restrictions were put in place and social events were canceled, a PS at the local VA, who was familiar with Connor through in-person VSs, encouraged him to attend the Virtual VS and attempted to help him with connecting virtually. Connor expressed apprehension and reluctance to navigate the virtual platform; however, he was amenable to using his phone to call into the Virtual VS. Connor reported he could no longer have visitors in his home, including his grandchildren, due to the pandemic. He also reported feeling anxious about leaving his home due to underlying medical conditions that made him vulnerable to COVID-19 and lacked social connection because of the safety measures he was taking to protect himself; the Virtual VS offered a platform for social connection.

Connor attended the Virtual VS daily. While his other social events were canceled, the Virtual VS provided a reliable outlet for social engagement, and his increased attendance suggested reduced loneliness; moreover, he began to share more personal information about himself, such as his financial difficulties, which prompted other attendees to offer information and community resources to support him. He reported to the Virtual VS host that he was enrolling in the local VA to assist him with his other psychosocial challenges. When Connor decided to enroll in VA services, he saved money by switching his medical care, substantially reducing his medication costs, and allowing him to more effectively manage his other healthcare needs.

3.3 Case 3—Virtual veterans socials: facilitated access to care

The final case illustrates how Virtual VSs can lead to healthcare utilization by enhancing awareness of one's own needs, as facilitated by a caring social group. In this case, Dave (name changed), an 80-year-old White male Vietnam-era veteran, was influenced to seek needed healthcare services. This veteran had attended three different VSs for several years. During the COVID-19 pandemic, the veteran received information about Virtual VSs from a PS at his local VA and was encouraged from PSs whom he had met through in-person VSs. Dave was adept with technology but preferred using his phone to call into the Virtual VS rather than using the virtual platform. He attended the Virtual VSs approximately 2 days per week.

During his participation in the Virtual VSs, he noted that he had a wound that he treated himself and that it was becoming increasingly

painful. Dave lived alone and had not told anyone about his injury, nor had he sought medical treatment. Other attendees discussed that he had reported this pain on a previous Virtual VS and asked him to show them the wound on camera. They persuaded him to seek immediate treatment. Dave was enrolled in VA services but had not considered scheduling an appointment. With encouragement from the other attendees and a subsequent phone call from a PS informing him of procedures for accessing urgent care services, Dave received treatment for his injury. Dave updated attendees at the Virtual VS and reported staying in the hospital for multiple days to treat the infection. He was grateful that he received encouragement and support from his peers, as it resulted in him accessing vital healthcare services and getting treatment for a potentially life-threatening infection. He has shared his story with other veterans to encourage them to utilize VA healthcare resources.

4 Discussion

Many lessons were learned during the transition from in-person to Virtual VSs. One is the value of Virtual VSs for increasing access for individuals who might not otherwise engage with services and supports. Another is the importance of community partnerships in facilitating social connection and the diffusion of information during community crises.

While in-person activities and services that were suspended due to COVID-19 pandemic restrictions have resumed, the same groups of individuals who faced obstacles to in-person care before the pandemic remain and benefit from the continued offering of flexible, hybrid, and virtual services (48). Furthermore, situations that can cause disruptions to in-person programming continue, with other pandemics increasingly likely (49), natural disasters, and extreme weather events such as heat, flooding, and drought. Additionally, health-related concerns (e.g., mobility issues or being immunocompromised), pose barriers to travel or participation in community events, and may continue to create obstacles to in-person care and connection for large numbers of people (50, 51). For all these reasons, the ongoing provision of virtual interventions and enhancement to community partnerships for clinical and non-clinical services is critical to meet the needs of veterans – especially during community, state, national, and global crises.

4.1 Impact of virtual veterans socials

Each case exemplifies key benefits of the Virtual VSs format, namely the facilitation of continued social support in the absence of in-person options, enhanced awareness of one's own needs, and readily available access to information and care options. The Virtual VSs experiences of attendees reported to and observed by Virtual VS host illustrate the benefits of these virtual gatherings, particularly during periods of heightened isolation such as the COVID-19 pandemic. In Case 1, Betty, demonstrates how attendees can assume meaningful, purposeful, and empowering roles in virtual social groups. By conducting buddy checks with fellow participants, Betty not only contributed to a supportive environment but also exemplified the potential for peer leadership within virtual communities. Moreover, Betty's engagement with the Virtual VSs appears to have

encouraged her exploration of additional virtual activities, including healthcare treatment, suggesting that these gatherings may serve as a gateway to broader utilization of supportive services.

Connor's case underscores the evolving nature of engagement that Virtual VSs can facilitate. Initially a sporadic and reticent attendee, Connor's attendance became more consistent and open following the transition to virtual formats. The virtual environment provided a safe and reliable platform for social interaction, ultimately enabling Connor to disclose personal challenges—such as financial difficulties—within the group. This openness led to peer-driven resource sharing and support, with positive outcomes in financial, social, and health domains. Financially, Connor gained access to community resources and cost-saving VA healthcare options. Socially, increased participation offered a crucial outlet for interpersonal connection during pandemic-related restrictions. Furthermore, Connor's engagement encouraged his enrollment in local VA care, highlighting the potential of Virtual VSs to foster supportive environments where veterans feel comfortable sharing challenges and accessing needed services.

Dave's experience further illustrates the potential health-related benefits of regular Virtual VS participation. The frequency of these gatherings enabled attendees to monitor changes in Dave's well-being over time, while the virtual platform provided ongoing access to social support and reminders about available healthcare resources. Encouragement from peers motivated Dave to seek care, demonstrating how Virtual VSs can facilitate access to healthcare for veterans who may otherwise underutilize needed services. Additionally, sharing Dave's success with peers may reinforce his continued use of health services and motivate others to seek care, amplifying the positive impact of these virtual gatherings.

Overall, these case examples collectively demonstrate that Virtual VSs have the potential to serve as a vital platform for peer support, resource sharing, and health service utilization among veterans. Further, Virtual VSs served a dual purpose: they provided PS hosts with a channel to reach potentially isolated veterans who might not otherwise access services while simultaneously offering veterans an opportunity for social connection.

4.2 Technological implementation and accessibility

During the COVID-19 pandemic, virtual interventions became common; for the first time, we *all* experienced a collective, extended obstacle to in-person services. The case examples above highlight one intervention's successful transition from in-person to virtual, not only continuing to provide veterans with social support and access to services and information. The Virtual VS was delivered via mobile phones, computers, and audio-only options, allowing accessibility for attendees with varying levels of technological proficiency. Virtual VS hosts assisted attendees prior to the meet-up to gradually build attendees' capacity to access the Virtual VS on their own. The platforms used required stable internet connections or data plans that can support usage, which can be challenging for those in rural areas or areas with less internet coverage, wireless signal, or other general resources (e.g., phone, laptop). The platforms (i.e., Zoom, Teams, and Webex) used to engage attendees consisted of features like video conferencing and screen sharing, helped create an engaging and

interactive experience for participants who could access chat, send images, reactions, or emojis to one another. VS hosts selected specific virtual platforms based on their comfort, attendee preferences and barriers associated with the platform (e.g., software update frequency, web browser compatibility) (41). The number of Virtual VS engagements during COVID-19 restrictions indicates that, in certain situations, virtual interventions can serve as a pragmatic community approach to increase access to information and reduce loneliness. The veteran population is, on average, older (age 65) than the general population than the general population (age 39) (52, 53). Although, there is a common myth that older adults are not interested in or capable of using technology (54), some veterans who appeared to receive the most benefit from the Virtual VS were older. However, it is also possible that older veterans may have had risk factors that made them more susceptible to loneliness than others (55) and Virtual VS contact may have appeared to benefit them in ways that may have not been beneficial or were disliked by others without those risk factors. Moreover, some of these older individuals were isolated and had a higher risk of becoming critically ill from in-person socializing during the COVID-19 pandemic (56).

Overall demand for the Virtual VS decreased substantially as in-person socializing gradually returned over the course of the COVID-19 pandemic, indicating many individuals' preference for in-person support. Moreover, VS hosts reported the VS "felt different than in-person...and not the same" suggesting that virtual interactions may not have been as rewarding as in-person VS interactions. Although many in-person VS resumed after restrictions were lifted, it is also possible that some Virtual VS attendees decided not to return to in-person VS if they did not find the intervention valuable, useful, or for other reasons that prevented them from attending. The Virtual VS is not a typical virtual intervention; it is designed to be a low-obstacle, highly accessible social support intervention, however barriers remain. Any military-affiliated or community supporter can attend a VS and there is no requirement that attendees engage with the VA healthcare system. While veterans who are enrolled in VA care have expressed a willingness to engage in VA services to reduce social isolation (27), there are many unenrolled veterans, due to the stigma of seeking care (57), mistrust of VA or medical establishment (58), or distance they would need to travel (59), who do not seek help within VA. The VSs were intended to be an inclusive social intervention accessible to all veterans, regardless of VA enrollment status. As of 2025 there were 178 known VS across 26 U.S. states and territories. The expansion of VSs to incorporate virtual options as needed reflects a commitment to ensuring veterans have resilient pathways to access healthcare information and social support systems in their communities.

5 Conclusion

The COVID-19 pandemic heightened feelings of loneliness and social isolation, compounding an issue already recognized as an epidemic in the United States (60). As such, there persists a crucial need for resilient and accessible interventions addressing these concerns. The VS virtual adaptation was catalyzed with the collaboration between government, community organizations, businesses, and institutions. Going forward, Virtual VSs may serve as

a valuable addition when in-person gatherings are not feasible, effectively supplementing—rather than replacing—traditional in-person VSs. The successful adaptation of the VS format to a virtual environment highlights its potential as a flexible tool for sustaining veteran engagement and support during periods of adversity. Additional evaluations of virtual and non-virtual VSs, including obtaining feedback directly from veteran participants, could further highlight ways to increase access to and support from VS programming. Overall, this community case study demonstrates that community partnerships forged through VSs have the potential to serve as crucial conduits for rapidly disseminating information and bolstering social support during emergencies.

5.1 Acknowledgment of conceptual or methodological constraints

The evaluation has several limitations. The community case study design is limited in nature and may not extend to a broader population outside of the community evaluated. Additionally, the evaluation's scope was intentionally limited to avoid disrupting the intervention and programming during an emergency declaration. Furthermore, the participant feedback described in these case studies may have been influenced by response bias or demand effects, as only Virtual VS hosts were interviewed for this evaluation, underscoring the need for more rigorous studies to gain a clearer understanding of program benefits. Overall, more systematic investigation is required to evaluate the impact of VSs on social connection. Ongoing studies are currently examining how this intervention affects loneliness and social isolation among participants.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was not obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article because this was considered evaluation and not research by the VA Bedford Healthcare System Institutional Review Board and exempt from written informed consent. Identifying details were changed to ensure anonymity. Verbal consent was obtained from participants and all data was anonymized.

Author contributions

JG: Writing – original draft, Writing – review & editing. EC: Writing – original draft, Writing – review & editing. HH: Writing – original draft, Writing – review & editing. ME: Writing – original draft, Writing – review & editing. RC: Writing – original draft. JM: Writing – original draft. JS: Writing – original draft. ER: Writing – original draft. CD: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. Limited portions of the manuscript were copy edited for

conciseness using OpenAI's ChatGPT- 3.5. Specifically, generative AI was employed to enhance the transitions and flow within select paragraphs of the manuscript. The authors provided their own text to the AI in increments of no more than four sentences at a time. This method ensured that the AI did not alter the original meaning of the text. By using small input sizes and specific queries, such as "review this for conciseness and retain the same meaning while using a scientific tone," the authors were able to maintain control over the content. This approach also helps to mitigate reviewer fatigue when editing for conciseness, as the human authors remain actively involved in the process.

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