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# From Code to Care and Digital Detection of Frailty: A Scoping Review of electronic Frailty Index (eFI) Applications Using Electronic Health Records


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## Abstract

The electronic Frailty Index (eFI) is a cumulative deficit model that quantifies frailty by summing health-related deficits recorded in a patient's electronic health record. This scoping review evaluated the emerging applications of eFI models, providing an overview of the current landscape. A comprehensive search of three databases identified peer-reviewed studies published between August 2020 and July 2025. Study characteristics, including purpose, sample characteristics, eFI model details, cut-off thresholds and outcome measures were extracted. A total of 80 studies were included. Most were conducted in the UK (n = 29, 36.2%), followed by the US (n = 23, 28.7%) and Australia (n = 6, 7.5%). The most common purpose was risk stratification (n = 40, 50%), followed by model development and validation (n = 26, 32.5%). The predominant model included 36 deficits (n = 35, 46.1%), followed by 54 deficits (n = 10, 13.2%) and 31 deficits (n = 8, 10.5%). By type, the Clegg-based eFI (36 deficits) was the most frequently used (42.5%), while the Pajewski-based eFI (45-59 deficits) accounted for 21.3% and the Veterans Affairs Frailty Index (VA-FI) or adaptations represented 7.5%. Among cut-off schemes, the four-level classification (Fit: 0-0.12, Mild: >0.12-0.24, Moderate: >0.24-0.36, Severe: >0.36) was most common (24 studies, 30%), followed by the simplified three-level scheme (14 studies, 18%). Mortality was the most frequently evaluated outcome (65%), followed by hospital-related utilization such as admissions, readmissions, length of stay and emergency visits (48%). These findings highlight the widespread adoption of eFI models for risk stratification and validation, with notable variability in deficit selection and model adaptation across settings.



**Keywords:** Geriatric Assessment; Risk Assessment; Frailty; Electronic Frailty Index; Review


## Abbreviations

eFI: electronic Frailty Index; EHR: Electronic Health Record; FI: Frailty Index

## Introduction

Frailty or frail status, refers to a state of increased vulnerability to stressors due to aging and the decline of multiple physiological systems [1-3]. It has gained prominence in personalized care management due to its strong association with adverse health outcomes. Patients identified as frail have been shown to be at increased risk of surgical complications, prolonged hospitalization, delayed recovery, disability and mortality [4-7]. In oncology, for instance, frail patients are more susceptible to treatment-related toxicities, tend to experience the side effects of chemotherapy and radiation more severely and may struggle to recover between treatment cycles [8-13].

Early recognition of frailty allows healthcare providers to tailor interventions through frailty-guided clinical management [14-18]. In geriatrics, screening for frailty enables geriatricians to customize treatment plans, minimize polypharmacy and focus on non-pharmacological interventions such as rehabilitation and nutrition. In oncology, assessing frailty helps oncologists determine treatment tolerability, select safer treatment options and plan supportive care to manage potential side effects, significantly improving outcomes and maintaining patients' quality of life [19,20]. In surgical and anesthetic care, patients identified as frail can receive tailored perioperative care, such as optimized nutrition or physical therapy, to enhance resilience and improve recovery outcomes [21,22]. In rehabilitation, assessing frailty enables therapists to prioritize fall prevention, increased monitoring, energy conservation, fatigue management and the consideration of adaptive equipment and environmental modifications [23,24].

A Frailty Index (FI) is commonly used to assess and classify a patient's level of frailty, such as categorizing them as robust, pre-frail or frail or into graded levels like robust, mild, moderate or severe frailty. There are three widely recognized approaches to assessing frailty: (1) the frailty phenotype, which emphasizes physical characteristics; (2) the deficit-based model, which estimates frailty based on the proportion of health-related deficits present; and (3) the comprehensive geriatric assessment, a multidimensional and interdisciplinary evaluation of medical, functional and psychosocial domains.

Published in 2001, the Fried Frailty Phenotype [1,25] defines frailty as meeting at least three out of five specific criteria that indicate compromised physical energetics: (1) unintentional weight loss, (2) slowed walking speed, (3) reduced grip strength, (4) low physical activity and (5) physical exhaustion. The Fried Frailty Phenotype is conceptually simple and clinically intuitive, employing standardized performance-based measures (e.g., grip strength and gait speed) that help reduce subjectivity. It is particularly well-suited for identifying individuals at risk of physical decline or functional limitations. However, despite its clinical strengths, the Fried Phenotype requires additional performance-based testing, which limits its feasibility in routine or acute care settings where time, space or equipment may be constrained [26-28].

Introduced in 2007, the Deficit Accumulation Model (Rockwood and Mitnitski Model) [2] defines frailty as a cumulative score based on the presence of health deficits (e.g., typically between 30 and 70 items spanning symptoms, functional limitations, laboratory tests and chronic conditions) [29-31]. Each deficit is scored from 0 (absent) to 1 (present) and the FI is calculated as the total score divided by the number of deficits assessed, yielding a value between 0 and 1, with higher values indicating greater frailty. While this model allows for scalable, data-driven assessment, it requires a large number of variables, which may be difficult to collect consistently across clinical settings. It also weights all deficits equally, regardless of clinical severity. In acute settings, its utility may be limited. For example, a young patient with an aggressive illness may appear non-frail, while someone with multiple minor chronic conditions may be classified as frail despite functional independence [32].

Comprehensive Geriatric Assessment (CGA)-based frailty scores offer a holistic evaluation across multiple domains, including physical health, cognition, functional status, psychological well-being and social support. Over the past decade, several tools have been developed to streamline the CGA process, such as the Clinical Frailty Scale (CFS) , Tilburg Frailty Indicator (TFI), Edmonton Frail Scale (EFS) , Geriatric 8 (G8) Screening Tool , Frailty Index based on Comprehensive Geriatric Assessment (FI-CGA) , Frailty Trait Scale (FTS) and Kihon Checklist (KCL) [33-40]. While CGA-based approaches provide a more comprehensive view of an older adult's overall health, they come with several limitations: lack of standardization in domain selection, complexity in data collection, time requirements and potential burden on patients. The multidimensional nature of CGA also demands standardized tools and coordinated data collection, which can be difficult to implement consistently in multidisciplinary settings. Moreover, some domains, such as social support and psychological health, often rely on subjective or self-reported data, introducing variability and potential bias in assessment [41].

The electronic Frailty Index (eFI) is grounded in the Deficit Accumulation Model that calculates frailty by identifying and summing up a set of health-related deficits recorded in a patient's Electronic Health Record (EHR). As a frailty assessment tool, the eFI holds promise for routine clinical use due to its efficiency, low cost, minimal burden, programmability and standardized approach, making it particularly useful for population-level screening and retrospective risk stratification. However, it shares several limitations inherent to deficit-based models. Its accuracy depends on the completeness and reliability of EHR coding. Incomplete data, inconsistent coding, outdated or static diagnoses can lead to misclassification. Similarly, the eFI also lacks direct physical performance measures (e.g., grip strength, gait speed), which are fundamental to the physical construct of frailty. In addition, it does not capture patient-reported outcomes such as fatigue, mood or perceived function and may overlook psychosocial context or clinical judgment, reducing its sensitivity to functional decline and quality of life. Despite these limitations, the eFI has been shown to effectively predict hospitalization and mortality. Furthermore, automating the eFI with routinely collected EHR data remains a promising strategy, leveraging real-time clinical information to support timely and accurate frailty identification.

This scoping review evaluated the emerging applications of eFI models, providing an overview of the current landscape. The specific objectives were to: (a) summarize the characteristics of published studies using the eFI, including study purpose, sample and outcome measures and (b) provide an overview of the current landscape of eFI use, including geographic distribution, purposes of eFI applications, model variations and cut-off thresholds.

**Ethical Statement**

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore, was exempt.

**Materials and Methods**

*Search Strategy*

A comprehensive literature search was conducted to identify peer-reviewed studies examining the application of the eFI using EHR. The search strategy was developed and executed collaboratively by two independent reviewers to ensure methodological rigor and comprehensive coverage of the relevant literature. Three electronic databases were searched: PubMed, CINAHL and PsycINFO.

The strategy included title- and abstract-specific searches using the primary term "electronic frailty index" [Title/Abstract] OR "eFI" [Title]. To capture a broader range of studies, a combination of Medical Subject Headings (MeSH) and keyword search terms was employed. The search terms included: "electronic frailty index"[Title/Abstract] OR "frailty index"[Title/Abstract] OR "cumulative deficit model"[Title/Abstract] OR Frailty[Mesh]) AND ("electronic health record"[Title/Abstract] OR EHR[Title/Abstract] OR "electronic medical record"[Title/Abstract] OR "Electronic Health Records"[Mesh]).

*Study Eligibility*

Titles and abstracts were screened based on the following inclusion criteria: (1) peer-reviewed original research articles; (2) published within the last five years (August 2020-July 2025); (3) written in English; (4) conducted on human subjects; (5) studies that explicitly described an eFI model and its components, elements or items in detail; and (6) utilized EHRs or medical databases for the construction or application of the eFI.

Studies were excluded if they: (1) were non-peer-reviewed publications, such as conference abstracts, letters, editorials, erratum or commentaries; (2) were review articles, meta-analyses or scoping reviews; (3) described software updates, usability or technical features of software, without reporting eFI-related data, analysis or outcomes; or (4) were qualitative mapping or semi-structured interview studies.

Two reviewers independently screened the titles and abstracts for eligibility. Full-text articles were retrieved for studies that met the inclusion criteria or when relevance was unclear. Discrepancies were resolved through discussion or consultation with a third reviewer.

*Data Extraction*

A standardized data extraction form was developed to systematically capture relevant information from each included study. The following details were collected: (a) first author, year of publication and country of study (or data source location); (b) purpose of the study, (c) purpose of eFI application (e.g., risk stratification, eFI model development and validation, clinical decision support, population surveillance); (d) study sample characteristics, including sample size, care setting; (e) study design (e.g., retrospective cohort, cross-sectional, etc.); (f) eFI model details, including the number and types of deficits included; (g) eFI cut-off thresholds used to classify frailty (e.g., robust, pre-frail, frail); (h) outcomes for which the eFI was applied (e.g., mortality prediction, hospitalization risk, functional decline); and (i) concurrent comorbidity or frailty measures used alongside the eFI (e.g., other comorbidity index).

In this review, each study was assigned to one of four eFI application categories based on its primary objective and use of the eFI. Studies were classified as risk stratification if they used the eFI to categorize individuals into risk groups (e.g., frail vs non-frail) to predict adverse outcomes or to assess how frailty status influences mortality, adverse outcomes or disease progression. eFI model development and validation included studies focused on creating, refining or validating an eFI model using EHR data. Clinical decision support referred to studies that integrated the eFI into clinical workflows to guide care pathway decisions. Population surveillance encompassed studies that applied the eFI to describe the epidemiology, prevalence and progression of frailty at both individual and population levels over time.

Data were independently extracted by two reviewers and cross-verified for consistency. Any discrepancies were discussed and resolved through consensus or consultation with a third reviewer, if necessary.

*Data Synthesis*

Data were tabulated and summarized using frequency counts and percentages to describe key study characteristics, including year of publication, country, purpose of eFI application, commonly used eFI models and applied cut-off thresholds. Study outcomes were also synthesized and the most frequently used deficits across eFI models were identified.

## Results

*Search Results*

Our literature search identified 125 records, of which 80 (64%) met the study's inclusion criteria. Most of the excluded studies were those with unclear or insufficient descriptions of the eFI model, while several others used the abbreviation "EFI" to refer to terms different from the intended "electronic frailty index". Among the 80 included studies, 44 reported the list of eFI deficits/items, either in the main manuscript or in the supplementary materials. Fig. 1 presents the flow diagram of the search strategy.

*Year*

Table 1 summarizes the included studies in eFI applications. Among the included studies, 5 were published in 2020, 11 in 2021, 20 in 2022, 14 in 2023, 12 in 2024 and 18 in 2025.

*Country*

Most studies (n = 29, 36.2%) were conducted in the UK, followed by 23 studies (28.7%) from the US and 6 studies (7.5%) from Australia. Together, these three countries accounted for 72.5% of the studies in this scoping review.

*Study Design*

Almost all studies employed a retrospective cohort design, as the data were derived from EHRs.

*Purpose of eFI Application*

The most common purpose is risk stratification (n = 40, 50%), followed by eFI model development and validation (n = 26, 32.5%). Population surveillance was reported in 12 studies (15%), while clinical decision support was the least common purpose, with only 2 studies (2.5%).

*Number of Deficits*

Of the studies included, 76 (95%) reported the number of deficits used in their eFI model, while 4 studies (5%) did not provide this information. The number of deficits varied substantially, ranging from 15 to 80. The most common number of deficits was 36 (reported in 35 studies, 46.1%), followed by 54 deficits (10 studies, 13.2%) and 31 deficits (8 studies, 10.5%). By model type, the Clegg-based eFI (36 deficits) [42] was the most widely used, accounting for 42.5% of studies. The Pajewski-based eFI (variations between 45 and 59 deficits) [43] represented 21.3%, while approximately 7.5% of studies employed the Veterans Affairs Frailty Index (VA-FI) [44] or its adaptations.

*eFI Cut-off Thresholds*

Among the reported eFI cut-offs, the Clegg, et al., based scheme (Fit: 0-0.12, Mild: >0.12-0.24, Moderate: >0.24-0.36, Severe: >0.36) was the most widely applied, used in approximately 24 studies (30%). The second most common approach was the simplified 3-level scheme (Fit: ≤0.10, Pre-frail: 0.10-0.21, Frail: >0.21), reported in about 14 studies (18%). The third most frequently applied was the expanded 5-level scheme (Non-frail: <0.10, Pre-frail: 0.10-0.20, Mild: 0.20-0.30, Moderate: 0.30-0.40, Severe: >0.40), used in roughly 10 studies (13%).

*Outcome Measures*

The most evaluated outcome was mortality across varying time frames, reported in 65% of studies. The second most frequent outcome was hospital-related utilization (e.g., length of stay, hospital admissions and readmissions, emergency visits), included in 48% of studies. Institutionalization and care transitions (e.g., transfer to skilled nursing facilities, initiation of long-term care or home care services) were reported in 23% of studies. Finally, disease-specific or functional outcomes (e.g., morbidity, complications, functional measures) were assessed in 10-26% of studies.

*Concurrent Comorbidity or Frailty Measures*

Few studies collected concurrent comorbidity or frailty measures. The Charlson Comorbidity Index (CCI) [45] was reported in 13 studies (17.1%). The Clinical Frailty Scale (CFS) [46] appeared in 7 studies (9.2%), while the Hospital Frailty Risk Score (HFRS) [47] was reported in 6 studies (7.9%).

*Common Deficits in eFI Models*

From the 44 included studies, a total of 1,669 individual deficits were extracted. After applying synonym mapping and merging clinically equivalent terms, the 40 most frequently reported deficits were identified. Ranked by frequency of mention, the leading deficits were: lung disease (COPD, asthma, respiratory issues, dyspnea) (40 mentions), hypertension (35 mentioned), diabetes, osteoporosis, atrial fibrillation, arthritis (27 mentioned), hearing impairment (including deafness, hearing problems), heart failure, fall history / risk of falls, peripheral vascular disease, thyroid disease, weight loss (anorexia, weight loss and anorexia) (24 mentioned), dementia / cognitive impairment (20 mentioned), cerebrovascular disease (stroke/TIA), urinary incontinence, coronary artery disease (CHD, MI, ischemic heart disease), visual impairment (blindness, poor vision), depression, peptic ulcer, polypharmacy, chronic kidney disease (18 mentioned), skin ulcer, activity limitation, anemia, cancer / malignancy, anxiety, sleep disturbance / insomnia, dizziness, urinary system disease (general), chronic pain (14 mentioned), fragility fracture, housebound status, social vulnerability, heart valve disease, hypotension, requirement for care (dependency), Parkinson's disease, foot problems and fatigue (10 mentioned).

| Author (Year) | Country | Objective (Purpose of eFI application*) | Sample | eFI model (adapted from) | eFI Cut-offs | Outcome Measures | Comorbidity / Frailty Measures (Concurrent validation measures) |
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| Broad (2020) [51] | UK | To examine the convergent validity of the eFI with the CFS (b) | Community dwelling people 65 years or over (n = 265) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild frailty: > 0.12 to 0.24<br>Moderate frailty > 0.24 to 0.36<br>Severe frailty: >0.36 | n/a | CFS |
| Coventry (2020) [52] | UK | To assess whether depression, alone or in combination with frailty, contributes to loss of independence in instrumental ADLs among older adults (a) | The Community Ageing Research 75+ Study (CARE75+) (n = 553) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: 0.13 to 0.24<br>Moderate: 0.25 to 0.36<br>Severely frail: >0.36 | 1. Nottingham Extended ADL (NEADL) scale<br>2. Geriatric Depression Scale (GDS) | n/a |
| Masoli (2020) | UK | To estimate associations | Patients aged | 36-deficits | Fit: 0 to 0.12 | 1. All-cause | n/a |

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| [53] | | between baseline BP and mortality/cardiovascular outcomes in a primary-care population aged above 75, stratified by frailty (a) | above 75 (n = 415,980) | (Clegg, 2016) | Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | mortality<br>2. Incident cardiovascular events: | |
| Ravensbergen (2020) [54] | NL | To evaluate whether an eFI can be used as a measure for daily functioning in research with community-dwelling older persons (b) | Community-dwelling older persons aged ≥75 years (n = 11,476) | 50-deficits (eFI-U; Drubbel, 2013) | n/a | 1. eFI-Utrecht (eFI-U)<br>2. GARS | n/a |
| Stewart (2020) [55] | US | To create a novel screening tool that identified patients who were most likely to benefit from pharmacist in-home medication reviews (b) | Patients aged 60 years or older with physical or cognitive impairments and enrolled in home-based primary care or transitional and supportive care (n = 25) | 59-deficits (Pajewski, 2019) | Non-frail: < 0.1<br>Prefrail: > 0.10 to ≤ 0.21<br>Frail: > 0.21 | 1. Age, gender<br>2. eFI score<br>3. LACE+ index score<br>4. Number of Beers Criteria medications | CCI |
| Callahan (2021) [56] | US | To evaluate the association of an eFI with post-operative outcomes for non-emergency surgeries (a) | Patients aged 65 or more, who underwent non-emergency surgery (n = 4,831) | 54-deficits (Pajewski, 2019) | Fit: ≤ 0.10<br>Pre-frail: 0.10 to ≤ 0.21<br>Frail: > 0.21 | 1. Inpatient length of stay<br>2. Discharge destination<br>3. 30-day readmission<br>4. 6-month all-cause mortality | CCI |
| Cheng (2021) [57] | US | To update the VA-FI (VA-FI-9) using ICD-10 codes (VA-FI-10) and assess whether VA-FI-10 maintains stability in measuring prevalence of frailty after the transition to ICD-10 (b) | Veterans aged 65 years and older | 31-deficits (VA-FI) | Non-frail: ≤ 0.1<br>Prefrail: >0.1 to 0.2<br>Mildly frail: >0.2 to 0.3<br>Moderately frail: >0.3 to 0.4<br>Severely frail: >0.4 | n/a | n/a |
| Gagesch (2021) [58] | CH | To develop an eFI in geriatric patients (b) | Patients within Swiss Frailty Network and Repository (SFNR) | 55-deficits | n/a | 1. Clinical Frailty Instrument (cFI) based on the Fried phenotype | n/a |
| Hollinghurst (2021) [59] | UK | To compare two different tools (eFI vs HFRS) for identifying frailty (b) | Patients aged 65+ who were admitted as an emergency (n = 126,600) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mildly frail: >0.12 to 0.24<br>Moderately frail: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Mortality<br>2. Hospital resource use<br>3. Care home admissions | HFRS |
| Ju (2021) [60] | HK | To develop a new eFI model using machine learning (gradient boosting) (b) | Patients with heart failure (n = 8,893) | 16-deficits (new eFI model) | n/a | 1. 30-day mortality<br>2. 90-day mortality | n/a |
| Liang (2021) [61] | China | To develop a new eFI model (b) | Patients ≥65 years old (n = 49,226) | 45-deficits (Pajewski, 2019) | Non-frail: 0 to 0.14<br>Frail: > 0.15 | 1. Hospital stay<br>2. Hospital death<br>3. Hospitalized costs | CGA |
| Lo (2021) [62] | AU | To develop a new eFI | Inpatients ≥ 70 | 39-deficits | Non-frail: < | n/a | REFS |

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| | | model (b) | years (development cohort n = 151, validation cohort n = 999) | (eFI-AH) | 0.25<br>Frail: > 0.25 | | |
| Pugh (2021) [63] | UK | To study trends in patient characteristics for adult critical care admissions and potential effects of resource constraints on admission patterns and processes of care in Wales (a) | Patients in Wales Critical Care (n = 85,629) | n/a (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Planned and unplanned admission<br>2. Comorbidity<br>3. Advanced respiratory support<br>4. Advanced cardiovascular support<br>5. Mortality | n/a |
| Szakmany (2021) [64] | UK | To examine frailty indices derived from population-scale linked data on ICU and hospitalised non-ICU patients with pneumonia to elucidate the influence of frailty on mortality (a) | Patients with a diagnosis of pneumonia or flu (n = 133,604) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | 1. In-patient mortality<br>2. 6-month mortality<br>3. 1-year mortality | HFRS<br>CCI |
| Shen (2021) [65] | CN | To assess whether the eFI is associated with mortality and chemotherapy adverse reactions (a) | Patients with lung cancer (n = 1,263) | 35-deficits (Searle, 2008) | Robust/Non-frail: 0 to < 0.2<br>Frail: ≥ 0.20 | 1. Overall Survival<br>2. Infection, bone suppression, neutropenia, thrombocytopenia, decreased hemoglobin, chemotherapy discontinuation, impaired liver function, gastrointestinal reactions<br>3. Length of hospitalization | n/a |
| Wilkinson (2021) [66] | UK | To assess frailty and atrial fibrillation (AF) prevalence in adults ≥65, evaluate oral anticoagulation (OAC) use and analyze AF outcomes by frailty level (d) | Patients aged ≥65 years (n = 536,955) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | 1. All-cause mortality and first stroke<br>2. First gastrointestinal or intracranial bleed, fall and TIA | n/a |
| Cheng (2022) [67] | US | To measure frailty and assess its prognostic value by applying an eFI to older patients with NSCLC in the Veterans Affairs (VA) health-care system (a) | Patients ≥65 years old with non-small cell lung cancer (NSCLC) (n = 42,204) | 31-deficits (VA-FI) | Non-frail: 0 to 0.1<br>Pre-frail: 0.1 to 0.2<br>Mildly frail: 0.2 to 0.3<br>Moderate-to-severely frail: >0.3 | 1. All-cause mortality<br>2. Acute hospitalizations<br>3. ER visits | n/a |
| Cook (2022) [68] | UK | To determine the impact of frailty on patient-reported outcomes following hip and knee arthroplasty (a) | Patients who had a hip arthroplasty (n = 42,512) and who had a knee arthroplasty (n = 49,208) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mildly frail: >0.12 to 0.24<br>Moderately frail: >0.24 to 0.36<br>Severely frail: >0.36 | 1. The Oxford hip and knee scores (12-item questionnaire) | n/a |
| Fogg (2022) | UK | To describe the structure | Patients aged | 36-deficits | Fit: 0 to 0.12 | 1. Prevalence of | n/a |

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| [69] | | of the dataset, cohort characteristics and planned analyses (d) | ≥50 years (n = 2,177,656) | (Clegg, 2016) | Mildly frail: 0.13 to 0.24 Moderately frail: 0.25 to 0.36 Severely frail: >0.36 | long-term conditions 2. Prevalence of frailty deficits | |
| Hickson (2022) [70] | UK | To evaluate the benefits of a model of care in which a dietitian provided care to patients at risk of malnutrition and frailty (c) | Patients aged ≥50 years, eFI 0.26 to 0.36 or BMI < 19 kgm-2 (n = 189) | 36-deficits | Fit: 0 to 0.12 Mildly frail: >0.12 to 0.24 Moderately frail: >0.24 to 0.36 Severely frail: >0.36 | 1. Frailty status 2. Nutritional status 3. Anthropometric measures 4. Dietary aims 5. Cost savings 6. Patient satisfaction | n/a |
| Hollinghurst (2022) [71] | UK | To investigate associations between dysphagia and age, frailty, gender and deprivation (a) | Individuals aged 65+ (n = 400,000) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12 Mildly frail: >0.12 to 0.24 Moderately frail: >0.24 to 0.36 Severely frail: >0.36 | 1. Dysphagia | n/a |
| Ibrahim (2022) [72] | UK | To evaluate the feasibility of assessing sarcopenia and frailty among older people attending fracture clinics (d) | Patients aged ≥65 years with a single wrist or upper arm fracture | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12 Mild: 0.13 to 0.24 Moderate: 0.25 to 0.36 Severely frail: >0.36 | 1. Falls and fractures 2. CGA 3. Acceptability of the assessments | FFP FRAIL Scale SOF CFS PRISMA-7 |
| Le (2022) [73] | US | To compare 4 electronic frailty metrics within a surgical population (a) | Patients who underwent abdominal surgical procedures (n = 37,186) | 38-deficits (FI-CSHA model, Howlett, 2014) | n/a | 1. 30-day postoperative morbidity 2. 30-day major postoperative complications | HFRS mFI-5 RAI |
| Lewis (2022) [74] | AU | To examine the feasibility of deriving an eFI and to describe the prevalence of frailty (d) | Australian Medicine Insight data platform (n = 79,251) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12 Mild frailty: > 0.12 to 0.24 Moderate frailty > 0.24 to 0.36 Severe frailty: >0.36 | n/a | n/a |
| Mak (2022) [75] | SE | To develop an eFI (b) | Patients with unplanned admissions (n = 18,225) | 48-deficits (Pajewski, 2019) | Fit: ≤ 0.15 Mild frailty: 0.16 to 0.2 Moderate frailty: 0.21 to 0.25 Severe frailty: > 0.25 | 1. In-hospital, 30-day and 6-month all-cause mortality 2. 30-day readmission to any of the 9 included clinics 3. Length of stay | CCI CFS HFRS |
| Nishimura (2022) [76] | JP | To assess the applicability of eFI and to evaluate their association with long-term outcomes (b) | Participants aged ≥50 years (n = 827,744) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12 Mildly frail: >0.12 to 0.24 Moderately frail: >0.24 to 0.36 Severely frail: >0.36 | 1. All-cause mortality 2. Use of government-supported long-term care (LTC) | n/a |
| Oates (2022) [27] | AU | To describe how an AI optimization technique called partial genetic | Residents aged 75 years and over (n = 592) | 35-deficits (Clegg, 2016) | Frail: > 0.21 | n/a | n/a |

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| | | algorithms can be used to refine the subset of features used to calculate an FI and favor features that have the least cost of acquisition (b) | | | | | |
| Orfila (2022) [77] | ES | To develop an eFI (eFRAGICAP) (b) | Individuals from the Information System for the Development of Research in Primary Care (SIDIAP) database (n = 253,684) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild frailty: > 0.12 to 0.24<br>Moderate frailty > 0.24 to 0.36<br>Severe frailty: >0.36 | 1. All-cause mortality<br>2. Institutionalization<br>3. Inclusion in a homecare program | CFS<br>RISC |
| Sarwar (2022) [78] | AU | To develop a new eFI model (b) | Residents in the residential aged care homes (n = 2,588) | 32-deficits (reFI model) | Fit: ≤ 0.13<br>Mildly frail: 0.13 to ≤ 0.26<br>Moderately frail: 0.26 to ≤ 0.39<br>Severely frail: > 0.39 | 1. 1, 3 and 5 years mortality | n/a |
| Semelka (2022) [79] | US | To examine the association between frailty and COVID-19 mRNA vaccine antibody response (a) | Adults aged 55 and older with self-reported Moderna or Pfizer COVID-19 mRNA vaccine (n = 1,677) | 54-deficits (Pajewski, 2019) | Non-frail: < 0.1<br>Prefrail: > 0.10 to ≤ 0.21<br>Frail: > 0.21 | 1. Odds of nonseroconversion<br>2. Odds of seroreversion | n/a |
| Shrauner (2022) [80] | US | To assess the association between eFI and risk of cardiovascular mortality and risk of atherosclerotic CVD (ASCVD) events (a) | Veterans aged ≥65 years (n = 3,068,439) | 31-deficits | Not frail: < 0.1<br>Pre-frail: > 0.1 to < 0.2<br>Mildly frail: > 0.2 to < 0.3<br>Moderately frail: > 0.3 to < 0.4<br>Severely frail: > 0.4 | 1. Cardiovascular mortality<br>2. Myocardial infarction/fatal myocardial infarction, stroke/fatal stroke and cardiovascular events | n/a |
| Stow (2022) [81] | UK | To study the association between area-level, multi-domain deprivation and frailty trajectories in the last year of life and over 1 year in a matched non-end-of-life sample (d) | People age ≥ 75 at end of life (n = 13,149) and age-, sex- and practice-matched individuals not at end of life (n = 13,149) | 36-deficits (Clegg, 2016) | n/a | n/a | n/a |
| Summerfield (2022) [82] | UK | To study the association between old age and frailty on the time to cancer diagnosis (a) | Cancer patients (n = 7,460) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Time to diagnosis | n/a |
| Wilkinson (2022) [83] | UK | To study the association between oral anticoagulation (OAC) and outcomes for people | Patients with a diagnosis of non-valvular AF (n = 89,996) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: | 1. All-cause mortality<br>2. Stroke<br>3. Severe bleeding | n/a |

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| | | with frailty and whether there is overall net benefit from treatment in people with atrial fibrillation (AF) (a) | | | >0.24 to 0.36<br>Severely frail: >0.36 | 4. TIA<br>5. Fall | |
| Wilkinson (2022) [84] | UK | To study the risk of frailty development in CKD and the impact on mortality and end-stage kidney disease (ESKD) (a) | Patients aged ≥40 years (n = 819,893) | 36-deficits (Clegg, 2016) | Non-frail: ≤ 4 deficits<br>Mild frailty: 5-8 deficits<br>Moder-ate frailty: 9-12 deficits<br>Severe frailty: ≥13 deficits | | n/a |
| Zhou (2022) [85] | HK | To develop a scalable predictive model in the form of an eFI (b) | Patients with pulmonary hypertension (PHTN) (n = 2,560) | 15-deficits (new eFI model) | n/a | 1. Complications: Development of cardiovascular and renal complications, diabetes mellitus after diagnosis of PHTN<br>2. Mortality after diagnosis of PHTN | n/a |
| Cheong (2023) [86] | UK | To (i) investigate the prevalence of anticholinergic prescribing for older patients and (ii) examine anticholinergic burden according to frailty status (d) | Patients aged ≥65 (n = 529,095) | 36-deficits (Clegg, 2016) | Fit: 0 to <0.12<br>Mildly frail: >0.12 to < 0.24<br>Moderately frail: >0.24 to <0.36<br>Severely frail: >0.36 | 1. Measurement of anticholinergic burden, Anticholinergic Cognitive Burden (ACB) scale | n/a |
| Fujita (2023) [87] | AU | To compare characteristics and predictive ability between the electronic frailty index-acute hospital (eFI-AH) with the hospital frailty risk score (HFRS) (a) | Patients aged ≥75 years admitted to an Australian metropolitan tertiary referral hospital (n = 6,771) | 37-deficits (eFI-AH) | Robust: < 0.05<br>Prefrail: 0.05 to < 0.25<br>Frail: > 0.25 | 1. In-hospital mortality<br>2. Long hospital stay (>10 days)<br>3. All-cause readmission<br>4. Fall-related readmission within 28 days from hospital discharge | HFRS |
| Cheng (2023) [88] | US | To describe the distribution of frailty status at pre-treatment by therapy type (b) | Older adults with acute myeloid leukemia (n = 166) | 54-deficits (Pajewski, 2019) | Fit: < 0.10<br>Prefrail: > 0.10 to < 0.21<br>Frail: > 0.21 | 1. Overall survival | HCT-CI |
| Chao (2023) [89] | US | To examine the current health status (d) | Gulf War (GW) veterans (n = 703) | 31-deficits (VA-FI) | Non-frail: 0 to 0.1<br>Pre-frail: 0.1 to 0.2<br>Mildly frail: 0.2 to 0.3<br>Moderately frail: 0.3 to 0.4<br>Severely frail: > 0.4 | 1. Kansas Gulf War and Health Questionnaire | n/a |
| Dulai (2023) [90] | UK | To evaluate the association between the validated NHS eFI and outcomes post-AF ablation (a) | Patients who had undergone atrial fibrillation (AF) ablation and aged ≥ 65 (n = 248) | 36-deficits (Clegg, 2013) | n/a | 1. Time to atrial arrhythmia<br>2. Recurrence of an atrial arrhythmia | n/a |

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| DuMontier (2023) [91] | US | To assess the construct validity of the VA-FI (b) | Veterans (n = 132) | 31-deficits (VA-FI) | Non-frail: ≤ 0.2<br>Mild-moderately frail: >0.2 to 0.4<br>Severely frail: > 0.4 | n/a | CGA<br>CFS<br>CCI |
| Elhussein (2023) [92] | UK | To identify and characterize older people with complex health needs based on healthcare resource use or frailty using large population-based linked records (d) | People aged > 65 Hospitalization cohort (n = 90,597); Frailty cohort (n = 110,225); Polypharmacy cohort (n = 116,076) | 36-deficits (Clegg, 2016) | n/a | 1. Use of oral bisphosphonates, statins and anti-hypertensives (1-month, 3-month and 1-year point prevalence)<br>2. Prescriptions of preventive treatments<br>3. Treatment episodes | n/a |
| Khanna (2023) [93] | US | To examine the association of frailty with adverse events after elective noncardiac surgery (a) | Patients who underwent noncardiac surgical procedures (n = 50,456) | 54-deficits (Pajewski, 2019) | Fit: < 0.10<br>Prefrail: > 0.10 to < 0.21<br>Frail: > 0.21 | 1. 30-day mortality<br>2. 30-day readmission<br>3. 30-day ED visit after surgery<br>4. Unexpected ICU admission after surgery<br>5. PSI 90<br>6. HAC CMS<br>7. Other hospital morbidity<br>8. Transfer to SNF after surgery | CCI |
| La (2023) [94] | US | To use the VA-FI to measure the prevalence of frailty in veterans and to determine whether frail patients have inferior survival compared to non-frail veterans (a) | Veterans with acute myeloid leukemia (AML) (n = 1,166) | 31-deficits (VA-FI) | Non-frail: 0 to 0.1<br>Pre-frail: 0.1 to 0.2<br>Mildly frail: 0.2 to 0.3<br>Moderate-to-severely frail: >0.3 | 1. Overall Survival | n/a |
| Lin (2023) [95] | TW | To investigate the predictive utility of an eFI in community elders (a) | Participants aged 65-80 years (n = 427) | 80-deficits | Low risk: eFI ≤ the median value<br>High risk: eFI > the median value | 1. Falls<br>2. ER visits<br>3. Hospitalizations within 24 months | n/a |
| Nishimura (2023) [50] | JP | To assess whether frailty at the time of oral anticoagulant (OAC) initiation is associated with subsequent bleeding or embolic events (a) | Patients aged ≥65 years with nonvalvular atrial fibrillation (AF) (n = 12,585) | 35-deficits | Fit: 0 to 0.12<br>Mildly frail: >0.12 to 0.24<br>Moderately frail: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Bleeding events<br>2. Embolic events | n/a |
| Mak (2023) [96] | SE | To examine the association of frailty with mortality and to compare the predictive accuracy of the eFI to other frailty and comorbidity measures (a) | COVID-19 patients (n = 3,980) | 48-deficits (Mak 2022 eFI model) | Fit: ≤0.15<br>Mild frailty: >0.15 to 0.2<br>Moderate frailty: >0.2 to 0.25 | 1. In-hospital mortality<br>2. 30-day mortality<br>3. 6-month mortality<br>4. 30-day readmission | CCI<br>CFS<br>HFRS |

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| | | | | | Severe frailty: >0.25 | 5. Length of hospital stay | |
| Stutsrim (2023) [97] | US | To examine the association of an automated eFI with outcomes (a) | Patients undergoing open, lower extremity vascular surgery (n = 295) | 54-deficits (Pajewski, 2019) | Fit: < 0.10<br>Prefrail: > 0.10 to < 0.21<br>Frail: > 0.21 | 1. Length of stay<br>2. 30-day readmission rate<br>3. Discharge destination<br>4. 1-year all-cause mortality | CCI |
| Walsh (2023) [98] | UK | To explore and predict trends in onset, prevalence and progression of frailty and the dynamics of frailty-related healthcare demand, outcomes and costs in the ageing population (d) | Adults aged ≥50 (n = 2,171,497) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: 0.13 to 0.24<br>Moderate: 0.25 to 0.36<br>Severe: >0.36 | 1. eFI score | n/a |
| Archer (2024) [99] | UK | To develop and externally validate the eFalls prediction model using routinely collected primary care electronic health records (EHR) | Patients aged ≥65 years (n = 660,417) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Any (one or more) ED attendance or hospital admission for a fall or fracture | n/a |
| Bunch (2024) [100] | US | To determine whether CT-derived measurements of muscle and adipose tissue are associated with frailty (a) | Patients aged 55 years and older (n = 886) | 54-deficits (Pajewski, 2019) | Non-frail: < 0.1<br>Prefrail: > 0.10 to ≤ 0.21<br>Frail: > 0.21 | 1. CT image L3 cross-sectional area | n/a |
| Fogg (2024) [101] | UK | To describe primary and secondary care service use and associated costs by eFI (a) | Patients aged ≥50 (n = 2,171,497) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: 0.13 to 0.24<br>Moderate: 0.25 to 0.36<br>Severely frail: >0.36 | 1. Primary care service use<br>2. Secondary care service use<br>3. Cost | n/a |
| Georgiev (2024) [102] | UK | To evaluate the utility of machine learning models developed using comprehensive linked routine primary and secondary care data to predict future dementia diagnosis (a) | Patients (n = 144,113) | 35-deficits (Clegg, 2016) | n/a | 1. Dementia code in either primary, secondary or death<br>2. All-cause mortality | n/a |
| Kong (2024) [103] | AU | To evaluate the comparability of frailty assessment tools (eFI, retrospective eFI (reFI) and CFS) in older residents of care facilities (b) | Individuals aged 65 or older (n = 813) | 36-deficits (Clegg 2016) and 32-deficits Retrospective eFI (reFI) (Sarwar, 2022) | eFI<br>Fit: 0 to 0.12<br>Mildly frail: >0.12 to 0.24<br>Moderately frail: >0.24 to 0.36<br>Severely frail: >0.36<br><br>reFI<br>Fit: 0 to 0.13<br>Mildly frail: >0.13 to 0.26<br>Moderately frail: >0.26 to 0.39<br>Severely frail: | 1. 32-deficits Retrospective eFI (reFI) (Sarwar 2022) | CFS |

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| | | | | | >0.39 | | |
| Lenoir (2024) [104] | US | To examine the joint association of these factors on acute healthcare utilization using two pragmatic measures (a) | Patients aged ≥ 65 years (n =47,566) | n/a (Pajewski, 2019) | Non-frail: < 0.1<br>Prefrail: > 0.10 to ≤ 0.21<br>Frail: > 0.21 | 1. Acute healthcare utilization<br>2. ED visits, observation stays and inpatient visits over one year of follow-up<br>3. Mortality | n/a |
| Lowry (2024) [105] | UK | To assess the relationship between the eFI and outcomes in older patients hospitalized with acute myocardial infarction (a) | Patients with cardiovascular disease (n = 4,670) | 36-deficits (Clegg, 2016) | Frail: ≥0.12<br>Mild frailty: 0.12-0.24<br>Moderate frailty: 0.25-0.36<br>Severe frailty: >0.36 | 1. All-cause mortality at 12 months<br>2. In-patient all-cause mortality<br>3. Hospital admission due to non-fatal myocardial condition<br>4. Cardiovascular death at 12 months<br>5. All-cause mortality at 3-years | CCI |
| Short (2024) [106] | UK | To examine the effect of frailty on mortality and other relevant outcomes (a) | Patients diagnosed with pleural disease (n = 54,566) | 36-deficits (Clegg 2016) | Fit: 0 to 0.12<br>Mildly frail: >0.12 to 0.24<br>Moderately frail: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Time to all-cause mortality<br>2. Time to pleural disease-related mortality<br>3. Time to first all-cause<br>4. Hospital admission after diagnosis;<br>5. Time to pleural disease related hospital admission<br>6. Re-admission within 90 day | CCI |
| Nakamaru (2024) [49] | JP | To assess the trajectory of frailty and the course of frailty progression to clinical outcomes of older patients with atrial fibrillation (AF) (c) | Residents aged <75 years (n = 6,247) | 35-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mildly frail: >0.12 to 0.24<br>Moderately frail: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Death<br>2. Embolism<br>3. Major bleeding | n/a |
| Sikron (2024) [107] | IL | To develop a new eFI model (Meuhedet Electronic Frailty Index [MEFI]) (b) | Patients of Meuhedet HMO aged 65 years and over (n = 20,986) | 36-deficits (MEFI model) | n/a | 1. One-year all-cause mortality<br>2. Hospitalization | CCI |
| Solsky (2024) [108] | US | To examine the Impact of frailty on adjuvant therapy (a) | Patients with breast cancer >65 years undergoing surgery (n = 133) | 54-deficits (Pajewski, 2019) | Fit: ≤ .10<br>Pre-frail: > 0.10 to ≤.21<br>Frail: > 0.21 | n/a | n/a |
| Wu (2024) [109] | US | To study the association between frailty and treatment selection (a) | Patients with advanced non-small cell lung cancer (NSCLC) (n = 1,547) | 31-deficits (VA-FI) | Non-frail: ≤ 0.2<br>Frail: >0.2 | 1. Receipt of intensive over non-intensive first-line treatment<br>2. Overall survival | n/a |
| Almatrafi | UK | To describe the prevalence | Patients | 36-deficits | Fit: 0 to 0.12 | 1. Response to the | n/a |

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| (2025) [110] | | of frailty and comorbidity in those invited for lung cancer screening (LCS) and evaluate their associations with response to telephone risk assessment invitation and subsequent uptake of LCS | randomized to the intervention arm of the Yorkshire Lung Screening Trial (YLST) (n = 27,761) | (Clegg, 2016) | Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | invitation for telephone lung cancer risk assessment<br>2. Uptake of low-dose computed tomography (LDCT) screening | |
| Auyeung (2025) [111] | HK | To develop a new eFI model (HK eFI) (b) | Hong Kong Hospital Authority (HA) database (2015, 1.14 million; 2016, 1.19 million; 2017,1.25 million; 2018, 1.31 million; 2019, 1.38 million) | 38-deficits | Fit: ≤ 0.125<br>Mild frailty: > 0.125 to 0.25<br>Moderate frailty: > 0.25 to 0.375<br>Severe frailty: >0.375 | 1. One-year mortality<br>2. Two-year mortality<br>3. Three-year mortality<br>4. Unplanned readmission | n/a |
| Best (2025) [112] | UK | To valid a previously developed eFI version 2 (eFI2) model (b) | Patients ≥65 years old (n = 660,417) | 36-deficits (eFI2 model) | n/a | 1. Hospitalization with fall or fragility fracture<br>2. Care home admission<br>3. All-cause mortality<br>4. New home care package | n/a |
| Duy (2025) [113] | US | To investigate whether an eFI is associated with visual field loss in glaucoma (a) | Subjects ≥65 years old with glaucoma (n = 1,163) | 54-deficits (Pajewski, 2019) | Fit: ≤ 0.10<br>Pre-frail: 0.10 to ≤ 0.21<br>Frail: > 0.21 | Baseline Mean Deviation (MD)<br>Change in Mean Deviation (MD) | n/a |
| Duy (2025) [114] | US | To compare the association of glaucoma and glaucoma suspect diagnoses with eFI (a) | Adults ≥65 years old with glaucoma (n = 4,147) | 54-deficits (Pajewski, 2019) | Fit: ≤ 0.10<br>Pre-frail: 0.10 to ≤ 0.21<br>Frail: > 0.21 | n/a | n/a |
| Fogg (2025) [115] | UK | To estimate frailty prevalence and severity among patients conveyed to hospital by ambulance, assess changes over time and identify key patient and incident characteristics to guide recommendations (d) | People aged ≥50 living in Wales (n = 1,264,094) | 36-deficits (Clegg, 2016) | Fit: 0 to < 0.12<br>Mild: 0.12 to < 0.24<br>Moderate: >0.24 to < 0.36<br>Severely frail: >0.36 | n/a | n/a |
| Kayo (2025) [116] | JP | To assess whether the eFI and VA-FI can be applied to administrative databases in Japan and evaluate the association between frailty and health outcomes (a) | Patients with cancer aged ≥65 years (n =5,176) | 36-deficits (Clegg, 2016) and 31-deficits (VA-FI) | eFI (Clegg, 2016)<br>Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36<br><br>VA-FI<br>Non-frail: 0 to < 0.1<br>Pre-frail: > 0.1 to 0.2<br>Mildly frail: > 0.2 to 0.3<br>Moderately | 1. All-cause mortality<br>2. The first observation of a decline in care-need level or all-cause mortality,<br>3. The first observation of a decline in care-need level, the first observation of long-term care facility (LTCF) admission or all-cause mortality | n/a |

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| | | | | | frail: > 0.3 to 0.4<br>Severely frail: > 0.4 | | |
| Kochar (2025) [117] | US | To develop a new eFI model (MGB-eFI) (b) | Patients who were ≥ 60 years (n = 518,449) | 31-deficits (MGB-eFI model) | Robust: < 0.1<br>Prefrail: 0.1 to 0.2<br>Frail: 0.2 to 0.3<br>Very frail: > 0.3 | 1. Time-to-mortality<br>2. Time to subsequent acute care visits<br>3. Hospital re-admissions within 90 days | n/a |
| Li (2025) [118] | CN | To develop a new eFI model (b) | Participants aged 65 or older (n = 28,144) | 30-deficits (new eFI model) | Robust: ≤ 0.10<br>Prefrail: > 0.10 to <0.25<br>Frail: ≥ 0.25 | 1. Hospitalization<br>2. Mortality | n/a |
| Namugosa (2025) [119] | US | To assess whether the eFI can serve as a proxy for frailty by comparing it with gait speed in older women with moderate-to-severe UI (b) | Patients aged 70 years and older, seeking treatment for urinary incontinence (UI) | 36-deficits (Clegg, 2016) | Fit: 0 to 0.12<br>Mild: >0.12 to 0.24<br>Moderate: >0.24 to 0.36<br>Severely frail: >0.36 | 1. Gait speed | n/a |
| Ruiz-Beltrán (2025) [120] | MX | To evaluate the predictive ability of traditional risk scores and frailty assessment for 30-day mortality in elderly patients undergoing cardiac surgery (a) | Patients aged ≥75 years old who underwent cardiac surgery (n = 203) | n/a (Clegg, 2016) | n/a | 1. 30-day mortality | CCI |
| Shiffer (2025) [121] | IT | To develop a new eFI model and to evaluate its prediction of outcomes among geriatric patients presenting to the emergency department (ED) (b) | Patients ≥65 years old (n =21,537) | 45-deficits (new eFI model) | Non-frail: < 0.124<br>Mildly frail: 0.125 to 0.159<br>Moderately frail: 0.159 to 0.204<br>Severely frail: > 0.205 | 1. Hospitalization rates<br>2. In-hospital mortality<br>3. ICU admission<br>4. 30-day ED readmission | n/a |
| Sikron (2025) [122] | IL | To describe the dynamic trajectory of frailty and determine what deteriorates first (d) | Meuhedet members aged 65 years and over (n = 119,952) | 36-deficits (Meuhedet Electronic Frailty Index [MEFI]) | Fit: 0 to 0.12<br>Mildly frail: 0.13 to 0.24<br>Moderately frail: 0.25 to 0.36<br>Severely frail: >0.36 | Frailty status | CCI |
| Tu (2025) [123] | KR | To evaluate the prognostic value of frailty measures (FMs) for all-cause mortality in older patients with NSCLC (a) | Patients with non-small cell lung cancer (NSCLC) aged ≥65 years (n = 4,799) | 28-deficits (Clegg, 2016) | Non-frail: < 0.04<br>Frail: >0.04 | 1. 1-year mortality<br>2. 3-year mortality<br>3. 5-year mortality | 27-item FI-Lab<br>40-item FI-combined |
| Velez (2025) [124] | US | To examine whether patients with diabetic retinopathy who are frail have higher rates of loss to follow-up compared with less-frail patients (a) | Patients aged 55 years or older (n = 249) | 50+ deficits (Pajewski, 2019) | Fit: < 0.1<br>Prefrail: > 0.10 to ≤ 0.21<br>Frail: > 0.21 | 1. Loss to follow-up (LTFU) | n/a |
| Wunnava (2025) [125] | UK | To improve the understanding whether there are differences in clinical outcomes between vascular patients with | Patients with CLTI (n = 183) | 36-deficits (NHS England) | Fit: 0 to 0.12<br>Mild: 0.13 to 0.24<br>Moderate: 0.25 to 0.36 | 1. Overall survival<br>2. Rates of major adverse limb (MALE)<br>3. Rates of | n/a |

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| | | chronic limb-threatening ischemia (CLTI) age over and under 80 (a) | | | Severely frail: >0.36 | cardiovascular events (MACE)<br>4. Complication rates<br>5. 30-day reintervention<br>6. Readmission rates | |
| Zhang (2025) [126] | CN | To examine the association between eFI and mortality and adverse events (a) | Patients ≥65 years old (n = 1,424) | 45-deficits (Pajewski, 2019) | Non-frail: < 0.27<br>Frail: ≥ 0.27 | 1. Duration of hospital stay<br>2. Hospital charges<br>3. Mortality status<br>4. Unfavorable prognosis | n/a |
| Zhou (2025) [127] | US | To develop a large language model-based binary classifier using accurately phenotyped datasets (Vulnerable Elders-13 Survey [VES-13] and eFI) to identify preoperative frailty from clinical notes (b) | Patients undergoing spine surgery (n = 479) and geriatric patients undergoing spine surgery (n = 998) | 54-deficits (Theou, 2013) | n/a | | n/a |

*Purpose of eFI application: (a) Risk stratification, (b) eFI model development and validation, (c) Clinical decision support and (d) Population surveillance.

ADL = activities of daily living; CCI = Charlson Comorbidity Index; CGA-FI = Comprehensive Geriatric Assessment Frailty Index; CFS = Clinical Frailty Scale; CMS: Centers for Medicare and Medicaid Services; ED: Emergency department; eFI = electronic Frailty Index; FFP = Fried Frailty Phenotype (FFP); GARS = The Groningen Activities Restriction Scale; HAC: Hospital-Acquired Condition; HCT-CI = Hematopoietic Cell Transplantation Comorbidity Index; HFRS = Hospital Frailty Risk Score; ICU: Intensive care unit; mFI-5 = 5-Factor Modified Frailty Index; PSI 90: Center for Medicare and Medicaid Services Patient Safety Indicator 90; RAI = Risk Analysis Index; REFS = Reported Edmonton Frail Scale; RISC = Risk Instrument for Screening in the Community; SOF = Study of Osteoporotic Fracture Criteria for Frailty (SOF); SNF: Skilled nursing facility; VA-FI = Veterans Affairs Frailty Index

**Table 1:** Summary of the included studies in eFI applications.

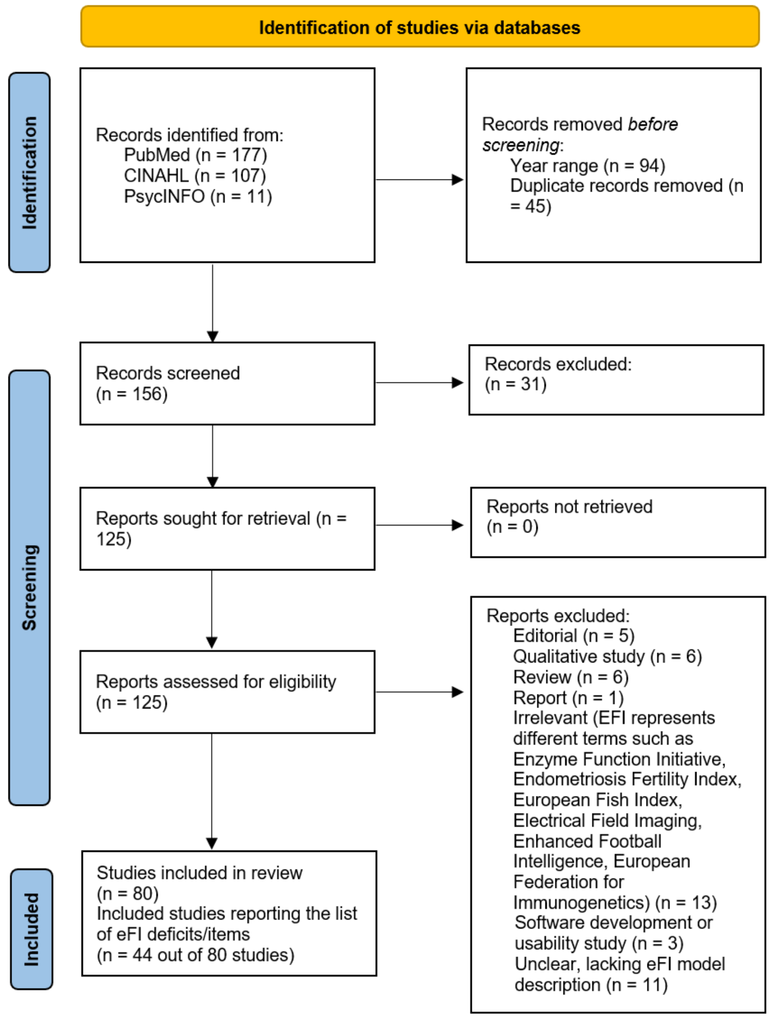


**Figure 1:** Flow diagram of searching strategy.

## Discussion

This scoping review examined the use of eFI models in the past five years. Most studies originated from the UK and US, with risk stratification being the most common application, followed by model development and validation. The Clegg-based eFI (36 deficits) and Pajewski-based eFI (45-59 deficits) were the most frequently applied, though considerable variation in deficit selection was observed in the Pajewski-based models. Overall, findings underscore the growing adoption of eFI for predicting outcomes such as mortality and healthcare utilization.

The process of developing and validating eFI models was consistently observed across the studies reviewed. Model development typically followed the cumulative deficit framework, with researchers identifying candidate health deficits from prior literature, clinical expertise or established models. Around 30-40 deficits were usually selected, with ideal candidates meeting the following criteria [38]: (1) association with health status and adverse outcomes, (2) prevalence that increases with age, (3) should not reach a ceiling effect at an early age (i.e., it should not be present in nearly everyone at midlife or earlier) and (4) covers multiple physiological systems. Additional considerations included: (a) prevalence ≥1% in the study population, (b) adequate data completeness, (c) each deficit should capture a distinct aspect of health rather than duplicating another variable (i.e., non-redundancy) and (d) can be reliably and repeatedly measured in the dataset or clinical setting [48].

Deficits commonly cover chronic diseases (e.g., diabetes, heart failure), laboratory values (e.g., albumin, cholesterol), functional impairments (e.g., falls, incontinence), symptoms (e.g., fatigue, weight loss), cognitive or mood disorders (e.g., dementia, depression) and sensory impairments (e.g., vision or hearing loss). To operationalize these deficits, researchers must match each candidate deficit with the corresponding data elements available in their system, most often using ICD or ICPC diagnosis codes, as well as prescription records, laboratory thresholds or functional assessments. Relevant data are then extracted from these EHR-coded sources to construct the eFI. Each deficit was coded as present (1) or absent (0) and the eFI score is calculated as the proportion of deficits present. The cut-offs may be determined within the development dataset using (a) empirical distribution-based (quantiles/percentiles), (b) predefined thresholds from earlier validated models or (c) outcome-driven thresholds (Cox regression, ROC curve analysis). Frailty categories were chosen for clinical practicality using cut-off thresholds. Model validation involved testing predictive validity against adverse outcomes, most commonly mortality and hospital utilization, using statistical methods such as Cox regression, ROC curves and AUC analyses. eFI models were also compared with other frailty measures, such as the Clinical Frailty Scale (CFS), to assess convergent validity. Although many studies adopted established eFI models such as the Clegg-based and Pajewski-based indices, we found considerable variation in their implementation, largely due to differences in coding systems across healthcare platforms. For example, the 36-deficit Clegg model was modified to 35 deficits in Japanese claims data because the variable “falls” was not captured, requiring recalculation of the frailty score using only the available diagnostic records [49,50]. Such adaptations underscore the practical challenges of applying standardized eFI models across diverse datasets and highlight the need for programming eFI algorithms directly into EHR platforms. Embedding eFI models within EHR systems not only ensures consistency and comparability but also facilitates their integration into clinical workflows for standardized risk stratification and decision support, while simultaneously providing researchers with readily available eFI data for secondary analyses and population-level research.

There were several limitations in this study. First, this review included only peer-reviewed, published studies, which may have introduced publication bias by overrepresenting risk stratification findings while underrepresenting purely descriptive results. The review was limited to English-language studies published between August 2020 and July 2025, which may have excluded relevant non-English evidence as well as earlier foundational work or very recent publications. Many studies cited the Clegg-based or Pajewski-based eFI models but did not provide itemized lists of individual deficits. As a result, our quantification of deficits across models may be subject to bias, although we attempted to follow a clear and transparent protocol whenever possible. Last, the process of merging clinically equivalent terms (e.g., “COPD,” “lung disease,” “respiratory disease”) involved subjective judgment, which may have introduced misclassification or bias in identifying the most common deficits.

## Conclusion

This review provided an overview of the current landscape of eFI applications. The findings indicated that certain countries placed greater emphasis on integrating eFI into healthcare and demonstrated notable variability in deficit selection and model adaptation across different settings.

## Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.


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## Author’s Contribution

All authors read and approved the final manuscript.

## References


1. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci. 2001;56:M146-56.
2. Rockwood K, Mitnitski A. Frailty in relation to the accumulation of deficits. J Gerontol A Biol Sci Med Sci. 2007;62:722-7.
3. Bandeen-Roche K, Xue Q-L, Ferrucci L, Walston J, Guralnik JM, Chaves P, et al. Phenotype of frailty: characterization in the women’s health and aging studies. J Gerontol A Biol Sci Med Sci. 2006;61:262-6.
4. Brummel NE, Bell SP, Girard TD, Pandharipande PP, Jackson JC, Morandi A, et al. Frailty and Subsequent Disability and Mortality among

Patients with Critical Illness. American Journal of Respiratory and Critical Care Medicine. 2017;196:64.
5. Muscedere J, Bagshaw SM, Kho M, Mehta S, Cook DJ, Boyd JG, et al. Frailty, Outcomes, Recovery and Care Steps of Critically Ill Patients (FORECAST): a prospective, multi-centre, cohort study. Intensive Care Medicine. 2024;50:1064.
6. Wozniak H, Beckmann TS, Dos Santos Rocha A, Pugin J, Heidegger C-P, Cereghetti S. Long-stay ICU patients with frailty: Mortality and recovery outcomes at 6 months. Ann Intensive Care. 2024;14:31.
7. Cano-Escalera G, Graña M, Irazusta J, Labayen I, Gonzalez-Pinto A, Besga A. Mortality risks after two years in frail and pre-frail older adults admitted to hospital. Journal of Clinical Medicine. 2023;12:3103.
8. Goede V. Frailty and cancer: Current perspectives on assessment and monitoring. Clin Interv Aging. 2023;18:505-21.
9. Boakye D, Rillmann B, Walter V, Jansen L, Hoffmeister M, Brenner H. Impact of comorbidity and frailty on prognosis in colorectal cancer patients: A systematic review and meta-analysis. Cancer Treat Rev. 2018;64:30-9.
10. Brouwers B, Dalmasso B, Hatse S, Laenen A, Kenis C, Swerts E, et al. Biological ageing and frailty markers in breast cancer patients. Aging (Albany NY). 2015;7:319-33.
11. Cespedes Feliciano EM, Hohensee C, Rosko AE, Anderson GL, Paskett ED, Zaslavsky O, et al. Association of Prediagnostic Frailty, Change in Frailty Status and Mortality After Cancer Diagnosis in the Women's Health Initiative. JAMA Netw Open. 2020;3:e2016747.
12. Dai S, Yang M, Song J, Dai S, Wu J. Impacts of Frailty on Prognosis in Lung Cancer Patients: A Systematic Review and Meta-Analysis. Front Med (Lausanne). 2021;8:715513.
13. de Arruda FN, Oonk MHM, Mourits MJE, de Graeff P, Jalving M, de Bock GH. Determinants of health-related quality of life in elderly ovarian cancer patients: The role of frailty and dependence. Gynecol Oncol. 2019;153:610-5.
14. Boreskie KF, Hay JL, Boreskie PE, Arora RC, Duhamel TA. Frailty-aware care: giving value to frailty assessment across different healthcare settings. BMC Geriatrics. 2022;22:13.
15. Orkaby AR, Forman DE. Applying frailty to guide myocardial infarction management: an important step towards precision medicine and personalized care for older adults. Eur Heart J Acute Cardiovasc Care. 2022;11:99-101.
16. Abbasi M, Rolfson D, Khera AS, Dabravolskaj J, Dent E, Xia L. Identification and management of frailty in the primary care setting. CMAJ : Canadian Medical Association Journal. 2018;190:E1134.
17. Grant SJ, Lipe B. Management of Frail Older Adults with Newly Diagnosed Multiple Myeloma - Moving Toward a Personalized Approach. Clin Lymphoma Myeloma Leuk. 2020;20(Suppl 1):S76-80.
18. Callahan KE. The future of frailty: Opportunity is knocking. Journal of the American Geriatrics Society. 2021;70:78.
19. O'Donovan A, Leech M. Personalised treatment for older adults with cancer: The role of frailty assessment. Technical Innovations and Patient Support in Radiation Oncology. 2020;16:30.
20. Ethun CG, Bilen MA, Jani AB, Maithel SK, Ogan K, Master VA. Frailty and cancer: Implications for oncology surgery, medical oncology and radiation oncology. CA Cancer J Clin. 2017;67:362-77.
21. Lin H-S, McBride RL, Hubbard RE. Frailty and anesthesia - risks during and post-surgery. Local and Regional Anesthesia. 2018;11:61.
22. Birkelbach O, Mörgeli R, Spies C, Olbert M, Weiss B, Brauner M, et al. Routine frailty assessment predicts postoperative complications in elderly patients across surgical disciplines - a retrospective observational study. BMC Anesthesiology. 2019;19:204.
23. Welford J, Rafferty R, Short D, Dewhurst F, Greystoke A. Personalised Assessment and Rapid Intervention in Frail Patients With Lung Cancer: The Impact of an Outpatient Occupational Therapy Service. Clin Lung Cancer. 2023;24:e164-71.
24. Scherrenberg M, Marinus N, Giallauria F, Falter M, Kemps H, Wilhelm M, et al. The need for long-term personalized management of frail CVD patients by rehabilitation and telemonitoring: A framework. Trends Cardiovasc Med. 2023;33:283-97.
25. Xue Q-L. The Frailty Syndrome: Definition and Natural History. Clin Geriatr Med. 2011;27:1-15.
26. Cesari M, Gambassi G, van Kan GA, Vellas B. The frailty phenotype and the frailty index: Different instruments for different purposes. Age Ageing. 2014;43:10-2.
27. Oates J, Shafiabady N, Ambagtsheer R, Beilby J, Seiboth C, Dent E. Evolving Hybrid Partial Genetic Algorithm Classification Model for Cost-effective Frailty Screening: Investigative Study. JMIR Aging. 2022;5:e38464.
28. Ambagtsheer RC, Archibald MM, Lawless M, Kitson A, Beilby J. Feasibility and acceptability of commonly used screening instruments to identify frailty among community-dwelling older people: a mixed methods study. BMC Geriatr. 2020;20:152.
29. Lachmann R, Stelmach-Mardas M, Bergmann MM, Bernigau W, Weber D, Pischon T, et al. The accumulation of deficits approach to describe frailty. PLoS ONE. 2019;14:e0223449.
30. Rockwood K. Conceptual Models of Frailty: Accumulation of Deficits. Can J Cardiol. 2016;32:1046-50.
31. Olivieri-Mui BL, Shi SM, McCarthy EP, Habtemariam D, Kim DH. Beyond the Health Deficit Count: Examining Deficit Patterns in a Deficit-Accumulation Frailty Index. Journal of the American Geriatrics Society. 2020;69:792.
32. Rockwood K, Mitnitski A. Limits to deficit accumulation in elderly people. Mech Ageing Dev. 2006;127:494-6.
33. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ. 2005;173:489-95.
34. Gobbens RJJ, van Assen MALM, Luijkx KG, Wijnen-Sponselee MT, Schols JMGA. The Tilburg Frailty Indicator: Psychometric properties. J Am Med Dir Assoc. 2010;11:344-55.
35. Rolfson DB, Majumdar SR, Tsuyuki RT, Tahir A, Rockwood K. Validity and reliability of the edmonton frail scale. Age Ageing. 2006;35:526-

9.
36. Navarro-Flores E, de Bengoa Vallejo RB, Losa-Iglesias ME, Palomo-López P, Calvo-Lobo C, López-López D, et al. The reliability, validity and sensitivity of the Edmonton Frail Scale (EFS) in older adults with foot disorders. Aging (Albany NY). 2020;12:24623-32.
37. Bellera CA, Rainfray M, Mathoulin-Pélissier S, Mertens C, Delva F, Fonck M, et al. Screening older cancer patients: first evaluation of the G-8 geriatric screening tool. Annals of Oncology. 2012;23:2166-72.
38. Searle SD, Mitnitski A, Gahbauer EA, Gill TM, Rockwood K. A standard procedure for creating a frailty index. BMC Geriatr. 2008;8:24.
39. Gilardi F, Capanna A, Ferraro M, Scarcella P, Marazzi MC, Palombi L, et al. Frailty screening and assessment tools: A review of characteristics and use in Public Health. Ann Ig. 2018;30:128-39.
40. Esenkaya ME, Dokuzlar O, Soysal P, Smith L, Jackson SE, Isik AT. Validity of the Kihon Checklist for evaluating frailty status in Turkish older adults. Geriatr Gerontol Int. 2019;19:616-21.
41. Pilotto A, Cella A, Pilotto A, Daragjati J, Veronese N, Musacchio C, et al. Three decades of comprehensive geriatric assessment: Evidence coming from different healthcare settings and specific clinical conditions. J Am Med Dir Assoc. 2017;18:192.e1-11.
42. Clegg A, Bates C, Young J, Ryan R, Nichols L, Ann Teale E, et al. Development and validation of an electronic frailty index using routine primary care electronic health record data. Age Ageing. 2016;45:353-60.
43. Pajewski NM, Lenoir K, Wells BJ, Williamson JD, Callahan KE. Frailty screening using the electronic health record within a medicare accountable care organization. J Gerontol A Biol Sci Med Sci. 2019;74:1771-7.
44. Orkaby AR, Nussbaum L, Ho Y-L, Gagnon D, Quach L, Ward R, et al. The burden of frailty among U.S. veterans and its association with mortality, 2002-2012. J Gerontol A Biol Sci Med Sci. 2019;74:1257-64.
45. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40:373-83.
46. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, et al. A global clinical measure of fitness and frailty in elderly people. CMAJ. 2005;173:489-95.
47. Gilbert T, Neuburger J, Kraindler J, Keeble E, Smith P, Ariti C, et al. Development and validation of a Hospital Frailty Risk Score focusing on older people in acute care settings using electronic hospital records: An observational study. Lancet. 2018;391:1775-82.
48. Rockwood K, Mitnitski A. Frailty defined by deficit accumulation and geriatric medicine defined by frailty. Clin Geriatr Med. 2011;27:17-26.
49. Nakamaru R, Nishimura S, Kumamaru H, Shoji S, Nakatani E, Yamamoto H, et al. Trajectories of Frailty and Clinical Outcomes in Older Adults With Atrial Fibrillation: Insights From the Shizuoka Kokuho Database. Circ Cardiovasc Qual Outcomes. 2024;17:e010642.
50. Nishimura S, Kumamaru H, Shoji S, Nakatani E, Yamamoto H, Ichihara N, et al. Frailty and subsequent adverse outcomes in older patients with atrial fibrillation treated with oral anticoagulants: The Shizuoka study. Res Pract Thromb Haemost. 2023;7:100129.
51. Broad A, Carter B, Mckelvie S, Hewitt J. The convergent validity of the electronic Frailty Index (eFI) with the Clinical Frailty Scale (CFS). Geriatrics (Basel). 2020;5:88.
52. Coventry PA, McMillan D, Clegg A, Brown L, van der Feltz-Cornelis C, Gilbody S, et al. Frailty and depression predict instrumental activities of daily living in older adults: A population-based longitudinal study using the CARE75+ cohort. PLoS One. 2020;15:e0243972.
53. Masoli JAH, Delgado J, Pilling L, Strain D, Melzer D. Blood pressure in frail older adults: associations with cardiovascular outcomes and all-cause mortality. Age Ageing. 2020;49:807-13.
54. Ravensbergen WM, Blom JW, Evers AW, Numans ME, de Waal MW, Gussekloo J. Measuring daily functioning in older persons using a frailty index: a cohort study based on routine primary care data. Br J Gen Pract. 2020;70:e866-73.
55. Stewart AE, Lovato JF, Zimmer R, Stewart AP, Hinely MT, Yang M. Development of a screening tool to identify patients likely to benefit from clinical pharmacist review in a home-based primary care population. J Am Pharm Assoc (2003). 2020;60:750-6.
56. Callahan KE, Clark CJ, Edwards AF, Harwood TN, Williamson JD, Moses AW, et al. Automated frailty screening at-scale for pre-operative risk stratification using the electronic frailty index. J Am Geriatr Soc. 2021;69:1357-62.
57. Cheng D, DuMontier C, Yildirim C, Charest B, Hawley CE, Zhuo M, et al. Updating and validating the U.S. veterans affairs frailty index: Transitioning from ICD-9 to ICD-10. J Gerontol A Biol Sci Med Sci. 2021;76:1318-25.
58. Gagesch M, Edler K, Chocano-Bedoya PO, Abderhalden LA, Seematter-Bagnoud L, Meyer T, et al. Swiss frailty network and repository: protocol of a Swiss personalized health network's driver project observational study. BMJ Open. 2021;11:e047429.
59. Hollinghurst J, Housley G, Watkins A, Clegg A, Gilbert T, Conroy SP. A comparison of two national frailty scoring systems. Age Ageing. 2021;50:1208-14.
60. Ju C, Zhou J, Lee S, Tan MS, Liu T, Bazoukis G, et al. Derivation of an electronic frailty index for predicting short-term mortality in heart failure: a machine learning approach. ESC Heart Fail. 2021;8:2837-45.
61. Liang Y-D, Xie Y-B, Du M-H, Shi J, Yang J-F, Wang H. Development and Validation of an electronic frailty index using routine electronic health records: An observational study from a general hospital in China. Front Med (Lausanne). 2021;8:731445.
62. Lo SY, Zhang M, Hubbard RE, Gnjidic D, Redston MR, Hilmer SN. Development and validation of a frailty index based on data routinely collected across multiple domains in NSW hospitals. Australas J Ageing. 2021;40:184-94.
63. Pugh RJ, Bailey R, Szakmany T, Al Sallakh M, Hollinghurst J, Akbari A, et al. Long-term trends in critical care admissions in Wales*. Anaesthesia. 2021;76:1316-25.

64. Szakmany T, Hollinghurst J, Pugh R, Akbari A, Griffiths R, Bailey R, et al. Frailty assessed by administrative tools and mortality in patients with pneumonia admitted to the hospital and ICU in Wales. Sci Rep. 2021;11:13407.
65. Shen Y, Wang Y, Shi Q, Hou L, Chen X, Dong B, et al. The Electronic Frailty Index is Associated with Increased Infection and All-Cause Mortality Among Older Patients with Primary Lung Cancer: A Cohort Study. Clin Interv Aging. 2021;16:1825-33.
66. Wilkinson C, Clegg A, Todd O, Rockwood K, Yadegarfar ME, Gale CP, et al. Atrial fibrillation and oral anticoagulation in older people with frailty: a nationwide primary care electronic health records cohort study. Age Ageing. 2021;50:772-9.
67. Cheng D, Dumontier C, Sheikh AR, La J, Brophy MT, Do NV, et al. Prognostic value of the veterans affairs frailty index in older patients with non-small cell lung cancer. Cancer Med. 2022;11:3009-22.
68. Cook MJ, Lunt M, Ashcroft DM, Board T, O'Neill TW. The impact of frailty on patient-reported outcomes following hip and knee arthroplasty. Age Ageing. 2022;51:afac288.
69. Fogg C, Fraser SDS, Roderick P, de Lusignan S, Clegg A, Brailsford S, et al. The dynamics of frailty development and progression in older adults in primary care in England (2006-2017): A retrospective cohort profile. BMC Geriatr. 2022;22:30.
70. Hickson M, Child J, Collinson A. Impact of a dietitian in general practice: Care of the frail and malnourished. J Hum Nutr Diet. 2022;35:145-53.
71. Hollinghurst J, Smithard DG. Identifying dysphagia and demographic associations in older adults using electronic health records: A National Longitudinal Observational Study in Wales (United Kingdom) 2008-2018. Dysphagia. 2022;37:1612-22.
72. Ibrahim K, Mullee MA, Cox N, Russell C, Baxter M, Tilley S, et al. The feasibility and acceptability of assessing and managing sarcopenia and frailty among older people with upper limb fracture. Age Ageing. 2022;51:afab252.
73. Le ST, Liu VX, Kipnis P, Zhang J, Peng PD, Cespedes Feliciano EM. Comparison of electronic frailty metrics for prediction of adverse outcomes of abdominal surgery. JAMA Surg. 2022;157:e220172.
74. Lewis ET, Williamson M, Lewis LP, Ní Chróinín D, Dent E, Ticehurst M, et al. The Feasibility of Deriving the Electronic Frailty Index from Australian General Practice Records. Clin Interv Aging. 2022;17:1589-98.
75. Mak JKL, Hägg S, Eriksdotter M, Annetorp M, Kuja-Halkola R, Kananen L, et al. Development of an electronic frailty index for hospitalized older adults in Sweden. J Gerontol A Biol Sci Med Sci. 2022;77:2311-9.
76. Nishimura S, Kumamaru H, Shoji S, Nakatani E, Yamamoto H, Ichihara N, et al. Assessment of coding-based frailty algorithms for long-term outcome prediction among older people in community settings: a cohort study from the Shizuoka Kokuho Database. Age Ageing. 2022;51:afac009.
77. Orfila F, Carrasco-Ribelles LA, Abellana R, Roso-Llorach A, Cegri F, Reyes C, et al. Validation of an electronic frailty index with electronic health records: eFRAGICAP index. BMC Geriatr. 2022;22:404.
78. Sarwar T, Jimeno Yepes AJ, Zhang X, Chan J, Hudson I, Evans S, et al. Development and validation of retrospective electronic frailty index using operational data of aged care homes. BMC Geriatr. 2022;22:922.
79. Semelka CT, DeWitt ME, Callahan KE, Herrington DM, Alexander-Miller MA, Yukich JO, et al. Frailty and COVID-19 mRNA Vaccine Antibody Response in the COVID-19 Community Research Partnership. J Gerontol A Biol Sci Med Sci. 2022;77:1366-70.
80. Shrauner W, Lord EM, Nguyen X-MT, Song RJ, Galloway A, Gagnon DR, et al. Frailty and cardiovascular mortality in more than 3 million US Veterans. Eur Heart J. 2022;43:818-26.
81. Stow D, Hanratty B, Matthews FE. The relationship between deprivation and frailty trajectories over 1 year and at the end of life: a case-control study. J Public Health (Oxf). 2022;44:844-50.
82. Summerfield C, Smith L, Todd O, Renzi C, Lyratzopoulos G, Neal RD, et al. The Effect of Older Age and Frailty on the Time to Diagnosis of Cancer: A Connected Bradford Electronic Health Records Study. Cancers (Basel). 2022;14:5666.
83. Wilkinson C, Wu J, Clegg A, Nadarajah R, Rockwood K, Todd O, et al. Impact of oral anticoagulation on the association between frailty and clinical outcomes in people with atrial fibrillation: nationwide primary care records on treatment analysis. Europace. 2022;24:1065-75.
84. Wilkinson TJ, Miksza J, Zaccardi F, Lawson C, Nixon AC, Young HML, et al. Associations between frailty trajectories and cardiovascular, renal and mortality outcomes in chronic kidney disease. J Cachexia Sarcopenia Muscle. 2022;13:2426-35.
85. Zhou J, Chou OHI, Wong KHG, Lee S, Leung KSK, Liu T, et al. Development of an Electronic Frailty Index for Predicting Mortality and Complications Analysis in Pulmonary Hypertension Using Random Survival Forest Model. Front Cardiovasc Med. 2022;9:735906.
86. Cheong V-L, Mehdizadeh D, Todd OM, Gardner P, Zaman H, Clegg A, et al. The extent of anticholinergic burden across an older Welsh population living with frailty: cross-sectional analysis of general practice records. Age Ageing. 2023;52:afad136.
87. Fujita K, Lo SY, Hubbard RE, Gnjidic D, Hilmer SN. Comparison of a multidomain frailty index from routine health data with the hospital frailty risk score in older patients in an Australian hospital. Australas J Ageing. 2023;42:480-90.
88. Cheng JJ, Tooze JA, Callahan KE, Pajewski NM, Pardee TS, Reed DR, et al. Assessment of an embedded primary care-derived electronic health record (EHR) frailty index (eFI) in older adults with acute myeloid leukemia. J Geriatr Oncol. 2023;14:101509.
89. Chao LL. Examining the current health of Gulf War veterans with the veterans affairs frailty index. Front Neurosci. 2023;17:1245811.
90. Dulai R, Uy CP, Sulke N, Patel N, Veasey RA. A retrospective analysis of frailty status on atrial fibrillation catheter ablation outcomes. Pacing Clin Electrophysiol. 2023;46:855-60.
91. DuMontier C, Hennis R, Yilidirim C, Seligman BJ, Fonseca Valencia C, Lubinski BL, et al. Construct validity of the electronic Veterans Affairs Frailty Index against clinician frailty assessment. J Am Geriatr Soc. 2023;71:3857-64.

92. Elhussein L, Jödicke AM, He Y, Delmestri A, Robinson DE, Strauss VY, et al. Characterising complex health needs and the use of preventive therapies in the older population: a population-based cohort analysis of UK primary care and hospital linked data. BMC Geriatr. 2023;23:58.
93. Khanna AK, Motamedi V, Bouldin B, Harwood T, Pajewski NM, Saha AK, et al. Automated Electronic Frailty Index-Identified Frailty Status and Associated Postsurgical Adverse Events. JAMA Netw Open. 2023;6:e2341915.
94. La J, Lee MH, Brophy MT, Do NV, Driver JA, Tuck DP, et al. Baseline correlates of frailty and its association with survival in United States veterans with acute myeloid leukemia. Leuk Lymphoma. 2023;64:2081-90.
95. Lin K-P, Li H-Y, Chen J-H, Lu F-P, Wen C-J, Chou Y-C, et al. Prediction of adverse health outcomes using an electronic frailty index among nonfrail and prefrail community elders. BMC Geriatr. 2023;23:474.
96. Mak JKL, Eriksdotter M, Annetorp M, Kuja-Halkola R, Kananen L, Boström A-M, et al. Two Years with COVID-19: The Electronic Frailty Index Identifies High-Risk Patients in the Stockholm GeroCovid Study. Gerontology. 2023;69:396-405.
97. Stutsrim AE, Brastauskas IM, Craven TE, Callahan KE, Pajewski NM, Davis RP, et al. Automated Electronic Frailty Index is Associated with Non-home Discharge in Patients Undergoing Open Revascularization for Peripheral Vascular Disease. Am Surg. 2023;89:4501-7.
98. Walsh B, Fogg C, Harris S, Roderick P, de Lusignan S, England T, et al. Frailty transitions and prevalence in an ageing population: longitudinal analysis of primary care data from an open cohort of adults aged 50 and over in England, 2006-2017. Age Ageing. 2023;52:afad058.
99. Archer L, Relton SD, Akbari A, Best K, Bucknall M, Conroy S, et al. Development and external validation of the eFalls tool: a multivariable prediction model for the risk of ED attendance or hospitalisation with a fall or fracture in older adults. Age Ageing. 2024;53:afae057.
100. Bunch PM, Rigdon J, Niazi MKK, Barnard RT, Boutin RD, Houston DK, et al. Association of CT-Derived Skeletal Muscle and Adipose Tissue Metrics with Frailty in Older Adults. Acad Radiol. 2024;31:596-604.
101. Fogg C, England T, Zhu S, Jones J, de Lusignan S, Fraser SDS, et al. Primary and secondary care service use and costs associated with frailty in an ageing population: longitudinal analysis of an English primary care cohort of adults aged 50 and over, 2006-2017. Age Ageing. 2024;53:afae010.
102. Georgiev K, Wang Y, Conkie A, Sinclair A, Christodoulou V, Seyedzadeh S, et al. Predicting incident dementia in community-dwelling older adults using primary and secondary care data from electronic health records. Brain Commun. 2025;7:fcae469.
103. Kong J, Trinh K, Hammill K, Chia-Ming Chen C. Not All Frailty Assessments Are Created Equal: Comparability of Electronic Health Data-Based Frailty Assessments in Assessing Older People in Residential Care. Biol Res Nurs. 2024;26:526-36.
104. Lenoir KM, Paul R, Wright E, Palakshappa D, Pajewski NM, Hanchate A, et al. The Association of Frailty and Neighborhood Disadvantage with Emergency Department Visits and Hospitalizations in Older Adults. J Gen Intern Med. 2024;39:643-51.
105. Lowry MTH, Kimenai DM, Doudesis D, Georgiev K, McDermott M, Bularga A, et al. The electronic frailty index and outcomes in patients with myocardial infarction. Age Ageing. 2024;53:afae150.
106. Short R, Carter B, Verduri A, Barton E, Maskell N, Hewitt J. The effect of frailty on mortality and hospital admission in patients with benign pleural disease in Wales: a cohort study. Lancet Healthy Longev. 2024;5:e534-41.
107. Hershkowitz Sikron F, Schenker R, Koom Y, Segal G, Shahar O, Wolf I, et al. Development and validation of an electronic frailty index in a national health maintenance organization. Aging (Albany NY). 2024;16:13025-38.
108. Solsky I, Cairns A, Martin T, Perko A, Friday S, Levine E, et al. The Impact of Frailty on Adjuvant Therapies Not Offered to or Declined by Breast Cancer Surgery Patients. Am Surg. 2024;90:365-76.
109. Wu JT-Y, Corrigan J, Su C, Dumontier C, La J, Khan A, et al. The performance status gap in immunotherapy for frail patients with advanced non-small cell lung cancer. Cancer Immunol Immunother. 2024;73:172.
110. Almatrafi A, Gabe R, Beeken RJ, Neal RD, Clegg A, Best KE, et al. Impact of frailty and comorbidity on initial response to lung cancer screening invitation and low-dose CT screening uptake: Findings from the Yorkshire Lung Screening Trial. J Med Screen. 2025;9691413251315087.
111. Auyeung TW, Kng CPL, Chan TY, Hui E, Leung CS, Luk JKH, et al. Developing an Electronic Frailty Index (eFI) and a biological age trajectory with a cohort of over one million older adults in Hong Kong. J Frailty Aging. 2025;14:100021.
112. Best K, Shuweihdi F, Alvarez JCB, Relton S, Avgerinou C, Nimmons D, et al. Development and external validation of the electronic frailty index 2 using routine primary care electronic health record data. Age Ageing. 2025;54:afaf077.
113. Duy W, Pajewski N, Williamson JD, Thompson AC. An Electronic Frailty Index Based on Deficit Accumulation May Predict Glaucomatous Visual Field Progression. Clin Ophthalmol. 2025;19:387-93.
114. Duy WD, Pajewski NM, Williamson JD, Thompson AC. The relationship between glaucoma and an electronic frailty index with the cumulative incidence of healthcare encounters for falls and fractures in older adults. J Frailty Aging. 2025;14:100051.
115. Fogg C, England T, Daniels H, Walsh B. Prevalence and severity of frailty amongst middle-aged and older adults conveyed to hospital by ambulance between 2010 and 2017 in Wales. Age Ageing. 2025;54:afaf124.
116. Kayo H, Yusuke K, Sakiko I, Mieko S, Tomomi S, Kunihiko T, et al. Evaluation of claims-based frailty measurements in older patients with cancer: a retrospective cohort study. Age Ageing. 2025;54:afaf015.
117. Kochar B, Cheng D, Lehto H-R, Jain N, Araka E, Ritchie CS, et al. Application of an Electronic Frailty Index to Identify High-Risk Older Adults Using Electronic Health Record Data. J Am Geriatr Soc. 2025;73:1491-7.
118. Li Q, Pan Y, Shao J, Li Y, Chen F, Wang J, et al. Development and validation of a generalizable electronic frailty index: a prospective study

in China. BMC Public Health. 2025;25:612.
119. Namugosa M, Mezes C, Rong A, Craven T, Crawford J, Parker-Autry C. Clinical Tools to Diagnose Frailty in Women With Geriatric Urinary Incontinence. Urogynecology (Phila). 2025;
120. Ruiz-Beltrán AM, Chacón-Loyola G, Barajas-Campos RL, Alcaraz-Guzmán A, Montoya-Hernández MA, Alcázar-Flores LD, et al. Performance of scoring systems for predicting mortality after cardiac surgery in the elderly. Arch Peru Cardiol Cir Cardiovasc. 2025;6:29-35.
121. Shiffer D, Desai A, Cesari M, Generali E, Greco M, Savioli G, et al. Enhancing emergency care for older persons: the role and impact of the electronic Frailty Index. Geroscience. 2025;47:3207-15.
122. Hershkowitz Sikron F, Schenker R, Shahar O, Akiva-Maliniak AB, Segal G, Koom Y, et al. Frailty transitions in electronic health records: who first? what first? Aging (Albany NY). 2025;17:1148-63.
123. Tu M-T, Tran T-N, Kwon H, Choi Y-J, Lee Y, Cho H. Prognostic value of electronic health records-based frailty measures for all-cause mortality in older patients with non-small cell lung cancer. J Geriatr Oncol. 2025;16:102130.
124. Gutierrez Velez M, Bearfield L, Chen A, Havunjian M, Whiteside H, Callahan K, et al. An Automated Frailty Index and Loss to Follow-Up Among Patients With Diabetic Retinopathy. JAMA Netw Open. 2025;8:e256920.
125. Wunnava SSJ, Ravulapalli K, El-Sayed T, Sivaharan A, Sillito S, Witham M, et al. Impact of Age Differences in Chronic Limb-Threatening Ischemia Outcomes in Octogenarians. Ann Vasc Surg. 2025;111:212-24.
126. Zhang F, Xiong YJ, Meng XD, Luo QF. The electronic frailty index is associated with in-hospital mortality and unfavorable prognosis in hospitalized elderly Chinese patients with gastrointestinal bleeding. J Clin Gastroenterol. 2025.
127. Zhou YQ, Litake O, Meineke MN, Tully JL, Xu N, Abdou W, Gabriel RA. A large language model approach to identifying preoperative frailty among older adults from clinical notes. J Am Geriatr Soc. 2025.