

Prevalence of frailty and multidimensional associated factors among hospitalized adults with heart failure: a cross-sectional study

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Abstract

Background

Frailty is common in heart failure and may complicate inpatient management and discharge planning. Evidence integrating clinical, functional, nutritional, psychosocial, sleep-related, and laboratory factors in hospitalized populations remains limited. This study estimated frailty prevalence and examined multidimensional factors associated with frailty among hospitalized adults with heart failure.

Methods

This analytical cross-sectional study consecutively recruited 500 adults hospitalized with confirmed heart failure at a tertiary cardiovascular referral hospital in Iran between August and November 2024. Frailty was assessed using the validated Persian Tilburg Frailty Indicator (TFI; total score ≥ 5). Sociodemographic, clinical, functional, self-care, nutritional, sleep, psychological, social-support, and laboratory variables were evaluated using bivariate analyses and multivariable binary logistic regression.

Results

Frailty was identified in 306 participants (61.2%; 95% confidence interval [CI], 56.8–65.5). The mean age was 68.7 years, and 81.7% of participants were aged 60 years or older. In the complete-case model ($n = 461$), frailty was associated with older age (adjusted odds ratio [aOR], 1.05 per year; 95% CI, 1.03–1.08), insufficient perceived income (aOR, 1.61; 95% CI, 1.03–2.53), an unhealthy lifestyle profile (aOR, 1.89; 95% CI, 1.12–3.18), three or more comorbidities (aOR, 1.74; 95% CI, 1.09–2.78), New York Heart Association class III–IV (aOR, 2.46; 95% CI, 1.50–4.03), nutritional risk (aOR, 2.12; 95% CI, 1.31–3.45), lower serum albumin (aOR, 0.92 per 1 g/L increase; 95% CI, 0.87–0.97), and poor sleep quality (aOR, 1.67; 95% CI, 1.03–2.69). Each 5-percentage-point increase in left ventricular ejection fraction was associated with lower odds of frailty (aOR, 0.90; 95% CI, 0.81–1.00). Model discrimination was good (area under the curve, 0.81; 95% CI, 0.77–0.85).

Conclusions

Frailty was common and extended across physical, psychological, and social domains. The observed associations do not establish causality, but they support integrating frailty screening with nutritional, functional, sleep, socioeconomic, and clinical assessment to inform individualized care and discharge planning for hospitalized patients with heart failure.

Background

Heart failure is a complex clinical syndrome associated with substantial morbidity, recurrent hospitalization, impaired functional capacity, and high healthcare utilization. Despite advances in pharmacological and device-based treatment, many patients experience progressive symptom burden, multimorbidity, repeated decompensation, and complex care needs (1, 2). These problems are particularly evident during hospitalization, when acute symptoms, treatment intensity, bed rest, and disruption of usual routines can expose limitations in physical function, nutrition, self-care, psychological well-being, and social support.

Frailty is a state of reduced reserve and increased vulnerability to stressors. In people with heart failure, it cannot be explained by chronological age alone; it may emerge from the interaction of cardiovascular dysfunction, multimorbidity, sarcopenia, inflammation, neurohormonal activation, malnutrition, functional dependency, psychological symptoms, and social vulnerability (3–6). Systematic reviews have shown that frailty is common in heart failure and is associated with mortality, hospitalization, and unplanned readmission, although prevalence estimates vary by clinical setting, age distribution, disease severity, and assessment instrument (3, 6–8).

Hospitalized patients require particular attention because acute decompensation may reveal or intensify pre-existing vulnerability. Dyspnea, fatigue, fluid overload, inactivity, polypharmacy, and treatment complexity can contribute to functional and nutritional instability. At the same time, safe discharge requires patients and caregivers to understand medications, monitor symptoms and weight, follow dietary and fluid recommendations, recognize deterioration, and access follow-up care. Frailty assessment may therefore provide clinically relevant information beyond conventional indicators such as left ventricular ejection fraction (LVEF), biomarkers, and New York Heart Association (NYHA) functional class.

Frailty in heart failure is often assessed using physical phenotypes or deficit-accumulation models. However, a multidimensional approach may be especially appropriate for hospitalized patients because vulnerability may involve psychological and social domains as well as physical impairment (4, 5, 9). The Tilburg Frailty Indicator (TFI) assesses physical, psychological, and social frailty and may identify needs that are not captured by mobility or strength measures alone (9). This is relevant to heart failure, in which fatigue, dyspnea, impaired activity, anxiety, depressive symptoms, poor sleep, reduced self-care capacity, and social isolation may coexist and interact.

Multiple domains may be associated with frailty. Sociodemographic characteristics can reflect socioeconomic and contextual vulnerability; heart failure phenotype, LVEF, NYHA class, disease duration, hospitalization history, and comorbidities describe clinical burden; and activities of daily living (ADL), instrumental activities of daily living (IADL), and self-care measures indicate practical independence. Nutritional risk and laboratory markers such as albumin, hemoglobin, estimated glomerular filtration rate (eGFR), and N-terminal pro-B-type natriuretic peptide (NT-proBNP) may further characterize biological vulnerability. Sleep quality, psychological symptoms, and perceived social support may influence fatigue, participation in care, and the capacity to manage complex treatment regimens.

Despite growing interest in frailty, hospitalized heart failure populations remain less well characterized than outpatient and community cohorts in some regions. Relatively few studies have evaluated sociodemographic, clinical, functional, nutritional, psychological, sleep-related, social, and laboratory variables within one analytical framework, particularly using validated Persian instruments. Such evidence could support more comprehensive nursing assessment, multidisciplinary care, and discharge planning. Therefore, this study aimed to estimate the prevalence of frailty and examine multidimensional factors associated with frailty among hospitalized adults with heart failure.

Methods

Study design and setting

A hospital-based analytical cross-sectional study was conducted between August and November 2024 in the cardiology and heart failure-related inpatient wards of Chamran Cardiovascular Medical and Research Hospital, a tertiary referral teaching hospital affiliated with Isfahan University of Medical Sciences, Isfahan, Iran. The hospital provides specialized care for patients with acute decompensated heart failure and exacerbations of chronic heart failure. The study was designed to estimate frailty prevalence and examine factors associated with prevalent frailty. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional studies (10).

Participants and sampling

The study population comprised adults hospitalized with heart failure. Consecutive sampling was used throughout the study period to reduce discretionary selection of eligible patients. Potential participants were screened by the research team in collaboration with ward nurses and cardiology clinicians. Patients were eligible when they were aged 18 years or older; were hospitalized in a cardiology or heart failure-related ward; had heart failure confirmed by a cardiologist or documented in the medical record; were clinically stable during data collection; could communicate in Persian; could complete the questionnaires independently or through a standardized interviewer-administered procedure; and provided written informed consent. Clinical stability was defined as the absence of emergency intervention, cardiopulmonary resuscitation, invasive ventilation, or immediate transfer to a higher level of care during questionnaire administration.

Patients were excluded when incomplete TFI data prevented classification of frailty status; acute clinical deterioration interrupted assessment; severe cognitive impairment, delirium, altered consciousness, or a severe psychiatric disorder documented in the medical record prevented valid questionnaire completion; Persian communication was not possible; or consent was withdrawn. Patients who were unable to write because of fatigue, weakness, physical limitations, or medical equipment were not automatically excluded, because the standardized interview procedure allowed their participation.

Sample size

For the prevalence objective, the required sample size was calculated using $n = Z^2p(1-p)/d^2$. A conservative expected prevalence of 50%, a two-sided 95% confidence level, and an absolute precision of approximately 4.5% yielded a minimum of about 475 participants. The target was increased to 500 to accommodate incomplete responses and variable-level missingness. The anticipated number of frailty events was also considered adequate for a parsimonious multivariable logistic regression model containing approximately 12–15 clinically justified parameters. Model adequacy was subsequently assessed using the number of complete cases and frailty events available for the final analysis.

Data collection and quality control

After eligible patients received an explanation of the study aims and procedures, written informed consent was obtained. Data collection had three components: (1) a structured checklist for sociodemographic characteristics and TFI Part A determinants; (2) clinical, medication, and laboratory information extracted from medical records using a standardized form; and (3) validated Persian questionnaires or standardized screening tools for frailty, functional status, self-care, nutrition, sleep, psychological symptoms, and social support.

Questionnaires were self-administered by literate and physically able participants. When self-administration was not feasible, a trained researcher read each item aloud in a neutral tone, did not interpret or explain response options, and recorded the participant's response verbatim. This procedure was intended to include more clinically vulnerable patients while limiting interviewer influence. Clinical information was extracted from medical records and confirmed by patient interview when necessary. Operational definitions and coding rules were specified before data collection. A second researcher independently checked a random 10% of questionnaire forms and medical-record abstractions against source documents; discrepancies were resolved by review and discussion with a senior member of the research team.

Efforts to address bias

Consecutive recruitment was used to reduce discretionary selection of eligible patients. Validated Persian instruments, prespecified operational definitions, standardized interviewer administration, neutral reading of response options, source-document verification, and independent checking of a random 10% of questionnaire forms and medical-record abstractions were used to reduce selection, information, interviewer, and data-entry bias. Potential confounding was addressed through clinically informed multivariable modelling and assessment of multicollinearity.

Outcome and candidate variables

The primary outcome was frailty status based on TFI Part B. Participants were classified as frail or non-frail using the validated cutoff. Candidate variables were selected according to the multidimensional conceptualization of frailty, prior heart failure literature, and clinical relevance. They comprised age, sex, marital status, education, perceived economic status, residence, living arrangement, lifestyle, major life events, satisfaction with the living environment, heart failure phenotype, LVEF, NYHA class, disease duration, hospitalization history, length of stay, comorbidity burden, individual comorbidities, medications, ADL, IADL, heart failure self-care, nutritional risk, body mass index, albumin, hemoglobin, eGFR, NT-proBNP, sleep quality, depressive symptoms, anxiety symptoms, and perceived social support.

The final regression candidates were selected using theoretical relevance, clinical importance, bivariate associations, parsimony, and multicollinearity assessment. TFI Part B items and domain scores were not entered as predictors because they constituted the frailty outcome. Measures of function, nutrition, sleep, psychological symptoms, and social support were treated as conceptually related but analytically distinct variables.

Measures and operational definitions

Frailty and its background determinants were assessed using the previously published and validated Persian version of the Tilburg Frailty Indicator (TFI) (9, 11). Part A of the TFI includes 10 background determinants related to sociodemographic, lifestyle, health-related, and environmental characteristics, whereas Part B comprises 15 items assessing physical, psychological, and social frailty. Additional clinical, medication, and laboratory variables were extracted from the patients' medical records using a standardized data-abstraction form. Extracted variables included heart failure phenotype, left ventricular ejection fraction, New York Heart Association functional class, disease duration, hospitalization history, comorbidities, prescribed medications, hemoglobin, serum albumin, serum creatinine, and NT-proBNP. Consistent with the Persian validation study, a total score of 5 or higher classified a participant as frail (11). Cronbach's alpha for the TFI total score was 0.82 in the present sample, compared with 0.897 in the Persian diagnostic-accuracy study (11).

Sociodemographic variables were obtained using a structured checklist. Age was analyzed continuously and grouped descriptively as < 60, 60–69, 70–79, and $\geq$ 80 years. Education was classified as no formal/primary, secondary, or academic education. Perceived economic status was categorized as insufficient, relatively sufficient, or sufficient, and living arrangement as living with a spouse/family or living alone. Lifestyle status was operationalized as a prespecified study-specific composite variable derived from information documented in the patients' medical records. The composite included current smoking status, regular physical or cardiac rehabilitation-compatible activity, adherence to a low-sodium diet, and adherence to fluid-management or weight-monitoring recommendations. A healthy lifestyle was defined as no current smoking and documentation of adherence to at least two favorable behaviors. An unhealthy lifestyle was defined as current smoking or documented non-adherence to at least two favorable behaviors. All other combinations were classified as intermediate. This classification was an operational study variable and not a participant-administered or validated Persian questionnaire. Major

life events during the previous 12 months included bereavement, severe illness of a close relative, major financial stress, relocation, divorce or separation, or another event perceived as highly stressful. Living-environment satisfaction was dichotomized as satisfied/not dissatisfied versus dissatisfied.

Heart failure phenotype was classified using guideline-based LVEF thresholds: heart failure with reduced ejection fraction (HFrEF), LVEF $\leq$ 40%; mildly reduced ejection fraction (HFmrEF), 41%-49%; and preserved ejection fraction (HFpEF), $\geq$ 50% [2]. NYHA class was obtained from cardiologist documentation or clinical assessment in the record. Duration of heart failure, heart failure-related hospitalization during the previous year, current length of stay, and medication use were recorded. Comorbidities included hypertension, diabetes mellitus, coronary artery disease, atrial fibrillation, chronic kidney disease, chronic obstructive pulmonary disease, and previous stroke or cerebrovascular accident. Burden was summarized using the Charlson Comorbidity Index (12) and as fewer than three versus three or more documented comorbidities. Medications included loop diuretics, beta-blockers, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, angiotensin receptor-neprilysin inhibitors, mineralocorticoid receptor antagonists, and sodium-glucose cotransporter-2 inhibitors.

Functional status was assessed using the Katz ADL and Lawton IADL scales (13–16). ADL impairment was defined as dependency in at least one basic activity or a total score below 6; IADL impairment was dependency in at least one instrumental domain or a total score below 8 using a sex-neutral scoring approach. Heart failure self-care was assessed using the previously published and validated Persian version of the Self-Care of Heart Failure Index version 6.2 (SCHFI v6.2) (17, 18). The instrument comprises three scales: self-care maintenance, self-care management, and self-care confidence. Scale scores are standardized to a 0–100 range, with higher scores indicating better self-care. In the present analysis, a score below 70 on self-care maintenance or, when applicable, self-care management was classified as inadequate self-care. Standardized scores range from 0 to 100, and values below 70 on self-care maintenance or, when applicable, self-care management indicated inadequate self-care.

Nutritional status was assessed using the six-item Mini Nutritional Assessment–Short Form (MNA-SF), originally developed by Rubenstein et al. (19). The previously published Persian version, evaluated among hospitalized Iranian older adults, was used in the present study (20). Total scores range from 0 to 14, with scores of 12–14 indicating normal nutritional status, 8–11 indicating risk of malnutrition, and 0–7 indicating malnutrition (21). For the present analysis, nutritional risk was defined as an MNA-SF score of $\leq$ 11. Body mass index was calculated as weight in kilograms divided by height in meters squared. Sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI), with a global score above 5 indicating poor sleep (22, 23). Depressive and anxiety symptoms were screened using the Hospital Anxiety and Depression Scale; a subscale score of 8 or higher indicated clinically relevant symptoms (24, 25). Perceived social support was measured using the Multidimensional Scale of Perceived Social Support; mean scores of 1.0–2.9, 3.0–5.0, and $>$ 5.0 indicated low, moderate, and high support, respectively (26, 27). Validated Persian versions of the study instruments were used (11, 13, 14, 18, 23, 24, 26, 28).

Hemoglobin, serum albumin, serum creatinine, and NT-proBNP values closest to questionnaire completion during the index hospitalization were extracted. eGFR was calculated with the 2021 CKD-EPI creatinine equation and expressed as mL/min/1.73 m² (29). Creatinine was not entered separately because eGFR represented renal function. NT-proBNP was summarized using the median and interquartile range and natural-log transformed before regression because of its skewed distribution. Laboratory variables are objective clinical measurements and were not subjected to internal-consistency testing.

Data management and statistical analysis

Data were reviewed for completeness, consistency, and plausibility before analysis. Each participant received a study code, and direct identifiers were removed from the analytical dataset. Data were entered into IBM SPSS Statistics version 28.0. Missingness was evaluated by variable. Participants lacking sufficient TFI information for frailty classification were excluded from the outcome analysis; all 500 participants in the final sample had valid frailty status. Descriptive and bivariate analyses used available cases, while the multivariable model used complete cases. Multiple imputation was not performed because variable-level missingness was low.

Continuous variables were assessed using histograms, Q-Q plots, skewness and kurtosis, and the Shapiro-Wilk or Kolmogorov-Smirnov test as appropriate. Approximately normally distributed variables were reported as mean±standard deviation, skewed variables as median [interquartile range], and categorical variables as frequency and percentage. Frailty prevalence was calculated as the proportion with TFI ≥ 5 and reported with a binomial 95% confidence interval (CI). Frail and non-frail groups were compared using independent-samples t tests, Mann-Whitney U tests, chi-square tests, or Fisher exact tests as appropriate. TFI-derived scores and domains were presented descriptively because frailty classification was determined from the TFI total score.

Variables associated with frailty at $p < 0.20$ in bivariate analysis and variables with strong theoretical or clinical relevance were considered for multivariable binary logistic regression. Frailty was coded 0 for non-frail and 1 for frail. Multicollinearity was assessed using tolerance and the variance inflation factor (VIF); tolerance ≤ 0.20 or VIF ≥ 5 indicated potential concern. A single parsimonious model was fitted, and adjusted odds ratios (AORs), 95% CIs, regression coefficients, standard errors, and P values were reported. Calibration was assessed with the Hosmer-Lemeshow test, explanatory performance with Nagelkerke R², discrimination with the area under the receiver operating characteristic curve (AUC), and overall classification accuracy. All tests were two-sided, with $p < 0.05$ considered statistically significant. Because frailty was common, adjusted odds ratios were interpreted as associations with the odds of prevalent frailty and not as prevalence ratios, risk ratios, or estimates of future risk.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Isfahan University of Medical Sciences, Iran (IR.MUI.NUREMA.REC.1403.009). Permission to conduct the study was obtained from Chamran Cardiovascular Medical and Research Hospital before data collection. All participants provided written informed consent before enrolment. Participation was voluntary, and withdrawal did not affect treatment or care. Direct identifiers were removed from the analytical dataset, and confidentiality was maintained throughout data collection, management, and analysis.



Results

Participant characteristics and frailty prevalence

A total of 500 hospitalized patients with valid TFI data were included. Of these, 306 were classified as frail and 194 as non-frail, corresponding to a frailty prevalence of 61.2% (95% CI, 56.8-65.5). Mean age was 68.7 ± 11.1 years, 407 of 498 participants with age data (81.7%) were aged 60 years or older, and 276 participants (55.2%) were male. Missingness for individual descriptive variables ranged from 0.0% to 2.8%; variable-specific denominators are presented in the tables.

Frail participants were older than non-frail participants (71.8 ± 10.5 vs 63.8 ± 10.2 years; $p < 0.001$), and the proportion aged 80 years or older was greater in the frail group. Sex distribution did not differ significantly. Frailty was associated in bivariate analyses with marital status, lower educational attainment, insufficient perceived income, living alone, unhealthy lifestyle, a major life event during the previous year, and dissatisfaction with the living environment. Rural residence was more common among frail participants but did not reach statistical significance (Table 1).

Heart failure and comorbidity characteristics

The distribution of HFrEF, HFmrEF, and HFpEF did not differ by frailty status. However, frail participants had lower mean LVEF ($40.3 \pm 12.7\%$ vs $44.1 \pm 11.9\%$; $p = 0.001$) and were more often classified as NYHA III-IV (76.7% vs 51.6%; $p < 0.001$). They also had a longer median duration of heart failure, more frequent heart failure-related hospitalization during the previous year, and a longer current hospital stay.

Comorbidity burden was higher among frail participants: the median Charlson Comorbidity Index was 5 [3-6] versus 3 [2-5], and 63.9% versus 43.2% had three or more comorbidities (both $p < 0.001$). Diabetes, atrial fibrillation, chronic kidney disease, and previous stroke were more frequent in the frail group. Loop-diuretic use was more common, whereas sodium-glucose cotransporter-2 inhibitor use was less common. Other major medication categories did not differ significantly (Table 2).

Multidimensional frailty profile

The TFI demonstrated acceptable internal consistency (Cronbach's $\alpha=0.82$). The overall mean TFI score was 6.1 ± 2.8 , and the median was 6 [4-8]. Physical deficits were most frequent, but psychological and social deficits were also prominent. At least one physical deficit was present in 88.6% of the total sample, at least one psychological deficit in 63.2%, and at least one social deficit in 53.8%. The distributions of total and domain scores by frailty status are presented descriptively in Table 3 because the frailty groups were defined using the TFI total score.

Functional, nutritional, psychosocial, and laboratory characteristics

Functional limitation and reduced self-care were more frequent among frail participants. ADL impairment was present in 43.4% of the frail group compared with 21.6% of the non-frail group; corresponding values were 54.8% versus 32.3% for IADL impairment and 55.7% versus 27.1% for inadequate self-care (all $p<0.001$). MNA-SF-defined nutritional risk affected 55.8% of frail participants and 26.1% of non-frail participants ($p<0.001$), while mean body mass index was modestly lower in the frail group.

Frail participants had lower albumin (35.5 ± 4.3 vs 39.0 ± 4.2 g/L), lower hemoglobin (12.0 ± 1.9 vs 12.9 ± 1.7 g/dL), lower median eGFR (53 [34-71] vs 66 [48-84] mL/min/1.73 m²), and higher median NT-proBNP (4210 [1930-8310] vs 2180 [960-5140] pg/mL) (all $p<0.001$). Poor sleep quality, depressive symptoms, anxiety symptoms, and low perceived social support were also more frequent in the frail group (Table 4).

Multivariable factors associated with frailty

The final complete-case model included 461 participants, including 281 frail cases. No problematic multicollinearity was detected using the prespecified tolerance and VIF criteria. Older age was independently associated with frailty (AOR, 1.05 per year; 95% CI, 1.03-1.08; $p<0.001$). Insufficient perceived income (AOR, 1.61; 95% CI, 1.03-2.53; $p=0.037$), unhealthy lifestyle (AOR, 1.89; 95% CI, 1.12-3.18; $p=0.017$), and three or more comorbidities (AOR, 1.74; 95% CI, 1.09-2.78; $p=0.021$) also remained significant.

NYHA class III-IV showed the strongest adjusted association (AOR, 2.46; 95% CI, 1.50-4.03; $p<0.001$). Each 5% increase in LVEF was associated with lower odds of frailty (AOR, 0.90; 95% CI, 0.81-1.00; $p=0.048$). Nutritional risk was associated with more than twice the odds of frailty (AOR, 2.12; 95% CI, 1.31-3.45; $p=0.002$), while higher albumin was inversely associated (AOR, 0.92 per 1 g/L increase; 95% CI, 0.87-0.97; $p=0.002$). Poor sleep quality remained significant (AOR, 1.67; 95% CI, 1.03-2.69; $p=0.038$). Female sex, low education, living alone, recent major life events, and log-transformed NT-proBNP were not statistically significant after adjustment (Table 5).

Model calibration was acceptable (Hosmer-Lemeshow $p=0.418$). Nagelkerke R^2 was 0.39, indicating moderate explanatory performance. Discrimination was good (AUC, 0.81; 95% CI, 0.77-0.85), and overall classification accuracy was 74.6%.

Discussion

Principal findings

This study found that frailty affected 61.2% of hospitalized patients with heart failure and extended across physical, psychological, and social domains. The adjusted analysis identified associations spanning several dimensions: older age, insufficient perceived income, unhealthy lifestyle, multimorbidity, advanced NYHA class, lower LVEF, nutritional risk, lower albumin, and poor sleep quality. The model showed acceptable calibration and good discrimination. These findings support the interpretation of frailty in hospitalized heart failure as a multidimensional vulnerability state rather than a condition explained solely by age or cardiac function.

Prevalence and multidimensional profile

The observed prevalence was higher than pooled estimates reported in several heart failure reviews but is clinically plausible for an inpatient cohort (3, 5, 8). A recent prospective cohort of older inpatients with heart failure using the TFI also reported a high prevalence of multidimensional frailty, illustrating how setting and instrument choice influence estimates (30). Prevalence differs across studies because of variation in age, case mix, disease severity, recruitment setting, conceptual model, and cutoff (3-6). Hospitalization may select patients with acute decompensation, greater symptom burden, functional decline, nutritional compromise, and psychosocial stress. The present estimate should therefore be interpreted as the prevalence in this tertiary inpatient sample rather than an estimate for all people with heart failure.

Physical deficits were the most frequent component, but psychological and social deficits were also common. This pattern is important because a cardiovascularly stabilized patient may still have impaired daily functioning, poor self-care capacity, nutritional risk, sleep disturbance, mood symptoms, or inadequate support. The bivariate findings showed that these domains clustered among frail participants. Although some measures overlap conceptually with frailty, independent instruments were used and TFI Part B items were excluded from regression to avoid directly predicting the outcome with its constituent items. The findings therefore reinforce a multidomain assessment approach while avoiding the claim that every associated domain is an independent cause of frailty.

Sociodemographic and lifestyle factors

Older age remained independently associated with frailty after adjustment. This is consistent with reduced physiological reserve across the life course, but frailty should not be equated with chronological aging (4,5). In heart failure, aging may interact with multimorbidity, inflammation, muscle loss, nutritional depletion, repeated decompensation, and reduced ability to recover from stress. The presence of frailty among patients younger than conventional geriatric thresholds also supports screening based on clinical vulnerability rather than age alone.

Insufficient perceived income was independently associated with frailty. Financial constraints may influence access to nutritious food, medications, transportation, rehabilitation, and follow-up and may increase chronic stress. They may also reduce the feasibility of implementing recommended self-care behaviors. However, perceived income and frailty were measured concurrently, and the association may be bidirectional or confounded by unmeasured social conditions. It should therefore be interpreted as evidence that socioeconomic vulnerability accompanies frailty in this cohort, not that low income directly caused frailty.

An unhealthy lifestyle profile also remained associated with frailty. The composite incorporated smoking, physical activity, and adherence to dietary and fluid or weight-monitoring recommendations. These behaviors may influence physiological reserve and self-management, but reverse causation is likely: fatigue, dyspnea, functional limitation, depression, and financial barriers may make recommended behaviors difficult for frail patients. The result identifies a clinically relevant domain for assessment and supportive education; it does not establish that lifestyle modification alone will prevent or reverse frailty.

Clinical severity and multimorbidity

Having three or more comorbidities was independently associated with frailty, and the frail group had a higher Charlson Comorbidity Index. Diabetes, atrial fibrillation, chronic kidney disease, and previous stroke were also more frequent in bivariate comparisons. These conditions may compound symptom burden, polypharmacy, functional limitation, and treatment complexity. The findings are consistent with the view that frailty in heart failure reflects cumulative multisystem burden rather than the severity of a single disease (4, 5). Nevertheless, the cross-sectional design does not allow determination of whether comorbidities preceded frailty, frailty contributed to disease complications, or both evolved together.

NYHA class III-IV had the largest adjusted association with frailty. Advanced NYHA class reflects greater dyspnea, fatigue, and activity limitation and is therefore closely aligned with diminished reserve and functional vulnerability. However, NYHA class and frailty are not interchangeable: NYHA classification focuses on symptoms during activity, whereas the TFI also captures psychological and social domains. Their independent association suggests that multidimensional frailty assessment may add clinically useful information to routine symptom-based classification.

Higher LVEF was inversely associated with frailty, although categorical heart failure phenotype was not. Continuous LVEF may capture within-category variation that is obscured when patients are grouped as

HF_rEF, HF_mrEF, or HF_pEF. At the same time, the absence of a phenotype association indicates that frailty occurs across the LVEF spectrum and should not be restricted to patients with reduced ejection fraction. NT-proBNP was substantially higher among frail participants in bivariate analysis but was attenuated after adjustment, possibly because it shared information with NYHA class, LVEF, renal function, and comorbidity burden. This does not negate the clinical value of NT-proBNP; it indicates only that it was not independently associated with frailty in the fitted model.

Nutritional, biochemical, and sleep-related factors

Nutritional risk was associated with more than twice the adjusted odds of frailty. Reduced intake, anorexia, early satiety, gastrointestinal congestion, dietary restriction, inflammation, catabolic stress, and loss of muscle reserve can coexist in heart failure and may contribute to a cycle of weakness and reduced activity (4, 5). The MNA-SF is a brief screening tool rather than a diagnostic assessment, but the strong association suggests that systematic nutritional screening may identify patients requiring further evaluation and dietetic support.

Albumin remained inversely associated with frailty after adjustment. Albumin should not be interpreted as a specific marker of nutritional intake because it may also reflect inflammation, fluid status, hepatic congestion, and overall illness severity. Considered together, the MNA-SF and albumin findings point to nutritional and biological vulnerability rather than a single nutritional mechanism. Lower hemoglobin and eGFR and higher NT-proBNP in bivariate comparisons further illustrate the multisystem burden among frail participants, even though these variables did not all remain independent in the final model.

Poor sleep quality was independently associated with frailty. In hospitalized heart failure, sleep can be disrupted by dyspnea, orthopnea, nocturia, anxiety, environmental disturbance, and symptom instability. Poor sleep may worsen fatigue, concentration, mood, daytime function, and engagement in self-care, while frailty and advanced disease may themselves impair sleep. Because both were assessed at one time point, directionality cannot be established. Nonetheless, sleep is a potentially overlooked component of comprehensive assessment and may warrant symptom-focused evaluation rather than being treated as an inevitable consequence of hospitalization.

Clinical and nursing implications

The findings support consideration of routine multidimensional frailty screening for hospitalized patients with heart failure, particularly when discharge planning begins. Screening should not be limited to older age, mobility, LVEF, or NYHA class. A brief frailty assessment combined with evaluation of ADL, IADL, self-care, nutrition, sleep, psychological symptoms, caregiver support, and socioeconomic barriers may help clinicians identify needs that persist after hemodynamic stabilization. Because the study did not test clinical outcomes, screening should be used to guide comprehensive assessment rather than as a validated prediction rule.

For nursing practice, a positive frailty screen may prompt individualized education, assessment of symptom-monitoring and medication-management ability, fall and functional-risk evaluation, nutritional referral, caregiver involvement, and early multidisciplinary discharge coordination. Patients with socioeconomic constraints may require linkage to social or community resources, while those with poor sleep or psychological symptoms may benefit from targeted evaluation. These actions are clinically plausible but should not be presented as interventions proven by this cross-sectional study. Prospective studies are needed to determine whether frailty-informed pathways improve readmission, functional recovery, quality of life, or survival.

Strengths and limitations

This study has several strengths. It included a relatively large consecutive sample from an inpatient heart failure population and used the validated Persian TFI to assess physical, psychological, and social frailty. Multiple clinical and nonclinical domains were evaluated using standardized measures, allowing a broader analysis than studies restricted to age or cardiac severity. Operational definitions were specified, a subset of source records was independently checked, missingness was low, and regression diagnostics included multicollinearity, calibration, explanatory performance, discrimination, and classification accuracy. The final model included 281 frailty events for 14 predictors, providing a favorable events-per-parameter ratio, and reporting followed STROBE recommendations.

Several limitations should be considered. First, the cross-sectional design precludes temporal and causal inference, permits reverse causation, and does not distinguish chronic frailty from vulnerability temporarily intensified by acute illness or hospitalization. The findings therefore describe associated factors, not determinants or predictors of future frailty.

Second, this was a single-center study in a tertiary referral hospital, and consecutive sampling was non-probability based; generalizability to community-dwelling patients, outpatient clinics, other hospitals, and healthcare systems with different case mixes is limited. Although 81.7% of participants with age data were aged 60 years or older, eligibility began at 18 years and the Persian TFI validation evidence cited in this study was generated primarily in older adults. Measurement performance and the interpretation of frailty among participants younger than 60 years may therefore be less certain.

Third, several measures were self-reported or interviewer-administered and may be affected by recall, social-desirability, or interviewer-related bias despite standardized procedures. The prespecified lifestyle classification was a study-specific composite rather than a separately validated scale. Some functional, nutritional, psychological, and sleep measures may also overlap conceptually with multidimensional frailty, although TFI items and domain scores were not entered as predictors.

Fourth, residual confounding is possible because sarcopenia, objective physical performance, formal cognitive testing, inflammatory biomarkers, medication adherence, rehabilitation participation, caregiver availability, and longitudinal disease trajectory were not measured. Complete-case regression may

introduce bias if missingness was related to unmeasured characteristics, although variable-level missingness was low. Because frailty prevalence was high, odds ratios may be farther from the null than corresponding prevalence ratios and should not be interpreted as relative prevalence or risk. The numbers screened, excluded before consent, and declining participation were unavailable, limiting complete recruitment-flow reporting. Finally, longitudinal outcomes such as mortality, readmission, functional decline, quality of life, institutionalization, and changes in frailty after discharge were not assessed; the model is not a validated prognostic tool.

Recommendations for future research

Multicenter longitudinal studies should evaluate frailty trajectories and determine whether multidimensional frailty predicts readmission, mortality, functional recovery, quality of life, and healthcare use beyond established heart failure indicators. The present model requires external validation before clinical prediction use. Intervention studies should then test whether frailty-informed nutritional, rehabilitation, sleep, self-care, psychological, and social-support strategies improve patient-centered and transitional-care outcomes.

Conclusions

Frailty was present in 61.2% of hospitalized adults with heart failure and involved physical, psychological, and social vulnerability. Associated factors spanned age, perceived income, lifestyle, multimorbidity, NYHA class, LVEF, nutritional risk, albumin, and sleep quality. These cross-sectional associations do not establish causality, but multidimensional screening may help identify patients requiring more intensive nursing, nutritional, functional, psychosocial, and discharge-planning support. Longitudinal and interventional research is required to establish prognostic value and determine whether frailty-informed care improves outcomes.

Abbreviations

ACEI	
angiotensin-converting enzyme inhibitor	
ADL	
activities of daily living	
aOR	
adjusted odds ratio	
ARB	
angiotensin receptor blocker	
ARNI	
angiotensin receptor-neprilysin inhibitor	

AUC
area under the receiver operating characteristic curve
BMI
body mass index
CI
confidence interval
CKD-EPI
Chronic Kidney Disease Epidemiology Collaboration
eGFR
estimated glomerular filtration rate
HF
heart failure
HFmrEF
heart failure with mildly reduced ejection fraction
HFpEF
heart failure with preserved ejection fraction
HFrEF
heart failure with reduced ejection fraction
IADL
instrumental activities of daily living
IQR
interquartile range
LVEF
left ventricular ejection fraction
MNA-SF
Mini Nutritional Assessment-Short Form
NT-proBNP
N-terminal pro-B-type natriuretic peptide
NYHA
New York Heart Association
PSQI
Pittsburgh Sleep Quality Index
SD
standard deviation
SGLT2
sodium-glucose cotransporter 2
TFI
Tilburg Frailty Indicator
VIF
variance inflation factor.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Isfahan University of Medical Sciences, Iran (IR.MUI.NUREMA.REC.1403.009), and permission was obtained from Chamran Cardiovascular Medical and Research Hospital before data collection. Written informed consent was obtained from all participants before enrolment. Participants were informed about the study objectives and procedures, the voluntary nature of participation, confidentiality protections, and their right to withdraw at any time without any effect on treatment or healthcare services.

Consent for publication

Not applicable. The manuscript does not contain identifiable individual-level information.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available because of ethical restrictions related to participant confidentiality. De-identified data may be available from the corresponding author on reasonable request and subject to approval by the relevant institutional authorities.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SD and SAR conceived and designed the study. SD, AK, and FZ contributed to data collection and study implementation. SAR and SD performed the statistical analysis and interpreted the findings. SD and SAR drafted the manuscript. AK and FZ critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work.

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Tables

Table 1
Sociodemographic characteristics and TFI Part A determinants

Variable	Total	Non-frail n = 194	Frail n = 306	P value
Age, years, mean $\pm$ SD	68.7 $\pm$ 11.1	63.8 $\pm$ 10.2	71.8 $\pm$ 10.5	< 0.001
Age group, n (%)	n = 498	n = 193	n = 305	< 0.001
< 60 years	91 (18.3)	54 (28.0)	37 (12.1)	
60–69 years	166 (33.3)	75 (38.9)	91 (29.8)	
70–79 years	160 (32.1)	51 (26.4)	109 (35.7)	
$\geq$ 80 years	81 (16.3)	13 (6.7)	68 (22.3)	
Sex, n (%)	n = 500	n = 194	n = 306	0.371
Male	276 (55.2)	112 (57.7)	164 (53.6)	
Female	224 (44.8)	82 (42.3)	142 (46.4)	
Marital status, n (%)	n = 497	n = 192	n = 305	0.004
Married/living with partner	292 (58.8)	125 (65.1)	167 (54.8)	
Widowed	131 (26.4)	42 (21.9)	89 (29.2)	
Single/divorced/separated	74 (14.9)	25 (13.0)	49 (16.1)	
Educational level, n (%)	n = 499	n = 194	n = 305	0.002
No formal/primary education	221 (44.3)	68 (35.1)	153 (50.2)	
Secondary education	177 (35.5)	72 (37.1)	105 (34.4)	
Academic education	101 (20.2)	54 (27.8)	47 (15.4)	
Perceived economic status, n (%)	n = 493	n = 190	n = 303	< 0.001
Insufficient	224 (45.4)	62 (32.6)	162 (53.5)	
Relatively sufficient	191 (38.7)	84 (44.2)	107 (35.3)	
Sufficient	78 (15.8)	44 (23.2)	34 (11.2)	
Place of residence, n (%)	n = 496	n = 193	n = 303	0.061
Urban	326 (65.7)	136 (70.5)	190 (62.7)	
Values are mean $\pm$ SD or n (%), unless otherwise indicated. Percentages use available data for each variable. P values compare non-frail and frail groups. TFI, Tilburg Frailty Indicator; SD, standard deviation.				

Variable	Total	Non-frail n = 194	Frail n = 306	P value
Rural	170 (34.3)	57 (29.5)	113 (37.3)	
Living arrangement, n (%)	n = 495	n = 192	n = 303	0.018
Living with spouse/family	391 (79.0)	162 (84.4)	229 (75.6)	
Living alone	104 (21.0)	30 (15.6)	74 (24.4)	
Lifestyle status, n (%)	n = 491	n = 190	n = 301	< 0.001
Healthy	118 (24.0)	61 (32.1)	57 (18.9)	
Intermediate	225 (45.8)	93 (48.9)	132 (43.9)	
Unhealthy	148 (30.1)	36 (18.9)	112 (37.2)	
Recent major life event, n (%)	n = 488	n = 188	n = 300	< 0.001
No	316 (64.8)	145 (77.1)	171 (57.0)	
Yes	172 (35.2)	43 (22.9)	129 (43.0)	
Dissatisfied with living environment, n (%)	n = 486	n = 187	n = 299	< 0.001
No	339 (69.8)	153 (81.8)	186 (62.2)	
Yes	147 (30.2)	34 (18.2)	113 (37.8)	
Values are mean $\pm$ SD or n (%), unless otherwise indicated. Percentages use available data for each variable. P values compare non-frail and frail groups. TFI, Tilburg Frailty Indicator; SD, standard deviation.				

Table 2
Heart failure-related clinical characteristics by frailty status

Variable	Total	Non-frail n = 194	Frail n = 306	P value
HF phenotype, n (%)	n = 496	n = 190	n = 306	0.612
HFrEF	238 (48.0)	88 (46.3)	150 (49.0)	
HFmrEF	101 (20.4)	41 (21.6)	60 (19.6)	
HFpEF	157 (31.7)	61 (32.1)	96 (31.4)	
LVEF, %, mean $\pm$ SD	41.8 $\pm$ 12.6	44.1 $\pm$ 11.9	40.3 $\pm$ 12.7	0.001
NYHA functional class, n (%)	n = 495	n = 190	n = 305	< 0.001
I-II	163 (32.9)	92 (48.4)	71 (23.3)	
III	243 (49.1)	78 (41.1)	165 (54.1)	
IV	89 (18.0)	20 (10.5)	69 (22.6)	
Duration of HF, years, median [IQR]	4.1 [1.8–7.6]	3.2 [1.1–6.1]	4.8 [2.3–8.5]	0.005
≥ 1 HF hospitalization in previous year, n (%)	n = 493	n = 190	n = 303	< 0.001
No	223 (45.2)	112 (58.9)	111 (36.6)	
Yes	270 (54.8)	78 (41.1)	192 (63.4)	
Current length of stay, days, median [IQR]	6 [4–9]	5 [3–8]	7 [4–10]	< 0.001
Charlson Comorbidity Index, median [IQR]	4 [3–6]	3 [2–5]	5 [3–6]	< 0.001
≥ 3 comorbidities, n (%)	n = 497	n = 192	n = 305	< 0.001
No	219 (44.1)	109 (56.8)	110 (36.1)	
Yes	278 (55.9)	83 (43.2)	195 (63.9)	
Hypertension, n (%)	323 (64.6)	116 (59.8)	207 (67.6)	0.079
Diabetes mellitus, n (%)	199 (39.8)	62 (32.0)	137 (44.8)	0.005

Values are mean $\pm$ SD, median [IQR], or n (%). P values compare non-frail and frail groups. ACEI/ARB/ARNI, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker/angiotensin receptor-neprilysin inhibitor; CCI, Charlson Comorbidity Index; HF, heart failure; HFmrEF, heart failure with mildly reduced ejection fraction; HFpEF, heart failure with preserved ejection fraction; HFrEF, heart failure with reduced ejection fraction; IQR, interquartile range; LVEF, left ventricular ejection fraction; MRA, mineralocorticoid receptor antagonist; NYHA, New York Heart Association; SD, standard deviation; SGLT2, sodium-glucose cotransporter 2.

Variable	Total	Non-frail n = 194	Frail n = 306	P value
HF phenotype, n (%)	n = 496	n = 190	n = 306	0.612
Coronary artery disease, n (%)	226 (45.2)	80 (41.2)	146 (47.7)	0.156
Atrial fibrillation, n (%)	151 (30.2)	47 (24.2)	104 (34.0)	0.021
Chronic kidney disease, n (%)	128 (25.6)	32 (16.5)	96 (31.4)	< 0.001
COPD, n (%)	91 (18.2)	29 (14.9)	62 (20.3)	0.134
Previous stroke/CVA, n (%)	72 (14.4)	16 (8.2)	56 (18.3)	0.002
Medication profile, n (%)				
Loop diuretics	421 (84.2)	153 (78.9)	268 (87.6)	0.010
Beta-blockers	346 (69.2)	141 (72.7)	205 (67.0)	0.182
ACEI/ARB/ARNI	296 (59.2)	125 (64.4)	171 (55.9)	0.060
MRA	273 (54.6)	109 (56.2)	164 (53.6)	0.573
SGLT2 inhibitors	174 (34.8)	78 (40.2)	96 (31.4)	0.044
Values are mean $\pm$ SD, median [IQR], or n (%). P values compare non-frail and frail groups. ACEI/ARB/ARNI, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker/angiotensin receptor-neprilysin inhibitor; CCI, Charlson Comorbidity Index; HF, heart failure; HFmrEF, heart failure with mildly reduced ejection fraction; HFpEF, heart failure with preserved ejection fraction; HFrEF, heart failure with reduced ejection fraction; IQR, interquartile range; LVEF, left ventricular ejection fraction; MRA, mineralocorticoid receptor antagonist; NYHA, New York Heart Association; SD, standard deviation; SGLT2, sodium-glucose cotransporter 2.				

Table 3
Prevalence and multidimensional profile of frailty

Variable	Total	Non-frail n = 194	Frail n = 306
TFI total score, mean $\pm$ SD	6.1 $\pm$ 2.8	3.2 $\pm$ 1.1	8.0 $\pm$ 1.9
TFI total score, median [IQR]	6 [4–8]	3 [2–4]	8 [6–9]
Frailty status, n (%)			
Non-frail, TFI < 5	194 (38.8)	194 (100.0)	—
Frail, TFI $\geq$ 5	306 (61.2)	—	306 (100.0)
Estimated frailty prevalence, % [95% CI]	61.2 [56.8–65.5]	—	—
Physical domain score, 0–8, mean $\pm$ SD	3.7 $\pm$ 2.0	2.1 $\pm$ 1.2	4.8 $\pm$ 1.7
Psychological domain score, 0–4, mean $\pm$ SD	1.6 $\pm$ 1.1	0.9 $\pm$ 0.8	2.1 $\pm$ 1.0
Social domain score, 0–3, mean $\pm$ SD	1.1 $\pm$ 0.9	0.7 $\pm$ 0.7	1.4 $\pm$ 0.9
TFI total score band, n (%)			
0–2	86 (17.2)	86 (44.3)	0 (0.0)
3–4	108 (21.6)	108 (55.7)	0 (0.0)
5–7	168 (33.6)	0 (0.0)	168 (54.9)
8–10	112 (22.4)	0 (0.0)	112 (36.6)
$\geq$ 11	26 (5.2)	0 (0.0)	26 (8.5)
At least one physical deficit, n (%)	443 (88.6)	149 (76.8)	294 (96.1)
At least one psychological deficit, n (%)	316 (63.2)	84 (43.3)	232 (75.8)
At least one social deficit, n (%)	269 (53.8)	76 (39.2)	193 (63.1)
Frailty was defined as a TFI total score $\geq$ 5. Values are mean $\pm$ SD, median [IQR], or n (%). Inferential tests were not reported for TFI-derived measures because frailty classification was determined from the TFI total score. IQR, interquartile range; SD, standard deviation; TFI, Tilburg Frailty Indicator.			

Table 4
Functional, nutritional, psychosocial, and laboratory characteristics

Variable	Total	Non-frail n = 194	Frail n = 306	P value
ADL impairment, n (%)	n = 492	n = 190	n = 302	< 0.001
No	320 (65.0)	149 (78.4)	171 (56.6)	
Yes	172 (35.0)	41 (21.6)	131 (43.4)	
IADL impairment, n (%)	n = 488	n = 189	n = 299	< 0.001
No	263 (53.9)	128 (67.7)	135 (45.2)	
Yes	225 (46.1)	61 (32.3)	164 (54.8)	
Low self-care ability, n (%)	n = 486	n = 188	n = 298	< 0.001
No	269 (55.3)	137 (72.9)	132 (44.3)	
Yes	217 (44.7)	51 (27.1)	166 (55.7)	
MNA-SF-based nutritional risk, n (%)	n = 491	n = 188	n = 303	< 0.001
No	273 (55.6)	139 (73.9)	134 (44.2)	
Yes	218 (44.4)	49 (26.1)	169 (55.8)	
BMI, kg/m ² , mean $\pm$ SD	26.6 $\pm$ 4.7	27.2 $\pm$ 4.3	26.2 $\pm$ 4.9	0.024
Albumin, g/L, mean $\pm$ SD	36.8 $\pm$ 4.6	39.0 $\pm$ 4.2	35.5 $\pm$ 4.3	< 0.001
Hemoglobin, g/dL, mean $\pm$ SD	12.3 $\pm$ 1.9	12.9 $\pm$ 1.7	12.0 $\pm$ 1.9	< 0.001
eGFR, mL/min/1.73m ² , median [IQR]	58 [39–77]	66 [48–84]	53 [34–71]	< 0.001
NT-proBNP, pg/mL, median [IQR]	3350 [1480–7050]	2180 [960–5140]	4210 [1930–8310]	< 0.001
Poor sleep quality, n (%)	n = 489	n = 188	n = 301	< 0.001
No	221 (45.2)	120 (63.8)	101 (33.6)	
Yes	268 (54.8)	68 (36.2)	200 (66.4)	
Values are mean $\pm$ SD, median [IQR], or n (%). Nutritional risk was defined as MNA-SF $\leq$ 11. P values compare non-frail and frail groups. ADL, activities of daily living; eGFR, estimated glomerular filtration rate; HADS, Hospital Anxiety and Depression Scale; IADL, instrumental activities of daily living; IQR, interquartile range; MNA-SF, Mini Nutritional Assessment-Short Form; MSPSS, Multidimensional Scale of Perceived Social Support; NT-proBNP, N-terminal pro-B-type natriuretic peptide; PSQI, Pittsburgh Sleep Quality Index; SD, standard deviation.				

Variable	Total	Non-frail n = 194	Frail n = 306	P value
ADL impairment, n (%)	n = 492	n = 190	n = 302	< 0.001
Depressive symptoms, n (%)	n = 490	n = 188	n = 302	< 0.001
No	293 (59.8)	141 (75.0)	152 (50.3)	
Yes	197 (40.2)	47 (25.0)	150 (49.7)	
Anxiety symptoms, n (%)	n = 490	n = 188	n = 302	< 0.001
No	259 (52.9)	122 (64.9)	137 (45.4)	
Yes	231 (47.1)	66 (35.1)	165 (54.6)	
Low social support, independent scale, n (%)	n = 487	n = 187	n = 300	0.004
No	323 (66.3)	139 (74.3)	184 (61.3)	
Yes	164 (33.7)	48 (25.7)	116 (38.7)	
Values are mean $\pm$ SD, median [IQR], or n (%). Nutritional risk was defined as MNA-SF $\leq$ 11. P values compare non-frail and frail groups. ADL, activities of daily living; eGFR, estimated glomerular filtration rate; HADS, Hospital Anxiety and Depression Scale; IADL, instrumental activities of daily living; IQR, interquartile range; MNA-SF, Mini Nutritional Assessment-Short Form; MSPSS, Multidimensional Scale of Perceived Social Support; NT-proBNP, N-terminal pro-B-type natriuretic peptide; PSQI, Pittsburgh Sleep Quality Index; SD, standard deviation.				

Table 5
Multivariable factors associated with prevalent frailty

Predictor	β	SE	Adjusted odds ratio	95% CI	P value
Age, per 1-year increase	0.052	0.013	1.05	1.03–1.08	< 0.001
Female sex	0.199	0.216	1.22	0.80–1.87	0.352
Low education	0.392	0.227	1.48	0.95–2.31	0.083
Insufficient perceived income	0.476	0.229	1.61	1.03–2.53	0.037
Living alone	0.246	0.287	1.28	0.73–2.24	0.386
Recent major life event	0.445	0.234	1.56	0.99–2.47	0.056
Unhealthy lifestyle	0.637	0.266	1.89	1.12–3.18	0.017
≥ 3 comorbidities	0.554	0.238	1.74	1.09–2.78	0.021
NYHA class III-IV	0.900	0.252	2.46	1.50–4.03	< 0.001
LVEF, per 5% increase	-0.105	0.053	0.90	0.81–1.00	0.048
Albumin, per 1 g/L increase	-0.083	0.027	0.92	0.87–0.97	0.002
ln NT-proBNP	0.329	0.180	1.39	0.98–1.98	0.066
MNA-SF-based nutritional risk	0.751	0.247	2.12	1.31–3.45	0.002
Poor sleep quality	0.512	0.245	1.67	1.03–2.69	0.038
Dependent variable: frailty status based on the TFI (non-frail = 0; frail = 1). Reference categories were male sex, secondary/academic education, relatively sufficient/sufficient income, healthy/intermediate lifestyle, fewer than three comorbidities, NYHA class I-II, no nutritional risk, and good sleep quality. The model used 461 complete cases, including 281 frail participants. Hosmer-Lemeshow P = 0.418; Nagelkerke R² = 0.39; AUC = 0.81 (95% CI, 0.77–0.85); overall classification accuracy = 74.6%. Because the outcome was common and the design was cross-sectional, odds ratios describe odds of prevalent frailty and should not be interpreted as prevalence ratios or future risks. aOR, adjusted odds ratio; CI, confidence interval; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; SE, standard error; TFI, Tilburg Frailty Indicator.					