INTERNAL MEDICINE JOURNAL

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doi:10.1111/imj.70502

ORIGINAL ARTICLE

Frailty transitions and their association with mortality in older adults

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Key words
frailty, geriatric assessment, mortality, polypharmacy, aged.

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Received 29 November 2025; accepted 12 May 2026.

Abstract

Background: Frailty is a dynamic condition in older adults, and transitions between frailty states may occur over time. However, predictors and clinical implications of changes in frailty status, particularly frailty improvement, remain insufficiently understood.
Aims: Predictors and clinical implications of changes in frailty status over time have not been studied in detail. This study aimed to evaluate these aspects.
Methods: In this retrospective cohort study, 2573 patients were screened. After applying exclusion criteria and including only those with longitudinal follow-up, 399 patients were included in the final analysis. Frailty was assessed by the Fried frailty phenotype. Participants were categorised as robust (0), pre-frail (1–2) and frail (3–5). Changes in frailty status from baseline and associations with overall survival were analysed.
Results: We included 399 outpatients from a geriatric clinic. The mean age was 83 ± 7 years, and 291 (73%) were women. At baseline, 9.3% ($n = 37$) were robust, 34.3% ($n = 137$) were pre-frail, and 56.4% ($n = 225$) were frail. Over a median follow-up of 14 months (interquartile range 12–23 months and range 6–71 months), 17.8% of participants improved, 16.0% deteriorated and 66.2% remained stable. Compared to baseline, weight loss and handgrip strength improved while walking speed worsened. Younger age (odds ratio (OR) 0.93, 95% confidence interval (CI) 0.88–0.97, $P = 0.003$) was independently associated with improvement of frailty status. In the adjusted model, higher glomerular filtration rate was not statistically significant but demonstrated a trend towards association with improvement in overall frailty status (OR 1.02, 95% CI 1.00–1.04, $P = 0.057$). Overall, frailty transitions were not significantly associated with survival; however, in pre-frail individuals, progression to frailty was associated with shorter survival (41 vs 65 months, $P = 0.010$). Among pre-frail participants, older age (OR 1.08, 95% CI 1.00–1.16, $P = 0.049$), higher number of medications (OR 1.25, 95% CI 1.07–1.45, $P = 0.005$) and higher vitamin D levels (OR 1.06, 95% CI 1.01–1.10, $P = 0.011$) independently predicted transition to frailty.
Conclusions: Frailty is potentially reversible, particularly in the pre-frail stage. Improvements in weight loss and muscle strength contribute to enhanced frailty status. Early identification and targeted interventions in pre-frail individuals may prevent progression and reduce adverse outcomes.

Introduction

Frailty is a clinical syndrome that reflects a state of increased vulnerability resulting from diminished

Funding: None.
Conflict of interest: None.

physiological reserves and impaired homeostatic mechanisms. Approximately one-third of older adults presenting to outpatient clinics are frail, and another third are pre-frail.[1] However, this proportion is even higher among hospitalised older adults, as well as those with dementia, cancer or chronic kidney disease.[2–5] Furthermore, in older adults, frailty has been linked to adverse consequences such as disability, frequent hospital admissions and premature mortality.[6,7] With global population ageing, identifying and managing frailty has become a significant priority, not only in geriatric medicine and public health, but also across all specialties that provide care for older adults.

Frailty is increasingly recognised as a dynamic condition rather than a fixed state. Longitudinal studies indicate that older adults often transition between robust, pre-frail and frail categories, making progression and improvement possible.[8,9] While worsening frailty has consistently been linked to higher mortality, the prognostic significance of improvement remains less clear. Some evidence suggests that targeted interventions, such as exercise, rehabilitation and comprehensive geriatric assessment (CGA), may reduce frailty. Yet, it is uncertain whether such changes translate into lower long-term mortality risk.[10,11]

Although worsening frailty has consistently been shown to predict poor outcomes, the prognostic significance of improvements in frailty remains far less confident. Some studies suggest that recovery or partial reversal of frailty is possible, particularly following interventions such as rehabilitation or surgery. Yet, it is unclear whether such improvements translate into better long-term survival.[8,11] This knowledge gap is significant, as identifying patients who improve their frailty could provide valuable insight into resilience and treatment responsiveness. By focusing on individuals whose frailty status improves over time, our study aims to clarify whether recovery in frailty is associated with reduced mortality risk, thereby advancing the clinical utility of frailty assessment tools and informing strategies to support healthy ageing.

Methods

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethical Board of Bezmialem University, approval number (E-54022451-050.04-216 365). Although this was a retrospective cohort study, written informed consent for secondary use of clinical data was routinely obtained from patients or their caregivers at the time of the initial CGA as part of standard outpatient geriatric care. CGA is usually performed during the patient's first visit. For those who do not undergo this assessment in their first visit, the evaluation is usually completed within the same week of the first visit, when the laboratory workup is also completed. Informed consent is obtained at the first visit for the anonymous use of our patients' clinical data in subsequent research studies.

This study included older adults aged ≥65 who underwent CGA in the outpatient geriatrics clinic of Bezmialem University Hospital. Evaluations were conducted between January 2018 and May 2025. Participants were censored at the date of last clinical follow-up or at the end of the study period (May 2025), whichever occurred first. The event time was defined as the date of death; patients alive at last follow-up were censored at the date of their last visit.

The majority of the data were obtained from electronic medical records. However, CGA records were retrieved from paper-based files. Clinical data were limited to outpatient geriatric clinic records. Inpatient hospitalisation data were not included in the analysis.

Baseline data included demographic characteristics, comorbidities, laboratory parameters, medication use and all CGA components recorded starting from the first visit after informed consent was obtained. The data were subsequently collected retrospectively for analysis.

A total of 2573 older adults were screened for eligibility. Of these, 53 individuals were excluded because of acute health problems at the time of assessment. An additional 230 patients were excluded because baseline frailty assessment was unavailable, and 19 individuals were excluded because they were younger than 65 years of age. Furthermore, 1872 patients were excluded due to the absence of longitudinal frailty status data (Fig. 1). Longitudinal transitions in frailty status were evaluated over a median follow-up of 14 months (interquartile range 12–23 months and range 6–71 months). Follow-

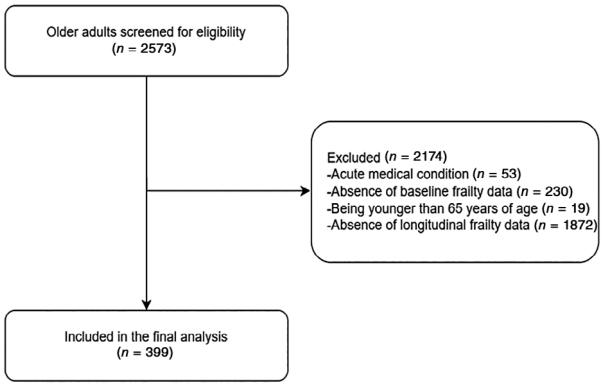

Figure 1 Flow diagram of participant selection and inclusion in the study. Flow diagram illustrating the screening, exclusion and inclusion process. The diagram details the number of individuals assessed for eligibility, excluded at each stage with specific reasons, and the final cohort included in the longitudinal analysis.

up CGAs were conducted as part of routine clinical care based on individual patient needs rather than at predefined study intervals. Participants had multiple follow-up visits; however, CGA was performed only twice per participant. No participant underwent more than two CGAs during the study period. For the analysis, we used the baseline CGA and the final available CGA. Although annual CGA is recommended as part of routine care, not all participants attended follow-up visits according to the recommended schedule.

In general, CGA is performed for patients deemed to benefit from such evaluation, and patients with acute problems were not included in this study. The study excluded individuals with suspected acute medical conditions or serious illnesses that could significantly affect their overall health status, such as an acute cerebrovascular event, sepsis, acute coronary syndrome and acute respiratory failure. In our clinical practice, patients who decline to undergo a CGA at the initial visit are not formally registered in the geriatric clinic database; therefore, they are not captured in the study dataset. Similarly, individuals with advanced osteoarthritis or neuromuscular disorders that impair mobility, those with immobility, delirium at the time of assessment, severe visual or hearing impairments that prevent adequate communication and patients undergoing haemodialysis are not eligible for CGA in our routine practice. Since a CGA is not performed in these patients, they are not formally recorded in the CGA registry, and thus, an exact number for these groups cannot be provided retrospectively.

These groups were excluded because their acute or severe clinical conditions preclude a reliable and standardised CGA. Acute illnesses are known to cause transient functional decline, delirium, haemodynamic instability and inflammatory responses, all of which can temporarily alter gait speed, grip strength, nutritional markers and cognitive performance. Including such patients would have introduced substantial misclassification bias into frailty scoring, as their measurements would have reflected an acute state rather than their baseline frailty. Additionally, individuals with immobility, severe osteoarthritis, neuromuscular disorders or sensory impairments cannot complete essential physical performance tests in a valid manner. Since our analysis relied on accurate and repeatable CGA measurements, exclusion of these groups was necessary to ensure internal validity and prevent systematic measurement errors that could distort frailty transitions over time.

Comprehensive geriatric assessment

All components of the CGA were performed as part of routine outpatient geriatric care for patients deemed to benefit from such evaluation, rather than as part of a study-specific protocol. Each geriatric syndrome was assessed using validated tools and in collaboration with caregivers who knew the patient to improve accuracy and account for longitudinal health information.

Functional status

Barthel and Lawton activities of daily living tests were used to evaluate basic and instrumental activities of daily living.[12,13]

Cognitive function and dementia

A geriatrician, a psychologist and a gerontologist interviewed each participant's family members/caregivers to learn about the participants' cognitive function and activities of daily living over the past few years. The Mini-Mental State Examination was used to evaluate cognitive function in all patients.[14] Moreover, neurocognitive assessments were conducted on the patients likely to have cognitive impairment via direct evaluations. Dementia was diagnosed according to the *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition, major cognitive impairment diagnostic criteria.[15]

Dynapenia

Muscle strength was assessed using handgrip strength, measured with a handheld dynamometer. Dynapenia was defined as handgrip strength of <27 kg for men and <16 kg for women, in line with the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) recommendations.[16,17]

Frailty

Frailty was assessed using the Fried frailty phenotype model.[6] According to this model, frailty is defined by the presence of three or more of the following five criteria. Individuals with one or two criteria are considered pre-frail, while those with none are classified as robust. This phenotype includes:

1 Weight loss: Participants were asked whether they had unintentionally lost weight in the past year. Unintentional weight loss was defined as a loss of more than 4.5 kg in the previous 12 months or a loss of >5% of body weight over the same period, not due to dieting or exercise.
2 Exhaustion: Self-reported exhaustion identified via specific questions from the CES-D scale. Participants were asked how often they felt this way during the past week. If they responded '3–4 days' or 'most of the time' to either question, they were considered to meet the exhaustion criterion.[18]

3 Low physical activity: Physical activity was evaluated using a modified version of the Minnesota Leisure Time Physical Activity Questionnaire.[18]
4 Slowness: Gait speed was measured over a 4-m walking distance with participants walking at their usual pace. The cut-off points were adjusted for gender and height.[6]
5 Weakness: Grip strength was measured using a handheld dynamometer. The lowest 20th percentile of grip strength was used as the cut-off, adjusted for gender and body mass index.[6]

Depression

Depressive symptoms were screened by the Geriatric Depression Scale (GDS-15), and the total score was analysed as a continuous variable.[19]

Malnutrition

Nutritional status was evaluated by using the Mini Nutritional Assessment (MNA) long-form, a validated tool widely used in older populations to detect malnutrition and its risk.[20]

Polypharmacy

Polypharmacy was assessed by counting the number of regularly used medications. Medication classes were not systematically categorised for this analysis. The total medication count was used as a continuous variable, and a threshold of ≥5 medications was set.[21]

Statistical analysis

Continuous variables are expressed as mean ± standard deviation or median (interquartile range), as appropriate, and categorical variables are presented as numbers and proportions. Chi-squared test was used for comparing qualitative measures between groups. Comparisons of continuous variables between groups were performed using the Kruskal–Wallis test, as several variables were not normally distributed. Bonferroni or Tamhane's tests were used as post hoc tests, as appropriate. Predictors of change in frailty status were evaluated using logistic regression analysis. Logistic regression models were used to identify factors associated with frailty improvement or worsening between baseline and the first follow-up assessment, irrespective of the exact follow-up duration. Because frailty status was assessed only at discrete study visits and the exact timing of transitions was unknown, time-to-event analyses were not appropriate. Additionally, follow-up intervals varied across participants in this real-world clinical setting, and our primary outcome of interest was transition in frailty status rather than change at a fixed time point. Covariate selection for multivariable logistic regression models was informed by established clinical relevance, prior literature and observed baseline distributions across frailty change groups. Unadjusted descriptive comparisons were used to guide model specification but were not used for inferential purposes. Results are expressed as odds ratios (ORs) with 95% confidence intervals (CIs). Age, sex and variables that had a significant association with the change in the frailty status in the univariate analysis were included in the multivariate regression model. Follow-up duration was included in the multivariable models, regardless of its univariate significance, to account for variability in the time interval between assessments. For multivariable logistic regression models, backward elimination was applied using a *P*-value threshold of 0.10 for variable removal. Survival curves were evaluated using the Kaplan–Meier method and analysed by the log-rank test. The event time was defined as the date of death; patients alive at last follow-up were censored at the date of their last visit. Statistical analysis was performed using SPSS 22.0 version (IBM SPSS, Chicago, IL, USA). A *P*-value of <0.05 was considered to be statistically significant. Frailty transitions between baseline and follow-up were visualised using a Sankey diagram to illustrate participants' flow across frailty categories.

Results

In this retrospective cohort study, 2573 patients were screened. After applying exclusion criteria and including only those with longitudinal follow-up, 399 patients were included in the final analysis. The characteristics of both included and excluded participants are presented in Table S1. The mean age was 83 ± 7, and 291 (73%) were women. At baseline, 9.3% (37 patients) were robust, 34.3% (137 patients) were pre-frail, and 56.4% (225 patients) were frail. After a median follow-up of 14 months (interquartile range 12–23 months and range 6–71 months), the corresponding proportions were 11.0% (44 patients), 33.3% (133 patients) and 55.6% (222 patients) respectively. During this period, 264 (66.2%) participants remained in the same frailty category, while 71 (17.8%) improved and 64 (16%) deteriorated. Of the 37 robust individuals at baseline, only 19 remained robust, 15 became pre-frail and three progressed to frailty. Among the 137 pre-frail participants, 19 reverted to a robust state, 72 remained pre-frail and 46 progressed to frailty. Of the 225 frail participants, 52 showed improvement (six became robust and 46 became pre-frail), while 173 remained frail (Fig. 2). A comparison of demographic and clinical factors among

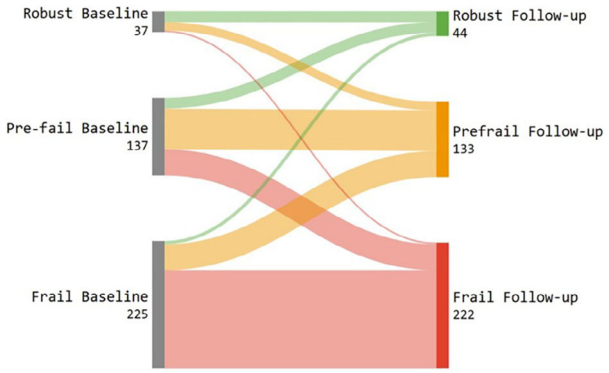

Figure 2 Frailty transitions over a median follow-up of 14 months. Distribution of frailty status among 399 participants at baseline and follow-up, illustrating transitions between robust, pre-frail and frail categories.

patients whose frailty status improved, remained the same or worsened is shown in Table 1.

Analysis of individual Fried components demonstrated that 8.3%–22.6% of patients improved, 10.5%–14.0% deteriorated, and the majority (65.9%–78.4%) remained stable across domains. Improvement was most frequent for weight loss (22.6%), whereas mobility and physical activity were more resistant to change (Table S2). Change in Fried components in improvement, no change and worsened groups is shown in Table S3, separately. Figure 3 shows participants were grouped into three categories based on changes in Fried frailty status over the follow-up period: improvement, no change and worsening. Within each group, we examined how the individual Fried frailty components changed, remained stable or worsened. Figure 3 illustrates which specific Fried subcomponents improved, remained unchanged or deteriorated within each trajectory group, highlighting patterns of change across the frailty domains.

Table 2 shows changes in scores of CGA parameters. Patients who improved in frailty status also showed significant improvements across multiple functional domains. Nutritional scores increased (MNA from 20.9 ± 4.8 to 24.0 ± 4.0, $P < 0.001$), while physical independence improved (Barthel index from 79.2 ± 21.4 to 90.0 ± 13.4, $P < 0.001$). Instrumental daily activities also showed recovery (Lawton score from 12 (5–19) to

Table 1 Baseline characteristics of patients based on improvement, no change and worsening in frailty status

	Improved ($n = 71$)	No change ($n = 264$)	Worsened ($n = 64$)
Demographics			
Age	79.8 ± 6.3	84.2 ± 6.8	81.3 ± 6.7
Female, %	51 (72%)	196 (74%)	44 (69%)
Body-mass index, kg/m^2	28.3 ± 6.6	28.5 ± 5.1	29.2 ± 4.5
Education, years	5 (0–8)	5 (0–8)	5 (3–9)
Diabetes mellitus, %	22 (31%)	91 (34%)	29 (45%)
Hypertension, %	46 (65%)	193 (73%)	49 (77%)
COPD, %	4/71	11/263	7/64
Cardiovascular disease, %	10 (14%)	77 (29%)	12 (19%)
Stroke %	11 (16%)	26 (10%)	3 (5%)
Parkinson	4 (6%)	21 (8%)	3 (5%)
Dementia, %	29 (41%)	134 (51%)	27 (42%)
Medication count	5 (3–8)	6 (4–9)	6 (4–10)
Laboratory evaluation			
GFR, mL/min/1.73 m^2	70 ± 14	59 ± 18	65 ± 18
LDL-cholesterol mg/dL	132 ± 39	133 ± 42	131 ± 39
HDL	53 ± 12	54 ± 16	54 ± 13
Triglycerides	107 (87–162)	115 (89–155)	108 (94–148)
TSH	1.19 (0.59–1.58)	1.40 (0.88–2.15)	1.42 (0.68–2.51)
HbA1c, %	6.4 ± 1.5	6.4 ± 1.3	6.4 ± 1.1
Serum albumin, g/dL	4.4 ± 0.3	4.3 ± 0.4	4.4 ± 0.4
Haemoglobin, g/dL	12.8 ± 1.6	12.4 ± 1.6	12.9 ± 1.4
Vitamin D, ng/mL	24 ± 12	24 ± 12	29 ± 15
Folate, ng/mL	6.9 (5.3–9.6)	6.9 (4.8–9.6)	7 (4.7–9.1)
Vitamin B12, pg/mL	368 (282–549)	401 (292–643)	356 (239–497)
Follow-up, months	14 (11–21)	14 (12–22)	18 (12–25)

Statistically significant difference between (i) 'Improved' versus 'No change'; (ii) 'No change' versus 'Worsened'; (iii) 'Improved' versus 'worsened'. NS, not significant in post hoc tests. COPD, chronic obstructive pulmonary disease; GFR, glomerular filtration rate; HbA1c, haemoglobin A1c; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TSH, thyroid-stimulating hormone.

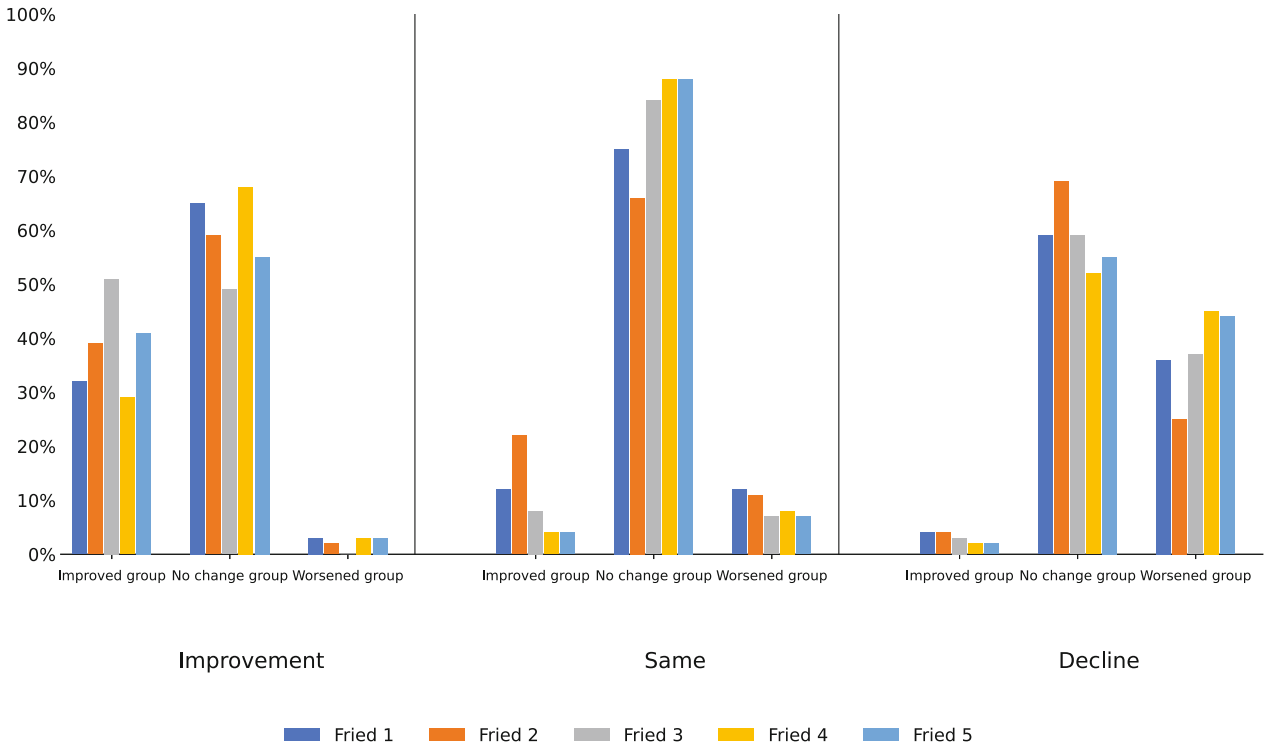

Figure 3 Frailty trajectories according to baseline Fried frailty criteria. Proportions of participants with baseline Fried frailty criteria across improvement, no change and worsening trajectories.

Table 2 Change in geriatric scores from baseline

	Improved ($n = 71$)	No change ($n = 264$)	Worsened ($n = 64$)
MNA			
Baseline	20.9 ± 4.8	21.4 ± 4.6	23.5 ± 3.8
Follow-up	24.0 ± 4.0	21.9 ± 4.7	22.3 ± 4.2
Bartel			
Baseline	88.4 ± 16.1	79.2 ± 21.4	90.3 ± 11.1
Follow-up	90 ± 13.4	74.2 ± 26.9	79.3 ± 23.7
Lawton			
Baseline	15 (9–19)	12 (5–19)	16 (11–22)
Follow-up	14 (10–19)	8 (2–16)	10 (4–19)
GDS			
Baseline	5 (1.3–8.0)	5 (1–8)	2 (1–4)
Follow-up	2 (1–4)	4 (2–8)	4 (2–6)
TUG			
Baseline	15 (11–20)	17 (13–26)	13 (11–17)
Follow-up	13 (11–16)	18 (13–28)	16 (14–21)
Dynapenia			
Baseline	45 (64%)	188 (71.2%)	18 (28.1%)
Follow-up	29 (40.8%)	184 (70.2%)	37 (58.7%)
Medication count			
Baseline	5 (3–8)	6 (4–9)	6 (4–10)
Follow-up	5 (4–9)	7 (5–9)	8 (5–10)

GDS, Geriatric Depression Scale; MNA, Mini Nutritional Assessment; TUG, timed up and go.

14 (10–19), $P < 0.001$). Depressive symptoms declined (GDS from 5 (1–8) to 2 (1–4), $P = 0.003$), and mobility improved significantly (TUG from 15 (11–20) to 13 (11–16), $P < 0.001$). In contrast, patients who worsened demonstrated declines in these parameters, whereas stable patients showed little or no change. The prevalence of dynapenia decreased markedly among patients who improved (from 64.3% to 40.8%, $P < 0.001$), remained unchanged in the stable group and increased among those who deteriorated. In sensitivity analyses restricted to participants with 9–18 months of follow-up, baseline geriatric assessment scores differed across frailty change categories in patterns consistent with the main analyses (Table S4).

Age, the number of medications, cardiovascular disease and glomerular filtration rate were associated with improvement in the frailty status in univariate analysis (Table 3). After inclusion of all these factors, along with female sex, in the multivariate regression model, younger age (OR 0.93, 95% CI 0.88–0.97, $P = 0.003$) was independently associated with improvement in frailty status. In the adjusted model, higher glomerular filtration rate was not statistically significant but demonstrated a trend towards association with improvement in

Table 3 Factors associated with improvement of frailty status

Variables	Model 1 (unadjusted)			Model 2 (adjusted)		
Age	0.92	0.89–0.96	**<0.001**	**0.93**	**0.88–0.97**	**0.003**
Female	0.94	0.53–1.66	0.818	0.91	0.43–1.90	0.804
Cardiovascular disease	0.47	0.23–0.96	**0.037**	0.57	0.23–1.39	0.568
The number of medications	0.91	0.84–0.98	**0.017**	0.95	0.85–1.05	0.305
GFR	1.04	1.0–1.06	**<0.001**	1.02	1.00–1.04	0.057
Albumin	2.63	0.71–9.73	0.148	—	—	—
Vitamin D	1.00	0.97–1.02	0.828	—	—	—
Follow-up (months)	0.98	0.95–1.01	0.174	0.98	0.95–1.02	0.303

Note: Statistically significant *P*-values are shown in bold. GFR, glomerular filtration rate.

overall frailty status (OR 1.02, 95% CI 1.00–1.04, $P = 0.057$).

During the follow-up, 34 patients (8.5%) died. The median overall survival (OS) for the cohort was 53 months, with no significant differences between patients who remained stable, improved or deteriorated in frailty status (52, 45 and 46 months respectively; $P = 0.807$). However, within the pre-frail group, progression to frailty was associated with significantly shorter OS compared to those who did not progress (41 vs 65 months, $P = 0.010$). Figure S1 shows the survival lines in these groups. In the pre-frail group, older age (OR 1.08, 95% CI 1.00–1.16, $P = 0.049$), a higher number of medications (OR 1.25, 95% CI 1.07–1.45, $P = 0.005$) and higher vitamin D level (OR 1.06, 95% CI 1.01–1.10, $P = 0.011$) were independent predictors for worsening to frailty after adjusting for these variables and sex. Comorbid conditions and other laboratory parameters, including haemoglobin, glomerular filtration rate and lipid profiles, did not show a significant association with worsening of the frailty status in this group. Among participants who were fit at baseline ($n = 37$), no baseline demographic, clinical or laboratory variables were significantly associated with frailty worsening during follow-up. Lower baseline estimated glomerular filtration rate showed a non-significant trend towards increased odds of frailty worsening in univariable analysis; however, this association did not persist after adjustment for age and sex. Overall, risk factor patterns for worsening frailty appeared less pronounced in the fit group than in pre-frail individuals.

Discussion

This study demonstrates that frailty is a dynamic condition, with approximately one in five older adults showing improvement and a similar proportion experiencing deterioration over a median follow-up of 14 months. While the overall distribution of frailty categories remained relatively stable, transitions were particularly frequent among pre-frail individuals, supporting the notion that this stage represents a critical window for intervention. Importantly, while we did not observe a significant association between overall frailty transitions (improvement or worsening) and mortality across the entire cohort, in the pre-frail group, progression to frailty was associated with shorter survival. This finding underscores the prognostic importance of preventing progression at the pre-frail stage, highlighting it as a critical window for intervention.

In the pre-frail group, older age, a higher number of medications and higher vitamin D levels were independent predictors of progression to frailty. Polypharmacy, a surrogate marker for multimorbidity and treatment burden, has been previously associated with frailty progression, likely due to increased risks of adverse medication effects and decreased physiological resilience.[22,23]

Survival analyses revealed that frailty transitions were not significantly associated with OS in the full cohort, although the limited number of events may have reduced statistical power. However, progression from pre-frail to frail was associated with shorter survival, emphasising that frailty progression at this stage may have prognostic significance. This observation is consistent with prior evidence indicating that worsening frailty predicts higher mortality risk.[24,25]

One possible explanation may relate to changes in overall medication burden. Although specific medication classes were not systematically recorded in our dataset, reductions in polypharmacy may potentially decrease exposure to high-risk medications, such as those with anticholinergic properties, which have been associated with adverse geriatric outcomes.[26,27] Interestingly, serum vitamin D levels were not independently associated with frailty improvement in our cohort. Likewise, despite previous evidence linking vitamin D deficiency to frailty and functional impairment,[28,29] our findings did not support a significant association; this is potentially owing to the fact that when vitamin D levels were low at baseline, they were replaced, or supplementation

effects were not captured. This paradoxical result may reflect reverse causality, in which individuals identified as at risk were more likely to receive vitamin D supplementation, leading to higher serum levels without functional benefit. Additionally, addressing polypharmacy may play a crucial role in reducing the risk of deterioration in this context.

Our findings align with earlier prospective studies that have reported that frailty is not an irreversible state.[8] Kojima showed that pre-frail individuals were at the highest risk of both progression and recovery, underscoring the clinical importance of identifying and targeting this subgroup.[9] In line with these reports, we found that nearly a third of pre-frail patients progressed to frailty, while 14% reverted to a robust state.

In the present study, increasing age was consistently associated with a lower likelihood of frailty improvement, aligning with previous research highlighting age as a dominant, non-modifiable risk factor in frailty trajectories.[7,9] As individuals age, physiological reserves decline, limiting the capacity for functional recovery even with interventions. These findings highlight that, although frailty is considered an age-independent geriatric syndrome, younger individuals may have a greater potential for recovery, further emphasising the need for early identification and intervention in the pre-frail stage.[30] Similarly, impaired renal function, as indicated by lower glomerular filtration rate values, significantly hindered improvement in frailty status. This finding corroborates earlier studies emphasising the bidirectional relationship between chronic kidney disease and frailty, where renal dysfunction accelerates physical decline and vice versa.[31,32]

While cardiovascular disease was initially identified as a significant predictor in the unadjusted model, its effect was attenuated after adjusting for other covariates. This may reflect overlapping pathways through which cardiovascular comorbidities, such as inflammation, reduced physical activity and polypharmacy, influence frailty.[33]

A reduction in weight loss and an increase in muscle strength also reflected transitions in frailty. Participants who improved demonstrated significant gains in nutritional status, physical independence, mobility and mood, whereas those who worsened experienced parallel declines. Weight loss and malnutrition have been found to be associated with negative clinical outcomes such as mortality, deterioration in white matter integrity, sarcopenia, sleep problems and falls.[34–37] On the other hand, in recent years, there has been an exponential increase in the literature investigating associations between handgrip strength and health outcomes.[38] Therefore, improving muscle strength and nutrition is crucial for recovery from frailty, and strategies targeting these factors need to be developed. These findings support the multidimensional nature of frailty, highlighting that interventions targeting nutrition, mobility and mental health may contribute to recovery. This interpretation is consistent with interventional studies showing that exercise programmes, nutritional supplementation and deprescribing strategies can mitigate frailty progression.[11,39] According to our results, implementing all these approaches during the pre-frail stage may be much more effective.

The strengths of this study include a relatively large sample size, use of standardised frailty criteria and longitudinal follow-up. However, several limitations should be noted. First, the observational design precludes causal inference. Second, potential confounders such as physical activity patterns, dietary quality or socio-economic factors were not fully explored. Third, detailed data on specific medication classes, including anticholinergic exposure, as well as information on vitamin D supplementation, were not systematically collected. Therefore, detailed medication classes could not be formally evaluated, nor could their potential contribution to frailty transitions be assessed. Fourth, although patients were evaluated in an interprofessional geriatrics clinic where individualised interventions are routinely provided as part of standard care, the frequency and type of follow-up varied between individuals. Variation in follow-up duration may have influenced the likelihood of observing frailty transitions in some participants. Because these interventions were neither protocolised nor systematically documented, they could not be reliably incorporated into the statistical models. As a result, frailty transitions observed in our study reflect real-world clinical practice rather than the effect of a structured intervention programme. This represents both a limitation, because intervention effects cannot be isolated, and a strength, as our findings describe frailty trajectories in typical outpatient geriatric care settings where treatment exposure is heterogeneous and patient-driven. We acknowledge that the absence of a fixed follow-up time point may limit direct comparisons of rates of change; however, this approach was chosen to reflect routine outpatient geriatric care. A further limitation is the relatively small sample size in certain subgroups, particularly among participants who were fit at baseline. The limited number of individuals in these subgroups reduced statistical power and, in some cases, precluded more comprehensive multivariable analyses. Therefore, subgroup findings should be interpreted with caution, and larger studies are needed to more robustly evaluate risk factors across different baseline frailty categories. Finally, mortality data may be underpowered to detect differences beyond the pre-frail subgroup.

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Conclusion

In summary, frailty is a dynamic process, with both improvement and deterioration occurring over time. Pre-frail individuals are at particular risk of adverse transitions, and progression at this stage is associated with poorer survival. Interventions addressing modifiable factors such as polypharmacy, renal function, nutrition and muscle health may help to stabilise or reverse frailty trajectories. Our results suggest that frailty assessment should be incorporated into routine geriatric care, with particular attention to pre-frail individuals. The observed improvements across multidomain assessments reinforce the potential benefits of comprehensive geriatric interventions over single-modality approaches.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

Figure S1. Overall survival according to change in frailty status among patients with prefrailty.
Table S1. Comparing baseline characteristics of participants included in and excluded from the longitudinal frailty analyses.
Table S2. Changes in Fried components in the whole cohort.
Table S3. Changes in Fried components in improvement, no change, and worsened groups.
Table S4. Scores of geriatric tests in the subgroup of patients who had 9 to 18 months of follow-up.