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Review Article

# Frailty measurement in research and clinical practice: An updated review

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ABSTRACT

Frailty is a highly prevalent geriatric condition, affecting between 12–24% of older adults globally. It remains a major cause of morbidity and mortality in older adults. Incorporating frailty measurement into clinical decision making can guide optimal patient care. This updated review presents an outline of current frailty definitions and measurement approaches in both research and clinical practice, including: Fried's frailty phenotype; Rockwood and Mitnitski's Frailty Index (FI) of cumulative deficits; Clinical Frailty Scale (CFS); Fatigue, Resistance, Ambulation, Illness and Loss of weight (FRAIL) scale; Edmonton Frail Scale (EFS); electronic Frailty Index (eFI); Hospital Frailty Risk Score (HFRS); Study of Osteoporotic Fractures (SOF) Index; Tilburg Frailty Indicator (TFI); Groningen Frailty Indictor (GFI); Multidimensional Prognostic Index (MPI); the Kihon Checklist (KCL); Geriatric 8 (G8) for oncology; the Essential Frailty Toolset (EFT) for cardiology; plus gait speed and grip strength. The main strengths and limitations of existing frailty measurements are summarised, including how well these measurements operationalise frailty in terms of their accuracy in identifying frailty, their basis on biological causative theory, and their ability to reliably predict patient outcomes and response to potential therapies.

## 1. Introduction

The world's population is living longer, and correspondingly, there is growing interest in how to maintain health and function across the lifespan. The leading global burden associated with an ageing population is the geriatric condition of frailty [1,2]. Frailty is major risk factor for morbidity and mortality [3–12], and affects a high proportion (12–24 %) of community-dwelling adults aged 65 years and over [13]. Over half of adults aged 65 years and over who present to hospital emergency departments are living with frailty [14]. Young and middle-aged adults can also develop frailty, particularly those living with chronic disease [15,16]. Frailty is highly prevalent among specific patient populations, including those with cancers [e.g. lung cancer) [17], chronic heart failure [18], atrial fibrillation [19], chronic obstructive pulmonary disease [20], inflammatory bowel disease [21] chronic kidney disease [22], rheumatoid arthritis [23], chronic pain [24], dementia [25] and diabetes [26]. There has been increasing interest in the concept of frailty in both clinical practice and healthcare policy because older adults encounter adverse health outcomes not solely explainable by age, co-morbidity, or physical functioning [2,27, 28].

### 1.1. What is frailty and why is it clinically important?

Frailty is defined as an age-related clinical state characterised by decreased physiological reserve, an increased vulnerability to stressors, and an increased risk of adverse outcomes such as falls, functional decline, hospitalisation, admission to residential care, infections and premature mortality [3,7,12,21,29–42]. An older person living with frailty often has unmet health and social care needs [43–45], a lowered quality of life [3,46], and increased risk of having or developing a chronic health condition [47–49]. Frailty also modifies the risks and benefits of usual treatments for chronic diseases [48,50–52]. Unfortunately, frailty can be misunderstood as part of the normal ageing process

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and, in turn, individuals with frailty are often treated solely on the basis of their chronic conditions [53]. Yet, frailty is a well-defined medical condition that can be prevented or managed with suitable interventions.

In clinical and surgical settings, recognition of frailty in patients can be used to structure and inform individualised care [31,50,54]. For example, knowledge of a patient's degree of frailty can guide medical decisions by alerting clinicians to the potential for poor follow-up outcomes [54–56]. In parallel, by recognising a patient's frailty, clinicians can provide patients and their families with appropriate counselling regarding the risks of medical intervention in the treatment plan and tailor the delivery of care or interventions to minimise these risks [57]. Results from frailty measurement can also be used to prompt proactive frailty-specific interventions such as medication review, nutritional supplementation, exercise referral, and social connection [58]. Furthermore, in the inpatient setting, the identification of frailty can also be used to inform discharge planning, including which health and social services or support will be required post-hospitalisation [54].

### 1.2. Characteristics of frailty

No international agreed standard for frailty measurement yet exists. However, there are commonly agreed concepts that define the condition. First, frailty manifests across the life-course [3,59,60]. In most cases, the antecedents of frailty begin before the age of 65 years [1], and even early life factors such as low birthweight and childhood growth are predictive of frailty in older age [61,62]. Second, frailty is not a natural part of the ageing process [1,28,60,61,63–66]. Rather, frailty is an extreme consequence of ageing [3,67]. Third, frailty is clinically distinct from the geriatric conditions of sarcopenia, malnutrition and cachexia, although it often co-occurs with one or more of these conditions [68–70]. Fourth, frailty is a dynamic condition along a continuum [3,71,72]. It is entirely possible for an individual to recover health and fitness after an illness or event that pushes them into frailty, or on the other hand, that person may regress to a more frail state. Fifth, frailty is a multidimensional condition, in which physical elements, socioeconomic circumstances, and psychological factors all contribute to its development [67]. Sixth, frailty is often thought of as the clinical state before disability [73], although frailty and disability certainly overlap in many individuals. Finally, frailty is based on biological theory, although the causal pathway has not been elucidated [1].

### 1.3. What causes frailty?

The pathophysiology underlying frailty is not fully understood. Generally, frailty is believed to be caused by the simultaneous decline of multiple physiological systems [1,29,64–66,74,75]. One working theory is that physiological systems (such as the cardiovascular, immune, endocrine, and musculoskeletal systems) have a built-in reserve in which an individual still functions normally [76]. Once this reserve is depleted across several physiological systems, the body can no longer adequately compensate for even minor disruptions to homeostasis, resulting in frailty [75]. This reserve depletion may also coincide with the nonlinear dynamics of biological ageing, with substantial dysregulation of metabolic systems at certain chronological ages [77].

Frailty risk can vary markedly between individuals. The development of frailty is influenced by numerous risk factors including: genetic background [61], age-related physiological changes such as impaired endocrine function [78,79], clinical factors such as chronic disease and its associated features including polypharmacy and systematic inflammation [79–81], malnutrition [70], psychological factors including the severity of depression [82], modifiable lifestyle factors (physical inactivity, sedentary behaviour and inadequate diet) [3,83], and environmental circumstances, such as socioeconomic position, living alone and social isolation [84–90].

### 1.4. Frailty measurement

Historically, a breakthrough in the operationalisation of frailty came in the mid-1990s, when frailty manifestations such as weight loss, slow gait speed, and low grip strength were grouped together to form combination scores [74]. These combination scores were found to be superior in the prediction of adverse outcome than when the individual components were considered in isolation. Subsequently, in 2001, two landmark conceptual models of frailty were proposed; first, Fried's Frailty Phenotype which considers five physical components of frailty [91], followed shortly after by Rockwood and Mitnitski's multidimensional, cumulative deficits model of frailty – the Frailty Index (FI) [64,92].

Nowadays, there are countless screening and diagnostic tools to identify frailty but no internationally accepted standard for frailty measurement. As a result, there is considerable debate regarding the choice of which measurement tool to use in terms of accuracy in identifying which individuals have frailty (construct validity), identifying which patients with frailty will be most responsive to treatment, and which will best predict adverse clinical outcomes (predictive validity) [74].

Ultimately, the choice of which frailty measurement should be used depends upon the setting (e.g. primary care, hospital, long term care), including the setting's patient case-mix and available resources. Another consideration influencing the choice of frailty measurement is how the results will be used - whether to guide patient management or to retrospectively analyse patient outcomes. Selecting the most appropriate frailty measurement is imperative to deliver optimal outcomes.

Frailty should also be regularly measured. For instance, international guidelines recommend that frailty should be routinely measured in all at-risk older adults, which typically includes adults aged 65 years and over, using a validated instrument [73,93]. Annual screening is recommended in community-dwelling older adults [73,94], with more frequent measurement recommended in hospital and long-term care settings.

### 1.5. Research question

This is an update of a review published in 2016 [74]. Over the past decade, there have been major advancements in frailty research, including new insights, measurements and perspectives. For example, the concept of frailty was predominantly confined to geriatric medicine a decade ago, whereas nowadays it is recognised across multiple medical practices. In addition, the volume of publications on frailty has increased substantially, from 10,000 publications ten years ago to over 50,000 papers now (PubMed). This updated review will incorporate the latest evidence on frailty measurements, including their clinical applications.

The aim of this review was to determine which operationalisations of frailty were most effective at measuring frailty, following several guidelines of frailty classification: that is, which measurements could accurately identify frailty; which could reliably predict patient outcomes and responses to potential therapies; and which were based on biological theory. This review incorporates several newly developed frailty measurements and updates the information about currently available measurements.

## 2. Methods

To identify studies reporting frailty measurements, EMBASE and PubMed databases were searched. The original search strategy from 2016 was updated to include new search terms. For instance, the term 'frailty' replaced 'frail elderly' in PubMed Search Headings in 2018. The search terms were thus broadly set as: 'frailty', 'frail elderly' and 'Geriatric Assessment/methods'. The initial search was performed in April 2025 and was restricted to studies published between January

2019 and May 2025. Studies prior to 2019 were not included because it was considered that if a frailty measurement had not been discussed in the literature in the past five years, then it was unlikely to have been recently used. The search was limited to English language articles. Titles and abstracts were screened against the inclusion criteria. Only full research papers and review articles were considered. Forward citation searching was also performed, in which the citations of relevant articles were searched. The following Population Implementation Comparator Outcome (PICO) was used:

- Population: aged ≥65 years.
- Implementation/indicator: frailty objectively measured in either observational, cross-sectional studies or randomised control trials.
- Comparator: n/a.
- Outcome: frailty classification or frailty prognosis.

### 2.1. Critiquing of frailty measurements

Frailty measurements were critiqued using the following standards based on Clegg's adaptation of Bell's Classification of Disease Criteria [74]:

**Table 1**
Characteristics of major frailty screening, case finding and assessment instruments.

| Instrument | Criteria assessed | Frailty classification | Time (min) | Frailty Measurement Critique[‡] | | | | | Purpose |
|---|---|---|---|---|---|---|---|---|---|
| | | | | From CGA[†] | Equipment Needed | Training Needed | Construct Validity | Predictive Validity | |
| Fried's Frailty Phenotype | 5 items: slowness, weakness, shrinking (weight loss), low physical activity, exhaustion | Frailty ≥ 3 items; Pre-frail 1–2 items, Robust = 0 items | <10 | × | ✓ | ✓ | ✓ | ✓ | Clinical measure |
| Frailty Index of cumulative deficits (FI) | ≥ 30 health deficits: ADLs, IADLs, mood, comorbidities, symptoms, cognition | Continuous score[§] (0–1) | 20–30 | ✓ | × | ✓ | ✓ | ✓ | Clinical measure |
| Frailty Index based on CGA (FI-CGA) | ≥ 30 health deficits from CGA (10 domains): ADL, IADL, co-morbidities, mood, cognition | Continuous score[§] (0–1) | <15 | ✓ | × | ✓ | ✓ | ✓ | Clinical measure |
| Clinical Frailty Scale (CFS) | Pictorial chart with corresponding written descriptions | 9 graded pictures from 1 (very fit) to 9 (terminally ill) | <5 | × | × | ✓ | ✓ | ✓ | Clinical measure; case finding |
| FRAIL Scale | 5 Items: Fatigue, Resistance, Ambulation, Illness, Loss of Weight | Frailty ≥3 items; Pre-frail 1–2 items; Robust = 0 items | <10 | ✓ | × | × | ✓ | ✓ | Case finding |
| Edmonton Frail Scale (EFS) | Cognition, health, nutrition, hospitalisation, social support, mood, function, continence | Frailty: severe 12–17; moderate 10–11; mild 8–9; vulnerable 6–7; not frail ≤ 5 | 5–10 | × | × | ✓ | ✓ | ✓ | Clinical measure; case finding |
| Electronic Frailty Index (eFI) | ≥ 30 health deficits from EMRs: comorbidities, ADLs, IADLs, symptoms, mood, cognition | Frailty: severe >0.36; moderate 0.24–0.36; mild >0.12–0.24; fit ≤0.12 | Auto | From EMR | × | × | ✓ | ✓ | Population screening; case finding |
| Hospital Frailty Risk Score (HFRS) | 109 health deficits from ICD-10 codes | Frailty risk: High >15; Intermediate 5–15; Low <5 | Auto | From EMR | × | × | ✓ | ✓ | Case finding |
| Study of Osteoporotic Fractures (SOF) Index | 3 Items: weight loss, reduced energy, unable to sit-to-stand 5x | Frailty ≥2 items; Pre-frail = 1 item; Robust = 0 items | <5 | × | × | × | ✓ | ✓ | Clinical measure; population screening |
| Tilburg Frailty Indicator (TFI) | 15 self-reported items, 3 domains: physical, psychological, social | Frailty ≥5 | <15 | × | × | × | ✓ | ✓ | Population screening |
| Groningen Frailty Indicator (GFI) | 15 self-reported items, 4 domains: physical, cognitive, social, psychological | Frailty ≥4 | <15 | × | × | × | ✓ | ✓ | Population screening |
| Multidimensional Frailty Indicator (MPI) | 8 items: co-morbidity, nutrition, ADL, IADL, cognition, pressure sore risk, polypharmacy, residence | Frailty > 0.66; Pre-frailty = 0.34–0.66; Robust <0.34 | <15 | ✓ | × | ✓ | ✓ | ✓ | Clinical measure |
| Kihon Checklist (KCL) | 25 self-reported items from CGA | Continuous score 0-25[§] | <10 | ✓ | × | ✓ | ✓ | ✓ | Population screening |
| Geriatric 8 (G8), oncology | 8 items: food intake, weight loss, mobility, neuropsychological, BMI, polypharmacy, health, age | Scored 0–17. Frailty ≤14 | <10 | ✓ | ✓ | ✓ | ✓ | ✓ | Clinical measure |
| Essential Frailty Toolset (EFT), cardiology | 4 items: weakness, cognition, anaemia, hypoalbuminemia | Scored 0 (no frailty) to 5 (high frailty) | <5 | × | × | ✓ | ✓ | ✓ | Clinical measure |

Source: Adapted from Dent et al. [74]. [†]Data used to derive the frailty measurement is available from routinely collected CGA data. [‡]Frailty measurements were critiqued using Clegg's adaptation of Bell's Classification of Disease Criteria [74]. [§]Higher score = more frail. Construct validity = accuracy in measuring the construct (concept) of frailty. Predictive validity = ability to predict adverse clinical events. Abbreviations: International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) diagnostic code; CGA = Comprehensive Geriatric Assessment; EMR = Electronic Medical Record.

1. Time taken to perform the measurement.
2. Data used to derive the frailty measurement is available from routinely collected data from a Comprehensive Geriatric Assessment (CGA).
3. Specialised equipment is required to measure frailty (for instance, a grip strength dynamometer).
4. Requirement for assessor training.
5. Validity and reliability. Reviews were initially consulted to determine the reliability and validity of frailty measurements. If no discussion of validity/reliability was included in these reviews, then relevant individual articles were searched.
6. The measurement is based on an underlying biological theory.
7. The measurement takes into account the continuum of frailty.
8. The measurement is able to predict surgical/medical outcomes and/or mortality.

A key distinction must also be made in our review between screening, case finding and assessment. Screening tools for frailty need to be low-cost, easy to use, and scalable across community-dwelling populations where frailty prevalence is low [74,95]. The aim of frailty screening is to identify frailty in its earliest stages, and in turn to implement targeted interventions to delay or reverse the progression of frailty [95]. Case finding for frailty involves proactively identifying frailty in high-risk populations, including in primary care, for the purposes of identifying which older adults will likely benefit from full clinical assessment [29]. Clinical frailty assessment involves detailed evaluation in healthcare settings to inform care planning and management [73]. Sometimes, frailty measurements serve multiple purposes, and it is not that clear whether they are, for example, a case finding or a screening tool.

## 3. Results

3882 studies were identified, containing over 50 different frailty measurements. Table 1 outlines major frailty screening, case finding and assessment tools outlined in this review. Several different approaches to frailty identification where identified, including:

1. The phenotypic approach of frailty of Fried and colleagues [28], which focuses on the physical symptoms of frailty. The phenotypic approach recognises frailty as syndrome and is increasingly known as 'physical frailty' in the literature. Other phenotypic measurements have since been developed, including the FRAIL scale [96]
2. The cumulative deficit Frailty Index (FI) approach of Rockwood and Mitnitski [97] which incorporates the multidimensional nature of frailty [64,97] and which has since been adapted to specific data sources (e.g. electronic medical records or laboratory data)
3. Mixed physical and psychosocial models, including the Edmonton Frail Scale (EFS) [74,98], and Tilburg Frailty Indicator (TFI) [99,100]
4. The pictorial-based Clinical Frailty Scale (CFS) [101,102]
5. Artificial Intelligence (AI) and machine learning algorithms

This review also recognised that the majority of frailty measurements were originally designed to operationalise frailty for research purposes, rather than for immediate clinical application [103]. Over time, several measurements have translated well into clinical practice. For example, the CFS is regularly used in acute care internationally for frailty case finding, patient triage, care planning, and perioperative risk assessment [104].

### 3.1. *Fried's frailty phenotype – the cardiovascular health study (CHS) index*

The phenotype approach for frailty was first proposed by Fried and colleagues [66]. Fried's frailty phenotype considers five physical characteristics of frailty: slowness (slow gait speed), low physical activity, exhaustion (two self-reported questions), shrinking (unintentional weight loss of more than 5 % of body weight in the last year), and weakness (low hand grip strength) [66]. By Fried's frailty phenotype, if an individual has three or more of these five characteristics, they are classified as frail; if one or two components are present, pre-frailty is diagnosed; if no components are present, then an individual is classified as robust [66]. Relatedly, it is the most commonly used frailty outcome measure in randomised controlled trials (RCTs) [105]. It was originally developed from the Cardiovascular Health Study (CHS) and is sometimes referred to as the CHS Index [106].

Assessment of frailty by Fried's frailty phenotype has been well tested for both validity and reliability across several settings, including in hospital, post-hospital rehabilitation, and long-term care. It has also been validated broadly across multiple diseases and countries. A limitation of Fried's frailty phenotype is that it may be less practical than other frailty measurements in busy clinical settings [54]. Accordingly, component measurements of Fried's frailty phenotype can, and often are, substituted with suitable alternative variables. Research by Theou and colleagues [107] reported that there are over 260 different versions of Fried's Frailty Phenotype in existence due to variable substitution. For instance, measured grip strength has been substituted with self-reported ability in 'lifting groceries' in retrospective epidemiological studies. However, these substitutions can influence both prevalence estimates and associations with mortality. Fried's frailty phenotype is commonly used in research studies.

### 3.2. *Frailty index (FI) of cumulative deficits*

The frailty index (FI) of cumulative deficits (FI-CD) was first proposed by Rockwood and Mitnitski in 2001 [64,92] and essentially represents an accumulation of health deficits [60,108]. The main premise of the FI is that the 'more things someone has wrong with them', the more frail they are likely to be [64]. To compute the FI, a list of 30 or more variables (health deficits) is usually required from a dataset [109,110]. The exact list of included health deficits is not fixed; rather, there are general guidelines which are followed to select which variables to include. For example, health deficits included in the FI should be associated with health rather than age, and should not saturate with prevalence at older ages [64,109]. There should ideally be a balance of multidisciplinary variables, reflecting a range of physiological systems [109] - a general guideline is that there should be no more than around one-third of variables from each domain. Domains include: physical measures (such as handgrip strength, gait speed, and BMI), co-morbidities, disabilities (activities of daily living (ADL) and instrumental ADL (IADL)), psychological variables (including depression and anxiety), symptoms of frailty such as weight loss and exhaustion, and poor self-reported health [29,64].

Once the FI variable list is selected, each variable is scored between 0 (does not have the health deficit) or 1 (has the health deficit). The variable scores are then summed and divided by the total number of variables included in the FI [60,64,109]. The resultant number (ratio) is the FI. For instance, if an individual has three health deficits in a list of 30, then their frailty index is 0.10 (3 divided by 30). The final score for a FI varies between 0 (no health deficits) to a theoretical maximum score of 1 (all health deficits present) [60,64,109]. The maximum FI score observed in community dwelling populations is around 0.67 [64] above which survival is not usually possible, although in hospital populations higher values have been observed [111].

The FI is well tested for reliability and validity across various settings and diseases [57,105,112–114], and has a strong ability to predict adverse outcomes [115]. Derivations of the FI include the Liver FI [116], the Claims-Based FI (CFI) [117] and the Laboratory Frailty Index (FI-Lab) – the latter consisting of routinely collected biomarkers, predominantly from blood [118,119]. The FI is regarded as an indicator of biological age as opposed to chronological age [60,97,109], and outperforms chronological age in survival models [61,108]. The FI was originally designed to be a continuous variable [64,97,101], although arbitrary cut-off thresholds are regularly used to classify frailty. Common cut-off thresholds for epidemiological studies of FI include: robust/fit (scores $\leq$0.10), pre-frail (scores $>$0.10 to $<$0.25), and frail (scores $\geq$ 0.25) [114]. Importantly, frailty as defined by the FI does not consider frailty to be a syndrome.

The FI has several strengths. By design, it can be derived from nearly any health dataset, where it can accurately predict an individual's susceptibility to adverse outcomes [60,108]. It also accounts for the dynamic nature of frailty, wherein any small changes in an individual's FI score reflect improvements or worsening of their frailty. Thus, the FI is ideal for use as an outcome measure for RCTs where detecting small changes in the level of frailty are important. Indeed, the most common application of the FI in trial settings has been reported to be in RCTs assessing treatment effect modification [105]. In addition, the FI has been proposed to distinguish between a person's underlying accumulative physiological damage across the lifespan and the usual, clinical symptoms associated with frailty [61]. Despite the many advantages of the FI, there are limitations. It can be cumbersome to apply in busy clinical practices where the data is collected manually. For instance, variables are often missing in routine clinical care. It requires mathematical computation, so the results are not instantly available unless a computer or calculator is available.

### 3.3. Frailty index derived from comprehensive geriatric assessment (FI-CGA)

Comprehensive Geriatric Assessment (CGA) is a gold standard clinical assessment for older adults, and involves medical, nutritional, functional and psychological assessments by a multidimensional team, paired with care planning and intervention [120]. Principles from the CGA form the basis of many frailty measurements. The frailty index derived from CGA (FI-CGA) is simply a FI-CD using data from a CGA. The FI-CGA was initially developed as a ten-domain index, with 14 CGA components included [121,122]. It was later expanded out by Rockwood and colleagues to include 52 CGA components [123]. The FI-CGA has a high degree of accuracy in predicting mortality [124].

### 3.4. Clinical frailty scale (CFS)

The Clinical Frailty Scale (CFS) is a rapid identification tool for frailty in the clinical setting [101,102], and was developed by Rockwood and colleagues using data from the Canadian Study on Health and Ageing [101,102]. It consists of judgement-based pictorial scale from 1 to 9, with corresponding text describing how to classify each of the nine pictures [101]. The lowest score of CFS is 1 (very fit) and the highest is 9 (terminally ill) [74,101]. The CFS can be extracted from records data or electronic medical records (EMRs) provided that a sufficient degree of functional data has been recorded and therefore can also be derived from CGAs. Recently, the CFS has been updated by Rockwood and colleagues to reflect the terminology used in current clinical practice.

The CFS has been extensively validated in both the hospital [11,102, 125] and community setting, including primary care [74,101,102]. In acute care, using the CFS to identify frailty was found to be less disruptive to older adults than other frailty measurements [54]. The CFS is the only frailty instrument recommended by the International Consortium for Health Outcomes Measurement (ICHOM) standard set of patient-centred outcomes measures for older people [126], and is thus recommended for use as an outcome measure for clinical trials in older adults. However, despite the many advantages of CFS, it does have limitations, including its high need for a proxy in the acute care setting ($>$50 %) [127], and its variable inter-rater reliability [128]. Notwithstanding this, CFS has recently been found to show moderate inter-rater reliability in acute care [127].

### 3.5. FRAIL scale

The five-component FRAIL scale was first developed by Morley and colleagues [129]. It is designed to be easy-to-apply in any clinical setting. Components include: Fatigue (felt tired most or all of the time in the past 4 weeks); Resistance (inability to climb up one flight of stairs); Ambulation (inability to walk one block); Illness (more than 5 co-morbidities); and Loss of Weight ($>$5 % over 1 year – either intentional or unintentional) [129]. Substitute measurements are often used in the application of the FRAIL scale. The FRAIL scale has been validated cross-culturally, and has shown feasibility for integration into primary health care systems internationally [130], with good criterion validity, low missing data rates, and adequate test-retest reliability [131]. A recent meta-analysis reported that the FRAIL scale showed better diagnostic accuracy than several other frailty screening tools [132]. A FRAIL Scale applicable to nursing homes/long term-care (FRAIL-NH) has also been developed [133]. One limitation noted with the FRAIL scale is that it has low responsiveness when measuring changes in frailty status over time [131].

### 3.6. Edmonton Frail Scale (EFS)

The Edmonton Frail Scale (EFS) is a hospital-based frailty instrument well tested for validity and reliability [74,98]. It was originally developed for older patients referred for CGA assessment [98]. The EFS assesses nine domains which can be extracted from a CGA [98]: cognition, general health status, functional independence, social support, medication use, nutrition, mood, continence, functional performance - the latter assessed using the Timed-Get-Up-and-Go (TUG) [134]. The maximum score of EFS is 17, with a higher score indicating a higher degree of frailty [98]. The five categories of frailty severity by the EFS are: not frail (scores 0–5), apparently vulnerable (scores 6–7), mildly frail (scores 8–9), moderately frail (scores 10–11), and severely frail (scores 12–17) [98]. The EFS is commonly used and has been well validated cross-culturally [56,135–140].

There are multiple advantages of the EFS. It is shorter to complete that a full CGA and can therefore be used as a case finding or brief, rapid assessment tool [74,98]. It is often applied to specific clinical populations in which other frailty measurements are restricted in their use – including in older podiatry [140], orthopaedic [138] and cardiovascular patients [137,141–143]. The EFS is predictive of multiple adverse health outcomes [56,137,142]. An adapted version, the Reported Edmonton Frail Scale (REFS) has been developed for use in the acute care setting. In hospitals with low resources, the EFS and REFS can provide a means to identify frailty without overloading finances [58].

### 3.7. Electronic frailty index (eFI)

An electronic frailty index (eFI) has been developed and validated using routine EMR data in the primary care setting [144–146]. It classifies an older person as either not frail, mildly frail, moderately frail or severely frail. The eFI score is strongly predictive of adverse clinical outcomes including mortality, admission to long-term care, and hospitalisation [144,145,147]. In primary care practices across England, the eFI is the recommended screening tool for frailty, where it is used to guide patient care [144,148]. In this context, eFI is used to stratify the entire practice population (aged 65 years and older), thereby allowing a passive assessment of frailty [149]. However, it is not recommended to identify frailty at an individual level [149,150]. Rather, those stratified as higher risk of frailty are recommended to be individually assessed (which may include use of short, individual-level tools such as CFS or FRAIL scale) and offered appropriate intervention based on their degree of frailty - which may be based on CGA in more severe degrees of frailty, or promotion of strength and balance or nutrition in those other milder frailty [151]. Other countries are testing the feasibility of eFI implementation in their primary care systems [146,152,153]. The eFI is also used in hospital settings [154,155]. An eFI version 2 (eFI2) has been developed and externally validated [156]. The eFI may be less useful for longitudinal research or for tracking frailty trajectories, as it largely consists of items, such as chronic conditions, that are irreversible, although one of the revised features of the eFI2 is the inclusion of time-criteria for some deficits to mitigate this limitation.

### *3.8. Hospital frailty risk score (HFRS)*

The Hospital Frailty Risk Score (HFRS) uses administrative data (hospital EMRs) to identify older persons with frailty [157]. It was originally validated in the acute care setting [157]. To compute the HFRS, specific weightings are assigned to each of 109 pre-determined International Classification of Diseases (ICD-10) codes listed in a patient's current EMR record on hospital admission, or in the two most recent hospital admissions over the two previous years [158]. An aggregate score is then determined, with the following cut-off scores used to classify risk of frailty: low risk (<5); intermediate (5–15); or high (>15) [157]. The HFRS has been successfully validated in the hospital setting across several countries [159–161]. However, since its development, the usability of the HFRS in clinical practice has been queried [162,163].

### *3.9. Study of osteoporotic fractures (SOF) index*

The Study of Osteoporotic Fractures (SOF) frailty index was developed to rapidly identify frailty from its namesake study [164]. Like Fried's frailty phenotype, the SOF index also considers frailty as phenotypic with an underlying causative theory [165]. The SOF index consists of three components: weight loss, reduced energy level, and low mobility [164]. Frailty is classified by the SOF index when two more characteristics are present: low mobility (assessed via a five-times chair stand test), exhaustion (an answer of 'no' to the question 'do you feel full of energy?') and weight loss (either intentional or unintentional) of 5 % or more in the previous year) [164]. The SOF is valid and reliable, and is an independent predictor of adverse outcomes in community-dwelling older adults [165]. The SOF is used for rapid, cost-effective population screening and clinical assessment of frailty [165,166], although it may over-screen frailty in inpatient settings as patients with a clinical condition often cannot perform a five-times-chair-rise [74].

### *3.10. The Tilburg Frailty Indicator (TFI)*

The Tilburg Frailty Indicator (TFI) is a self-administered questionnaire developed in the Netherlands during 2010 [99,100]. It contains 15 simple self-reported items, encompassing: physical components (health, weight loss, difficulty in walking, balance, hearing, vision, gripping and tiredness); psychological factors (memory, feeling down, anxiety and coping); and social elements (living alone, social isolation, social support). Scores $\geq$5 are indicative of frailty [99]. The TFI shows good validity and reliability for community-dwelling older people [99,167] and accurately predicts mortality [168]. In recent years, some cross-cultural validations of the TFI have become available [169,170]. Because of the self-reported design of the TFI, a limitation includes its potential for reporting bias.

### *3.11. Groningen frailty indicator (GFI)*

The Groningen Frailty Indicator (GFI) was developed in the Netherlands and contains 15 dichotomous self-reported items, comprising of: physical factors (independence in shopping, walking, dressing, toileting; physical fitness, vision, hearing; weight loss and polypharmacy); a cognitive component (memory issues); social factors (emptiness, missing others, feeling abandoned); and a psychological component (feeling downhearted or sad; feeling nervous or anxious) [171,172]. Frailty by GFI is classified on a spectrum ranging from a score of 0 (normal activity without restriction) to 15 (completely disabled), with scores $\geq$4 indicative of frailty [172]. As a frailty measurement, the GFI shows good feasibility and reliability [171], with good constructive validity [173], moderate internal consistency and adequate discriminative ability [171,172,174]. It is also predictive of adverse outcomes, including in oncology patients [175,176]. The GFI has been proposed for co-use with the FI as part of a two-step frailty screening process: the FI extracted from healthcare data to be used initially, with referral to a GFI questionnaire for patients with a high FI score [177]. Cross-cultural validation of the GFI has occurred in recent years [178,179]. As per the TFI, a limitation includes its potential for reporting bias due to its self-reported design.

### *3.12. Multidimensional prognostic instrument (MPI)*

The Multidimensional Prognostic Instrument (MPI) was developed by Pilloto and colleagues as a prognostic tool for hospitalised older patients [180]. It is derived from eight CGA components: medication number, ADL, IADL, cognitive status, nutritional status, risk of developing pressure sores, co-morbidity and living status [180]. Problems for each component are classified as either major (1 point), minor (0.5 points) or none (0 points) [180,181]. Scores are then summed and divided by eight, with scores >0.66 graded as frailty [180]. The MPI has been well tested for validity and reliability in the hospital setting [181], and is predictive of both mortality [182] and functional decline [181,183], including in surgical patients [184,185]. The MPI is predominantly used in Italy, although international studies have adopted this measure [111,113,181,182].

### *3.13. Kihon check-list (KCL)*

The Kihon Check-list (KCL) was developed in Japan as a tool to predict future functional disability [186]. It consists of 25 self-reported questions that cover seven domains: ADL, physical activity, nutritional status, oral function, house-boundedness, cognitive status, and depressive mood [186,187]. Questions are dichotomous (yes/no answers) and the scoring of KCL is based on similar principles to the FI-CGA [188]. The KCL is a valid and reliable measurement for frailty [188,189], and shows predictive ability for adverse clinical outcomes in both community-dwelling older adults [188,190–192] and cardiology patients [192–194]. Several studies have cross-culturally adapted and validated the KCL [195–198], indicating its applicability in diverse populations. Shortfalls of the KCL include in its reliance on self-reported measures, and accordingly, results may deviate from those of clinical measurement of frailty.

### *3.14. Geriatric 8 (G8) for oncology patients*

The Geriatric 8 (G8) screening tool was developed for older people with cancer, to distinguish those who are fit to undergo treatment from those who may benefit from additional GCA [199]. The tool contains 8 items, which were largely derived from the Mini Nutritional Assessment (MNA) questionnaire: food intake, weight loss, mobility, neuropsychological problems, BMI, polypharmacy, self-reported health and age. G8 scores range from 0 (no frailty) to 17. The total G8 score is inversely related to the degree of frailty, with a cut-off score of $\leq$14 used to classify frailty [199]. The G8 has been widely validated for diagnostic accuracy and predictive validity across older populations with various types of cancer [200]. It is also predictive of post-operative cancer surgery complications [199]. Although G8 is one of the most frequently studied and best performing frailty measurements among older patients with cancer, there have been concerns regarding its specificity and negative predictive value, with a corresponding tendency to over-screen for frailty [200].

### 3.15. Essential frailty toolset (EFT) for cardiology patients

The Essential Frailty Toolset (EFT) was developed in 2017 by Afilalo and colleagues for patients undergoing cardiovascular surgery and contains four components: lower-extremity weakness (five-times chair rise ≥15 s); cognitive impairment (MMSE <24); anaemia (haemoglobin level <13 g/dL in men or <12 g/dL in women) and hypoalbuminemia (serum albumin <3.5 g/dL) [201]. If any of these frailty components are present, a score of 1 point is given, with the exception of the chair rise test, when 2 points is given for non-completion. The EFT is scored from 0 (no frailty) to 5 (highest frailty) [201]. The EFT is validated predominantly in patients having transcatheter aortic valve implantation (TAVI) [202], and has also been validated for online, face-to-face assessment in cardiology patients [203]. The EFT is predictive of adverse clinical outcomes in patients undergoing cardiac surgery [204, 205], and is recommended as a tool predict short- and immediate-term mortality in patients scheduled for TAVI [202].

### 3.16. Individual frailty measurements

Frailty can also be screened using its underlying characteristics, such as gait speed and grip strength. Gait speed is highly predictive of adverse clinical outcomes in various population groups, including community-dwelling older adults [206], surgical patients [207,208], and those living with chronic disease [209–211]. Gait speed has high accuracy in identifying older adults who are truly frail, although it does have a tendency to over-screen [212]. It is applicable clinically, although there often are difficulties in measuring out a walking course of suitable length in a clinical setting. Low grip strength can also be used as a single measure of frailty, and has been found to be predictive of both mortality and hospitalisation in older adults [213].

### 3.17. Other frailty measurements

For this review, we prioritised commonly used instruments to measure frailty, which were most aligned with our specific assessment criteria relevant to our research question. Frailty measurements beyond the scope of the review include: the Pictorial Fit-Frail Scale (PFFS) [52], the PRISMA-7 [214], the Gérontopôle Frailty Screening Tool (GFST) [215], the Vulnerable Elders Survey (VES) (vulnerability often considered to be akin to frailty), the Frailty Trail Scale (FTS) [216], the Frail Non-Disabled (FiND) instrument for frailty screening [217], the Frailty Risk Score (FRS) [217], the Health Deficits Index (HDI) [217], the SHARE Frailty Instrument developed from the Survey of Health, Aging and Retirement in Europe [218], the Spanish Frailty-VIG [219], the Sherbrooke Postal Questionnaire [220], the Frailty Groupe Iso-Ressource Evaluation (FRAGIRE) tool [221], the Frailty Index for Elders (FIFE) [222], the EASY-Care Two step Older persons Screening (EASY-Care TOS) [223], Kaigo-Yobo Checklist (KYCL) [224], the electronic Frailty Score (eFS) [225], the Comprehensive Frailty Assessment Instrument (CFAI) [226], the Clinical Global Impression of Change in Physical Frailty (CGIC-PF) [227], the Comprehensive Assessment of Frailty (CAF) test for cardiology patients [228], the Myeloma Frailty Score (MFS) [229] for patients with multiple myeloma [229], the Risk Analysis Index (RAI) [230] for surgical populations, and multiple others. Functional decline indices such as the Identification of Seniors at Risk (ISAR) score [231] and the Hospital Admission Risk Profile (HARP) [232] may also be considered to be frailty measurements, given that functional decline is an outcome of frailty [233]. Similarly, the Short Physical Performance Battery (SPPB) [234], whilst not included in this review, is sometimes considered to be a frailty measurement. There is ongoing research to develop a blood-based biomarker approach for frailty identification [235]. Artificial Intelligence [236] and machine learning techniques (e.g. partial genetic algorithms) [237] have also been successfully used to accurately identify older adults with frailty from routinely collected data, and will likely play a large role in case finding older adults with frailty in the near future [238]. Wearable technologies, such as smartwatches and wireless inertial sensors to assess gait, are increasingly being used to monitor changes in an individual's frailty status [238].

## 4. Discussion

This updated review provides guidance on frailty measurements commonly used in frailty research and in clinical practice. We found a multitude of measurements used to identify frailty, ranging from quick, simple frailty screening measurements to sophisticated, time-intensive assessments. The number of publications on frailty measurement found in our five-year literature search ($n$ = 3882) was almost ten-fold higher than in our previous review conducted in 2016 ($n$ = 422) [74]. In addition, many new frailty measurements have emerged for subtypes of frailty, such as oral frailty, nutritional frailty, social frailty, and cognitive frailty. However, the quality and value of some of these new measurements are of questionable quality and have not been widely adopted.

Based on the findings of this updated review, there are several potential future options for frailty measurement. One option is, as part of a consensus process, to decide on one frailty measurement from the multitude of already existing measurements. Indeed, having a single, universal frailty measurement would be advantageous in terms of providing consistent comparison of frailty prevalence worldwide. Yet on the other hand, having one frailty measurement could be problematic because frailty measurements can be likened to 'horses for courses', wherein different frailty measurements are suited to different populations or settings. Some are better for population-level frailty screening, whereas others are best suited for clinical screening, or for clinical assessment. A compromise may therefore be to agree on the circumstances in which specific measures may be more or less optimal. A second approach could be to develop a new gold-standard frailty standard measurement. However, countless research groups have tried to do exactly this, which partially explains why there are an abundance of frailty measurements in existence today. A third option could be to garner consensus for the use of one frailty measurement for screening or case finding and a second one for a full assessment. For instance, the eFI is explicitly designed for population stratification, with subsequent individual-level assessment for people identified as high risk [149]. Each of these three options have both strengths and weaknesses, and ongoing discussion by clinicians and researchers is needed to discern the best path forwards.

No matter the path forward for the future of frailty measurement, it is important that frailty is recognised in the clinical setting to identify frailty in older adults or in those living with one or more chronic conditions. Incorporating measurement of frailty into clinical practice may provide a means for clinicians to identify and manage the condition early into its progression. The decision regarding which frailty measurement to use should be informed by the resources available and the purpose of measurement (e.g. research or clinical practice). In addition, it is crucial that clinicians select a frailty measurement that has been validated in the setting in which they are practicing – for instance, frailty instrument validity varies across primary care, hospital settings, and long-term care settings. Yet in many studies included in this review, frailty measurements were modified somewhat from their original, validated version, without clear explanations about this modification. This lack of consistent reporting can skew findings and interpretation of results, and in turn impact on clinical utility.

This review uncovered that very few frailty measurements had been validated against meaningful outcomes using Patient Reported Outcome Measures (PROMs). Recent literature has flagged the urgent need to use PROMs in frailty measurement research [239]. Similarly, we found that many older adults were screened and/or assessed for frailty by proxy rather than in person. Future research is needed on the feasibility and cost-effectiveness of implementing frailty measurements in clinical practice, including implementation science research involving the assessment of barriers and enablers to successful implementation. Research is also needed wherein healthcare professionals, older adults and their carers are asked their opinion as to what frailty measurement means to them and which screening and assessment measurements they prefer [94].

## 5. Conclusion

Against the backdrop of population ageing, frailty continues to move to the frontline of both clinical practice and healthcare research. Measurement of frailty often is an integral part of routine clinical care for older adults and for those living with co-morbidity. There is no gold standard frailty measurement available, and correspondingly, there are a multitude of frailty measurements available, each with various strengths and weaknesses. In this review, we outlined commonly used frailty measurements in both research and clinical practice. A high-quality frailty measurement should be able to accurately identify frailty, be able to predict patient outcomes and response to treatment, and be based on an underlying biological theory. Based on these criteria, the two most common frailty measurements, Fried's Frailty Phenotype and Rockwood and Mitnitski's Frailty Index appeared to be the most robust measurements for use by clinicians and researchers. This review was designed to be a valuable resource for clinicians, academics, and healthcare policy makers.

## Learning points

- Frailty measurement should be incorporated into clinical practice as part of routine care for older patients.
- There is no internationally agreed standard measurement for frailty.
- Multiple frailty measurements exist, making it difficult to choose which frailty measurement to use.
- Decisions regarding which frailty measurement to use should be guided by the intended purpose, available resources, and the setting.
- The two most common frailty measurements (both with high validity and reliability) are Fried's frailty phenotype and Rockwood and Mitnitski's Frailty Index.
- There is no "one" perfect frailty measurement currently available
- Different frailty measurements have different purposes, including screening, case finding or clinical assessment.

## Declaration of competing interest

The authors declare that they have no conflicts of interest.

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