Association between Hospital Frailty Risk Score and length of hospital stay, hospital mortality, and hospital costs for all adults in England: a nationally representative, retrospective, observational cohort study

Andrew Street, Laia Maynou, Joanna M Blodgett, Simon Conroy

Summary

Background Studies have shown that the Hospital Frailty Risk Score (HFRS) is significantly associated with length of stay, in-hospital mortality, and costs in people aged 75 years and older. However, its applicability to hospitalised adults of all ages is unclear. We aimed to examine the association between the HFRS and these three outcomes in a nationally representative sample of adults aged 18 years and older, admitted for emergency hospital care.

Methods The analytical sample comprised 1 478 554 emergency hospital admissions for 653 294 patients—a 5% random sample of all emergency admissions for those aged 18 years and older to any English National Health Service acute hospital between April 1, 2011, and March 31, 2019. Admissions were categorised into zero (HFRS=0), low (0< HFRS <5), intermediate (5≤ HFRS ≤15), or high (HFRS >15) frailty risk categories. We analysed the association between these categories and three outcomes: length of stay (Poisson model), in-hospital death (probit model); and hospital costs (generalised linear model). Models controlled for patient characteristics and temporal effects and were run separately across nine age groups (18–24 years, 25–34 years, 35–44 years, 45–54 years, 55–64 years, 65–74 years, 75–84 years, 85–94 years, and ≥95 years).

Findings The prevalence of high frailty risk increased with age, from 210 (0·2%) of 96 296 admissions for those aged 18–24 years to 9414 (42·0%) of 22 431 admissions for those aged 95 years and older. There were significant associations between frailty risk and both length of stay and costs across all age groups; the magnitude of the associations increased with age. For example, for those aged 18–24 years with high frailty risk, length of stay was 4·5 days (95% CI 3·8–5·3) longer and costs were £1217 higher (796–1638) than for someone with a zero frailty risk. For those aged 95 years and older with high frailty risk, length of stay was 15·3 days (13·5–17·1) longer and costs were £2557 higher (2234–2880) than for someone with a zero frailty risk. The association between frailty risk and in-hospital mortality increased up to age 65–74 years—those in this age group with high frailty risk had a probability of dying in hospital that was 2·3% greater (1·99–2·61) than those with zero frailty risk. This association decreased for older age groups.

Interpretation Although designed for people aged 75 years and older, the HFRS was significantly associated with length of stay, in-hospital death, and hospital costs for all adults admitted to hospital, with a greater magnitude of effect with increasing age. Frailty dashboards that use the HFRS for older people could be extended to all people aged 18 years and older, offering the potential for holistic, frailty attuned interventions for younger people, such as earlier life course interventions to delay or prevent frailty and related outcomes.

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Introduction

Frailty is defined as a physiological syndrome characterised by decreased reserve and diminished resistance to stressors, resulting from cumulative decline across multiple physiological systems, and causing susceptibility to adverse outcomes.[1]

In older people, frailty is an established concept that supports clinical decision making and care delivery.[2,3] The clinical utility of frailty measurement can be conceptualised at the micro, meso, and macro levels of health care. At the micro level (individual clinician–patient interaction), frailty identifies the presence of complexity and the need for more person-centred, holistic assessment, as well as sensitising the clinician to the possible treatment framework (restorative *vs* palliative). At the meso (hospital) level, frailty measurement can be used to assess patient flows, mapped against service provision—for example, identifying areas in a hospital where there are high proportions of people with frailty, but a paucity of holistic care provision. At the macro level, frailty measurement could be used to inform system

Research in context

Evidence before this study
We searched MEDLINE from Jan 1, 2021, to March 31, 2024, for studies published in English, using the following search terms: (Frailty/) AND ("Sensitivity and Specificity"/ OR "Predictive Value of Tests"/ OR ROC Curve/ OR "Diagnostic Techniques and Procedures"/ OR exp Physical Examination/ OR Symptom Assessment/ OR Psychometrics/ OR Prevalence/) AND (adult/ or middle aged/ or young adult/ NOT exp Aged/). Frailty is an established concept in the care of older people and has been shown to be a powerful marker of the risk of adverse outcomes in diverse populations of older people in a range of settings. The Hospital Frailty Risk Score (HFRS) permits an estimation of frailty risk using routinely collected data and has been shown to identify the risk of length of hospital stay, costs, and mortality in older people with various clinical conditions.

Added value of this study
Using a nationally representative sample of emergency hospital admissions, we showed that the HFRS was significantly associated with longer length of hospital stay, greater probability of dying in hospital, and higher costs across all adult age groups, not just those aged 50 years and over.

Implications of all the available evidence
The HFRS can be used on routinely collected data in people aged 18 years and older to estimate the risk of long hospital stays, high hospital costs, and death. The use of HFRS could permit hospitals and health-care systems to efficiently identify individuals or clusters of patients who might benefit from special attention to mitigate the risk of these adverse hospital outcomes.

design (eg, by creating frailty registries to support case management) and potentially act as a case-mix adjuster to inform commissioning decisions.

Broadly speaking, there are two key approaches to measuring frailty. The phenotypic approach uses physical signs, such as weight loss, exhaustion, low physical activity, slow walking speed, and weak grip strength, to grade degrees of frailty.[4] Although widely used in older people, this approach has little validity in younger people, with these signs being less prevalent and insufficiently sensitive to identify clinically relevant variability.[5–7] By contrast, the deficit accumulation approach measures frailty by assessing the cumulative number of health deficits an individual has acquired over their life course, such as physical impairments and cognitive decline.[8–10] Scores are attached to each deficit and aggregated to construct a frailty index, with higher values indicating greater frailty. This approach usually draws upon secondary data, allowing general application across the life course and different populations. The Hospital Frailty Risk Score (HFRS) aligns with the deficit accumulation approach[11] and combines a weighted set of 109 three-character ICD-10 diagnostic codes recorded in routine hospital datasets to generate a frailty risk score for people admitted to hospital.

There is some evidence that frailty might have a role as a risk factor for adverse outcomes in younger people, primarily those aged 50 years and older.[12–15] However, there is also evidence of frailty being associated with adverse outcomes in children with heart conditions and hospitalised adults aged 30–50 years, and an association was found in a cohort study of participants with a mean age of around 40 years.[8,16] Two studies have examined frailty using the HFRS in hospitalised people aged 16 years and older—a single-centre study with around 750 000 participants[17] and a multicentre study with just under 1000 participants.[18]

See Online for appendix

We aimed to examine the association between the HFRS and three outcomes—length of hospital stay, in-hospital mortality, and hospital costs—in a nationally representative sample of adults aged 18 years and older, admitted for emergency hospital care.

Methods

Study design and participants
We extracted from the Hospital Episode Statistics (HES) a 5% random sample of all 15 770 456 adult patients admitted as an emergency to English hospitals between April 1, 2011 and March 31, 2019 (figure 1). Patients were included if they had an emergency hospital admission during this period and were aged 18 years or older and otherwise were excluded. The first 2 years of data were used solely to construct the HFRS to ensure consistent construction using a full 2 years' worth of historical data for all patients.[19] Thus, the analytical sample comprised 653 294 patients admitted to hospital between April 1, 2013, and March 31, 2019. With many patients being admitted more than once, 1 478 554 emergency admissions were yielded in total. People aged 75–84 years formed the largest age group, comprising 111 860 patients who had 281 955 emergency admissions. Those aged 95 years and older formed the smallest group, comprising 9729 patients who had 22 431 emergency admissions.

Costs were missing for 27 761 (1·9%) of 1 478 554 observations, as documented in the appendix (p 6). Other missing values are shown in the appendix (p 6). The index of multiple deprivation was missing for 19 932 (1·3%) of 1 478 554 observations because either the patient did not have an English postcode or the postcode was not recorded. The HFRS could not be constructed for 28 observations because of missing diagnostic information and sex was not recorded for 110 observations.

Data on race and ethnicity were not analysed due to a high degree of missingness in the dataset and high levels of inaccuracy when coded.

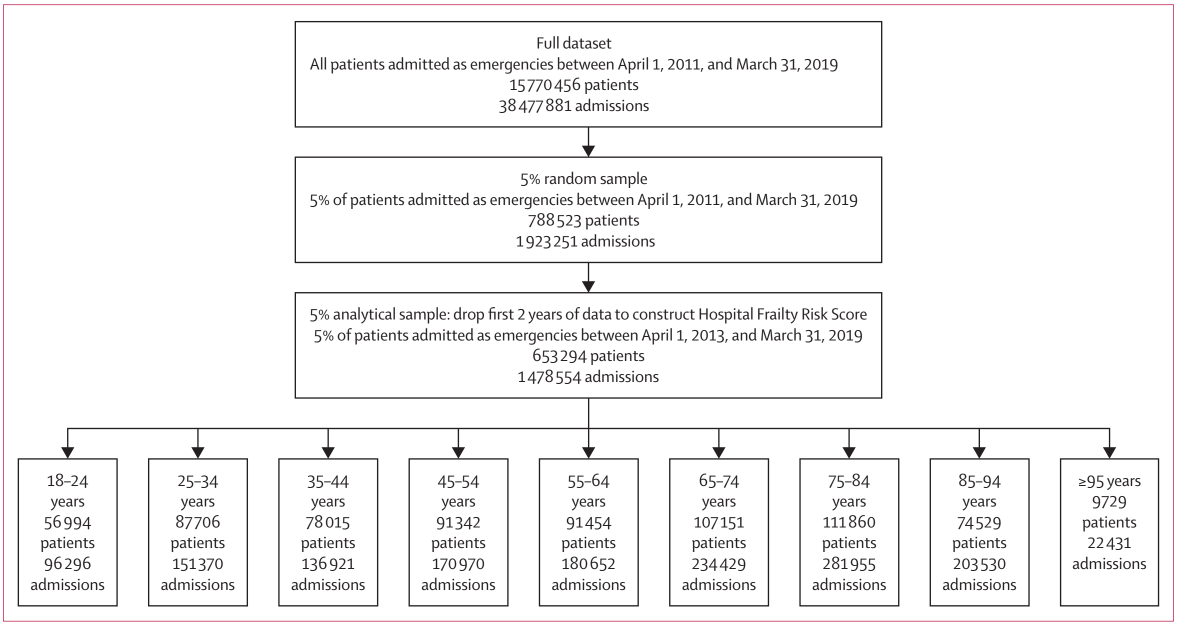

Figure 1: **Sample selection**

The London School of Economics and Political Science granted ethics approval for the study (reference 152005).

Exposure

The HFRS was developed for patients aged 75 years and older.[11] The score is calculated by combining a weighted set of 109 three-character ICD-10 diagnostic codes recorded in the medical record during the current admission and the two most recent emergency admissions occurring in the past 2 years.[19] The HFRS ranges between 0 (zero frailty risk) and 173·2.

Commonly, patients have been categorised as having low (HFRS <5), intermediate (5≤ HFRS ≤15), or high (HFRS >15) frailty risk.[11] However, among adults younger than 75 years, a large proportion of patients have an HFRS of zero. Hence for the main analyses in this study, we categorised patients into four groups: zero risk (HFRS=0), lower risk (0< HFRS <5), intermediate risk (5≤ HFRS ≤15), or high risk (HFRS >15). A supplementary set of analyses applied the three more common categories.

Outcomes

We constructed three outcome variables for each patient (appendix p 2). Length of stay was calculated as the difference between the patient's discharge and admission dates. We determined whether the patient died in hospital using the discharge method variable, which records the circumstances under which a patient left hospital. We calculated the cost of each patient's hospital stay according to the Healthcare Resource Group to which they were assigned (appendix pp 6–7).

Covariates

Our analyses controlled for various covariates, specified in more detail in the appendix (p 3). The covariates were sex; the socioeconomic conditions of where patients lived; the Charlson comorbidity index; number of operation codes; number of emergency admissions in the past year; and presence of ambulatory care sensitive conditions. To capture temporal effects, we accounted for day, month, and year of hospital admission and whether the patient was admitted on a public holiday. In the analysis of length of stay, we controlled for whether the patient died in hospital and, in the analysis of in-hospital mortality, we controlled for length of stay.

Statistical analysis

We used Poisson models to analyse length of stay; probit models to analyse the probability of in-hospital death; and generalised linear models with a gamma log link to analyse costs. These regression models were run separately for each of nine age groups (18–24 years; 25–34 years; 35–44 years; 45–54 years; 55–64 years; 65–74 years; 75–84 years; 85–94 years; and ≥95 years). The models took the general form:

$$y_i = \propto + \delta_L HFRS_i^L + \delta_I HFRS_i^I + \delta_H HFRS_i^H + \sum_{m=1}^{M} \beta_m \boldsymbol{X}_{mi} + \sum_{t=1}^{T} \lambda_t \boldsymbol{V}_{ti} + \varepsilon_i$$

where $y_i = (LoS_i,\ M_i,\ c_i)$ indicates one of the three outcomes: length of stay, LoS_i, in-hospital death, M_i, or hospital costs, c_i, with patient admissions indexed as $i = 1...I$. The dummy variables:

$$HFRS_i^L,\ HFRS_i^I \text{ and } HFRS_i^H$$

indicate whether the patient was categorised respectively as having low, intermediate, or high frailty risk, with those having zero frailty risk forming the reference category. The patient covariates appear as vector **X**, with temporal effects captured by vector **V** (the estimates λ_t are not reported in the tables). ε_i is a classic error term. SEs are clustered at the patient level, recognising that patients might have been admitted more than once during the study period.

Our interest was in the regression coefficients for δ_L, δ_I, and δ_H and how these estimates varied across age groups. If the estimates were positive and statistically significant, then those with low, intermediate, and high frailty risk would have had longer length of stay, greater likelihood of in-hospital death, and higher costs than patients assessed as having zero frailty risk. Coefficients are reported as average marginal effects, with length of stay reported in days, in-hospital death in percentage points, and costs in pounds sterling.

We did three sensitivity analyses. First, we analysed the probability of having a length of stay of more than 10 days, as featured in Gilbert and colleagues.[11] Second, we applied a Cox proportional hazards model to analyse in-hospital mortality. Third, we used three HFRS categories, combining those with zero (HFRS=0) and low (0< HFRS <5) risk scores, consistent with the original categorisation.[11] We also did subgroup analyses for people with diagnoses of obesity, hypertension, substance misuse, anxiety, depression, and psychosis.

Statistical analysis was done using Stata 15.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Mean length of stay increased monotonically across age groups, from 2·69 days (SD 15·01) for those aged 18–24 years to 9·93 days (13·86) for those aged 95 years and older (table). Similarly, in-hospital mortality increased with age. 101 (0·1%; SD 3·24) of 96 296 patients aged 18–24 years died in hospital, increasing to 7468 (5·3%; 22·45) of 22 431 patients aged 95 years and older. Mean costs increased from £1382 (SD 3464) for those aged 18–24 years to £2821 (2910) for those aged 95 years and older.

Noting that the HFRS could not be constructed for 28 observations, we recorded how the 1 478 526 emergency admissions were distributed across each of the four HFRS categories and age groups (figure 2). Briefly, as age rises, frailty risk increases. At one extreme, of the 96 296 admissions for those aged 18–24 years, only 210 (0·2%) were classified in the high frailty risk category. At the other extreme, of the 22 431 admissions for those aged 95 years and older, 9414 (42·0%) were categorised in the high frailty risk category.

The value of the HFRS for each patient's admission is driven by whether they have one of the 109 ICD three-digit codes and the HFRS weight attached to that code, with these weights ranging from 0·1 to 7·0 (eg, F00 Dementia in Alzheimer's disease). The presence of these diagnoses varies across age groups, as illustrated for the 30 ICD-10 codes with an HFRS weight greater than 2·0 (figure 3). The distribution of most ICD-10 codes is skewed towards those in older age bands (eg, R29 Tendency to fall; N39 Other disorders of urinary system; W19 Unspecified fall) but for some ICD-10 codes, the skew is less pronounced or absent (eg, I69 Sequelae of cerebrovascular disease; S00 Superficial injury of head; R31 Unspecified haematuria; R56 Convulsions).

Across all age groups, the HFRS categories had a significant association with length of stay, even for those in the 18–24 years group (figure 4A). Compared with someone with a zero HFRS aged 18–24 years, length of stay was 1·3 days (95% CI 1·1–1·6), 2·3 days (1·9–2·6), and 4·5 days (3·8–5·3) longer for someone in the low, intermediate, and high HFRS categories, respectively. The magnitude of these effects became larger for older age groups. For example, for those aged 95 years and older, compared with someone with a zero HFRS, length of stay was 5·2 days (3·4–7·1), 10·7 days (8·9–12·5), and 15·3 days (13·5–17·1) longer for someone in the low, intermediate, and high HFRS categories, respectively.

Compared with those with zero frailty risk, HFRS categories had significant associations with in-hospital death in all age groups, except for those aged 95 years and older (figure 4B). The associations grew in magnitude up to age 65–74 years but lessened thereafter. For example, for those aged 18–24 years, compared with someone with a zero HFRS, the probability of in-hospital death was 0·1% (95% CI 0·02–0·13) greater for those in the low HFRS category, 0·3% (0·18–0·34) greater for those in the intermediate category, and 0·3% (0·16–0·48) greater for those in the high category. For those aged 65–74 years, the probability of dying in hospital was 0·8% (0·53–1·02), 2·1% (1·84–2·36), and 2·3% (1·99–2·61) greater, respectively, for those with low, intermediate, and high frailty risk than for those with zero risk. For those aged 95 years and older, there was no significant association between HFRS category and in-hospital mortality; of note, most people in this group (18 801 [83·8%] of 22 431) were in the intermediate and high HFRS categories with only 441 (2·0%) in the referent zero frailty group.

All three HFRS categories are associated with significantly higher hospital costs across all age groups (figure 4C). Compared with someone with a zero HFRS, for those aged 18–24 years costs were £94 (95% CI 38–149), £372 (257–487), and £1217 (796–1638) higher, respectively,

	18–24 years (n=96 296)	25–34 years (n=151 370)	35–44 years (n=136 921)	45–54 years (n=170 970)	55–64 years (n=180 652)	65–74 years (n=234 429)	75–84 years (n=281 955)	85–94 years (n=203 530)	≥95 years (n=22 431)
Outcomes									
Length of stay, days	2·69 (15·01)	2·93 (15·98)	3·51 (14·58)	4·23 (14·85)	5·25 (14·92)	6·56 (14·66)	8·22 (14·45)	9·87 (14·58)	9·93 (13·86)
Mortality	0·1% (3·24)	0·1% (3·46)	0·3% (5·60)	0·6% (7·81)	1·2% (10·80)	1·9% (13·60)	2·6% (15·80)	3·7% (18·80)	5·3% (22·45)
Costs, £	1381·51 (3463·96)	1395·38 (3218·97)	1557·06 (3448·77)	1775·91 (3435·67)	2099·48 (3369·78)	2383·29 (3326·92)	2646·2 (3081·50)	2852·15 (3007·26)	2821·28 (2910·45)
Long length of stay (>10 days)	3·65% (18·75)	4·40% (20·50)	6·10% (23·94)	8·38% (27·71)	11·71% (32·15)	16·37% (37·00)	23·07% (42·13)	30·08% (45·86)	31·39% (46·41)
Exposure Hospital Frailty Risk Score									
Zero	41·62% (49·29)	41·76% (49·32)	34·43% (47·52)	27·87% (44·84)	22·91% (42·03)	16·74% (37·33)	8·95% (28·54)	3·74% (18·97)	1·97% (13·88)
Low	50·21% (50·00)	48·39% (49·97)	51·10% (49·99)	51·47% (49·98)	48·64% (49·98)	43·42% (49·56)	32·93% (46·99)	20·63% (40·47)	14·22% (34·92)
Intermediate	7·95% (27·05)	9·40% (29·19)	13·35% (34·01)	18·24% (38·61)	23·58% (42·45)	30·09% (45·86)	37·44% (48·40)	41·02% (49·19)	41·85% (49·33)
High	0·22% (4·66)	0·45% (6·69)	1·12% (10·52)	2·42% (15·37)	4·87% (21·53)	9·76% (29·67)	20·69% (40·51)	34·61% (47·57)	41·97% (49·35)
Covariates									
Female sex	62·65% (48·37)	61·82% (48·58)	53·93% (49·85)	49·84% (50·00)	46·32% (49·86)	46·70% (49·89)	51·44% (49·98)	60·76% (48·83)	73·23% (44·28)
Age, years	21·15 (1·97)	29·44 (2·86)	39·52 (2·92)	49·65 (2·85)	59·56 (2·89)	69·70 (2·83)	79·61 (2·83)	88·63 (2·70)	96·95 (2·64)
Charlson comorbidity index									
0	82·71% (37·82)	81·07% (39·18)	71·07% (45·34)	55·87% (49·65)	40·04% (49·00)	28·77% (45·27)	22·42% (41·70)	21·51% (41·09)	26·02% (43·8%)
1	14·83% (35·54)	14·25% (34·96)	19·06% (39·28)	23·81% (42·59)	26·82% (44·30)	27·09% (44·44)	26·31% (44·03)	27·34% (44·57)	28·25% (45·02)
2	1·84% (13·44)	2·90% (16·77)	5·52% (22·84)	10·02% (30·03)	14·57% (35·28)	17·74% (38·20)	19·84% (39·88)	20·17% (40·13)	19·79% (39·85)
≥3	0·62% (7·87)	1·78% (13·23)	4·34% (20·39)	10·30% (30·40)	18·56% (38·88)	26·39% (44·08)	31·43% (46·42)	30·98% (46·24)	25·93% (43·83)
Ambulatory care sensitive conditions	11·25% (31·60)	9·79% (29·72)	11·39% (31·77)	14·39% (35·10)	18·20% (38·59)	20·38% (40·28)	20·28% (40·21)	18·32% (38·69)	17·02% (37·58)
Index of multiple deprivation									
1 (most deprived)	16·96% (37·57)	17·84% (38·28)	17·18% (37·72)	15·77% (36·44)	14·24% (34·95)	11·28% (31·63)	10·06% (30·07)	7·98% (27·10)	7·43% (26·23%)
2	14·00% (34·70)	15·12% (35·82)	13·84% (34·54)	13·36% (34·02)	12·14% (32·66)	10·49% (30·65)	9·54% (29·37)	8·67% (28·14)	8·37% (27·70)
3	12·32% (32·86)	12·95% (33·58)	12·15% (32·68)	11·60% (32·03)	11·13% (31·44)	10·21% (30·28)	9·92% (29·89)	9·69% (29·58)	9·25% (28·97)
4	11·06% (31·36)	11·05% (31·36)	11·09% (31·40)	10·83% (31·08)	10·19% (30·25)	10·22% (30·30)	9·96% (29·95)	9·92% (29·89)	10·11% (30·14)
5	9·40% (29·19)	9·53% (29·37)	9·33% (29·08)	9·60% (29·46)	10·00% (30·00)	10·15% (30·20)	10·38% (30·50)	10·57% (30·75)	10·91% (31·18)
6	8·41% (27·76)	8·39% (27·72)	8·31% (27·61)	8·89% (28·46)	9·32% (29·07)	10·33% (30·43)	10·49% (30·65)	10·93% (31·20)	11·29% (31·64)
7	7·48% (26·31)	7·10% (25·68)	7·47% (26·28)	8·06% (27·22)	9·22% (28·94)	10·03% (30·04)	10·18% (30·24)	10·79% (31·03)	11·30% (31·67)
8	7·09% (25·66)	6·53% (24·70)	7·43% (26·23)	7·73% (26·71)	8·54% (27·95)	9·82% (29·75)	10·28% (30·38)	10·88% (31·14)	11·07% (31·38)
9	6·96% (25·45)	6·28% (24·26)	6·93% (25·40)	7·48% (26·31)	8·10% (27·29)	9·35% (29·11)	9·95% (29·93)	10·78% (31·01)	10·18% (30·24)
10 (least deprived)	6·31% (24·32)	5·21% (22·22)	6·25% (24·21)	6·67% (24·95)	7·12% (25·72)	8·13% (27·33)	9·25% (28·97)	9·79% (29·72)	10·09% (30·12)
Number of hospital admissions in the past year									
0	65·89% (47·41)	64·86% (47·74)	63·35% (48·18)	60·26% (48·94)	57·38% (49·45)	52·97% (49·91)	47·36% (49·93)	42·92% (49·50)	42·71% (49·47)
1	16·83% (37·42)	17·36% (37·88)	17·46% (37·96)	18·14% (38·53)	19·53% (39·64)	21·25% (40·91)	23·71% (42·53)	25·87% (43·79)	26·40% (44·08)
2	6·60% (24·82)	6·84% (25·24)	7·16% (25·78)	7·94% (27·03)	9·11% (28·77)	10·47% (30·61)	12·44% (33·01)	14·08% (34·78)	14·60% (35·31)
≥3	10·69% (30·89)	10·94% (31·22)	12·03% (32·53)	13·66% (34·35)	13·98% (34·68)	15·32% (36·01)	16·49% (37·11)	17·14% (37·68)	16·30% (36·94)
Number of operation codes in patient record	1·15 (2·24)	1·34 (2·37)	1·58 (2·63)	1·81 (2·87)	2·00 (3·05)	2·05 (3·08)	1·91 (2·88)	1·67 (2·52)	1·31 (2·08)

Data are mean (SD). Absolute numbers of patients are shown in the appendix (p 4).

***Table:* Descriptive statistics**

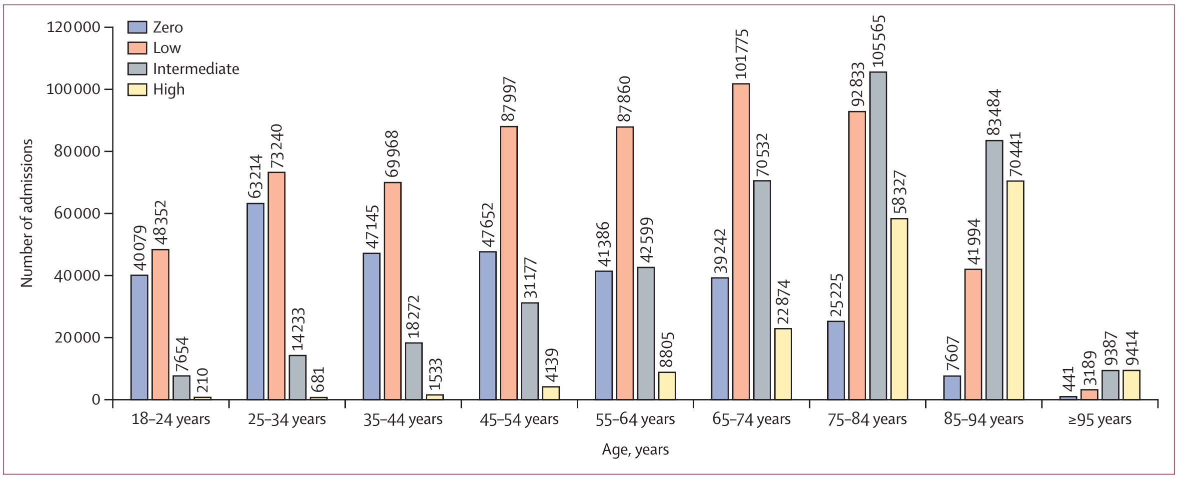

Figure 2: **Distribution of Hospital Frailty Risk Score by age group (total sample 1 478 526 people; diagnostic codes were missing for 28 observations)**

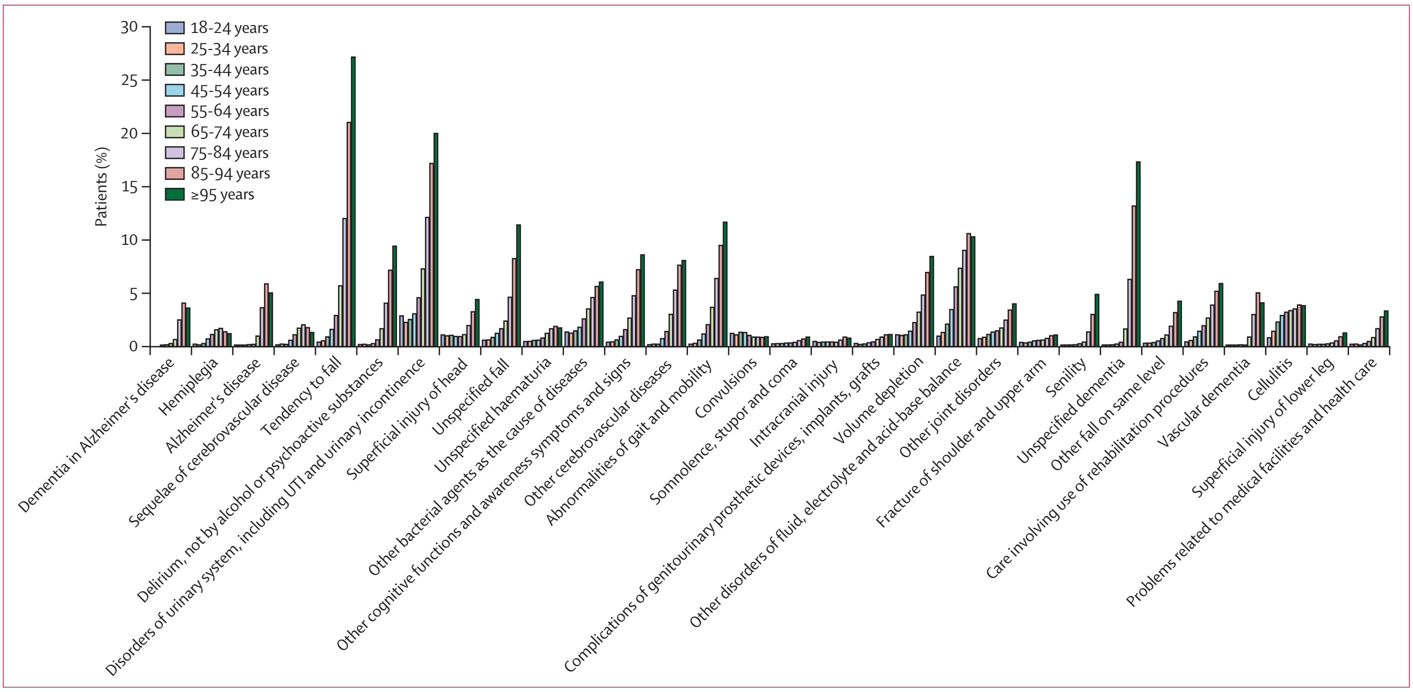

Figure 3: **Distribution of ICD-10 codes with Hospital Frailty Risk Score weight greater than 2·0, by age group**
UTI=urinary tract infection.

for someone in the low, intermediate, and high HFRS categories. Costs rise progressively across age groups. For those aged 95 years and older, compared with someone with a zero HFRS, costs were £796 (465–1127), £1758 (1439–2077), and £2557 (2234–2880) higher, respectively, for someone in the low, intermediate, and high HFRS categories.

The HFRS categories were all significantly associated with long length of stay (>10 days) and the magnitude of these effects became larger for older age groups (appendix pp 12–14). Compared with someone with a zero HFRS, for someone aged 18–24 years in the high HFRS category the probability of a long length of stay was 8·5% (95% CI 7·4–9·6) higher and for someone aged 95 years or older with high frailty risk the probability was 50% (41·8–58·4) higher.

When applying the Cox proportional hazards model for the analysis of in-hospital mortality, we found large hazard ratios, particularly in younger age groups, indicating that frail individuals are more likely to die earlier than non-frail individuals (appendix pp 15–18).

We report results of combining the zero and lower frailty risk categories into a single low frailty risk category (appendix pp 19–23), as used by Gilbert and colleagues.[11] Combining the zero and lower categories reduced the size of the estimated effects associated with the intermediate and high frailty risk categories but they remained significant for all three outcomes and across all age groups (with the exception of intermediate frailty risk and in-hospital mortality for those aged ≥95 years).

In subgroup analyses, except for those diagnosed with psychosis, the HFRS categories were all significantly associated with longer length of stay, higher costs, and higher probability of in-hospital death (appendix pp 24–32).

Discussion

We showed that the HFRS was able to identify adults as young as 18 years who were at risk of clinically and economically important longer length of stay, dying in hospital, and higher costs. There were statistically significant associations between increased frailty risk and these outcomes in all age groups (except for in-hospital mortality for those aged ≥95 years). In all age groups, those with high frailty risk had a longer length of hospital stay and higher costs than someone with zero frailty risk and the magnitude of these differences increased progressively as age increased. The magnitude of the association between frailty risk and in-hospital mortality increased up to age 65–74 years and decreased thereafter. These findings are promising for future application of frailty risk constructed using routine hospital data to help identify those at increased risk of long hospital stays, in-hospital mortality, and high hospital costs.

For these analyses, we used four rather than the usual three HFRS categories, and those with an HFRS score of zero formed the reference group. Across all age bands, length of stay and costs for patients in each of the four categories were significantly different to length of stay and costs for patients in the other categories. However, the probability of in-hospital mortality was not significantly different for those in the intermediate and high frailty risk categories. The greater ability of the HFRS to discriminate for length of stay and costs is likely related to the use of ICD-10 codes, which capture syndromes such as delirium, immobility, and falls, which are stronger predictors of longer hospital stays (and hence costs) than of death.

Multiple studies have shown that the HFRS predicts adverse outcomes in a range of different hospital populations of patients aged 75 years and older.[20] Unlike most other frailty measures, the HFRS has the advantage that it can be used to measure risk across the entire population of adults admitted to hospital, given its use of the 109 ICD-10 codes that capture a wide array of health domains. Therefore, whether the HFRS should be used routinely as an automated risk score is an important question. Implementation of the HFRS into hospital systems permits low-cost identification of cohorts of people likely to stay in hospital for longer, who are at risk of in-hospital death, and who are likely to incur high costs.

With the growing use of electronic health records globally, it would be relatively straightforward to automate generic risk assessments, for example combining the HFRS with physiological measurements, such as the UK National Health Service Early Warning Score,[21] and

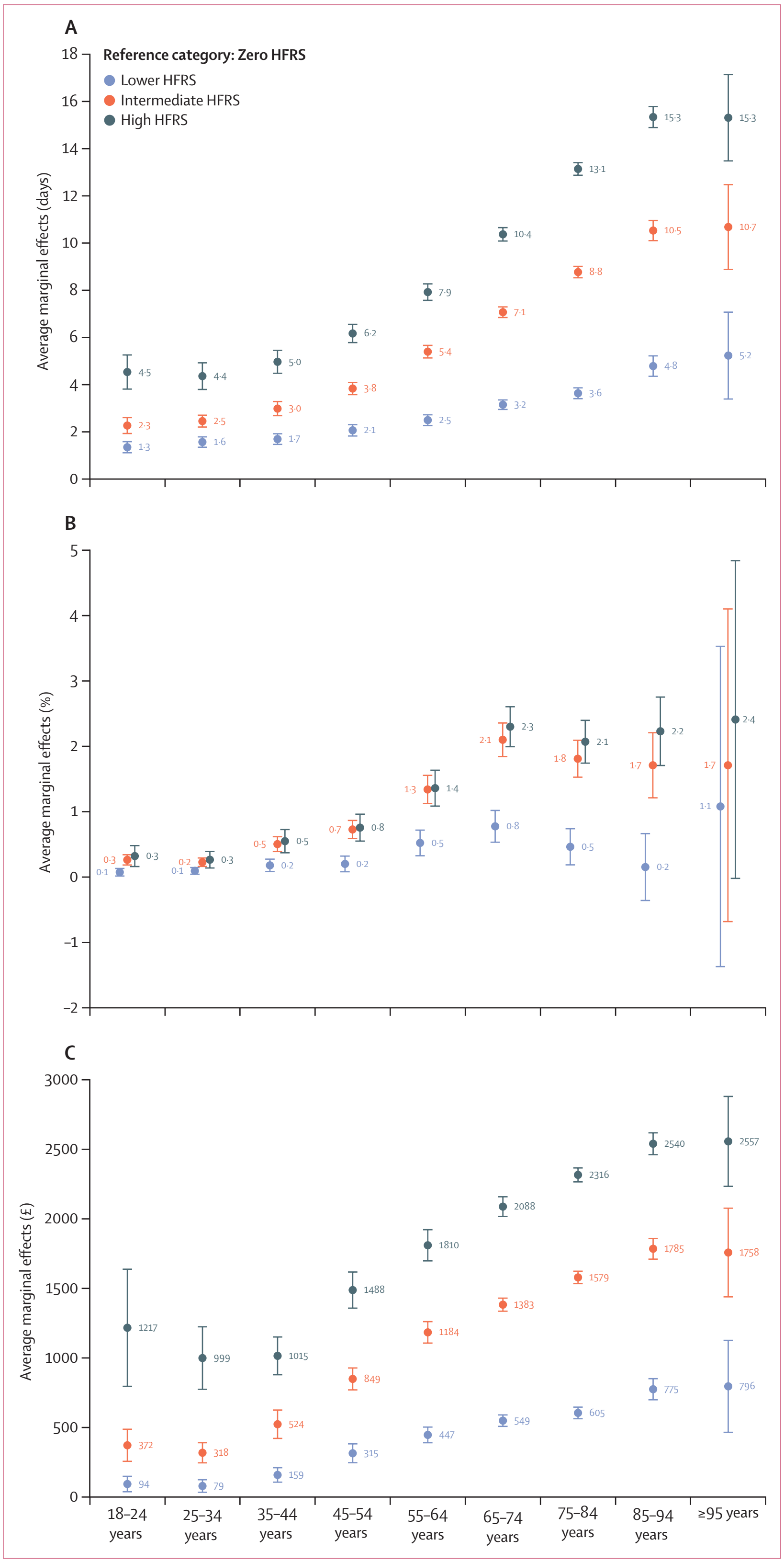

***Figure 4:* Model estimates for HFRS categories**

(A) Length of stay. (B) In-hospital mortality. (C) Costs. Error bars show 95% CIs. HFRS=Hospital Frailty Risk Score.

highlight to clinical teams those people who require special attention to mitigate the risk of adverse outcomes. People at risk would need a detailed holistic assessment, akin to the Comprehensive Geriatric Assessment,[22] after which interventions can be tailored to the individual. Such approaches have been suggested using multimorbidity-based clusters,[23] but the advantage of frailty-based risk assessments is that they are more holistic, taking account of wider elements of risk that are common in populations who are hospitalised, such as falls or reduced mobility.[24] The aim of such an approach would be to make evidence-based practice accessible, quick, and easy to apply in real-life settings. Use of routine administrative hospital data, made available in an accessible and actionable fashion, could markedly reduce the amount of effort currently directed at risk assessments and free up time for direct clinical care.[25]

Our study has various strengths. First, the analyses were applied to a large 5% random sample of the entire population of adult patients who had an emergency admission to hospital in England in the 7-year period up to March 31, 2019. Second, we calculated the HFRS in an optimal and consistent fashion for all observations, with 2 years' worth of data used solely for the purpose of constructing the HFRS but not included in the analyses.[19] Third, we were able to examine the validity of the HFRS at different stages of the adult life course, with separate sets of analyses done for each of nine age groups. Fourth, we used routinely collected administrative data, allowing us to control for a large set of covariates that, if not included in our analyses, might have led to overestimation of the association between the HFRS categories and the outcomes of interest.

However, there are also limitations to our study. A 100% sample would have been preferable but the 5% sample, consisting of 653 294 patients who had 1 478 554 emergency admissions, still makes this the largest study to date to apply the HFRS. The data report in-hospital death but we did not have access to records that would have allowed analysis of 30-day mortality. Individuals with serious conditions who have not been previously admitted to hospital would not be picked up by an automated HFRS capture process. This is a limitation of any score based on past information.

If individuals could be identified as having frailty risk at an early stage in their life course, this might permit early intervention to mitigate the risk of adverse outcomes in later life. As with older people, identifying frailty at younger ages could permit changes at the micro, meso, and macro levels of the health-care system, with an added opportunity to identify frailty risk earlier in the life course and intervene earlier to prevent development of more severe levels of frailty and associated adverse outcomes. Although we do not know what interventions might be most effective at younger ages,[26] holistic approaches, grounded in the biopsychosocial model of care that also takes account of the social determinants of health, might be reasonably assumed to be effective. As with older people living with frailty, it is unlikely that a single intervention at a single point in time will be sufficient to address outcomes that are driven by frailty, which is a multifaceted condition that accumulates over the life course. A theoretical advantage of initiating targeted interventions in early life is that these might diminish future need for more expensive interventions by expanding the number of years lived in good health.[27] Exercise and nutritional interventions appear effective in early stages of frailty in older people,[28] and such approaches could be tested in younger people. However, more focused approaches are likely needed, including efforts to improve uptake of health-care interventions, as well as addressing socioeconomic factors, such as access to health care, living conditions, and employment opportunities.[29] These efforts might be better targeted if the HFRS were to be embedded into electronic health records, enabling automated flagging of people at increased risk of frailty.

Contributors

AS, LM, and SC conceived and conceptualised the study. AS and LM developed the methodological approach, accessed and verified the data, and did the analyses. AS, LM, and SC wrote the first draft of the manuscript. All authors contributed to interpretation of data and to critical revision of the manuscript and approved the final version for publication. AS is guarantor of the study. AS and LM had access to the raw data. All authors had final responsibility for the decision to submit for publication.

Declaration of interests

SC is paid as clinical lead for national frailty improvement collaboratives in England. All other authors declare no competing interests.

Data sharing

The paper was produced using Hospital Episode Statistics provided by NHS Digital under data sharing agreement NIC-354497-V2J9P. These data can be obtained from a third party and are not publicly available. This paper has been screened to ensure no confidential information is revealed.

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