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Review Article

Frailty measurement in research and clinical practice: A review

Elsa Dent [a,b,*], Paul Kowal [c,d], Emiel O. Hoogendijk [e,f]

[a] Centre for Research in Geriatric Medicine, School of Medicine, The University of Queensland, Brisbane, Australia
[b] School of Public Health, The University of Adelaide, Adelaide, Australia
[c] WHO SAGE, Department of Health Statistics and Information Systems, World Health Organization, Geneva, Switzerland
[d] University of Newcastle Research Centre for Generational Health and Ageing, Newcastle, Australia
[e] Department of General Practice & Elderly Care Medicine, EMGO + Institute for Health and Care Research, VU University Medical Center, Amsterdam, The Netherlands
[f] Department of Epidemiology & Biostatistics, EMGO + Institute for Health and Care Research, VU University Medical Center, Amsterdam, The Netherlands

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ABSTRACT

One of the leading causes of morbidity and premature mortality in older people is frailty. Frailty occurs when multiple physiological systems decline, to the extent that an individual's cellular repair mechanisms cannot maintain system homeostasis. This review gives an overview of the definitions and measurement of frailty in research and clinical practice, including: Fried's frailty phenotype; Rockwood and Mitnitski's Frailty Index (FI); the Study of Osteoporotic Fractures (SOF) Index; Edmonton Frailty Scale (EFS); the Fatigue, Resistance, Ambulation, Illness and Loss of weight (FRAIL) Index; Clinical Frailty Scale (CFS); the Multidimensional Prognostic Index (MPI); Tilburg Frailty Indicator (TFI); PRISMA-7; Groningen Frailty Indicator (GFI), Sherbrooke Postal Questionnaire (SPQ); the Gérontopôle Frailty Screening Tool (GFST) and the Kihon Checklist (KCL), among others. We summarise the main strengths and limitations of existing frailty measurements, and examine how well these measurements operationalise frailty according to Clegg's guidelines for frailty classification — that is: 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

There is accumulating evidence that frailty may become one of the world's most serious health issues. A global epidemiological transition is currently occurring, in which mortality is becoming more likely to result from age-related degenerative diseases than from infectious diseases [1]. These age-related diseases often manifest in frailty, which can result in serious functional limitations and susceptibility to adverse outcomes. Frailty exists in around a quarter of people aged over 85 years, and places a heavy burden on health and aged care systems [2–4]. With the number of older people dramatically expanding in almost all countries, frailty prevalence is expected to soar [5].

1.1. What is frailty?

Frailty is a geriatric condition characterised by an increased vulnerability to external stressors [5,6]. It is strongly linked to adverse outcomes, including mortality, nursing home admission, and falls [7–11]. Frailty is different conceptually from ageing, disability, and co-morbidity although it is distinctly related to these factors [12–18]. For example, although frailty prevalence increases with age, it occurs independently from chronological age [7,10].

Frailty does not yet have an internationally recognised standard definition, although the general premise is that frailty may be considered to be a geriatric syndrome [18–25] reflecting multi-system dysfunction [6,10,23,25–27] and in which individuals are able to dynamically transition between severity states [12,27–29]. Multiple reasons exist as to why it is so difficult to define frailty, including: its complex aetiology [10,30]; the often independent work of frailty researchers [31,32]; and the inherent difficulty in distinguishing frailty from both ageing and disability [18,22,33]. Regardless of these issues, and perhaps because of them, international groups such as the World Health Organization (WHO) and the International Association of Geriatrics and Gerontology (IAGG) are working on an internationally accepted frailty definition [22,34].

1.2. What causes frailty?

Frailty has a strong biological component, and it is thought to result from cumulative cellular damage over the life-course [12,35,36]. The specific pathophysiological pathways underpinning frailty are not yet clearly known [10,37], although there is evidence that both malnutrition and sarcopenia (muscle wastage) may have similar causal

* Corresponding author at: Centre for Research in Geriatric Medicine, School of Medicine, The University of Queensland, Brisbane, Australia.
E-mail addresses: e.dent@uq.edu.au (E. Dent), kowalp@who.int (P. Kowal), e.hoogendijk@vumc.nl (E.O. Hoogendijk).

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pathways [38–40]. Inflammation is one such pathway, and is well established as a causal factor for frailty [23–25,30,41]. Pro-inflammatory cytokines can influence frailty either directly, for instance by promoting protein degradation [27], or indirectly by altering metabolic processes [30].

The biological causative mechanisms of frailty are different from those processes causing the ageing process [27]. Frailty occurs when not one, but multiple physiological systems decline [5,10,23,27,36]: the more physiological systems that are in a diminished state, the greater the likelihood of frailty [42]. While physiological systems do lose some of their homeostatic reserve at advanced ages, there is an inherent reserve buffer, suggested to be around 30%, which an individual can lose and still function well [43]. Frailty is thought to result when this threshold is surpassed in multiple physiological systems — so much so that repair mechanisms cannot maintain system homeostasis [27]. Pre-frailty (latent frailty) is thought to be the silent precursor to frailty, manifesting as frailty when external stressors, such as acute illness, injury or psychological stress, occur [27].

Other factors linked with frailty development include (i) sociodemographic influences, such as poverty, living alone, area deprivation and low education level [19,27,30,44]; (ii) psychological factors, including depression [45]; (iii) nutritional issues such as malnutrition and poor oral health, [10,27,46]; (iv) polypharmacy [30]; (v) diseases (cancer, endocrine disorders, dementia) and their associated complications [30]; and (v) low physical activity [30].

1.3. Frailty measurement

Regardless of what definition of frailty is used, to be applied practically, frailty first needs to be operationally defined. A breakthrough in frailty measurement came in the mid-1990s, when it was verified that when frailty manifestations, such as slow walking speed and weight loss, were grouped together to form combination scores, prediction of adverse clinical outcomes was better than when components were considered alone [47,48]. Frailty combination scores have been used to operationally define frailty ever since. In 2001, Fried and colleagues proposed their landmark frailty phenotype measurement, which assessed frailty by measuring five of its physical components [6]. Following this, and also in 2001, Rockwood and Mitnitski released their accumulated deficits model of frailty, which considered not only the physical components of frailty, but also the psychosocial aspects of frailty [49]. Both of these frailty models are highly regarded and in common use today.

Nowadays, a plethora of frailty measurements are in existence. Identifying which frailty measurement is most suitable for clinical and/or research application is currently a topic of heated debate. Moreover, multiple reviews have highlighted the need for a *standard* measurement of frailty in research and/or clinical practice [12,17,19,23,31,34,50–52]. A standard measurement would allow for consistent recognition of frailty worldwide.

Critically, a frailty measurement should fulfil a number of criteria. First and foremost, it should be able to accurately identify frailty. Additional qualities it should possess as identified by Clegg et al. [10] using Bell's disease classification guidelines [53] include: (i) an ability to reliably predict adverse clinical outcomes; (ii) an ability to reliably predict patient response to potential therapies; and, (iii) be supported by a biological causative theory. Frailty measurements should also be simple to apply [10]. Of further importance is their level of application. For instance, some frailty measurements may be more applicable for use in population health studies as screening tools, whereas others may work best in the clinical setting either for the screening or diagnosis of frailty.

1.4. Research question

To date, no reviews have yet independently placed a wide range of frailty measurements under scrutiny using Clegg's criteria for frailty measurement. The aim of this review was to determine which operationalisations of frailty were best at measuring frailty according to Clegg's guidelines of frailty classification: that is, which measurements could accurately identify frailty; which could reliably predict patient outcomes and response to potential therapies; and which were based on biological theory.

2. Methods

To identify studies reporting frailty measurements, EMBASE and PubMed databases were searched. Search terms were broadly set as: 'frail elderly' and 'Geriatric Assessment/methods'. The initial search was performed in July 2015 and was restricted to studies published between January 2009 and July 2015. Studies prior to 2009 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. A "lateral search" 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 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:

1. Time taken to perform the measurement.
2. Data used to derive the frailty measurement is available from routinely collected CGA data.
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.

3. Results

422 studies were identified. From these studies, 29 different frailty measurements were identified. Overall, frailty measurements were used for frailty classification and prognosis across a broad range of medical patients, including: geriatric, oncology, surgical, orthopaedic, cardiovascular and renal patients. The majority of these medical studies used frailty measurement as a prognostic tool, with Fried's frailty phenotype and the FI being the most common frailty measurements applied to these studies. Table 1 outlines the frailty measurements identified in the present study, and ranks them against quality criteria. The various frailty measurements identified and their details are outlined in Subsections 3.1–3.16.

3.1. Fried's Frailty Phenotype — the Cardiovascular Health Study (CHS) index

Fried's Frailty Phenotype is a popular measurement of frailty, often known as the Cardiovascular Health Study (CHS) Index from the study

Table 1
Comparisons of selected frailty operational definitions.[a]

Index	Country of origin	Time (min)	# items	Components	Frailty	Requirements of frailty measurements					Measurement used in the clinical or population setting?
						Data CGA[b]	Special equipment	Assessor training	Valid & reliable	Outcome prediction	
CHS	USA	<10	5	Weight loss, low physical activity, exhaustion, slowness, weakness	Frailty ≥3items; pre-frail 1–2 items; Robust = none	x	✓	✓	✓	✓	Both
FI-CD	Canada	20–30	30+	Accumulated health deficits: score of 0 (no deficits) to 1.0 (all deficits)	A continuous score. Frailty cut-off suggested >0.25	✓	x	✓	✓	✓	Both
FI-CGA	Canada	<15	30+	10 domains, 52 items (originally 14): including ADL, IADL, Co-morbidities, Mood & Cognition	A continuous score. Frailty cut-off suggested >0.25	✓	x	✓	✓	✓	Clinical
SOF	USA	<5	3	Weight Loss, Exhaustion, Unable to Rise from Chair 5 times	Frailty ≥2 items; pre-frail = 1 item; robust = 0 items	x	x	x	✓	✓	Both
EFS	Canada	<5	9	Cognition, health (2×), hospitalisation, social support, nutrition, mood, function, continence	Frailty = scores ≥7	x	x	✓	✓	✓	Clinical
FRAIL	USA	<10	5	Fatigue, Resistance, Ambulation, Illness, Loss of Weight	Frailty ≥3 items; Pre-frail 1–2 items; robust = 0 items	✓	x	x	✓	More studies needed	Both
CFS	Canada	<5	1	Visual and written chart for frailty with 9 graded pictures. 1 = very fit; 9 = terminally ill	A continuous score. Frailty cut-off point ≥5	x	x	✓	✓	✓	Clinical
MPI	Italy	<15	8	Co-morbidity, Nutrition, Cognition, Polypharmacy, Pressure Sore Risk, Living Status, ADL, IADL	Frailty >0.66; Pre-frailty = 0.34–0.66; robust <0.34	✓	x	✓	✓	More studies needed	Both
TFI	The Netherlands	<15	15	Self-reported in 3 domains: physical, psychological and social	Frailty = scores ≥5	x	x	x	✓	More studies needed	Population-level screening
PRISMA-7	Canada	<10	7	Self-reported: age (>85 years), male, social support and ADLs	Frailty = scores ≥3	x	x	x	✓	More studies needed	Population-level screening
GFI	The Netherlands	<15	15	Self-reported in 4 domains: physical, cognitive, social and psychological	Frailty = scores ≥4	x	x	x	x	More studies needed	Population-level screening
SPQ	Canada	<5	6	Self-reported: living alone, polypharmacy, mobility, eyesight, hearing, memory	Frailty = scores ≥2	x	x	x	x	More studies needed	Population-level screening
GFST	France	<5	6	2 parts: (i) self-report (lives alone, weight loss, fatigue, mobile, memory, gait (ii) clinical judgement	Identified by clinical judgement, after screening	x	x	✓	x	More studies needed	Population-level screening
KCL	Japan	<10	25	25 items from CGA, scoring as per FI-CGA	A continuous score. Frailty cut-off suggested >0.25	✓	x	✓	✓	More studies needed	Population-level screening

Abbreviations: CHS = Cardiovascular Health Study Index (Fried's Frailty Phenotype); FI-CD = Frailty Index of Accumulated Deficits; FI-CGA = Frailty Index derived from Comprehensive Geriatric Assessment; SOF = Study of Osteoporotic Fracture (SOF) Index; EFS = Edmonton Frailty Scale; FRAIL = Fatigue, Resistance, Ambulation, Illness and Loss of Weight Index; CFS = Clinical Frailty Scale; MPI = Multidimensional Prognostic Index; TFI = Tilburg Frailty Index; GFI = Groningen Frailty Indicator; SPQ = Sherbrooke Postal Questionnaire; GFST = Gérontopôle Frailty Screening Tool (GFST); KCL = Kihon Check-list.

[a] Frailty measurements are evaluated by clinical or research staff, unless otherwise indicated (for example, by patient self-report). All frailty measurements were based on a biological theory, with the exception of the CFS.

[b] 'Data CGA' implies that the data for the frailty measurement is obtainable readily from a Comprehensive Geriatric Assessment (CGA).

it was originally applied to [6]. The CHS index considers frailty by its physical characteristics, or 'phenotype', defining the condition as the presence of three or more of: shrinking (unintentional weight loss of 4.5 kg or more in the last year), weakness (low grip strength), exhaustion (self-reported), slowness (slow walking speed) and low physical activity [6]. It has a solid foundation of biological causative theory [6,54] and has been applied to multiple epidemiological studies where it is predictive of adverse clinical outcomes, including mortality [6,55–57]. Despite its widespread use, a major factor inhibiting clinical application of the CHS index is its inclusion of measurements not routinely used for patient assessment — grip strength, for example. Also of note, the CHS index does not include psychosocial components of frailty.

3.2. Frailty Index of Accumulative Deficits (FI-CD)

The Frailty Index (FI) of Accumulative Deficits (FI-CD) was first proposed by Rockwood and Mitnitski as a way to incorporate the multidimensional nature of frailty into an operational definition [49]. The FI-CD is underpinned by biological causative theory [12,58] and involves the accumulation of 30 or more co-morbidities, symptoms, diseases, disabilities or any deficiency in health with the idea that a greater number of health deficits indicates higher frailty [59]. The FI-CD is expressed as a ratio. For instance, if a list of possible health deficits obtainable from a study cohort is 50, a person with five of these deficits has a frailty index of 0.1. The exact list of health deficits for inclusion in the FI-CD does not specifically matter, other than they should: increase in incidence but not have a ceiling effect with age; be reflective of a range of physiological systems; and be associated with health and not age per se [59]. Comprehensive guidelines for creating a FI-CD have been provided by Searle et al. 2008 [59].

The FI-CD is well validated, and has been applied to multiple datasets, including the Survey of Health, Ageing and Retirement (SHARE) study in Europe, where it is termed the SHARE-FI [60,61]. Ideally, the FI-CD should be used as a continuous variable, however for comparison studies, various cut-off points have been considered to identify frailty [62,63]. Importantly, the FI-CD has been recently adapted to a clinical model for mice, which has huge implications for frailty intervention studies [64,65].

Several studies have found that the FI-CD has a higher predictive ability of adverse clinical events than other frailty measurements in both hospital and community settings [62,66,67]. Additionally, it has been reported that it is the total FI-CD score, rather than type of health deficits included in the FI-CD, that is most predictive of adverse outcomes [12]. An upper limit the FI-CD is believed to exist at around 0.67, beyond which survival is unlikely [68].

Despite its many positive attributes, the FI-CD does have its limitations: it can be time consuming to calculate and its mathematical nature, although simple, renders it unpopular clinically [69]. However, when derived from data already collected in a Comprehensive Geriatric Assessment (CGA), construction of a FI can be time-efficient, as detailed in Section 3.3.

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

The frailty index derived from CGA (FI-CGA) is simply a FI-CD using data from a CGA. CGA is the global standard clinical assessment for older people, and includes medical, nutritional, functional and psychological assessments by a multidimensional team. The FI-CGA was initially developed as a ten-domain index, with 14 CGA components included [70,71]. It was later expanded out by Rockwood and colleagues to include 52 CGA components [58]. The CGA is used as a clinical standard for frailty assessment and has been found to be highly associated with the FI-CD [70]. Nowadays, many clinical studies have adopted a FI-CGA for frailty assessment. FI-CGA has been found to predict patient response in multiple fields, including: oncology, orthopaedics, immunology, urology, pulmonology, and cardiology [25,72,73].

3.4. Study of Osteoporotic Fractures (SOF) Index

The Study of Osteoporotic Fractures (SOF) frailty index, like the CHS index, considers frailty to be phenotypic in nature, with an underlying biological causative theory [74]. The SOF is easy to apply, with frailty classified as the presence of ≥2 components out of list of three: weight loss (intentional/unintentional, >5% in the last year), exhaustion (an answer of 'no' to the question 'do you feel full of energy?') and low mobility (inability to perform a chair rise five times). The SOF is valid and reliable, and has been found to be an independent predictor of adverse outcomes in community-dwelling older people [75]. It generally compares well to the FI and the CHS regarding adverse outcome prediction [62,67,74,76]. The SOF is suited for both population screening and clinical assessment, although it does tend to over-screen frailty in the hospital setting because patients with an acute medical condition often cannot perform a five-times-chair-rise.

3.5. Edmonton Frailty Scale (EFS)

The Edmonton Frail Scale (EFS) is a valid and reliable measurement tool for the identification of frailty in the hospital setting [77]. The EFS is scored out of 17, and contains nine components: cognition; general health status: self-reported health: functional independence: social support; polypharmacy; mood; continence; and functional performance [77]. Component scores are summed, and the following cut-off scores used to classify frailty severity: not frail (0–5); apparently vulnerable (6–7); mildly frail (8–9); moderately frail (10–11) and severely frailty (12–17) [77]. With only nine components, the EFS is much simpler to extract from CGAs than the FI-CGA. The EFS is increasingly being used to identify frailty in specific clinical populations [78,79], and an adapted version, the Reported EFS has been developed for acute care [80].

3.6. Fatigue, Resistance, Ambulation, Illness, Loss of Weight (FRAIL) Index

Recently proposed by the International Association of Nutrition and Ageing (IANA), FRAIL is comprised of five components: Fatigue (self-report), Resistance, Ambulation (slow walking speed), Illness and Loss of weight (5% or more in the past year) [81]. When three or more of these components are present, an older person is classified as frail. FRAIL is judged to be clinically advantageous due to its simple nature and ability to be obtained from data already included in a patient CGA [81]. It has been found to be predictive of mortality in specific populations [82,83]. Further validation studies of FRAIL are needed for both hospitalised and community dwelling older people.

3.7. Clinical Frailty Scale (CFS)

The Clinical Frailty Scale (CFS) is a well validated frailty measurement that originated from Dalhousie University in Canada [84]. It is scored on a scale from 1 (very fit) to 9 (terminally ill) and is based on clinical judgement [84]. Each point on its scale corresponds with a written description of frailty, complemented by a visual chart to assist with the classification of frailty. A score ≥5 is considered to be frail [84]. The CFS can be extracted from data from medical charts, and therefore can also be derived from CGAs. The CFS has been validated as an adverse outcome predictor in hospitalised older people [85,86].

3.8. Multidimensional Prognostic Instrument (MPI)

The Multidimensional Prognostic Instrument (MPI) was developed as a prognostic tool for hospitalised older patients [87], and has been judged to be a multidimensional frailty instrument, albeit with a

simpler nature than the FI-CD [88]. The MPI is derived from eight CGA components: medication number, instrumental ADLs (IADLs), ADLs, cognitive status, nutritional status, risk of developing pressure sores, co-morbidity and living status [87]. Problems for each component are classified as either classed as major (1 point), minor (0.5 points) or none (0 points) [87,88]. Scores are then summed and divided by eight, with scores >0.66 graded as frailty [87,88]. Compared with other frailty measurements, the MPI shows a higher predictive ability of adverse outcomes [88], although additional research is needed to confirm this finding.

3.9. Tilburg Frailty Indicator (TFI)

The Tilburg Frailty Indicator (TFI) is a self-administered questionnaire developed in the Netherlands during 2010 [89,90]. 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 ≥5 are indicative of frailty [89]. The TFI shows good validity and reliability for community-dwelling older people [89,91]. The physical components of the TFI have been found to show good predictive ability of adverse outcomes, as opposed to its social components [90].

3.10. PRISMA-7

PRISMA-7 contains seven simple self-reported components to identify frailty: older than 85 years; male; health problems which limit activities; support of another person needed; health problems requiring staying at home; social support; and use of a cane/walker/wheelchair [92]. Each component is scored with a 'yes/no' answer, with a total score ≥3 deemed as frailty [92]. The PRISMA-7 shows good accuracy in identifying frailty in community-dwelling older people [93], however it has a tendency to over-screen for frailty [94], thereby limiting its ability as a screening tool.

3.11. Groningen Frailty Indicator (GFI)

The Groningen Frailty Indicator (GFI) is a widely used frailty measurement developed in the Netherlands, with moderate internal consistency and adequate discriminative ability [95–98]. It 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) [97,98]. Frailty by GFI is classified on a spectrum ranging from a score of 0 (normal activity without restriction) to 15 (completely disabled), with scores ≥4 indicative of frailty [95]. The GFI shows good feasibility and reliability as a frailty measurement [95,97], and 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 [99]. Studies of the GFI have been predominantly been confined to the Netherlands, and cross-cultural validation studies are required.

3.12. Sherbrooke Postal Questionnaire (SPQ)

The Sherbrooke Postal Questionnaire (SPQ) comprises six questions with dichotomous answers: living alone; ≥3 medications; mobility; eyesight; hearing; and memory problems [100]. Component scores are summed, with a total score ≥2 considered to be frailty [101]. The SPQ shows inconsistent validity in frailty identification when compared to TFI and GFI [96,101]. Further validation studies of SPQ are needed, as are studies determining its ability to predict adverse outcomes in older people.

3.13. Gérontopôle Frailty Screening Tool (GFST)

The Gérontopôle Frailty Screening Tool (GFST) is designed for early recognition of frailty in community-dwelling older people and shows good potential as a frailty screening tool [5,102]. It comprises two steps: a questionnaire is performed first, followed by a clinician's judgement of frailty status [103]. The questionnaire includes six components: living alone, involuntary weight loss, fatigability, mobility, memory complaints and slow gait speed (≥4 s for 4 m), with all questionnaire components having three potential answers: yes/no/unknown [103].

A downside of the GFST is that does not give any specific guidance for the clinician about how to identify frailty, and after the six initial screening questions, it contains one question for the clinician to answer: "do you think your patient is frail?" No reliability studies have yet been performed on the GFST and its predictive ability has not yet been established. Validation studies of the GFST also need to be performed cross-culturally.

3.14. Kihon Check-list (KCL)

The Kihon Check-list (KCL) is a recently validated frailty measurement tool containing 25 items widely used in Japan [104,105]. It is based on similar principles to the FI-CGA and shows predictive ability for functional decline in community-dwelling older people [106]. Cross-cultural validation of the KCL is needed.

3.15. Individual frailty measurements

Individual factors underlying frailty can also be used to screen for frailty. Gait speed is one such example [94,107,108], and in all likelihood, may be best indicator of frailty among all of Fried's frailty components [109]. Importantly, gait speed also has a close association with adverse health outcomes in older people [110,111]. Gait speed is applicable clinically, although it does over-screen for frailty [94], and there are fundamental difficulties in measuring out a walking course 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 functional decline and long LOS in hospitalised older patients [112,113], and mortality in community-dwelling adults [114]. It has also been found to be a good marker of poor mobility [115].

3.16. Other frailty measurements

Other frailty measurements beyond the scope of this review include: the self-rated Health Deficits Index (HDI) [116], the Frailty Risk Score (FRS) [117], the Vulnerable Elders Survey (VES) (vulnerability is considered to be frailty) [118], the Frailty Trail Scale (FTS) [119], the Frail Non-Disabled (FiND) instrument for frailty screening [120], the 'G8' (specifically for cancer patients) [121], and multiple others. In addition, given that functional decline is an outcome of frailty, functional decline indices may also be considered to be frailty measurements [14]. These indices include: the Identification of Seniors at Risk (ISAR) score [122] the Score Hospitalier d'Evaluation du Risque de Perte d'Autonomie (SHERPA) [123] and the Hospital Admission Risk Profile (HARP) [47]. Important to note is that a more objective assessment/measurement tool like the Short Physical Performance Battery (SPPB) [127] may well be the unifying tool for frailty, and while not included in this review, has many of the same limitations as other measurements of frailty which are based on physical performance.

4. Discussion

This review showed that there are a multiple measurements used to identify frailty in older people. There was a wide range in the applicability of these frailty measurements: from short, fast and crude frailty screening instruments to the sophisticated, time-consuming measurements. Many frailty measurements had not been robustly validated in the literature, and their prognostic ability was rarely determined. Moreover, many frailty measurements were modified somewhat from their original, validated version, which in turn, can have a striking impact on frailty classification. This concern is echoed in a recent meta-analysis by Theou and colleagues, which found 262 different versions of Fried's Frailty Phenotype [124].

Based on the findings of this review, there are three potential future options for frailty measurement. Firstly, as part of a consensus, we can decide on *one* frailty measurement from the multitude of already existing measurements. Having just one measurement would be advantageous given that it would allow comparison of frailty prevalence worldwide. However, having one frailty measurement may not be best route forward. Frailty measurements can be likened to 'horses for courses', wherein different frailty measurements are suited to different populations [17]. Some are better for population-level frailty screening, whereas others are best suited for clinical screening, or for clinical assessment. For instance, the visual-chart based CFS or the easy-to-apply SOF are both well suited for clinical screening, whereas the FI-CGA is designed for frailty assessment in the clinical setting, the latter of which can be applied to almost any dataset that records CGA patient-level data.

Secondly, a new gold frailty standard measurement could be developed. However, countless research groups have done exactly this, which partially explains why there are so many frailty measurements in existence today. Thirdly, we could use one frailty measurement for screening and a second one for a full assessment, as suggested by recent research. For instance, frailty screening and assessment combinations could be performed by pairing the CHS index and the FI [125]. It remains to be seen which of these three future options for frailty measurement will be chosen.

Nonetheless, no matter what frailty measurement/s become the international standard, it is important that frailty is recognised in the clinical setting. Frailty is often misconstrued to be part of the normal ageing process and older patients are treated on the basis of their medical condition/s alone, rather than accounting for their frailty status [57]. Incorporating measurement of frailty into clinical practice may provide a means for clinicians to identify and manage the condition early into its progression. Advancements in health informatics and electronics will play a role in future frailty measurement [126].

5. Conclusion

As the world's population ages, frailty is moving to the forefront of health and medical research. Multiple factors contribute to frailty, including malnutrition, pathophysiology and psychological factors. Frailty does not yet have a gold standard definition, although it is generally considered to be geriatric condition characterised by an increased vulnerability to external stressors. There are a plethora of frailty measurements worldwide, with the quality of measurements varying widely. A quality frailty measurement should be able to identify frailty; be able to predict patient outcomes and response to potential treatments; and be based on biological theory. Based on these criteria, the two most common frailty measurements, Fried's Frailty Phenotype (the CHS index) and Rockwood and Mitnitski's FI, appear to be the most robust assessment tools for use by clinicians and researchers today. Future studies should focus on comparing frailty measurements worldwide. Frailty measurement should be incorporated into clinical practice as part of routine care for older patients.

Learning points

- Frailty measurement should be incorporated into clinical practice as part of routine care for older patients.
- There is no international standard measurement for frailty.
- A large number of frailty measurements exist, making it difficult to choose which frailty measurement to use.
- Frailty measurements range from short, fast and crude frailty screening instruments to sophisticated, time-consuming measurements.
- The quality of frailty measurements varies widely, with many measurements needing cross-cultural validation studies.
- The two most commonly used 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 in existence today. Some measurements are better for population-level frailty screening, whereas others are best suited for clinical screening, or assessment.

Conflict of interest statement

The authors state that they have no conflicts of interest.

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