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Behavioural and psychological factors associated with pre-frailty in community-dwelling adults aged 40 and over: a cross-sectional study

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Abstract

Frailty and pre-frailty are major public health concerns. While frailty is typically associated with older adults, evidence suggests that pre-frailty commonly starts in middle-age. This study examined associations between behavioural and psychological correlates of pre-frailty and frailty in adults from 40 years to help identify at-risk individuals and inform interventions. Participants ($N = 321$, mean age = 56 (10.55), 83% female) completed questionnaires on frailty status, physical activity, co-morbidities, quality of life, loneliness, social isolation, and attitudes towards ageing. Participants were classified as non-frail (35%), pre-frail (60%), or frail (5%). One-way ANCOVAs, controlling for age, BMI, and co-morbidities, found that pre-frail participants reported feeling older than their chronological age ($F = 2.37$, $p < .014$, $\eta^2 = .398$); and pre-frail and frail participants reported greater loneliness ($F = 6.31$, $p = .022$, $\eta^2 = .073$) and negative attitudes toward ageing ($F = 2.41$, $p = .004$, $\eta^2 = .210$) compared to non-frail participants. These findings indicate the need for targeted holistic interventions in middle age to prevent or delay frailty.

Public significance statement

This study highlights that feeling older than your actual age, loneliness, and negative attitudes toward ageing can signal early frailty, even in people as young as 40. These findings align with the World Health Organisation's Decade of Healthy Ageing initiative, which emphasises the importance of fostering positive attitudes toward ageing to support healthy ageing outcomes. These insights stress the importance of mental health and maintaining social connections in ageing successfully. By recognising and addressing these early warning signs, communities and healthcare providers can implement targeted interventions to help people stay healthier for longer, potentially reducing healthcare costs and improving quality of life as our population ages.

Keywords Pre-frailty, Middle-aged adults, Behavioural factors, Psychological factors, Quality of life, Public health

Introduction

Background

Physical frailty is a state of increased vulnerability and is characterised by symptoms including diminished physical capabilities, resilience, and recovery [22, 44]. A common tool for measuring and categorising physical frailty is the Fried Phenotype [22]. Development of this measure has

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led to a more nuanced understanding of frailty through the identification of its precursor,pre-frailty, a condition where individuals are not yet considered clinically frail but carry a greater risk of progression into clinical frailty than the general population [22]. With an ageing global population, frailty and pre-frailty are increasingly pertinent health concerns. Global estimates suggest approximately 12% of individuals aged over 50 years are frail, with pre-frailty affecting nearly 46% [41]. In Australia, 21% of those aged over 65 are considered frail, and an additional 48% are pre-frail [55]. With projections indicating that the proportion of the Australian population aged over 65 will rise to 18% by 2027, there is an increasing urgency to address frailty and pre-frailty [54].

The increasing recognition of frailty has prompted exploration of physiological and psychological factors beyond the conventional frailty measures that may be associated with, help predict, or influence, the physiological decline associated with frailty. In adults aged over 65, low physical activity, high sedentary behaviour, low quality of life, loneliness, and social isolation are cross sectionally associated with higher levels of pre-frailty and/or frailty [9, 16, 23, 24, 30, 35, 37, 48, 53]. It is important to note that low physical activity is often included as part of the operationalisation of physical frailty, such as in the Fried Phenotype, which may explain its consistent association with frailty in cross-sectional studies. Other factors, such as loneliness and negative attitudes towards ageing, represent broader psychological and social influences that extend beyond the physical components of frailty. Additionally, more positive attitudes towards ageing have been associated with reduced physical frailty levels in adults over 60 years, while negative attitudes towards ageing have been linked with frailty in nursing home residents with an average age of 84 [9, 23]. These findings are particularly relevant in the context of the World Health Organisation's Decade of Healthy Ageing initiative, which highlights the importance of fostering positive attitudes toward ageing as a critical component of promoting healthy ageing and reducing the burden of frailty globally [63]. In addition to these factors, social determinants of health, such as socioeconomic status, education, and access to healthcare, also play a critical role. Research has shown that individuals with lower levels of formal education or lower socioeconomic status are at increased risk of frailty, even at younger ages [8, 52]. These determinants highlight the importance of addressing systemic inequities and integrating social interventions into frailty prevention strategies. It is not yet known if these factors and social determinants, and their relationship to frailty and pre-frailty, extend to a younger, middle-aged cohort.

Recent international studies have shown a notable prevalence of pre-frailty among adults aged 40 to 65 years. Hanlon et al. [26] reported that 38% of adults in the United Kingdom within this age bracket were identified as pre-frail according to the Fried Phenotype. Similarly, Gordon et al. [25] reported that 30% of Australian women and 43% of men aged between 50 and 59 years were classified as pre-frail using the same criteria. Despite this, the majority of literature on frailty and pre-frailty and contributing factors focuses on older adults, primarily aged 75 years and above [2, 17, 58].

Given the high prevalence of pre-frailty in adults aged 40–65, it is important to identify potentially modifiable contributing factors, providing opportunities to reduce the onset and progression of pre-frailty. Previous research has shown that incorporating behavioural and psychological data into predictive models can significantly improve their accuracy and utility in clinical settings [12, 18, 56]. This is crucial for identifying at-risk individuals and designing comprehensive and multifaceted interventions to inform behaviour change interventions, such as programs aimed at increasing physical activity or improving social engagement [1, 5]. A deeper understanding of these relationships can inform public health policies and community programs aimed at promoting healthy ageing, fostering resilience, and enhancing social support networks among middle-aged adults as well as reducing healthcare costs and improving the quality of life for individuals as they age. Understanding the behavioural and psychological predictors of frailty and pre-frailty will inform interventions to promote healthy and successful ageing [27, 37, 47].

This study aimed to examine associations between physiological and psychological factors, and frailty and pre-frailty in an age diverse cohort of adults aged 40 years and over. Based on the existing literature on older adults, it was hypothesised that in middle-aged adults, frailty and pre-frailty would be associated with lower levels of physical activity, poorer quality of life, higher levels of loneliness and social isolation, negative attitudes towards ageing, and a higher felt age.

Method

Study design

An online cross-sectional survey was administered through Qualtrics between November [45] and April 2023. Ethical approval was gained from Flinders University Human Research Ethics Committees (Project no. 5580). Informed consent was obtained from all participants. This study is reported according to STROBE guidelines (STROBE checklist see Supplementary file 1).

Setting and participants

Participants were recruited purposively to complete an online survey from the general community through social media advertising on Facebook, LinkedIn, and Twitter/X, and via the Flinders University 'Participate in Research Studies' webpage and Research Bulletin. Social media posts included general descriptions of the study as examining health and ageing in adults aged 40 and over.

The term "frailty" was not specifically emphasised in the advertisements to avoid biasing the sample towards individuals who self-identify with frailty. Instead, the advertisements encouraged broad participation to explore diverse factors influencing health and ageing. To ensure data quality, the survey included an attention check item instructing participants to select a specific response. Participants were eligible if they were aged 40 years or older, could provide informed consent, and had access to an internet-enabled device to complete the survey. Participants who failed the attention check, or did not answer enough of the FRAIL Scale questions to assess frailty, were excluded from the analysis.

Survey instruments

Demographic information

The survey included demographic questions including age, height, weight, sex, living situation, country of residence, and highest level of education.

Physical activity

Physical activity was assessed using the short form International Physical Activity Questionnaire (IPAQ) [15]. Seven items were included covering four different categories of physical activity: vigorous, moderate, walking, and sedentary time based on time spent sitting. Participants were asked to recall the frequency and average duration of physical activity in each domain over the previous seven days. This questionnaire has demonstrated strong reliability and validity in people aged 15–69 years, as well as good validity and mostly adequate reliability in adults aged 69 and older [10, 14, 57, 59].

Co-morbidities

Kabboord et al. [31]'s modified Functional Comorbidity Index was included to record co-morbidities relevant to physical function. This 18-item list documented the presence or absence of 18 diagnoses, resulting in a cumulative sum score, with higher scores indicating a greater number of comorbidities. This index has demonstrated strong reliability and validity in adults aged 42 and over [19, 31, 32].

Quality of life

Quality of life (QOL) was assessed using the 12-item Short Form Survey (SF-12) [60]. The SF-12 items are divided into two components: the Physical Component Summary (PCS) and the Mental Component Summary (MCS), each consisting of six items covering eight life domains. The SF-12 has demonstrated reliability and validity both cross-culturally and across a diverse age range (21 + years) in assessing the impact of participants' health on their everyday functioning [46, 60]. In the present sample the SF-12 demonstrated excellent internal reliability ($\alpha = 0.91$).

Frailty

Frailty status was assessed using the FRAIL Scale developed by the Geriatric Advisory Panel of the International Academy of Nutrition and Ageing [61]. This scale was included due to its ability to assess frailty status through remote data collection and self-report, as opposed to the Fried Phenotype which requires in-person assessment [22]. The FRAIL scale identifies frailty status through the presence of deficits in five domains: fatigue, resistance, ambulation, illnesses, and weight loss. Participants received a score of 1 for the presence of a deficit in each domain. Participants were categorised based on their summed scores as non-frail (0), pre-frail (1–2), or frail (3–5). FRAIL scale scores are predictive of morbidity and mortality with a similar sensitivity to the Fried Phenotype [21]. The FRAIL scale has previously demonstrated validity and reliability in adults over 60 [40] and additionally in women aged 50–66 [51]. Psychometric properties have not been previously examined in adults 40–65, however internal reliability in the present sample was good ($\alpha = 0.76$).

Felt Age

Participants were invited to provide their subjective or felt age, a single item measure frequently included in assessing older adults' perceptions toward their own ageing [13]. Following Li et al. [37], this was measured by asking participants "What age do you feel most of the time?". As a single-item measure, subjective age does not allow for internal consistency reliability. However, it has demonstrated construct and criterion validity in prior research, showing consistent associations with health outcomes and perceptions of ageing [37].

Loneliness

The 3-item UCLA Loneliness Scale was included to quantify loneliness [28]. The scale items measure three dimensions of loneliness: relational connectedness, social connectedness, and self-perceived isolation. The scale uses three response categories: 'hardly ever', 'some of the time', and 'often'. Scores are then summed and examined continuously,scores range from 3–9 with 9 indicating greater loneliness. The 3-item loneliness scale has previously demonstrated strong reliability and validity in adults over 54 [28]. Psychometric properties for this scale have not been explored in adults aged 40–54, however, internal reliability for this scale in the present sample was excellent ($\alpha = 0.92$).

Social isolation

Social isolation was measured with the 6-item Lubben Social Network Scale (LSNS-6) [38]. Each item asked participants the frequency of various forms of contact with various social connections (e.g. "How many relatives do you feel close to such that you could call on them for help?"). Responses ranged from 0—5 with 5 indicating more social engagement. Scores range from 1 – 30 with lower scores indicating greater social isolation. The LSNS-6 has previously demonstrated strong reliability and validity in adults aged 60+ [11]. The LSNS-6 does not have published psychometric properties for adults aged 40–60 years, however, internal reliability in the present sample was good ($\alpha = 0.70$).

Attitudes to ageing

The 12-item Attitudes to Ageing Questionnaire (AAQ; [36] assessed participants' attitudes towards ageing. Each item consisted of a statement 'e.g., old age is a depressing time of life' where participants responded with a score on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). The sum of scores on all items represented an overall attitude to ageing, with a higher total score indicating a more negative attitude to ageing. The scale has demonstrated cross-cultural validity and reliability in older adults, primarily aged 60 and over [33, 36, 49]. Reliability and validity have not previously been assessed in adults aged 40–60, however, the AAQ demonstrated good internal reliability in the present sample ($\alpha = 0.80$).

Data analysis

Data analysis was completed using IBM SPSS (IBM Corp [29]. Participants were removed from the data set if their surveys were incomplete (i.e. missing any of the frailty measure questions, $n = 208$), they were identified as bots through a reCAPTCHA item ($n = 3$), or they failed an attention check item ($n = 4$). Duplicates were identified through Internet Protocol address and email addresses and removed ($n = 27$). Independent t-tests and chi-square tests were conducted to compare included and excluded participants on available demographic variables, such as age, BMI, and gender. Not all measures could be compared due to incomplete and intermittent responses in the excluded group, and sample sizes for these comparisons varied accordingly. Participants were grouped according to frailty status,descriptive statistical methods were employed to compute frequencies and aggregate scores for each of the outcome measures. The threshold for statistical significance was a p-value of less than 0.05. Extreme outliers were considered values three standard deviations away from the mean and removed [43]. To explore the overall associations between frailty status and continuous variables, one-way Analysis of Variance (ANOVA) tests were used. To quantify the magnitude of the observed effects within these analyses, Games-Howell post hoc analyses were run, and effect sizes were calculated and interpreted using the partial eta squared (η^2) values. A small effect was indicated by $\eta^2 = 0.01$, a medium effect $\eta^2 = 0.06$, and a large effect was $\eta^2 = 0.14$. Additionally, one-way Analysis of Covariance (ANCOVA) were performed on all outcome variables to control for age, comorbidities, and Body Mass Index (BMI) as covariates.

Given that frailty is traditionally studied in adults over 65, but increasing evidence highlights the relevance of frailty in middle-aged populations, subgroup analyses focused on participants aged 40–65 years [7, 25]. This age range was selected to explore frailty risk factors in a younger cohort, where early identification and intervention could have significant preventative implications. Further analyses examined the individual components of the FRAIL Scale within this group to better understand the drivers of pre-frailty.

Results

Participants

Study population

The online survey received 563 initial responses, and 242 participants were excluded based on the exclusion criteria (Fig. 1). Of these, 208 participants were excluded due to missing data, primarily in key variables required for frailty status assessment. There were no statistically significant differences between included ($n = 321$) and excluded participants ($n = 208$) across key descriptive variables. For excluded participants, mean age was 55.4 (SD = 11.2, $n = 74$, $p = 0.45$), and BMI was 28.1 (SD = 7.8, $n = 58$, $p = 0.62$). No significant differences were found for gender (81.3% female, $n = 63$, $p = 0.78$), comorbidity scores (M = 2.1, SD = 2.0, $n = 56$, $p = 0.68$), or education status (70.4% tertiary, $n = 61$, $p = 0.61$).

Characteristics of the sample

Participants were categorised into three groups according to their frailty status: non-frail ($n = 113$), pre-frail ($n = 191$), and frail ($n = 17$). All participants were community-dwelling and resided in Australia. Non-frail participants had a significantly higher age, lower BMI, and lower number of co-morbidities than pre-frail and frail participants (Table 1). There was a significant association between frailty status and education level, with a greater proportion of frail participants reporting lower levels of formal education (Table 1). The most common comorbidities were arthritis (28%), depression (28%), and anxiety (27%).

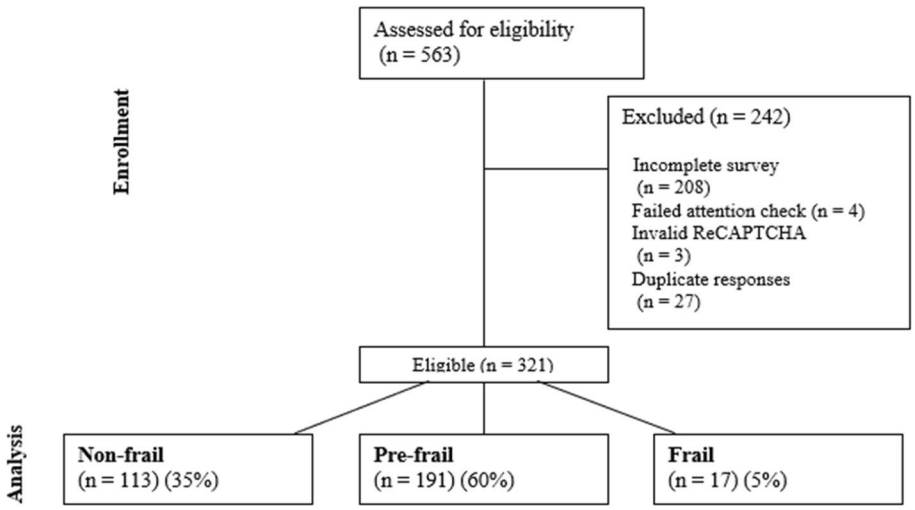

Fig. 1 Participant flow diagram

Table 1 Differences in sample across frailty status on demographic variables

Variable	Total ($n=321$)	Non-frail ($n=113$)	Pre-frail ($n=191$)	Frail ($n=17$)	F-value [a]	*P*
Age [years] [†]	55.88 (10.55)	57.85* (10.58)	54.86* (10.36)	54.24 (11.10)	3.10	.046* (.019)[a]
BMI	27.65 (7.28)	25.64* [Δ] (5.17)	28.50* (7.90)	31.43 [Δ] (8.95)	8.23	< .001*** (.049)
Highest Education Level[‡]					14.62	.012* (.23)
Some high school	14 (4.40)	2 (1.77)	8 (4.19)	4 (23.53)		
Year 12 or equivalent	22 (6.90)	4 (3.54)	13 (6.81)	5 (6.81)		
Trade school (e.g. TAFE)	49 (15.30)	12 (10.62)	29 (15.18)	29 (15.18)		
Bachelor's degree	144 (44.90)	55 (48.67)	86 (45.03)	86 (45.03)		
Master's degree	71 (22.10)	28 (24.78)	86 (45.03)	41 (21.47)		
PhD or Higher	21 (6.50)	12 (10.78)	41 (21.47)	9 (4.71)		
Functional Comorbidities Index	1.99 (1.94)	1.16* [Δ] (1.23)	2.24* [♦] (1.92)	4.82 [Δ♦] (2.65)	36.59	< .001*** (.187)

[†] Mean (SD)

[‡] n (percent) (All categorical variables)

[a] One-way ANOVAs (η^2)

[b] Chi-square test (χ^2, Cramér's V)

Games-Howell post hoc significance indicated as follows: * non-frail vs. pre-frail, [Δ] non-frail vs. frail, and [♦] pre-frail vs. frail

Cross-sectional associations of frailty status and behavioural and psychological factors

There were significant differences between frailty categories for all outcomes except total activity time (IPAQ) (Table 2). Post-hoc analyses revealed that individuals with frailty were significantly more likely than non-frail and pre-frail individuals to feel older than their biological age (non-frail $p=0.002$; pre-frail $p=<0.001$), score lower in mental wellbeing (SF-12 MCS) (non-frail $p=<0.001$; pre-frail $p=<0.001$), and possess a more negative attitude towards ageing (non-frail $p=<0.001$; pre-frail $p=0.023$) (Table 2). In addition, frail individuals were significantly more likely than non-frail individuals to feel lonelier ($p=<0.001$) and score lower in physical wellbeing (SF-12 PCS) ($p=0.026$). Further, pre-frail individuals were significantly more likely than non-frail individuals to feel older than their biological age, score lower in mental wellbeing (SF-12 MCS) ($p=<0.001$), possess a more negative attitude towards ageing ($p=<0.001$), feel lonelier ($p=<0.001$), and have a smaller social network ($p=0.006$). While combined IPAQ physical activity time was not significantly different across groups, when examining vigorous activity time, differences were significant ($p=0.002$). Post-hoc analysis revealed these differences were between non-frail and pre-frail participants where non-frail participants reported greater vigorous activity time. After controlling for age, BMI, and comorbidities

Table 2 The relationship between pre-frailty/frailty and various behavioural and psychological factors

Variable	Total ($n=321$)	Non-frail ($n=113$)	Pre-frail ($n=191$)	Frail ($n=17$)	F-value [a]	P
Age [years] [†]	55.88 (10.55)	57.85* (10.58)	54.86* (10.36)	54.24 (11.10)	3.10	.046* (.019)[a]
BMI[§]	27.65 (7.28)	25.64* [Δ] (5.17)	28.50* (7.90)	31.43 [Δ] (8.95)	8.23	< .001*** (.049)
Functional Comorbidities Index	1.99 (1.94)	1.16* [Δ] (1.23)	2.24* [♦] (1.92)	4.82 [Δ♦] (2.65)	36.59	< .001*** (.187)
Felt age	52.11 (15.19)	46.78* [Δ] (11.77)	53.66* [♦] (14.67)	70.18 [Δ♦] (22.64)	22.69	< .001*** (.125)
IPAQ MET[¶] Hours	65.39 (78.71)	78.51 (80.63)	58.07 (76.94)	61.06 (79.22)	2.40	.092 (.015)
IPAQ Average Weekday Minutes Sitting	400.80 (222.59)	256.11 (210.62)*	420.75 (214.92)*	473.25 (326.92)	3.99	.019* (.025)
SF12[#] Physical Component Summary	36.14 (4.51)	35.70 [Δ] (4.04)	36.13 (4.66)	39.17 [Δ] (4.76)	4.48	.012* (.027)
SF12 Mental Component Summary	39.14 (7.44)	41.83* [Δ] (5.39)	38.51* [♦] (7.68)	28.43 [Δ♦] (4.88)	30.40	< .001*** (.161)
Attitude to Ageing Questionnaire Scores	41.20 (8.65)	45.63* [Δ] (7.15)	39.18* [♦] (8.39)	33.27 [Δ♦] (7.40)	31.04	< .001*** (.167)
3-Item UCLA Loneliness Scores	5.35 (1.95)	4.57* [Δ] (1.57)	5.70* (1.99)	6.88 [Δ] (1.90)	19.04	< .001*** (.107)
LSNS-6[‡]	23.12 (5.04)	24.17* (4.77)	22.49* (5.15)	23.12 (4.70)	3.93	.021* (.025)

[†] Mean (SD)

[§] Body Mass Index

[¶] International Physical Activity Questionnaire: Metabolic Equivalent of Task

[#] Short Form 12

[‡] 6 item Lubben Social Network Scale

[a] One-way ANOVAs (η^2)

Games-Howell post hoc significance indicated as follows: * non-frail vs. pre-frail, [Δ] non-frail vs. frail, and [♦] pre-frail vs. frail

Table 3 The relationship between pre-frailty/frailty and various behavioural and psychological factors when controlling for Age, BMI, and comorbidities

Variable	F	P (partial eta squared)
Felt age	2.37	.014** (.398) [a]
IPAQ[¶] MET Hours	1.14	.380 (.857)
IPAQ Average Weekday Minutes Sitting	1.34	.086 (.183)
SF12[#] Physical Component Summary	1.39	.315 (.887)
SF12 Mental Component Summary	1.39	.315 (.887)
Attitude to Ageing Questionnaire Scores	2.41	.004** (.210)
3-Item UCLA Loneliness Scores	6.31	.022* (.046)
LSNS-6[‡]	1.11	.484 (.073)

[a] One-way ANCOVAs (η^2)

[§] Body Mass Index

[¶] International Physical Activity Questionnaire: Metabolic Equivalent of Task

[#] Short Form 12

[‡] 6 item Lubben Social Network Scale

(ANCOVAs) the group differences for felt age, attitudes to ageing, and loneliness remained significant (Table 3).

Frailty and behavioural and psychological factors in adults aged 40–65

Of participants aged 40 to 65 years ($n=252$), 63.1% were classified as pre-frail while 46.4% of participants aged over 65 ($n=69$) were pre-frail. There was a greater percentage of frail individuals in the over 65 age group (5.8%) than in the 40- to 65-year-old age group (5.2%). To better understand the high levels of pre-frailty in the 40–65-year-old age group, individual components of the FRAIL Scale were examined. The fatigue component was the primary driver of pre-frailty, with 62% of participants in this group reporting they felt tired most or all of the time, compared to 43% of participants over 65. The resistance component of the FRAIL scale had 8.3% of 40–65-year-old participants indicating they would have difficulty walking up 10 flights of steps without resting. Additionally, for the ambulation FRAIL scale component 9.1% of 40–65-year-old participants indicated they would have difficulty walking several hundred yards/meters without assistance. Finally, 45.6% of participants in this age range had one or more co-morbidity. Physical activity time was not significantly different across frailty status groups for either age range independently.

Discussion

This study explored associations between physiological and psychological factors, and frailty status in adults aged 40 years and over. Negative attitudes to ageing, smaller social networks, loneliness, sedentary behaviour, and a higher felt age were associated with pre-frailty and frailty. These findings extend the previous evidence and understanding in frailty in older adults to a more age diverse cohort including younger adults from 40 years. However, when age, BMI, and number of co-morbidities were controlled for, the associations remained only for felt age, attitudes to ageing, and loneliness. These findings suggest that frailty risk factors may be apparent earlier than

expected. The association with negative attitudes towards ageing highlights the importance of fostering positive perceptions of ageing as a public health priority, aligning with the World Health Organisation's Decade of Healthy Ageing initiative [63]. This initiative highlights the role of positive attitudes in promoting healthy ageing and reducing frailty at a population level. Smaller social networks and higher loneliness levels imply that social factors play a role in the early stages of frailty, emphasising that social integration and mental health are important considerations across the lifespan. The association between feeling older than one's chronological age and pre-frailty suggests that subjective age is an important consideration for future research on frailty.

These findings align with previous research demonstrating the significant influence of psychological and social determinants of health on frailty. For instance, education status (a measure of socioeconomic status) is a strong predictor of frailty in older adults (60+) [8, 52]. The present study similarly identified higher levels of frailty in participants who had experienced less formal education. The higher prevalence of fatigue observed in the 40–65 age group compared to participants aged over 65 may reflect the unique stresses associated with midlife, including balancing work, family, and other responsibilities. These findings align with the role of social factors, such as smaller social networks and higher loneliness levels, in frailty. This highlights the importance of addressing midlife stressors as part of frailty prevention strategies, alongside interventions to improve social integration and mental health across the lifespan.

The study findings also aligned with Buckinx et al. [9] and Gale and Cooper [2] who identified loneliness and negative attitudes towards ageing as determinants of increased frailty levels among older populations (60+). The current study extends this understanding to a younger cohort, suggesting that these factors are relevant across a broader age range. Further, strategies to keep people involved in their communities from a younger age appear crucial. The identification of these factors in a younger demographic also supports the need for early interventions and preventative measures which could delay or prevent the onset of frailty. For example, [2] advocate for preventive measures, in particular exercise interventions, that can be implemented before significant frailty develops. Previous research has begun to demonstrate the effectiveness of preventative physical exercise intervention in this younger age range for reversing pre-frailty [6].

Given the associations between pre-frailty and social isolation and negative attitudes to ageing, our findings suggest that interventions aimed at improving social connectivity and modifying negative perceptions of ageing may be beneficial. Community engagement programs, such as intergenerational initiatives, have shown promise in enhancing social networks and reducing loneliness by fostering relationships between older and younger generations through shared activities like mentoring, storytelling, and hobbies [34]. Given the benefits associated with exercise, these is an opportunity for social connection through involvement in sporting clubs or walking/running groups which have previously demonstrated social and physical benefits in adults aged 40–65 [45, 50]. Social prescribing, where healthcare professionals refer adults over the age of 65 to local social activities or groups, has been associated with improvements in social participation and mental wellbeing [42]. Electronic communication tool interventions using e-mail have also demonstrated effectiveness at reducing social isolation in adults with a mean age of 66 [20]. Similar interventions have potential to improve social connectivity and mitigate negative perceptions of ageing in a younger cohort. Future research should further investigate how these tools could be effectively modified, translated, and implemented in this age group to prevent frailty.

Contrary to previously established relationships between physical activity and frailty status in older adults, the present study found no significant differences in overall levels of physical activity across frailty groups after controlling for age, BMI, and comorbidities [10, 14, 57, 59]. While initial findings indicated a difference in isolated vigorous activity, this difference did not remain significant after adjusting for these variables. It should be noted that the quantity of moderate and vigorous physical activity across all participants was high compared to previous cutoff values used in the IPAQ and compared to national averages for the age range [4], [15]. This may, in part, be a product of selection bias where more active individuals with an interest in exercise were more likely to participate in the study.

Strengths and limitations

This study has several strengths. Data collection was comprehensive and used a wide range of validated instruments in a diverse cohort of adults aged 40 and over. The large sample enhanced the statistical power and reliability of the results. Additionally, controlling for key confounding variables such as age, BMI, and comorbidities strengthened the validity of the observed associations. However, this study has a number of limitations that warrant consideration. First, the cross-sectional design impacts the ability to infer causal relationships between the behavioural and psychological factors measured and frailty status. A longitudinal study is needed to determine the directionality of these associations and to better understand frailty

progression. Reliance on self-reported data may also introduce bias, particularly in the assessment of physical activity and health-related behaviours. Second, this was a convenience sample recruited online, which may limit generalisability. The sample had a higher level of education than the general population. In Australia, approximately 45% of the population have vocational or tertiary qualifications in comparison to the 89% of the study sample [3]. This may partly reflect the recruitment methods, as participants were primarily recruited through social media and university platforms, which may have attracted individuals with higher educational attainment. The educational attainment of participants may influence their health literacy and attitudes towards ageing and health, which are not necessarily representative of broader populations. The measures used, such as the IPAQ and AAQ, although validated in older adults, may not fully capture the nuances of physical activity patterns and attitudes towards ageing in middle-aged adults. This could have impacted the estimations of the associations between these factors and frailty.

While this study included a diverse range of psychological and social factors, other potential determinants of frailty, such as dietary habits, sleep patterns, and genetic factors, were not considered. Including these variables in future research could provide a more comprehensive understanding of the factors contributing to frailty and pre-frailty. Similarly, while the LSNS-6 [38] measures the number of meaningful social connections, it focuses more on the structural aspect (number of connections) rather than the functional aspect (quality of support). The LSNS-6, therefore, does not capture the emotional dimensions of social networks, which are crucial to understanding loneliness. Future studies could focus on the quality as well as the quantity of social connections, examining the emotional support derived from existing relationships. In regard to the physical activity, not all forms of physical activity may be equally beneficial in preventing frailty. Future research could focus on the quality or types of physical activity that could prevent frailty. For example, strength/resistance training, which is not directly captured by the IPAQ but is the most effective way to increase muscle strength, mass and function, a primary and critical mode for frailty reversal/prevention [39]. Additionally, balance and flexibility activities are not directly captured but also recommended forms of physical activity [4, 62]. This notion is supported by existing literature emphasising the multifaceted nature of physical activity and its varied impacts on health outcomes [10, 57].

Conclusions and implications

This study identified the relationships between behavioural, psychological, and social factors in the development of frailty and pre-frailty among adults aged 40 and over, highlighting the role of loneliness, social isolation, and negative attitudes towards ageing. The relevance of these findings to global public health initiatives, such as the Decade of Healthy Ageing, demonstrates the importance of integrating psychological and social dimensions into frailty prevention strategies. These findings extend our understanding of factors linked to frailty and pre-frailty to an age diverse cohort and underscore the potential of early interventions and preventative measures tailored to mitigate these risks. The results highlight the need for a multifaceted approach to frailty prevention, combining psychosocial interventions with physical activity programs. Future research should focus on longitudinal designs to establish causality and expand demographic diversity to enhance the generalisability and applicability of the findings in varied socio-economic and cultural settings, ultimately aiming to improve quality of life and reduce the burden of frailty globally.

Supplementary Information

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Supplementary Material 1.

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Not applicable.

Authors' contributions
T.H.B—Conceptualisation, data collection, data analysis, first manuscript draft, manuscript authoring and drafting L.K.L—Conceptualisation, manuscript reviewing and drafting, editing S.J.G—Conceptualisation, manuscript reviewing and drafting, editing I.P.—Conceptualisation, manuscript reviewing and drafting, editing.

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Data availability
The data that support the findings of this study are available from the corresponding author, T.B., upon reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was gained from the Flinders University Human Research Ethics Committees (Project no. 5580). The present study adhered to the ethical principles for research involving human participants outlined in the Declaration of Helsinki. Informed consent was obtained from all participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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