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Detection of frailty in older patients using a mobile app:

cross-sectional observational study in primary care

Abstract

Background
The main instruments used to assess frailty are the Fried frailty phenotype and the Fatigue, Resistance, Ambulation, Illnesses, and Loss of Weight (FRAIL) scale. Both instruments contain items that must be obtained in a personal interview and cannot be used with an electronic medical record only.

Aim
To develop and internally validate a prediction model, based on a points system and integrated in an application (app) for Android, to predict frailty using only variables taken from a patient's clinical history.

Design and setting
A cross-sectional observational study undertaken across the Valencian Community, Spain.

Method
A sample of 621 older patients was analysed from January 2017 to May 2018. The main variable was frailty measured using the FRAIL scale. Candidate predictors were: sex, age, comorbidities, or clinical situations that could affect daily life, polypharmacy, and hospital admission in the last year. A total of 3472 logistic regression models were estimated. The model with the largest area under the receiver operating characteristic curve (AUC) was selected and adapted to the points system. This system was validated by bootstrapping, determining discrimination (AUC), and calibration (smooth calibration).

Results
A total of 126 (20.3%) older people were identified as being frail. The points system had an AUC of 0.78 and included as predictors: sex, age, polypharmacy, hospital admission in the last year, and diabetes. Calibration was satisfactory.

Conclusion
A points system was developed to predict frailty in older people using parameters that are easy to obtain and recorded in the clinical history. Future research should be carried out to externally validate the constructed model.

Keywords
frail elderly; frailty; general practice; mobile applications; statistical models.

INTRODUCTION

Frailty can be considered a biological syndrome of diminishing functional reserves and resistance to stressors, because of the cumulative decline of multiple physiological systems.[1,2] As it produces preventable situations in older people, such as early mortality, its diagnosis is important.[3–6] Frailty, therefore, becomes a state prior to disability, and screening can allow primary and secondary prevention measures to be implemented in those people at high risk of adverse events.[7–10]

Different scales have been used to assess frailty, including the:

- Fried phenotype of frailty;
- Edmonton Frail Scale (EFS); and
- Fatigue, Resistance, Ambulation, Illnesses, and Loss of Weight (FRAIL) scale/questionnaire.[7–10]

The Fried phenotype of frailty is the most widely used tool in research.[11,12] Fried *et al* identified a phenotype of frailty that was predictive of adverse outcomes, such as death;[13] however, using the tool involves having answers to personal questions that must be obtained through an interview. The published and validated EFS allows for easy measurement of frailty status in primary care using simple questions.[14] The FRAIL questionnaire is predominantly based on physical criteria; in addition to these factors, early signs of impairment in patient functioning and socioeconomic factors are taken into account. The comorbidity indicators may help us evaluate incipient impairments in functioning when assessing aspects of organicity in older people; as such, using indices in clinical practice that evaluate comorbidity will help practitioners to make an early diagnosis of the developing impairments that are the result of ageing in the population.[15,16]

The Fried phenotype and FRAIL questionnaire have important practical limitations: they require a personal interview with the patient.[11,14] Accordingly, the risk of frailty of a particular patient cannot be determined by simply examining their medical records. However, if it were possible to determine this risk from records alone, a screening tool could be created to warn doctors that a patient is at high risk of presenting with frailty. In light of these considerations, a study was conducted with the aim of constructing and internally validating a prediction model for frailty in older patients (aged ≥60 years); this would be adapted to a points system and integrated into an easy-to-use mobile application (app) for Android (*Frailty Predictor*). Using the model and app, clinicians would be able to estimate a patient's probability of frailty; in this way, health professionals would have

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How this fits in

Frailty is a common geriatric syndrome associated with a high risk of mortality. The two most common measurements for frailty are the Fried phenotype and the Fatigue, Resistance, Ambulation, Illnesses, and Loss of Weight scale, better known as the FRAIL scale. As these are difficult to use for screening in daily clinical practice (having too many people in the health centre would be a problem if these scales were used for screening), a scoring system using only clinical variables to predict frailty was developed. It was found to have high standards in terms of internal validation but must be validated externally.

access to a tool to enable improved decision making in an older population.

METHOD

Study design and participants

This cross-sectional observational study analysed a purposive sample of patients in the Valencian Community. All patients aged ≥60 years who sought primary care services from the health centres of Monóvar, Las Acacias, and Marina Española (province of Alicante, Health Area of Elda), and the Port of Sagunto (province of Valencia, Health Area of Sagunto), from January 2017 to May 2018, were invited to participate. Patients were excluded if they:

- did not wish to participate in the study;
- were marginalised;
- had moderate or severe cognitive decline;
- were living in homes for elderly people; or
- received home care.

Variables and measurements

The main study variable was defined as the presence of frailty. This was assessed with the FRAIL scale;[11,14] a patient was identified as frail when three or more of the five scale criteria — fatigue, resistance, ambulation, illnesses (hypertension, diabetes, cancer, chronic lung disease, heart attack, congestive heart failure, angina pectoris, asthma, arthritis, stroke, kidney disease) and weight loss — were met. The questions were asked during a personal interview with the patient, within appointments made by the patient for another reason, lasting around 5 minutes. The application of the FRAIL scale is recommended in Spain by the Ministry of Health, Social Services, and Equality as a screening tool for frailty,[17] which is based on international literature.[18,19]

In addition, the Charlson Comorbidity Index was used; this assesses the following comorbidities:[15]

- cerebrovascular disease;
- diabetes;
- chronic obstructive pulmonary disease (COPD);
- coronary heart disease (CHD);
- congestive heart failure;
- dementia;
- peripheral vascular disease;
- chronic renal disease; and
- cancer.

Through the presence or absence of these comorbidities, this index indicates the risk of mortality in patients over a period of 6 months.[15] For this study, each of the comorbidities was used independently. Additionally, the following clinical variables were recorded:

- Parkinson's disease;
- Arthrosis or advanced musculoskeletal disease;
- major auditory or visual deficit;
- polypharmacy (at least three drugs prescribed by physicians); or
- hospital admission in the last year.

These clinical variables are included in the Valencian Community Regional Department of Health's definition of the frail older person but were not present in the rest of the questionnaires, as highlighted by Suay Cantos *et al*,[20] which were based on scientific literature.[21]

Finally, aside from the indicated variables covered by the questionnaires, the following were obtained using the patient's electronic medical record:

- sex;
- age;
- previous diagnosis of atrial fibrillation (AF); and
- relevant factors for frailty.[21,22]

As candidate predictors, the sex and age of the patient were selected, together with those comorbidities or clinical conditions that could have a considerabe effect on the daily life of an older person and, consequently, increase their risk of frailty — namely, AF, stroke, CHD, Parkinson's disease, COPD, arthrosis or advanced musculoskeletal disease, hearing loss or visual deficit, polypharmacy,

Table 1. Descriptive characteristics and adjusted odds ratios for predicting frailty in older people

	Total sample, *n* (%)[a]	With/at risk of frailty, *n* (%)[a,b]	Adjusted OR[c] (95% CI)	*P*-value
Total	621 (100)	126 (20.3)		
Variable				
Male sex	256 (41.2)	34 (13.3)	0.43 (0.27 to 0.69)	<0.001
Mean age, years	73.1 (SD 8.0)	77.4 (SD 7.9)	1.07 (1.04 to 1.10)	<0.001
Atrial fibrillation	61 (9.8)	21 (34.4)	n/m	n/m
Stroke	29 (4.7)	14 (48.3)	n/m	n/m
CHD	71 (11.4)	27 (38.0)	n/m	n/m
Parkinson's disease	7 (1.1)	4 (57.1)	n/m	n/m
COPD	43 (6.9)	12 (27.9)	n/m	n/m
Arthrosis or advanced musculoskeletal disease	307 (49.4)	80 (26.1)	n/m	n/m
Hearing loss or visual deficit	229 (36.9)	60 (26.2)	n/m	n/m
Polypharmacy	452 (72.8)	121 (26.8)	6.95 (2.73 to 17.70)	<0.001
Hospital admission in the last year	104 (16.7)	41 (39.4)	2.81 (1.69 to 4.66)	<0.001
Diabetes	147 (23.7)	49 (33.3)	1.98 (1.25 to 3.14)	0.004
Dementia	21 (3.4)	13 (61.9)	n/m	n/m
Peripheral vascular disease	38 (6.1)	15 (39.5)	n/m	n/m

[a]Unless otherwise specified. [b]Percentage calculated from subsample with relevant variable, not whole sample. [c]Variables in the multivariate model are those with an OR. Goodness-of-fit of the model: $\chi^2 = 6.41$, P = 0.602 (Hosmer–Lemeshow test). Area under the receiver operating characteristic curve = 0.78 (standard error 0.021). CHD = coronary heart disease. CI = confidence interval. COPD = chronic obstructive pulmonary disease. n(%) = absolute frequency (relative frequency). n/m = not in the multivariate model. OR = odds ratio.

hospital admission in the last year, diabetes, dementia, and peripheral vascular disease. Dialysis was not considered, as there were few cases and cancer was not considered because of the great variability of sites and prognoses. To blind the assessment, the patient was asked all the subjective questions of the outcome first, so the answers were not related to the other predictors.

Sample size calculation

The sample size used when developing a prediction model should be based on the ratio of events per variable (EPV). This is defined as the total number of events (cases of frailty) divided by the number of predictors included in the model. The EPV value must be ≥10 for a sample size needed to develop a predictive model. Nevertheless, in cases of predictors with low prevalence, it is advisable to raise the EPV to at least 20.[23] In the study presented here, the EPV had to be 25 to reduce the risk of overfitting in future external validations. However, external validation studies should still be carried out to confirm this.

Statistical analysis

Variables were described using absolute and relative frequencies, and means with standard deviations (age). There were no data missing from the study variables. As age is a continuous variable, its functional form was studied through power analysis (likelihood ratio test), finding that the quadratic power did not show differences with linearity. As such, age was included in the multivariate model as a linear predictor. Taking into account the fact that there were 14 potential predictors and the multivariate model could not include more than five (the total number of events was 126, EPV>25), all the models with one, two, three, four, and five predictors were estimated, thereby ensuring evaluation of all the possible combinations. The area under the receiver operating characteristic curve (AUC) was assessed for all combinations, and that with the maximum AUC — that is, the combination with the greatest discrimination — was selected to construct the model.

The calibration of the model was evaluated using soft calibration (splines).Palazón-Bru *et al* made a review of this topic and they indicated this point for the calibration.[24] Calibration and discrimination must be adequate to state that the model is valid, and, when this is done on the same sample on which it was developed, it constitutes an internal validation. This validation was performed through 1000 bootstrap samples.

All analyses were conducted with a significance of 5% and, for each relevant parameter, its associated confidence interval

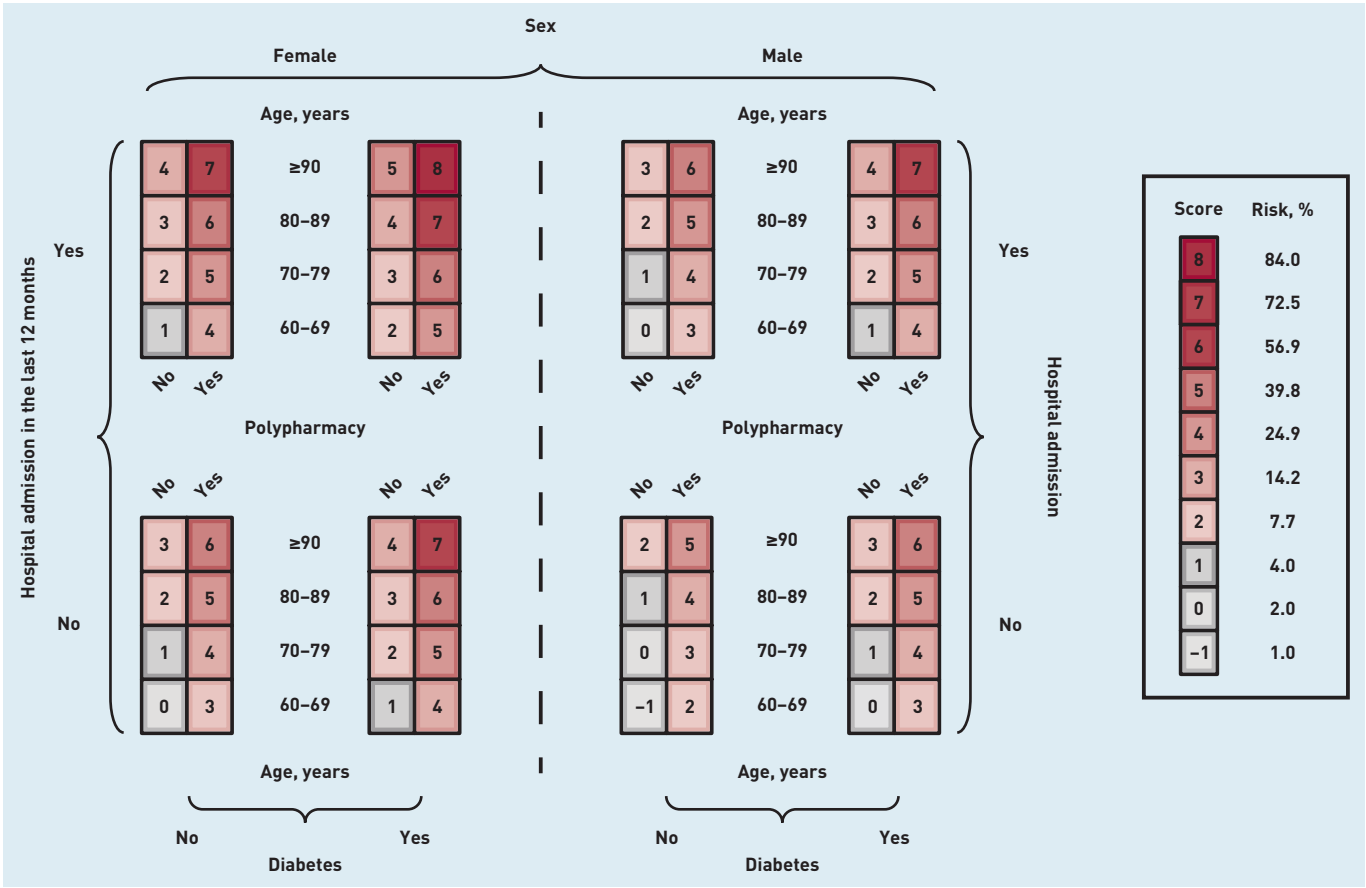


Figure 1. Scoring system to predict frailty in older people using easy-to-use parameters.

(CI) was calculated. The statistical packages used were SPSS Statistics (version 25) and R (version 3.5.1).

The predictive model has been integrated into a mobile application for Android (*Frailty Predictor*), which is free to download for all users of Google Play.

RESULTS

Of the total of 621 older patients included in the study, 126 were frail (20.3%, 95% CI = 17.1 to 23.5). Regarding the descriptive characteristics of the sample (outlined in Table 1), the mean age was 73.1 years, 41.2% were male, and there was a high prevalence of comorbidities, ranging from 1.1% to 49.4%. The majority of the sample used multiple medications (72.8%), and a sixth had been admitted to hospital in the last year (16.7%).

The number of possible logistic regression models totalled 3472. In total, there were 14 predictors (Table 1) and so models were estimated as follows: 2002 models with five predictors, 1001 with four predictors, 364 with three, 91 with two, and 14 with one predictor.

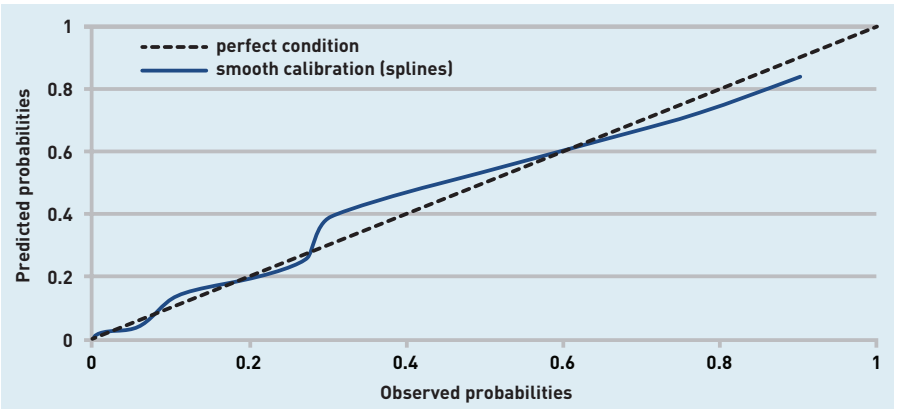
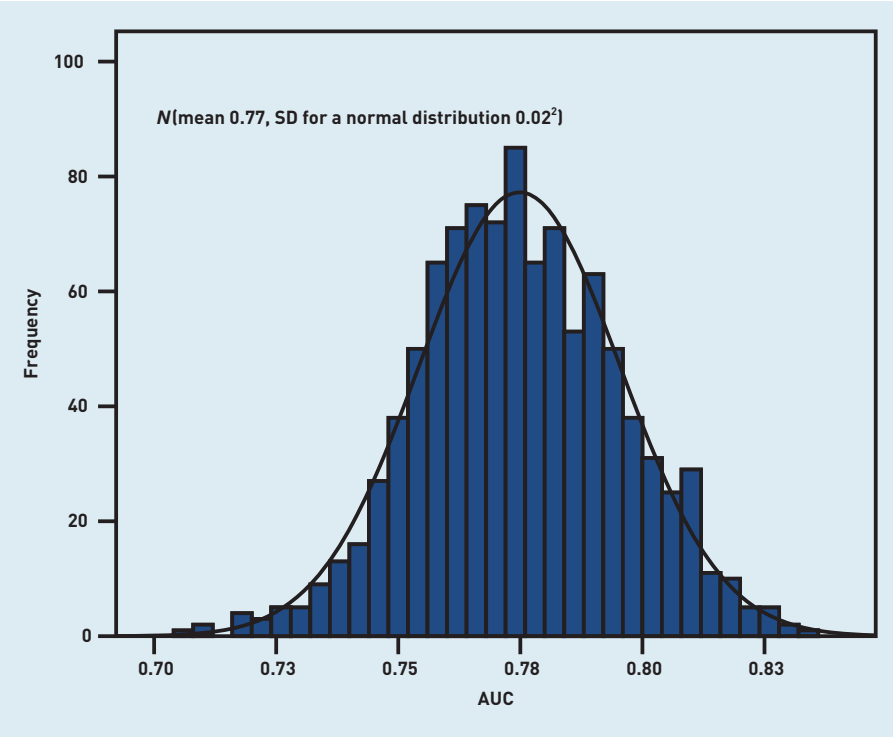


Figure 2. AUC distribution in the internal validation of the scoring system (bootstrapping).
AUC = area under the receive operating characteristic curve. SD = standard deviation.

Figure 3. Smooth calibration in the internal validation of the scoring system (bootstrapping).



After analysing all 3472 models, that with the highest AUC (0.78) included the following variables as predictors:

- female sex;
- age;
- polypharmacy;
- hospital admission in the last year; and
- diabetes.

This model was adapted to the points system (Figure 1) so, with knowledge of these characteristics for a given patient, the risk of frailty can be determined. This points system was internally validated through 1000 bootstrap samples, obtaining good discrimination and calibration: the mean AUC was close to 0.80 (Figure 2) and the smooth curve satisfactorily fit the perfect condition (observed = expected) (Figure 3).

DISCUSSION

Summary

Through this study, a points-based screening system to predict frailty using clinical variables that are readily available in a patient's medical record was constructed and internally validated, thereby allowing the risk to be calculated quickly. In addition, the system has been integrated into a mobile application for Android, giving health professionals a tool to improve decision making in older people.

The scoring system had a good discrimination (AUC = 0.78) and included as predictors: sex, age, polypharmacy, hospital admission in the last year, and diabetes. Furthermore, calibration was satisfactory.

Strengths and limitations

The main strength of the study is the clinical idea through which a prediction model was developed and internally validated to calculate the risk of frailty in just a few seconds. By using clinical variables that are in a patient's electronic medical record, the risk of frailty can be quickly calculated without requiring a consultation with the patient. Knowing the risk of frailty is relevant as it is an important predictor of serious adverse events in older people; of these adverse events, mortality is the most frequent.[3–6] Frailty, therefore, becomes a pre-disability state, the screening for which may allow primary and secondary prevention measures to be implemented in a population at high risk of adverse events.[7]

The study presented here was based on the statistical methodology recommended by leading experts in the development of predictive models in health sciences,[25] and the power of the performance of the tool was good. The model is simple to use — neither the points system nor the app require the patient to be present, unlike the tools currently available to identify frailty. Validated questionnaires were used for the reference population, and all data were recorded carefully, rigorously, and methodically.

It is assumed that the study has a selection bias as the sampling was not random, but comprised patients aged ≥60 years who attended a consultation at the health centres. The cut-off of the sample to perform a frailty study is supported by a systematic review.[21] In order to generalise the results, it would have been better to perform stratified, randomised sampling of all the visits carried out at the participating health centres. Nevertheless, in the consultations there were no major differences between groups according to age and sex.[26]

It should be noted that a multivariate analysis was carried out in the prediction of variables to minimise confounding bias; the model that best predicted frailty was selected from a total of almost 3500. This is a way to minimise confusion bias.

There are several ways to define a patient as 'frail' and, in most cases, the decision is unlikely to be a binary one — this is an inherent issue with the definition of frailty. Consequently, this approach should be improved with a standardised definition of frailty.

Comparison with existing literature

In clinical practice it is very difficult to make a diagnosis using the Fried phenotype. Although it is the most widely used tool in frailty research, the presence of frailty in a particular subject is based on various specific, complex instruments (for example, dynamometers) that are not usually available in routine clinical practice.[11,12] The FRAIL scale is used in routine clinical practice conditions but completing it requires time, which is scarce in daily clinical practice in Spain, as in other countries. In the study presented here, a frailty prediction model for older people has been adapted to a points system, allowing clinicians to quickly estimate the risk of frailty in their patients and improve decision making in an older population.

The prevalence of frailty identified in the study sample (20.3%) was within the international range (5.0 to 58.0%).[27]

The predictive factors used in the frailty risk prediction model were sex, age, polypharmacy, hospital admission in the last year, and diabetes. The authors expected age, polypharmacy, and hospital admission in the last year to be among the factors found in the points-based frailty detection model as these are clinical variables included in the Valencian Community Regional Department of Health's definition of a frail, older person.[20] Diabetes is a factor that is part of the short-form Charlson Comorbidity Index scale.

Multiple diseases and the three major cardiovascular risk factors (hypertension, diabetes mellitus, and hyperlipidaemia) are more closely linked to patients with cognitive impairment than to the rest of the older population.[28] Although sex is not on any of the scales used in the study, females consistently tend to have a greater association with the risk of cognitive deterioration, regardless of age, other markers, and the area studied.[11,29]

Implications for research and practice

The results from this study demonstrate that an instrument is now available that quickly determines whether an older patient is at risk for frailty, through the use of their electronic medical record and an app. For those at risk of frailty, an appointment can then be scheduled with the primary care physician so that interventions can be put in place to avoid an increase in mortality; such interventions could include a combination of muscle strength training and protein supplementation, as proposed by Travers *et al*.[30]

The findings presented here indicate that the points system has good predictive capacity and may be used in clinical practice for both the prevention and diagnosis of frailty — however, it must first be externally validated by determining discrimination and calibration in other geographical areas.

Given all that frailty entails for the older person and the family environment, older females who have diabetes, take many medications, and have been admitted to hospital in the previous 12 months should be given a comprehensive intervention to avoid rapidly deteriorating and becoming frail.

Another relevant result of this study is that a patient taking multiple medications is six times more likely to be frail. This is obviously associated with multimorbidity; for this reason, an important recommendation would be to have proper and balanced nutrition, based on a diet rich in proteins and, at the same time, physical exercise should be carried out daily, both aerobic and anaerobic.[30] Health systems should offer comprehensive care to the ageing population and should be capable of providing closer monitoring.[30]

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Ethical approval

The study was approved by the Clinical Research Ethics Committee of Elda General University Hospital (reference number: ANFRA15, 28 September 2015) and Sagunto Hospital (reference number: ANFRA, 22 February 2017). All patients gave their written informed consent for their personal and clinical data to be used for research purposes.

Provenance

Freely submitted; externally peer reviewed.

Competing interests

The authors have declared no competing interests.

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