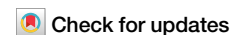


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Depression and social connectedness as mechanisms linking frailty to quality of life in older African migrants in Australia



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Older Sub-Saharan African (SSA) migrants often face cumulative stressors that heighten vulnerability with age. Frailty acts as a chronic stressor that reduces quality of life, partly through its association with depression, while social networks may reduce the effect of depression on quality of life. We analysed cross-sectional data from 205 SSA migrants aged 50 years and above in Australia. We tested a moderated mediation model, guided by the Stress Process and Social Buffering frameworks, using structural equation modelling with 5,000 bootstrap resamples. Frailty was positively associated with depression ($\beta = 0.72, p < 0.001$), and depression was negatively associated with quality of life ($\beta = -0.54, p < 0.001$). Depression mediated the frailty–quality of life relationship ($\beta = -0.38, p < 0.001$), while social networks also moderated the depression–quality of life path ($\beta = 0.13, p = 0.004$). These findings highlight the psychological and social pathways linking frailty and well-being in later life. Interventions that address both physical and mental health while fostering strong social networks could enhance resilience and improve quality of life among older SSA migrants in Australia.

Older migrants from Sub-Saharan Africa (SSA) are one of the most underrepresented groups in ageing and health research globally, despite facing profound health inequities in later life¹. In High-Income Countries (HICs), these individuals often age in contexts shaped by structural racism, cultural dislocation, and exclusion from mainstream services^{2–4}. Although many migrated decades ago for work, education and family reunification, their current experiences of ageing are shaped by long-standing exposure to structural inequality, and limited access to responsive care systems^{3–5}. Life-long exposure to socio-economic hardship, racialized labor markets, and fragmented social support systems often converge in old age and heighten the vulnerability of these migrants to complex health conditions^{6,7}.

In Australia, older SSA migrants often age within environments shaped by linguistic, cultural, and systemic barriers to equitable care. The population of older African migrants in Australia nearly doubled in the last decade from about 74,090 in 2011 to 134,710 in 2021⁸. This growth reflects both the ageing of early migrant cohorts and continued arrival of new migrants. Many early migrants now entering older age may be faced with depression, and social isolation which reflect both health and social integration challenges^{9–11}. Qualitative studies of African migrant communities have documented difficulties in navigating primary care, cultural mistrust of health systems, and stigma around mental health help-seeking, with reliance on informal community and faith-based supports^{5,12}. These challenges are

often exacerbated by the lack of culturally appropriate health and social care systems^{3,13}, and are likely to interact with existing socio-economic disadvantage, multimorbidity and functional decline to reduce the Quality of Life (QoL) of these older migrants.

One important lens for understanding these ageing-related challenges is frailty. Frailty is a multidimensional condition reflecting accumulated physical, psychological, and social health deficits¹⁴. Globally, older migrants from low- and middle-income countries and ethnic minority groups have been noted to be at increased risk of frailty than the general population². In Europe, for instance, older migrants were found to be 37.3% frailer than non-migrants in Northern Europe, 12.2% in Western Europe, and 5.0% in Eastern Europe¹⁵. Despite these insights, research on frailty among SSA migrants in Australia remains limited. Frailty is likely to manifest earlier and more severely in these migrant groups than their non-migrant counterparts due to cultural mismatches in service delivery, and unmet preventive care needs^{2,6}.

More recently, frailty has been associated with psychological consequences, particularly in the form of depressive symptoms^{16,17}. Declines in physical autonomy, social participation, and perceived loss of control can lead to emotional distress and a decreased sense of purpose. These outcomes (depression and diminished QoL) are often exacerbated in migrant populations, where mental health needs are under-recognized, and access to

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Table 1 | Sample characteristics of participants (N = 205)

Variable	N	%	Mean	SD	Min	Max	Skew
Sex							
Male	115	56.10					
Female	90	43.90					
Age-group							
50–69 years	98	47.80					
70 years plus	107	52.20					
Marital status							
Unmarried	63	30.73					
Married	142	69.27					
Educational status							
Low	71	34.63					
High	134	65.37					
Employment status							
Unemployed	61	29.76					
Employed	144	70.24					
Length of stay							
≤10 years	87	42.44					
>10 years	118	57.56					
Frailty status							
Robust	106	51.7					
Pre-frail	48	23.4					
Frail	51	24.9					
Frailty Index	205		0.13	0.14	0.00	0.69	1.50
Depression	205		0.33	0.36	0.00	1.75	1.28
Quality of life	205		9.82	2.29	3.32	13.00	-0.11
Social network	205		30.69	15.52	9.00	75.00	0.65

Values are presented as frequencies (%) for categorical variables and means (SD) for continuous variables.

culturally appropriate mental health support remains limited^{12,18,19}. Depression, in this context, may function as a key psychological mechanism through which frailty decreases QoL in later life. More importantly, depression among older SSA migrants may not be entirely a reaction to functional decline, but may reflect deeper experiences of cultural isolation, invisibility within the healthcare system, and cumulative disadvantage^{9,12,20}. Feelings of loss of identity, and the absence of traditional social roles can compound the psychological toll of ageing, especially in environments where older migrants are undervalued⁴. Moreover, mental health stigma within some SSA communities, combined with linguistic and cultural barriers to accessing care¹², may delay recognition and treatment of depressive symptoms. These dynamics position depression as both a consequence and a driver of poor QoL for older SSA migrants.

Amidst these challenges, social networks (comprising family relationships, community ties, and faith-based connections) can serve as important protective resources for older migrants^{5,12}. For many older migrants, such networks play an instrumental role in maintaining emotional wellbeing and navigating the complexities of ageing in a foreign cultural and institutional environment^{4,21}. However, the buffering effects of these networks may be limited by physical distance from family, weakened intergenerational relationships, or marginalization from mainstream community life^{4,22,23}. Understanding the protective, yet sometimes fragile, role of these social networks is important to unpack how psychological and social processes jointly shape the ageing experience for older SSA migrants.

Guided by the Stress Process Model²⁴ and the Social Buffering Hypothesis²⁵, this study conceptualises frailty as a chronic stressor that undermines psychological wellbeing and QoL through its influence on depressive symptoms, while viewing social connectedness as a resource that

buffers these effects. Together, these frameworks provide a theoretical foundation for understanding how physical vulnerability, psychological distress, and social resources interact to shape wellbeing in later life among migrants from SSA living in Australia.

Drawing on these frameworks, this study investigates the psychological and social pathways through which frailty influences QoL in this population of older migrants. Specifically, we examined whether depression mediates the relationship between frailty and QoL, and whether the strength of social networks moderates the association between depression and QoL. This study aims to deepen our understanding of how psychological distress and social resources shape ageing outcomes among underserved migrant populations. Our findings also offer important implications for public health policy, particularly in designing culturally responsive interventions that strengthen resilience and social connection in later life.

Results

Participant characteristics

A total of 205 older African migrants participated in the Afro-Diasporic study on Ageing, Health and Frailty (see Table 1). Just over half of the participants were male (56.1%), and most were married (69.3%). Educational attainment was high, with 65.4% reporting high level of education. A little over half of the participants were aged 70 years and above (52.2%) with most of them currently employed (70.24%). More than half of the respondents (57.56%) have lived in Australia for more than ten years. The mean FI score was 0.13 (SD = 0.14), with 24.9% of participants classified as frail, 23.4% as pre-frail, and 51.7% as robust. The average depression score was 0.33 (SD = 0.36), and the mean QoL score was 9.82 (SD = 2.29). Social

network scores varied considerably (Mean = 30.69, SD = 15.52), reflecting diverse levels of perceived social connectedness.

Bivariate correlation and assumption analyses

The results of the preliminary analyses are presented in Table 2. Frailty was positively associated with depression ($r = 0.73$, $p < 0.001$) and negatively associated with QoL ($r = -0.68$, $p < 0.001$). Depression was also negatively associated with QoL ($r = -0.76$, $p < 0.001$). Social networks showed small but significant positive associations with QoL ($r = 0.19$, $p < 0.05$) and negative associations with frailty ($r = -0.20$, $p < 0.05$).

Variance Inflation Factors (VIFs) ranged from 1.04 to 2.22, indicating no multicollinearity concerns. Visual inspection of residual plots and normal probability plots confirmed linearity, normality, and homoscedasticity assumptions were met.

Depression as a mediator between frailty and quality of life

The results of the mediation analysis as presented in Table 3 showed that frailty was positively associated with depression ($\beta = 0.72$, $p < 0.001$, 95% CI [1.39, 2.16]). Depression was also negatively associated with QoL ($\beta = -0.55$, $p < 0.001$, 95% CI [-4.39, -2.81]). This pattern indicates that individuals experiencing greater frailty are more likely to report depressive symptoms, which subsequently reduce their QoL.

We observed a significant indirect effect ($\beta = -0.39$, $p < 0.001$, 95% CI [-8.48, -4.57]), which confirms that depression helped explain how frailty is associated with QoL. The direct effect of frailty on QoL remained significant ($\beta = -0.17$, $p = 0.007$, 95% CI [-4.69, -0.56]). This suggests that while depression explains a substantial portion of the association, frailty also exerts an independent negative influence on QoL. The path diagram illustrating the mediation effect is presented in Fig. 1. The mediation model demonstrated excellent fit to the data ($\chi^2(0) = 0.00$, n.s., CFI = 1.00, TLI = 1.00, RMSEA = 0.00 [90% CI: 0.00–0.00], SRMR = 0.00).

Role of social networks in buffering the effect of depression on quality of life

The results of the moderated mediation analysis as presented in Table 4 showed that frailty was positively associated with depression ($\beta = 0.72$, $p < 0.001$, 95% CI [1.39, 2.16]), and depression was negatively associated with QoL ($\beta = -0.54$, $p < 0.001$, 95% CI [-4.39, -2.70]). There was a significant interaction between depression and social networks ($\beta = 0.13$,

$p = 0.004$, 95% CI [0.02, 0.10]), indicating that the negative effect of depression on QoL was weaker among individuals with stronger social networks as presented in Fig. 2. The indirect effect of frailty on QoL through depression remained significant ($\beta = -0.38$, $p < 0.001$, 95% CI [-8.53, -4.39]), while the direct effect of frailty on QoL also remained significant ($\beta = -0.20$, $p = 0.002$, 95% CI [-5.09, -1.02]). The model demonstrated excellent fit to the data, $\chi^2(1) = 1.18$, $p = 0.28$, CFI = 1.00, TLI = 0.99, RMSEA = 0.03 (90% CI [0.00, 0.19]), and SRMR = 0.007. The model also explained 56.6% of the variance in depression and 68.5% of the variance in QoL. The comparison between the mediation and moderated mediation models showed no significant difference in fit ($\Delta\chi^2(1) = 1.18$, $p = 0.28$), indicating that adding the interaction term did not meaningfully change model performance.

Discussion

This study draws on the stress process model and the social buffering hypothesis to examine the psychological and social pathways linking frailty to QoL among older SSA migrants in Australia. Our moderated mediation model demonstrated excellent fit and explained substantial variance in both depression and QoL, providing robust evidence that frailty is significantly associated with lower QoL in this population. Importantly, this relationship was only partially explained by depression, indicating that frailty exerts both a direct and indirect effect on QoL. This suggests that the psychological impact of frailty is not merely an outcome of physical decline but may also reflect deeper emotional and social vulnerabilities that accumulate over time.

Among older SSA migrants in Australia, frailty may heighten depressive symptoms through its interaction with culturally and socially specific stressors including loss of independence and difficulties accessing culturally responsive care^{9,12,20}. Physical decline can also disrupt valued roles within family and community networks, evoke a sense of invisibility, and potentially amplify existing experiences of marginalization. These dynamics

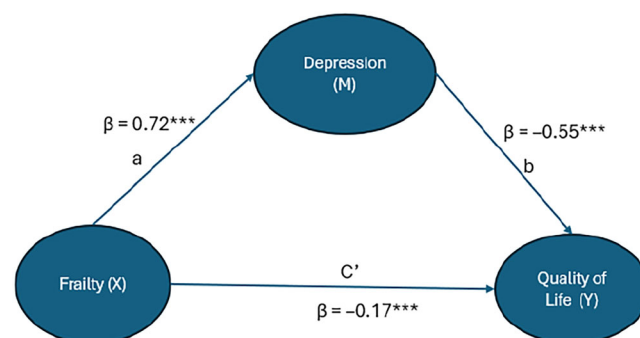


Fig. 1 | Mediation model showing the indirect effect of frailty on quality of life through depression. Standardized path coefficients (β) are shown. Frailty (X) served as the independent variable, depression (M) as the mediator, and quality of life (Y) as the dependent variable. The path from frailty to depression was positive, and the path from depression to quality of life was negative, indicating a significant indirect effect of frailty on quality of life through depression. * $p < 0.001$ for all paths shown.

Table 2 | Bivariate correlations between key variables (Pearson r)

	1	2	3	4
1 Frailty	1			
2 Depression	0.73***	1		
3 Quality of Life	-0.68***	-0.76***	1	
4 Social network	0.20*	0.13	-0.19*	1

Correlation coefficients represent Pearson's r values. * $p < 0.05$. *** $p < 0.001$.

Table 3 | Path estimates for the mediation model

Path	Estimate	SE (Boot)	z	p-value	95% CI	Std. beta
Frailty → Depression (a1)	1.821	0.197	9.22	<0.001	[1.388, 2.162]	0.715
Social Networks → Depression (a2)	-0.001	0.001	-0.45	0.65	[-0.003, 0.002]	-0.026
Depression → QoL (b1)	-3.534	0.407	-8.68	<0.001	[-4.391, -2.810]	-0.548
Frailty → QoL (c')	-2.791	1.043	-2.68	0.007	[-4.694, -0.562]	-0.170
Indirect Effect (a1*b1)	-6.434	1.000	-6.43	<0.001	[-8.479, -4.567]	-0.392
Total Effect	-9.225	0.838	-11.01	<0.001	[-10.847, -7.516]	-0.562

Estimates are based on 5000 bootstrap samples. All paths are standardized.

SE (Boot) Standard Error, z z-statistic (estimate divided by SE), CI 95% Confidence Interval, Std. Beta Standardized beta coefficient.

Table 4 | Path estimates from the moderated mediation model

Path	Estimate	SE (Boot)	z	p-value	95% CI	Std. Beta
Frailty → Depression (a1)	1.821	0.197	9.22	<0.001	[1.388, 2.162]	0.715
Social Networks → Depression (a2)	−0.001	0.001	−0.45	0.65	[−0.003, 0.002]	−0.026
Depression → QoL (b1)	−3.447	0.431	−8.00	<0.001	[−4.392, −2.699]	−0.536
Depression × Social Networks → QoL (b2)	0.058	0.020	2.86	0.004	[0.018, 0.098]	0.126
Frailty → QoL (c')	−3.245	1.046	−3.10	0.002	[−5.089, −1.016]	−0.198
Indirect Effect (a1*b1)	−6.276	1.060	−5.92	<0.001	[−8.533, −4.389]	−0.383
Moderated Indirect (a1*b2)	0.106	0.041	2.60	0.009	[0.028, 0.189]	0.090
Total Effect	−9.416	0.839	−11.22	<0.001	[−10.962, −7.623]	−0.492

SE (Boot) Standard Error based on 5000 bootstrap resamples, z z-statistic (estimate divided by SE); CI 95% Confidence Interval; Std. Beta Standardized beta coefficient.

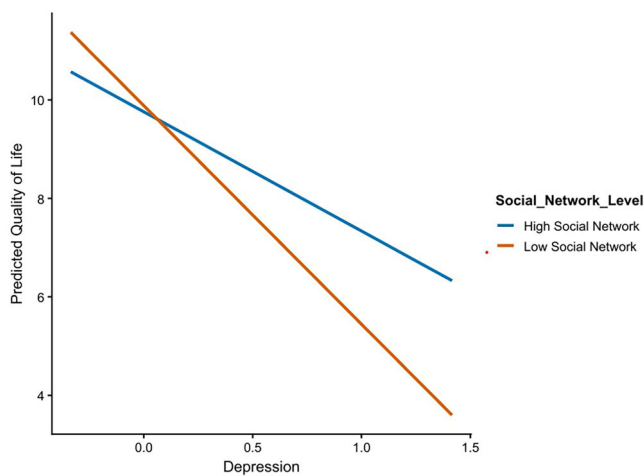


Fig. 2 | Moderating effect of social networks on the depression–quality of life relationship. The plot illustrates the interaction between depression and social network level in predicting quality of life. The negative association between depression and quality of life is weaker among participants with higher social networks (blue line) compared to those with lower social networks (orange line), indicating a buffering effect.

make the emotional effect of frailty particularly pronounced and may explain why depression becomes a key pathway through which frailty undermines QoL.

Consistent with prior research^{16,26}, our results confirm that psychological distress serves as an important mechanism through which physical health vulnerabilities such as frailty affect wellbeing in later life. For older migrants from SSA living in Australia, this connection may be compounded by long-term effect of cumulative disadvantage often seen in older migrant populations^{27,28}. The significant indirect effect observed in our findings also underscore the need for frailty interventions that integrate mental health support, especially in culturally diverse ageing populations. Consequently, interventions that address both physical decline and emotional wellbeing may be more effective when complemented by efforts to strengthen culturally meaningful social connections that support mental health in later life²⁹.

Our findings provide empirical support for the Social Buffering Hypothesis, suggesting that while social networks were not directly associated with QoL, they moderated the negative association between depression and QoL. Older migrants with stronger social ties were less affected by the emotional consequences of psychological distress, reinforcing the protective role of close relationships in later life^{30,31}. These connections can offer affirmation, reduce feelings of isolation, and foster continuity and meaning^{32,33}. The protective role of social networks has recently been reported among African migrants in South Australia, where social ties and faith-based or community networks were described as key sources of

emotional validation, practical help, and belonging that mitigated distress and loneliness²⁰. Similarly, African migrants in Western Australia reported drawing on family, community, and religious networks as core coping resources that sustain meaning and resilience under post-migration stress¹⁰.

It is important to note that although social networks buffered the negative association between depression and QoL, this moderation was partial, suggesting that the measures used in our study may not have fully captured the complexity of social connectedness among older SSA migrants. Specifically, it is possible that the OPQOL, which emphasizes individual-level perceptions, and the Lubben Social Network Scale-6, which focuses on the frequency and size of social contacts, do not fully capture the depth or quality of social connectedness that may indirectly shape QoL. There is the need for more culturally grounded measures of social connectedness that capture the quality, reciprocity, and emotional significance of relationships in African-diasporic ageing contexts. From a social buffering perspective, the value of social networks may lie less in how many connections older migrants have, and more in the emotional reassurance, understanding, and sense of belonging those relationships provide^{34,35}.

To effectively support ageing migrants, policymakers should invest in community-based social infrastructure, including culturally tailored programs and peer support groups, to enhance meaningful social ties and promote mental wellbeing. For instance, community mental health programs in diverse refugee and migrant populations that incorporate peer support and culturally adapted psychoeducation have been shown to reduce psychological distress and increase engagement with services³⁶.

Our study has several strengths. It was grounded in two well-established theoretical frameworks (the Stress Process Model and the Social Buffering Hypothesis) which guided our exploration of the psychological and social mechanisms linking frailty and QoL among older migrants. We used statistically rigorous moderated mediation models to test complex pathways that mirror real-world dynamics. The use of structural equation modelling with bootstrap resampling further enhanced the robustness of our findings, enabling precise estimation of indirect and interactive effects. Our focus on older migrants from SSA, a group underrepresented in ageing, migration, and public health research, contributes to a more inclusive evidence base and offers insights into how individual-level factors, often situated within broader systemic contexts, may influence later-life health outcomes. Despite these strengths, some limitations are acknowledged. First, the cross-sectional design precludes causal interpretations of the observed relationships. Longitudinal research is needed to assess how frailty, depression, and social networks evolve over time among ageing migrant populations. For instance, longitudinal analyses of the ‘Building a New Life in Australia’ cohort have shown that higher emotional and instrumental support predicts lower psychological distress over time³⁷, while social integration stressors such as loneliness and low belonging are associated with worsening distress trajectories among resettled refugees³⁸. Second, the sample, while community-based and diverse in its country of origin, may not capture the full spectrum of lived experiences among older SSA migrants in Australia. Third, although we focused on depression and social networks,

other potentially important moderators such as acculturation stress, health literacy, or discrimination were not included and should be explored in future work.

In conclusion, this study provides evidence that, among older SSA migrants in Australia, depression partially mediates the relationship between frailty and QoL, while strong social networks buffer the negative effect of depression. These findings indicate that the emotional and social consequences of frailty among older SSA migrants in Australia occur within migration-related and cultural contexts that shape their ageing experiences. Interventions aimed at reducing frailty-related distress and enhancing social connectedness should be culturally and contextually tailored to SSA communities in Australia. Public health policies that strengthen community-based, culturally appropriate social infrastructures (such as intergenerational programs and faith-based peer support) can improve QoL and promote healthy ageing among older SSA migrants.

Methods

Study participants and design

We used cross-sectional data from the Afro-Diasporic study on Ageing, Health and Frailty to explore the psychological and social mechanisms that link frailty to QoL among older SSA migrants in Australia. We recruited participants aged 50 years and above between August 2024 and March 2025 through community-based networks and cultural associations across Australia and via outreach efforts designed to improve engagement and representation. The online survey link was shared through established community channels, including African cultural associations and networks, community and religious leaders, and platforms for African researchers and academics residing in Australia. Eligibility criteria included: being born in an SSA country, being a community dweller, aged 50 years or older, and providing informed consent. We employed a snowball recruitment approach to increase participation. We used the 2021 census data from the Australian Bureau of Statistics (ABS) to determine place of birth and ancestry of people living in Australia. We stratified this by age groups and calculated our sample size based on the population of people (aged 50 years and above) from SSA. A total of 205 participants completed the survey, yielding a response rate of 53.4%. This response rate is considered acceptable for community-based studies involving older migrant populations, due to language, cultural, and logistical barriers that often hinder participation³⁹. The participants in our final sample migrated from West Africa (38.6%), East Africa (27.9%), Southern Africa (20.8%), and Central Africa (12.7%).

Data collection procedure

We collected quantitative data using a hybrid approach that combined online surveys and face-to-face interviews, hosted on the Qualtrics platform. We pre-tested the survey link and questionnaire among five older people from SSA. We secured the Qualtrics platform with access controls and monitored daily to ensure data integrity, participant safety, and technical reliability. The first author conducted face-to-face interviews along with trained research assistants across various Australian states and Territories (New South Wales, South Australia, Victoria, Northern Territory, Tasmania, and Western Australia). Interviews were conducted in English. Each interview lasted between 45 min and an hour. All the research assistants were of African descent and had good knowledge of working with SSA communities. We provided standardised training for the research assistants to ensure procedural consistency and ethical compliance during data collection. The training covered informed consent procedures, confidentiality and data protection, cultural sensitivity, accurate administration of survey items, use of the Qualtrics platform, and handling of potential participant distress. The study was approved by the Torrens University Australia Human Research Ethics Committee (approval number: 0353). All study participants provided either verbal or written consents prior to participating in the study. The study was conducted in accordance with the declaration of Helsinki (for human research subjects) and relevant national/institutional guidelines.

Measures

We constructed a Frailty Index (FI) from 28 self-reported health deficits, based on the deficit accumulation approach^{40,41}. These deficits captured indicators across several health domains (physical, psychological, social, and the diagnoses of chronic diseases). Each item was measured using a 5-point Likert scale, ranging from (1 = No difficulty) to (5 = Extreme difficulty). To standardise the scale and facilitate index computation, we recoded all the items to a 0–1 range, with: 1 = 0.00 (no deficit), 2 = 0.25, 3 = 0.50, 4 = 0.75, and 5 = 1.00 (full deficit). In addition to these Likert-scale items, we included several binary variables (e.g., diagnosis of chronic diseases), which were coded as 0 (not diagnosed) or 1 (diagnosed). We computed an FI score for each participant by summing the 28 recoded item scores and dividing by the total number of deficits (28), resulting in a continuous variable ranging from 0 to 1, where higher values represented a greater degree of frailty. Participants were classified as robust (non-frail) if their FI score was ≤ 0.10 , prefrail if the score was >0.10 and ≤ 0.21 , or frail if the score was >0.21 ⁴². The scores from the 28 FI items demonstrated excellent internal consistency (Cronbach's $\alpha = 0.93$). We used the FI as the independent variable (X) in both the mediation and moderated mediation models.

Depression was measured using the Patient Health Questionnaire-2 (PHQ-2). The PHQ-2 is a widely used and validated screening tool for measuring depression in community and clinical settings^{43,44}. The PHQ-2 consists of two items that ask participants how often they have felt little interest or pleasure in doing things (anhedonia), and how often they felt down, depressed, or hopeless. We rated the responses on a 4-point Likert scale, ranging from: 0 = Not at all to 4 = Every day. We rescaled each item to a 0–1 range (0 = 0.00, 1 = 0.25, 2 = 0.50, 3 = 0.75, 4 = 1.00) and then summed them up to produce a total depression score ranging from 0 to 2, with higher scores indicating more severe depression. The scores from the two depression scale items demonstrated good internal consistency (Cronbach's $\alpha = 0.70$). We used depression as a continuous mediator (M) in both the mediation and moderated mediation models.

Quality of Life was measured using the Older People's Quality of Life (OPQOL) scale. OPQOL is a validated multidimensional instrument specifically developed for use among older people⁴⁵. The scale captures subjective wellbeing across a range of domains relevant to later life. These domains include self-rated health, ability to perform daily activities, satisfaction with personal relationships, satisfaction with living conditions, sense of control and independence, enjoyment of life, and financial adequacy. Participants rated each item on a 5-point Likert scale, ranging from 1 = Strongly disagree to 5 = Strongly agree. We recoded each of the 13 OPQOL items to a 0–1 scale, where 0 represented the lowest QoL and 1 the best QoL. We summed up the recoded items to produce a composite QoL index ranging from 0 to 13, with higher scores indicating better overall QoL. The scores from the 13-item OPQOL scale demonstrated excellent internal consistency (Cronbach's $\alpha = 0.94$). We used QoL as the dependent variable (Y) in both the mediation and moderated mediation models.

Social networks were measured using the Lubben Social Network Scale (LSNS-6), a widely validated tool designed to measure perceived social support from family, friends, and community ties among older people⁴⁶. The LSNS-6 includes items assessing the number of family members and friends the participant sees or hears from at least monthly, the number of family members and friends the participant feels comfortable confiding in, and the number of family members and friends the respondent feels close to and can call on for help. We summed up the item scores to create a total social network score, with higher values indicating greater social network. The scores from the LSNS-6 demonstrated good internal consistency (Cronbach's $\alpha = 0.80$). We used social network as a covariate in the mediation analysis, and moderator (W) in the moderated mediation model. In the latter model, we tested whether social connectedness attenuates the negative effect of depression on QoL.

Hypotheses tested in the study

Grounded in the stress process and social buffering frameworks, we proposed the following hypotheses:

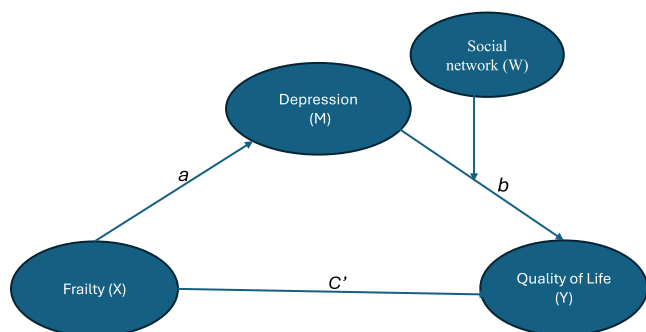


Fig. 3 | Conceptual model illustrating the moderated mediation of depression and social networks in the frailty-quality of life relationship. The diagram represents the hypothesized moderated mediation model. Frailty (X) is associated with depression (M), which in turn is related to quality of life (Y). Social network (W) moderates the path between depression and quality of life. Paths *a*, *b*, and *c'* denote the direct and indirect effects tested in the model.

H1: Greater frailty will be associated with depression
 H2: Depression will be associated with lower QoL
 H3: Depression will mediate the relationship between frailty and QoL
 H4: The relationship between depression and QoL will be moderated by social networks such that the negative effect of depression on QoL is weaker at higher levels of social networks.

Statistical analysis

We assessed whether the data met the assumptions of linear regression before conducting the main analyses. Normality was evaluated using histograms and normal probability plots, while linearity and homoscedasticity were checked through residual scatterplots. Multicollinearity was assessed using tolerance values and Variance Inflation Factors (VIF), with VIF < 10 indicating acceptable levels. No major assumption violations were detected.

We also computed bivariate correlations to explore direct associations among the main study variables: frailty (X), depression (M), QoL (Y), and social networks (W). Pearson's correlation coefficients were used to determine the strength and direction of relationships between variables. Our decision to proceed with mediation and moderated mediation analyses was based on both statistical and theoretical considerations. The preliminary analyses were performed using IBM SPSS Statistics version 30.0. Statistical significance was set at $p < 0.05$.

Following the assumption tests and bivariate analysis, we tested a simple mediation model in which depression mediates the association between frailty and QoL. Frailty (predictor), depression (mediator), and QoL (outcome) were mean-centered and treated as continuous variables. We included covariates (age, sex, employment, education status, marital status, length of stay in Australia, and social network) in both the mediator and outcome equations in the mediation model. Model parameters were estimated using maximum likelihood estimation with 5000 bootstrapped resamples to generate bias-corrected 95% confidence intervals for direct, indirect, and total effects. This model is conceptually equivalent to PROCESS Model 4⁴⁷. We used the *lavaan* package in R (version 4.5.0) for the mediation analysis.

Subsequently, we tested a second stage moderated mediation model to examine whether social networks moderate the effect of depression on QoL in the indirect pathway from frailty to QoL via depression. This model corresponds conceptually to PROCESS Model 14⁴⁷, where the path from depression to QoL is moderated by social networks. We used the *lavaan* package in R (version 4.5.0) for the moderated mediation analyses. We treated all focal variables as observed and continuous. Frailty, depression, and social networks were mean-centred, and an interaction term (Depression $\times$ Social Networks) was computed to test for moderation. We included covariates (age, sex, employment, education status, marital status, and length of stay in Australia) in both the mediator and outcome equations.

Social networks were specified as both a moderator of the depression-QoL relationship and as a covariate in the outcome equation. We estimated the parameters using maximum likelihood estimation with 5000 bootstrapped resamples to generate bias-corrected 95% confidence intervals for direct, indirect, and interaction effects. We used established indices: the chi-square test (χ^2), Comparative Fit Index (CFI ≥ 0.90), Tucker-Lewis Index (TLI ≥ 0.90), Root Mean Square Error of Approximation (RMSEA ≤ 0.08), and Standardized Root Mean Square Residual (SRMR ≤ 0.08) to evaluate the model fit^{48,49}. A diagram illustrating the conceptual model for the moderated mediation effect is presented in Fig. 3. We also compared the mediation and moderated mediation models using a chi-square difference test to evaluate whether including the interaction term improved overall model fit.

Data availability

The data used in this study are not publicly available due to ethical concerns. The data can be made available on reasonable requests to the corresponding author. The R script used to perform the mediation and moderated mediation analyses is available on reasonable request to the corresponding author.

Code availability

The R script used to perform the mediation and moderated mediation analyses is available on reasonable request to the corresponding author.

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Author contributions

G.D.: Conceptualization, Methodology, Formal analysis, Project administration, Software, Writing-Original draft, Writing-Review and Editing, Validation. P.W.: Conceptualization, Methodology, Validation, Writing – review & editing. L.M.: Methodology, Validation, Writing – review & editing. P.A.: Methodology, Validation, Writing – review & editing. R.A.: Conceptualization, Validation, Methodology, Writing – review & editing.

Competing interests

The authors declare no competing interests.

Additional information

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