Review Article

Identification and Measurement of Frailty: A Scoping Review of Published Research from Singapore

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Abstract

Introduction: The Asia-Pacific Clinical Practice Guidelines for the Management of Frailty recommended the use of validated measurement tools for identifying frailty. In an effort to contribute to the development of best practice guidelines in frailty identification and measurement, our scoping review aimed to present a summary of published research on this topic among older adults in Singapore. Our findings are important given the need to consider the context of use and the goals of measurement in using validated tools. Materials and Methods: We searched PubMed and CINAHL® for articles describing the identification and measurement of frailty among older adults (≥60 years) in Singapore and mined the bibliographies of eligible articles. An article was eligible if it involved empirical research on frailty using a structured frailty definition. We described such articles and the conceptual definitions they used, and summarised their operationalisation of frailty. Results: Our search yielded 165 records. After 2-stage screening of titles/abstracts and full-text articles, we retained 32 eligible articles for data extraction and thematic analysis. The extant literature in Singapore includes observational cross-sectional and longitudinal studies and intervention studies across community and tertiary care settings. Eligible articles commonly used the frailty phenotype and the deficit accumulation models in defining frailty, and reported measuring components of physical, cognitive, and/or social frailty. Conclusion: Our scoping review provided a broad evidence synthesis of the underpinnings of research on frailty identification and measurement in Singapore. Consistently applying standard methods and approaches in frailty identification and measurement can support evidence-based practice and policies in Singapore.

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Key words: Conceptual definitions, Evidence synthesis, Frailty research, Older adults

Introduction

Around a decade ago, frailty was an emerging research area and a nascent concept in many clinical specialties.[1] Today, its growing relevance in both research and clinical practice is sustained amid the ageing of populations across the world including Singapore. Ongoing initiatives in Singapore aim to equip the healthcare system with the capacity and infrastructure required for managing frailty in one of the most rapidly ageing populations;[2] such an endeavour warrants a consistent approach in identifying frailty.

Older adults with frailty have been broadly described in the international literature as "lacking in general strength and are unusually susceptible to disease or to other infirmity".[3] Until recently, frailty in older Singaporeans had been loosely applied to describe functionally dependent older adults[4] or a subgroup of hospitalised older patients.[5] A seminal review of international studies on the identification of frailty from 1997 to 2009 described an overview of clinical definitions, screening tools, and severity measures of frailty,[6] which guided subsequent research in the extant literature. Standard scientific inquiry and the growing importance of frailty measurement in clinical practice fuelled the initial development of the now commonly used conceptual models in defining frailty.[7,8] One such model described frailty as a clinical phenotype that consists of: 1) slow gait speed, 2) low physical activity, 3) shrinking,

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4) exhaustion, and 5) weakness; the presence of at least 3 of these attributes indicated frailty.[7] An alternative approach described a frailty index based on the accumulated number of clinically assessed deficits.[8-10] These early frameworks mainly pertained to the physical domain of frailty; more recent frameworks have considered the cognitive and social domains as well.[11]

The recently published Asia-Pacific Clinical Practice Guidelines for the Management of Frailty (AP-CPGMF) strongly recommended using a valid measurement tool in identifying frailty and emphasised the importance of adapting the guidelines to the local context.[12] Despite significant progress in developing comprehensive conceptual models, there is an apparent lack of consensus on the "component elements" of frailty.[6] This raises an important issue, because consistency in defining any construct is essential in obtaining valid and reliable measurements. Hence, a key step in guiding the selection of appropriate measures and applying a more consistent definition of frailty will require an overview of the scope of research on frailty identification and measurement in Singapore.

We conducted a scoping review of research involving the identification and measurement of frailty in Singapore to glean insights that can inform the selection of valid measurement tools for use in research and clinical settings, and enable the translation of relevant research into policy and practice. An overarching goal is to engage the local research community in frailty identification and measurement as well as stakeholders from the government and healthcare sectors. Specifically, we aimed to examine the following information from published studies in Singapore: a) characteristics of articles on frailty identification; b) definitions of frailty used; c) domains of frailty investigated; d) conceptual models applied to identify and measure frailty; e) corresponding component elements of frailty considered (i.e., indicators, factors, subdomains); and e) measurement tools used to identify frailty and/or determine its severity.

Materials and Methods

Published procedures for conducting scoping reviews guided our methodology.[13] Briefly, we identified the relevant articles, extracted data from the eligible ones, charted data using quantitative summaries and qualitative thematic synthesis, and examined the implications of the review findings for research, policy and practice.

Data Sources and Search Strategy

We searched PubMed and CINAHL® and performed reference mining of eligible articles to find additional relevant articles. We focused on empirical studies in Singapore that involved the identification and measurement of frailty among older adults. Our search strategy included database-indexed terms and equivalent free-text terms for the following key concepts: frailty, older adults, identification, and Singapore (Table 1). We did not apply any date and language limits or search filters in the database search (Appendix 1). Hence, the search results carried forward to the title and abstract screening stage included articles indexed in the databases up to the last date of search in May 2018. Even without applying language limits, the search did not generate articles published in a non-English language.

Study Selection and Data Extraction

Our review included articles that satisfied all of the following criteria: 1) reported empirical research based on primary and/or secondary data; 2) conducted in Singapore; 3) used data on older adults (i.e., sample mean ≥60 years or ≥1 participant aged ≥60 years); 4) specified the identification, measurement and/or assessment of frailty (i.e., measured frailty as a research variable); and 5) used a clear definition of frailty (i.e., a definition specific to the study or adapted from a frailty model). A clear definition of frailty is a key inclusion criterion given that frailty overlaps

Table 1. Overview of Search Strategy

Concept	Key Words
#1 Frailty	Frailty or frail or vulnerable or vulnerability
#2 Older adults	Aged or elderly
#3 Identification (definition, markers)	Risk factors
	Association
	Health status indicators
	Markers or biological markers or clinical markers
	Gait speed
	Physical activity
	Weight loss
	Cognitive impairment
	Depressive symptoms
	Exhaustion
	Weakness
	Hand grip strength
	Deficit or accumulation or cumulative
	Identification, assessment, measurement
#4 Identification (methods)	Health surveys
	Diagnosis
	Rating scales or index
	Risk assessment or case finding or geriatric assessment
	Disability evaluation
	Forecasting
	Patient care planning
#5 Singapore	Singapore

Search construction in databases: (#1 and #2) and (#3 or #4) and #5

with related concepts such as disability, weak hand grip strength, or weakness;[10,14] specifying this condition ensured that the articles included in our review considered frailty as a distinct concept.

We identified relevant articles through 2 stages of screening and 1 round of reference mining. In the first screening stage, each author screened the titles and abstracts of all articles from the search results independently using EndNote X7[15] reference manager and the Rayyan[16] web application for systematic reviews. In stage 2, each author further screened the full text of eligible titles and abstracts separately. We resolved conflicting assessments in the title and abstract screening (12 articles) through discussion; in the full-text screening (10 articles), the process mainly involved clarifying the definition of frailty. Finally, prior to data extraction, one author mined the reference lists of all eligible articles.

We obtained the full text of all eligible articles for data extraction. Key data extracted and summarised from the eligible articles include the basic study characteristics (e.g., first author name, publication year, primary aims, study design, etc.), and the following methodological information: a) frailty definition used; b) frailty domains examined (e.g., physical, cognitive, social, etc.); c) underlying conceptual approach specified or implied (e.g., phenotype, deficit accumulation, etc.); d) component elements of frailty measured (i.e., the factors, indicators, subdomains, which form or reflect the concept of frailty as defined in the underlying conceptual approach used in the article); e) operationalisation of the component elements; f) general scoring procedure and/or measurement cutoff values; g) frailty classification presented (e.g., frail, prefrail, non-frail); and h) references to the original conceptual models of frailty cited. We performed data extraction using EndNote X7 and MS Office Suite.

Data Synthesis

We described a quantitative summary of important study characteristics, which represents an overview of the recent developments in frailty identification research in Singapore. In addition, we put together a qualitative thematic analysis of the common definitions of frailty, as well as the conceptual models extensively used and adapted in published studies. We also teased out the salient variations in measuring various components of frailty.

Results

Our database search generated 165 records with 142 unique titles and abstracts (Fig. 1). After sequentially applying each inclusion criteria in the title and abstract screening, we excluded 88 articles that did not satisfy at least 1 criteria. We assessed the full text of the remaining 54 articles, of which we excluded 22 due to the lack of a clear definition of frailty or the omission of its operationalisation and measurement procedure. We finally identified 32 eligible articles for data extraction.

Characteristics of Eligible Articles

Table 2 describes the objectives and data sources, key variables examined, sample size, and study setting of the eligible articles, including the characteristics of the population of older adults they examined (i.e., age, disease condition, if specified). Although not mutually exclusive, the eligible articles measured frailty domains as independent or predictor variables (63%), or outcomes (44%). Several papers reported the relationship of frailty with respect to outcomes such as malnutrition,[17] mortality,[18,19] postsurgery outcomes,[20] healthcare utilisation,[21] and individual component elements of frailty such as walking/gait speed, functional status, and cognitive status.[22-24] A few papers investigated the impact of frailty transition on cognitive status[25] and the role of biological markers in frailty status and progression.[26] Studies that examined frailty transition/progression compared differences in frailty scores at baseline and 12 months later; an increase in frailty scores defined an increasing frailty state (progression).[25,26]

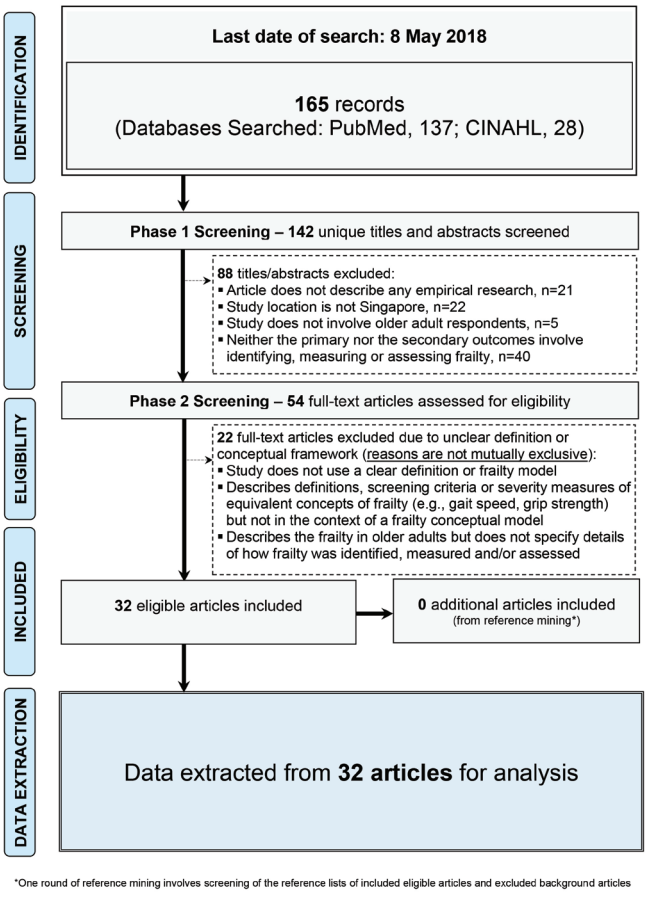

Fig. 1. Review flow diagram. Template from: Moher D. Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporing Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097.doi:10.1371/journal.pmed1000097. For more information, visit www.prisma-statement.org.

Table 2. Characteristics of Articles Included in the Review, n = 32

Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Longitudinal Design, n = 10						
Chong MS, et al (2015a)§	To study frailty transitions and change in cognitive status over 1-year follow-up among subjects with cognitive impairment	I/P: frailty transitions; D/O: cognitive status	122	(MCI or mild-moderate probable AD)	≥55	Buchman; Fried‖¶
Chia, et al (2016)#	To assess how a trans-institutional transdisciplinary programme was initiated incorporating seamless prehabilitation and rehabilitation to enhance the outcome further (postsurgery risk of morbidity)	I/P: frailty (risk stratification); D/O: postsurgery risk of morbidity	117	(Patients who received major colorectal resection)	(75 – 97)	Fried's criteria‖
Kua, et al (2016)**	To examine which frailty measure, Modified Fried Criteria and reported Edmonton frail scale, is a better predictor of early postoperative complications in a group of older hip fracture patients seen in the orthogeriatric service	I/P: frailty; D/O: postoperative complications	100	(Older adults admitted to the orthopaedic surgery unit)	≥60	Modified Fried Criteria; Edmonton Frail Scale‖††
Tay, et al (2016)‡‡	To examine the independent and combined effects of inflammation (IL-6 and TNF-α) and alterations in distinctly regulated endocrine axes on baseline frailty status and progressive physical frailty at 1 year, among older adults across a continuum of cognitive impairment	I/P: biological markers; D/O: frailty, frailty progression	99	Community-dwelling older adults with MCI and mild-moderate AD	≥55	Buchman; Fried‖¶

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

*Study-specific data were collected unless specified otherwise in brackets (Name of Dataset).

†Most articles reported community-based settings, tertiary care settings (i.e., tertiary hospitals) are enclosed in brackets ( ).

‡Most studies only reported inclusion criteria for age; if reported, the age range of participants are enclosed in brackets ( ).

§Chong MS, Tay L, Chan M, Lim WS, Ye R, Tan EK, et al. Prospective longitudinal study of frailty transitions in a community-dwelling cohort of older adults with cognitive impairment. BMC Geriatr 2015;15:175.

‖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.

¶Buchman AS, Boyle PA, Wilson RS, Tang Y, Bennett DA. Frailty is associated with incident Alzheimer's disease and cognitive decline in the elderly. Psychosom Med 2007;69:483-9.

#Chia CL, Mantoo SK, Tan KY. 'Start to finish trans-institutional transdisciplinary care': a novel approach improves colorectal surgical results in frail elderly patients. Colorectal Dis 2016;18:O43-50.

**Kua J, Ramason R, Rajamoney G, Chong MS. Which frailty measure is a good predictor of early post-operative complications in elderly hip fracture patients? Arch Orthop Trauma Surg 2016;136:639-47.

††Hilmer SN, Perera V, Mitchell S, Murnion BP, Dent J, Bajorek B, et al. The assessment of frailty in older people in acute care. Australas J Ageing 2009;28:182-8.

‡‡Tay L, Lim WS, Chan M, Ye RJ, Chong MS. The independent role of inflammation in physical frailty among older adults with mild cognitive impairment and mild-to-moderate Alzheimer's disease. J Nutr Health Aging 2016;20:288-99.

§§Chew J, Lim WS, Chong MS, Ding YY, Tay L. Impact of frailty and residual subsyndromal delirium on 1-year functional recovery: A prospective cohort study. Geriatr Gerontol Int 2017;17:2472-8.

‖‖Rockwood K, Andrew M, Mitnitski A. A comparison of two approaches to measuring frailty in elderly people. J Gerontol A Biol Sci Med Sci 2007;62:738-43.

¶¶Chong E, Ho E, Baldevarona-Llego J, Chan M, Wu L, Tay L. Frailty and risk of adverse outcomes in hospitalized older adults: a comparison of different frailty measures. J Am Med Dir Assoc 2017;18:638.e637-638.e611.

##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.

***Tan KY, Kawamura YJ, Tokomitsu A, Tang T. Assessment for frailty is useful for predicting morbidity in elderly patients undergoing colorectal cancer resection whose comorbidities are already optimized. Am J Surg 2017;204:139-43.

†††Chong E, Chan M, Lim WS, Ding YY. Frailty predicts incident urinary incontinence among hospitalized older adults – a 1-year prospective cohort study. J Am Med Dir Assoc 2018;19:422-7.

‡‡‡Morley JE, Malmstrom TK, Miller DK. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. J Nutr Health Aging 2012;16:601-8.

§§§Chong E, Ho E, Baldevarona-Llego J, Chan M, Wu L, Tay L, et al. Frailty in hospitalized older adults: comparing different frailty measures in predicting short- and long-term patient outcomes. J Am Med Dir Assoc 2018;19:450-7.e3.

‡‡‡‡Lu Y, Tan CT, Nyunt MS, Mok EW, Camous X, Kared H, et al. Inflammatory and immune markers associated with physical frailty syndrome: findings from Singapore longitudinal aging studies. Oncotarget 2016;7:28783-95.
§§§§Mitnitski AB, Graham JE, Mogilner AJ, Rockwood K. Frailty, fitness and late-life mortality in relation to chronological and biological age. BMC Geriatr 2002;2:1.
‖‖‖‖Merchant RA, Banerji S, Singh G, Chew E, Poh CL, Tapawan SC, et al. Is trunk posture in walking a better marker than gait speed in predicting decline in function and subsequent frailty? J Am Med Dir Assoc 2016;17:65-70.
####Merchant RA, Chen MZ, Tan LWL, Lim MY, Ho HK, van Dam RM, et al. Singapore Healthy Older People Everyday (HOPE) study: prevalence of frailty and associated factors in older adults. J Am Med Dir Assoc 2017;18:734.e9-734.e14.
**** *Nyunt MSZ, Soh CY, Gao Q, Gwee X, Ling ASL, Lim WS, et al. Characterisation of physical frailty and associated physical and functional impairments in mild cognitive impairment. Front Med (Lausanne) 2017;4:230.
††††Vaingankar JA, Chong SA, Abdin E, Picco L, Chua BY, Shafie S, et al. Prevalence of frailty and its association with sociodemographic and clinical characteristics, and resource utilization in a population of Singaporean older adults. Geriatr Gerontol Int 2017;17:1444-54.
‡‡‡‡Wei K, Nyunt MSZ, Gao Q, Wee SL, Ng TP. Frailty and malnutrition: related and distinct syndrome prevalence and association among community-dwelling older adults: Singapore Longitudinal Ageing Studies. J Am Med Dir Assoc 2017;18:1019-28.
§§§§Yash Pal R, Kuan WS, Koh Y, Venugopal K, Ibrahim I. Death among elderly patients in the emergency department: a needs assessment for end-of-life care. Singapore Med J 2017;58:129-33.
‖‖‖‖Lunney JR, Lynn J, Hogan C. Profiles of older medicare decedents. J Am Geriatr Soc 2002;50:1108-12.
¶¶¶¶Chye L, Wei K, Nyunt MSZ, Gao Q, Wee SL, Ng TP. Strong relationship between malnutrition and cognitive frailty in the Singapore Longitudinal Ageing Studies (SLAS-1 and SLAS-2). J Prev Alzheimers Dis 2018;5:142-8.
#####Ge L, Yap CW, Heng BH. Prevalence of frailty and its association with depressive symptoms among older adults in Singapore. Aging Ment Health 2018:1-6.
******Pannérec A, Migliavacca E, De Castro A, Michaud J, Karaz S, Goulet L, et al. Vitamin B12 deficiency and impaired expression of amnionless during aging. J Cachexia Sarcopenia Muscle 2018;9:41-52.
†††††Tan LF, Lim ZY, Choe R, Seetharaman S, Merchant R. Screening for frailty and sarcopenia among older persons in medical outpatient clinics and its associations with healthcare burden. J Am Med Dir Assoc 2017;18:583-7.
‡‡‡‡‡Rolfson DB, Majumdar SR, Tsuyuki RT, Tahir A, Rockwood K. Validity and reliability of the Edmonton Frail Scale. Age Ageing 2006;35:526-9.
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‖‖‖‖Feng L, Nyunt MS, Gao Q, Feng L, Lee TS, Tsoi T, et al. Physical frailty, cognitive impairment, and the risk of neurocognitive disorder in the Singapore Longitudinal Ageing Studies. J Gerontol A Biol Sci Med Sci 2017;72:369-75.
¶¶¶¶¶Feng L, Zin Nyunt MS, Gao Q, Feng L, Yap KB, Ng TP. Cognitive frailty and adverse health outcomes: findings from the Singapore Longitudinal Ageing Studies (SLAS). J Am Med Dir Assoc 2017;18:252-8.
######Teo N, Gao Q, Nyunt MSZ, Wee SL, Ng TP. Social frailty and functional disability: findings from the Singapore Longitudinal Ageing Studies. J Am Med Dir Assoc 2017;18:637.e13-637.e19.
*******Kwok BC, Pua YH, Mamun K, Wong WP. The minimal clinically important difference of six-minute walk in Asian older adults. BMC Geriatr 2013;13:23.
††††††Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85-94.
‡‡‡‡‡‡Ng TP, Feng L, Nyunt MS, Feng L, Niti M, Tan BY, et al. Nutritional, physical, cognitive, and combination interventions and frailty reversal among older adults: a randomized controlled trial. Am J Med 2015;128:1225-36.e1221.
§§§§§§Ng TP, Nyunt MSZ, Feng L, Feng L, Niti M, Tan BY, et al. Multi-domains lifestyle interventions reduces depressive symptoms among frail and pre-frail older persons: randomized controlled trial. J Nutr Health Aging 2017;21:918-26.

Table 2. Characteristics of Articles Included in the Review, n = 32 (Cont'd)

Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Chew, et al (2017)§§	To investigate the association of frailty with incomplete delirium recovery at discharge (i.e., residual subsyndromal delirium) and examine its mediating role in the relationship between frailty and functional recovery at 12 months postdelirium	I/P: frailty; D/O: functional recovery	234	(Patients admitted to the geriatrics unit)	≥65	Rockwood Frailty Index‖‖
Chong E, et al (2017)¶¶	To: 1) compare the performance of frailty measures: fatigue, resistance, ambulation, illnesses, and loss of weight, FRAIL scale; Tilburg Frailty Indicator; and Clinical Frailty Scale using the widely adopted Frailty Index as gold standard, and 2) compare their ability to predict negative outcomes in hospitalised older adults	I/P: frailty; diagnostic performance of frailty measures; D/O: in-hospital mortality, length of stay, institutionalisation, functional decline	210	(Patients admitted to the department of geriatric medicine)	≥65	RockwoodClinical Frailty Scale##

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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‖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.

¶Buchman AS, Boyle PA, Wilson RS, Tang Y, Bennett DA. Frailty is associated with incident Alzheimer's disease and cognitive decline in the elderly. Psychosom Med 2007;69:483-9.

[#]Chia CL, Mantoo SK, Tan KY. 'Start to finish trans-institutional transdisciplinary care': a novel approach improves colorectal surgical results in frail elderly patients. Colorectal Dis 2016;18:O43-50.
[**]Kua J, Ramason R, Rajamoney G, Chong MS. Which frailty measure is a good predictor of early post-operative complications in elderly hip fracture patients? Arch Orthop Trauma Surg 2016;136:639-47.
[††]Hilmer SN, Perera V, Mitchell S, Murnion BP, Dent J, Bajorek B, et al. The assessment of frailty in older people in acute care. Australas J Ageing 2009;28:182-8.
[‡‡]Tay L, Lim WS, Chan M, Ye RJ, Chong MS. The independent role of inflammation in physical frailty among older adults with mild cognitive impairment and mild-to-moderate Alzheimer's disease. J Nutr Health Aging 2016;20:288-99.
[§§]Chew J, Lim WS, Chong MS, Ding YY, Tay L. Impact of frailty and residual subsyndromal delirium on 1-year functional recovery: A prospective cohort study. Geriatr Gerontol Int 2017;17:2472-8.
[||]Rockwood K, Andrew M, Mitnitski A. A comparison of two approaches to measuring frailty in elderly people. J Gerontol A Biol Sci Med Sci 2007;62:738-43.
[¶¶]Chong E, Ho E, Baldevarona-Llego J, Chan M, Wu L, Tay L. Frailty and risk of adverse outcomes in hospitalized older adults: a comparison of different frailty measures. J Am Med Dir Assoc 2017;18:638.e637-638.e611.
[##]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.
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[‡‡‡‡‡]Wei K, Nyunt MSZ, Gao Q, Wee SL, Ng TP. Frailty and malnutrition: related and distinct syndrome prevalence and association among community-dwelling older adults: Singapore Longitudinal Ageing Studies. J Am Med Dir Assoc 2017;18:1019-28.
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Table 2. Characteristics of Articles Included in the Review, n = 32 (Cont'd)

Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Tan KY, et al (2017)[***]	To examine whether frailty is useful in predicting adverse outcomes in optimised elective older colorectal surgery patients	I/P: frailty; D/O: postsurgery outcomes, mortality	83	(Patients for elective colorectal resection)	(75 – 93)	Fried's criteria[‖]
Chong E, et al (2018a)[†††]	To examine the ability of frailty to predict incident urinary incontinence in hospitalised older adults	I/P: frailty; D/O: urinary incontinence	210	(Patients admitted to the geriatrics unit)	≥65	Morley FRAIL scale[‡‡‡]
Chong E, et al (2018b)[§§§]	To compare the diagnostic performance of the FRAIL scale, Clinical Frailty Scale, and Tilburg Frailty Indicator and their ability to predict negative outcomes 12 months after enrolment	I/P: diagnostic performance of measures; D/O: mortality, length of stay, institutionalisation, functional decline	210	(Patients admitted to the geriatric medicine unit)	≥65	RockwoodClinical Frailty Scale[###]
Tan QL, et al (2018)[‖‖]	To examine the feasibility and effects of conducting a 12-week structured Functional Power Training programme in a housing estate	I/P: programme evaluation; D/O: functional outcomes, frailty	9	Community-dwelling older adults	≥55	Morley FRAIL scale[‡‡‡]

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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‡‡‡‡Lu Y, Tan CT, Nyunt MS, Mok EW, Camous X, Kared H, et al. Inflammatory and immune markers associated with physical frailty syndrome: findings from Singapore longitudinal aging studies. Oncotarget 2016;7:28783-95.

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Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Cross-Sectional Design, n = 15						
Chong MS, et al (2014)[¶¶¶]	To explore if there are stage-specific differences in the relationship between frailty and cognitive impairment	I/P: frailty; D/O: cognitive impairment	122	MCI and mild-moderate probable AD	≥55	Buchman; Fried[¶]
Ng, et al (2014)[###]	To develop a frailty risk prediction tool based on simple and routine clinical measurements and validated it for use in primary care using data from cohorts of community-living older adults (SLAS-2)	I/P: clinical measurements; D/O: frailty	1685	Community-dwelling older adults	≥55	Fried's criteria[§]

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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Chong MS, et al (2015b)[****]	To explore factors associated with frailty across the continuum of healthy ageing to cognitive impairment (MCI, mild and moderate AD) (GERILABS)	I/P: cognitive, functional characteristics; D/O: frailty	299	Community-dwelling	≥50	Buchman; Fried[¶]
Ng, et al (2015a)[††††]	To explore the association of specific subsets of markers of immune senescence and the immune risk profile with frailty (SLAS-2)	I/P: biological markers; D/O: frailty	421	Community-dwelling older adults	≥55	Fried's criteria[l]
Lu, et al (2016)[‡‡‡‡]	To identify frailty-related inflammatory markers and immunological phenotypes in a cohort of community-dwelling adults	I/P: biological markers; D/O: frailty	76	Community-dwelling older Chinese adults	≥55	Fried; Mitnitski[§§§§]

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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Table 2. Characteristics of Articles Included in the Review, n = 32 (Cont'd)

Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Merchant, et al (2016)¶¶¶¶	To identify early adaptations in posture in walking preceding actual decline in gait speed among healthy Chinese men	I/P: walking posture; D/O: gait speed	90	Community-dwelling Chinese men	(60 – 80)	Rockwood Clinical Frailty Scale##
Merchant, et al (2017)####	To investigate the prevalence of frail and prefrail states and their association with polypharmacy, multimorbidity, cognitive and functional status, and perceived health status among community-dwelling older adults in Singapore (HOPE)	I/P: frailty/prefrailty; D/O: frailty; health-related outcomes	1051	Community-dwelling older adults from northwest Singapore	≥65	Morley FRAIL scale[36]
Nyunt, et al (2017)*****	To characterise the physical frailty phenotype and its associated physical and functional impairments in MCI (SLAS-2)	I/P: physical and functional impairments; D/O: frailty	1938	Community-dwelling older adults	≥55	Fried's criteria¶

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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Wei, et al (2017)‡‡‡‡‡	To investigate the prevalence of prefrailty/frailty and nutritional risk; their overlapping prevalence; compare sociodemographic, physical, and mental health risk factors and their association independent of other factors (SLAS)	I/P: sociodemographic, clinical factors; D/O: frailty, nutritional risk	6045	Community-dwelling older adults	(55 – 98)	Fried's criteria[l]
Yash Pal, et al (2017)§§§§§	To determine the incidence and nature of death among patients aged ≥65 years in an emergency department; describe trajectories of death	I/P: frailty; D/O: incidence, trajectories of death	197	(Patients in emergency department)	≥65	Lunney¶¶¶¶

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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Table 2. Characteristics of Articles Included in the Review, n = 32 (Cont'd)

Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Chye, et al (2018)¶¶¶	To examine the prevalence of malnutrition among older adults in the Singapore Longitudinal Ageing Study cohort by their physical frailty and cognitive status (SLAS-1 and SLAS-2)	I/P: frailty, cognitive status; D/O: malnutrition	5414	Two cohorts of a population-based study of community dwelling older adults	≥55	Fried's criteria[l]
Ge, et al (2018)#####	To: 1) estimate the prevalence of frailty among community-dwelling older adults, and 2) investigate the independent association between level of frailty and depressive symptoms (PHI)	I/P: frailty; D/O: frailty; depressive symptoms	1942	Community-dwelling adults	≥60	Rockwood Clinical Frailty Scale[##]
Pannerec, et al (2018)******	To examine whether ageing and frailty associate with altered vitamin B12 homeostasis in humans and investigated the underlying molecular mechanisms using preclinical models (SLAS)	I/P: vitamin B12 homeostasis; D/O: ageing, frailty	238	Community-dwelling older adults	≥55	Fried's criteria[l]
Tan LF, et al (2018)††††††	To examine whether the Sarcopenia-frailty and Edmonton frail screening tools are clinically useful in identifying patients at risk for negative health outcomes who would benefit from intervention	I/P: frailty (screening tools); D/O: risk of negative outcomes	115	(Older adults attending specialist outpatient clinics)	≥65	Rolfson; Edmonton Frail Scale‡‡‡‡‡‡

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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††Hilmer SN, Perera V, Mitchell S, Murnion BP, Dent J, Bajorek B, et al. The assessment of frailty in older people in acute care. Australas J Ageing 2009;28:182-8.

‡‡Tay L, Lim WS, Chan M, Ye RJ, Chong MS. The independent role of inflammation in physical frailty among older adults with mild cognitive impairment and mild-to-moderate Alzheimer's disease. J Nutr Health Aging 2016;20:288-99.

§§Chew J, Lim WS, Chong MS, Ding YY, Tay L. Impact of frailty and residual subsyndromal delirium on 1-year functional recovery: A prospective cohort study. Geriatr Gerontol Int 2017;17:2472-8.

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†††Chong E, Chan M, Lim WS, Ding YY. Frailty predicts incident urinary incontinence among hospitalized older adults – a 1-year prospective cohort study. J Am Med Dir Assoc 2018;19:422-7.

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‖‖Tan QLL, Chye LMY, Ng DHM, Chong MS, Ng TP, Wee SL. Feasibility of a community-based functional power training program for older adults. Clin Interv Aging 2018;13:309-16.

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****Chong MS, Tay L, Ismail NH, Tan CH, Yew S, Yeo A, et al. The case for stage-specific frailty interventions spanning community aging to cognitive impairment. J Am Med Dir Assoc 2015;16:1003.e13-9.

††††Ng TP, Camous X, Nyunt MSZ, Vasudev A, Tan CTY, Feng L, et al. Markers of t-cell senescence and physical frailty: insights from Singapore Longitudinal Ageing Studies. NPJ Aging Mech Dis 2015;1:15005.

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[*****]Nyunt MSZ, Soh CY, Gao Q, Gwee X, Ling ASL, Lim WS, et al. Characterisation of physical frailty and associated physical and functional impairments in mild cognitive impairment. Front Med (Lausanne) 2017;4:230.
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Author (Year)	Study Objectives and Data Source*	Key Variables Examined	Sample Size	Study Setting† and Population Group	Age‡ (Years)	Frailty Model(s)
Combination of Cross-Sectional and Longitudinal Design, n = 4						
Feng, et al (2014)[§§§§§§]	This study aimed to examine the cross-sectional and longitudinal relationships between physical frailty at baseline and depressive symptoms at baseline and at follow-up (SLAS-1)	I/P: frailty; D/O: depressive symptoms	1827	Community-dwelling older Chinese adults	≥55	Fried's criteria[l]
Feng, et al (2017a)[¶¶¶¶¶¶]	To test the following hypotheses: 1) physical frailty is associated with a higher likelihood of prevalent cognitive impairment, 2) physical frailty and cognitive impairment independently predict an increased risk of incident MCI and dementia, and 3) cognitive frailty markedly increases the risks of developing NCD (SLAS-1)	I/P: frailty; D/O: cognitive impairment; risk of MCI and dementia; risk of developing NCDs	1575	Community-dwelling older Chinese adults	≥55	Fried's criteria[l]
Feng, et al (2017b)[########]	To determine whether concurrent physical frailty and cognitive impairment, compared with physical frailty alone, substantially increased the risk of mortality, functional disability, hospitalisation, and impaired quality of life (SLAS-1)	I/P: frailty, cognitive impairment; D/O: risk of mortality, disability, hospitalisation, impaired quality of life	2375	Community-dwelling older Chinese adults	≥55	Fried's criteria[l]

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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Teo, et al (2017)[######]	To examine the association between the social frailty (SF) phenotype and functional disability, independent of the physical frailty (PF) phenotype, and compare the abilities of the PF, SF, and combined SF and PF indexes for predicting functional disability (SLAS-1)	I/P: frailty; D/O: functional disability	2406	Community-dwelling older adults	≥55	Fried's criteria[l]
Intervention Design (Randomised Controlled Trial), n = 3						
Kwok, et al (2013)[*******]	To examine the minimal clinically important difference for the 6-minute walk distance among frail Asian older adults (EFFECT)	I/P: frailty; D/O: 6-minute walking distance	73	Community-dwelling older adults with fear of falling	70, mean	Guralnik[†††††††]
Ng, et al (2015b)[‡‡‡‡‡‡‡]	To compare the effects of 6-month interventions with physical exercise, nutritional supplementation, cognitive training, and a combination of these with usual care control in reducing frailty	I/P: effects of intervention programme; D/O: reduced frailty	246	Community residents in the southwest region of Singapore	≥65	Fried's criteria[l]
Ng, et al (2017)[§§§§§§§]	To examine the effects of multiple-domain lifestyle interventions among older persons in reducing depressive symptoms; association of changes in frailty outcome with changes in depression outcomes	I/P: effects of intervention programme; D/O: frailty; depressive symptoms	246	Community-dwelling older adults	≥65	Fried's criteria[l]

AD: Alzheimer's disease; D/O: Dependent/outcome variable; EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; GERILABS: Longitudinal Assessment of Biomarkers for characterisation of early sarcopenia and predicting frailty and functional decline in community-dwelling Asian older adults study; HOPE: Healthy Older People Everyday Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); I/P, independent/predictor variable; MCI: Mild cognitive impairment; NCD: Neurocognitive disorder; PHI: Population Health Index (survey conducted in the Central Region of Singapore); SLAS: Singapore Longitudinal Ageing Study; WISE: Well-being of the Singapore Elderly

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[||||||]Feng L, Nyunt MS, Gao Q, Feng L, Lee TS, Tsoi T, et al. Physical frailty, cognitive impairment, and the risk of neurocognitive disorder in the Singapore Longitudinal Ageing Studies. J Gerontol A Biol Sci Med Sci 2017;72:369-75.
[¶¶¶¶¶]Feng L, Zin Nyunt MS, Gao Q, Feng L, Yap KB, Ng TP. Cognitive frailty and adverse health outcomes: findings from the Singapore Longitudinal Ageing Studies (SLAS). J Am Med Dir Assoc 2017;18:252-8.
[######]Teo N, Gao Q, Nyunt MSZ, Wee SL, Ng TP. Social frailty and functional disability: findings from the Singapore Longitudinal Ageing Studies. J Am Med Dir Assoc 2017;18:637.e13-637.e19.
[*******]Kwok BC, Pua YH, Mamun K, Wong WP. The minimal clinically important difference of six-minute walk in Asian older adults. BMC Geriatr 2013;13:23.
[†††††††]Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85-94.
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[§§§§§§§]Ng TP, Nyunt MSZ, Feng L, Feng L, Niti M, Tan BY, et al. Multi-domains lifestyle interventions reduces depressive symptoms among frail and pre-frail older persons: randomized controlled trial. J Nutr Health Aging 2017;21:918-26.

Our quantitative summary (Fig. 2) shows that the number of relevant publications on frailty identification in Singapore has substantially increased over the last 5 years. Although the majority of publications reported using study-specific data (53%), a substantial proportion (31%) used data from the Singapore Longitudinal Ageing Studies.[17,22,27-34] The majority of papers reported investigations in the community setting (68%). Finally, published works in Singapore largely involved observational cross-sectional (47%) and longitudinal studies (31%), with a few randomised controlled trials (9%).

Frailty Domains and Definitions

Among the frailty domains of current interest, physical frailty has been the most widely investigated (72%) in Singapore; the remainder of articles presented investigations on physical frailty in combination with at least 1 other domain (i.e., cognitive, social, and psychological frailty). Table 3 summarises the commonly adopted definitions of frailty per domain in the local literature.

Components of Frailty: Conceptual Models and Operationalisation

Table 4 presents a synopsis of the conceptual models used in the eligible articles, including the operationalisation and measurement of the frailty components investigated therein. The eligible articles were largely based on the frailty phenotype (e.g., Fried criteria,[7] Buchman's composite measure,[35] FRAIL [Fatigue, Resistance, Ambulation, Illnesses, & Loss of Weight] scale[36]) and the deficit accumulation model (e.g., Rockwood,[9] Mitnitski[8]). Some studies used Fried's frailty phenotype with a number of modifications.[28,30,31] Individual studies used each of these frameworks alone or in combination (e.g., physical frailty phenotype combined with models measuring cognitive[37] and psychosocial[38] frailty).

In organising the conceptual models, we noted substantial variations in the physical frailty components measured even among the articles that shared the same conceptual basis.[23,39,40] For example, Fried's criteria originally used "shrinking, weakness, exhaustion, slowness, and low activity" to describe the characteristics of frailty.[7] A number of articles[22,27,40,41] directly applied Fried's criteria in their investigations. Other studies[18,39] based on Fried's criteria used "weight loss, grip strength, exhaustion, walking speed, and physical activity", which deviate from the original nomenclature of frailty components but are nonetheless related. Frailty components considered in studies based on deficit models (i.e., frailty index)[42-44] included items that are commonly available in comprehensive geriatric assessments, such as the number of chronic diseases, functional performance, laboratory markers, strength, and

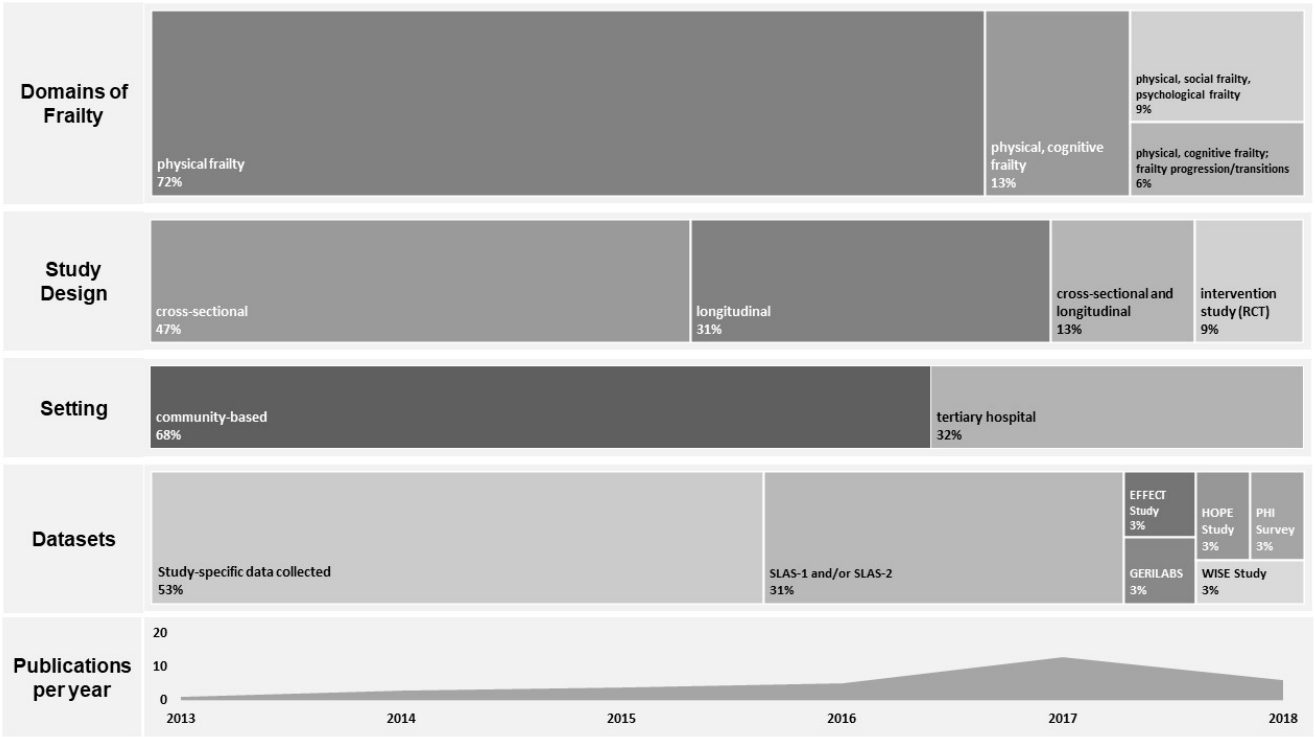

Fig. 2. Chart showing the eligible articles at a glance (n = 32). EFFECT: Evaluation of the Frails' Fall Efficacy by Comparing Treatments Study; GERILABS: Longitudinal Assessment of Biomarkers for Characterisation of Early Sarcopenia and Predicting Frailty and Functional Decline in Community-Dwelling Asian Older Adults Study; HOPE: Healthy Older People Every day Study (embedded in the Singapore Population Health Studies cohort Bukit Panjang); PHI: Population Health Index survey; SLAS-1 and 2: Singapore Longitudinal Ageing Studies (Waves 1 and 2); WISE: Well-being of the Singapore Elderly

Table 3. Common Definitions of Frailty in the Reviewed Articles

Definitions*	Conceptual Model	Domains Covered
A physical phenotype comprising criteria of shrinking, weakness, exhaustion, slowness, and low physical activities.†	Frailty phenotype	Physical frailty
A continuous composite measure of frailty consisting of grip strength, timed walk, body composition, and fatigue.‡	Frailty phenotype	Physical frailty
Frailty phenotype based on self-report: fatigue, resistance, ambulation, illness, and loss of weight.§	Frailty phenotype	Physical frailty
The simultaneous presence of both physical frailty and cognitive impairment without concurrent dementia or other dementias.‖,¶,#,**	None	Physical, cognitive frailty
A multifaceted concept that involves a continuum of being at risk of losing, or having lost general or social resources, social behaviours and activities, and self-management abilities that are important for fulfilling basic social needs.††	None	Social frailty
Diminished strength, physiologic malfunctioning leading to increased vulnerability to minor stressors that ultimately results in adverse health outcomes.§	Index of deficit accumulation	Physical frailty
The cycle of frailty indicates reduced levels of nutrition and activity, age-related musculoskeletal changes, and disease as being the possible precursors to loss of muscle mass as seen in the onset of sarcopenia, which progressed to decreased walking speed, strength, and power along with respiratory and metabolic changes.‡‡	Index of deficit accumulation	Physical frailty
A syndrome with multiple reduced physiologic functions that increases an individual's vulnerability for developing increased dependency and/or death.§§	Index of deficit accumulation	Physical, social frailty
A non-specific state of impaired strength, endurance, and balance; vulnerability to trauma and stressors; and high risk for morbidity, disability, mortality and institutionalisation; identification of biomarkers associated with developing frailty.‖‖	Index of deficit accumulation	Physical, social frailty
A state of decreased functional reserve and resistance to stressors that are associated with a high prevalence of adverse health outcomes, such as poor functional and cognitive status, falls, institutionalisation, and mortality.¶¶	Index of deficit accumulation	Physical, cognitive, social frailty

*These definitions were either used or adapted by the reviewed articles (i.e., studies conducted in Singapore). The citations may refer to the articles included in the review or the original studies cited in these articles.

†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.

‡Buchman AS, Boyle PA, Wilson RS, Tang Y, Bennett DA. Frailty is associated with incident Alzheimer's disease and cognitive decline in the elderly. Psychosom Med 2007;69:483-9.

§Morley JE, Malmstrom TK, Miller DK. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. J Nutr Health Aging 2012;16:601-8.

‖Chye L, Wei K, Nyunt MSZ, Gao Q, Wee SL, Ng TP. Strong relationship between malnutrition and cognitive frailty in the Singapore Longitudinal Ageing Studies (SLAS-1 and SLAS-2). J Prev Alzheimers Dis 2018;5:142-8.

¶Feng L, Zin Nyunt MS, Gao Q, Feng L, Yap KB, Ng TP. Cognitive frailty and adverse health outcomes: findings from the Singapore Longitudinal Ageing Studies (SLAS). J Am Med Dir Assoc 2017;18:252-8.

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**Merchant RA, Chen MZ, Tan LWL, Lim MY, Ho HK, van Dam RM, et al. Singapore Healthy Older People Everyday (HOPE) study: prevalence of frailty and associated factors in older adults. J Am Med Dir Assoc 2017;18:734.e9-734.e14.

††Bunt S, Steverink N, Olthof J, van der Schans CP, Hobbelen JSM. Social frailty in older adults: a scoping review. Eur J Ageing 2017;14:323-34.

‡‡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.

§§Hilmer SN, Perera V, Mitchell S, Murnion BP, Dent J, Bajorek B, et al. The assessment of frailty in older people in acute care. Australas J Ageing 2009;28:182-8.

‖‖Mitnitski AB, Graham JE, Mogilner AJ, Rockwood K. Frailty, fitness and late-life mortality in relation to chronological and biological age. BMC Geriatr 2002;2:1.

¶¶Rolfson DB, Majumdar SR, Tsuyuki RT, Tahir A, Rockwood K. Validity and reliability of the Edmonton Frail Scale. Age Ageing 2006;35:526-9.

gait characteristics, to name a few. Studies that examined the cognitive and psychosocial domains of frailty[17,22,26,32,33,45,46] measured cognitive impairment and sociodemographic data, respectively, as their relevant frailty components.

The operationalisation of frailty components also varied across the eligible articles. For instance, different studies defined shrinking/weight loss as unintentionally losing ≥4.5 kilogrammes in the last 3 months,[40] 6 months,[22] or 12 months.[18] Similarly, several studies defined weakness by measuring hand grip strength[24-26,45] or knee extension strength.[22,23,29,41]

Procedures for calculating frailty scores were relatively more consistent. In general, investigations that used the frailty phenotype deemed frailty as the presence of 3 out of 5 components. Alternatively, a frailty index score of 0.25 denotes frailty based on the deficit accumulation model.[42] Studies that investigated cognitive frailty used a standard test for cognitive impairment (i.e., Mini Mental State Examination [MMSE]) to operationalise cognitive frailty.[17,32,33,46] Cutoff scores for cognitive frailty across several papers ranged from ≤26 to ≤23 in the MMSE. The social frailty index (range 0-7), is based on the presence

Table 4. Conceptual Models of Frailty Identification and Measurement in the Reviewed Articles

Index Reference*	Reviewed Articles	Frailty Components	Operationalisation, Scoring, and Categories of Frailty
Physical Frailty – Frailty Phenotype			
Guralnik (1994)‡	Kwok, et al (2013)§	• Moderate frailty	• Assessed based on established guidelines for instructions • Cutoff: scored 5 to 9 (Short Physical Performance Battery is considered moderate frailty)
Fried (2001)‖	Feng, et al (2014)¶	• Shrinking • Slowness • Weakness • Exhaustion • Low activity	Modifications to Fried's criteria: • Low activity: score below the lowest sex-adjusted quintile of the total • Cutoff: score 1 for each component present; Frail = 3 to 5 points; prefrail = 1 to 2; non-frail = 0 • Categories: frail, prefrail, non-frail
	Ng, et al (2014);# Ng, et al (2015);** Pannerec, et al (2018)††	• Shrinking • Slowness • Weakness • Exhaustion • Low activity	Modifications to Fried's criteria: • Low activity (physical activities): self-reported hours spent doing light, moderate, vigorous activities; total amount of time spent on moderate and vigorous activities per week; activity time below the gender-specific lowest quintile (low activity) • Cutoff: score 1 point for each component present; frail = 3 to 5 points; prefrail = 1 to 2; robust = 0 • Categories: frail, prefrail, robust
	Ng, et al (2015);‡‡ Ng, et al (2017);§§ Nyunt, et al (2017)‖‖	• Shrinking • Slowness • Weakness • Exhaustion • Low activity	• Shrinking: BMI of 18.5 kg/m^2 and/or unintentional weight loss ≥10 pounds in the last 6 months • Slowness (6-minute fast gait speed test): lowest quintile values stratified for gender and height • Weakness (leg muscle strength using dominant knee extension): in lowest quintiles • Exhaustion: score of <10; total (range 3 to15); "Did you feel – worn out/tired/ have a lot of energy" • Low activity: average minutes per day spent on physical activities; lowest quintile is classified as low activity • Cutoff: 1 = present, 0 = absent; total score 0 to 5; frail = 3 to 5; prefrail = 1 to 2; robust = 0 • Categories: frail, prefrail, robust
	Chia, et al (2016);¶¶ Tan KY, et al (2017)##	• Weight loss • Grip strength • Exhaustion • Walking speed • Physical activity	• Weight loss: >10 pounds or 5% weight loss in the past year • Grip strength: BMI and gender-specific cutoffs • Exhaustion: "How often in the last week did you feel: (a) everything you did was an effort? (b) you could not get going?" Responses are scored as follows: 1 day = 0; 1 to 2 days = 1; 3 to 4 days = 2; more than 4 days = 3; scoring 2 or 3 on either question is considered exhaustion • Walking speed (15-ft walk): >7 seconds (short: <173 cm males, <159 cm females); >6 s (tall: >173 cm males, >159 cm females) • Physical activity (MLTA): <383 kcal/wk (male); <270 kcal/wk (female) • Cutoff: frail = 3 of the 5 criteria are satisfied • Categories: positive, negative for frailty; frail-positive

AD: Alzheimer's disease; BMI: Body mass index (measured as weight/height); FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; IADL: Instrumental activities of daily living; MCI: Mild cognitive impairment; MFC: Modified Fried Criteria; MLTA: Minnesota Leisure Time Activity; MMSE: Mini Mental State Examination; POMA: Performance Oriented Mobility Assessment

*The Index Reference refers to the original papers cited in the articles.

†Based on a comprehensive geriatric assessment (CGA) where items comprised medical comorbidities, premorbid functional performance in activities of daily living before onset of the acute illness, presence of sensory, and swallowing impairment, laboratory markers, etc.

‡Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85-94.

§Kwok BC, Pua YH, Mamun K, Wong WP. The minimal clinically important difference of six-minute walk in Asian older adults. BMC Geriatr 2013;13:23.

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¶¶¶¶Chong E, Ho E, Baldevarona-Llego J, Chan M, Wu L, Tay L. Frailty and risk of adverse outcomes in hospitalized older adults: a comparison of different frailty measures. J Am Med Dir Assoc 2017;18:638.e637-638.e611.
#####Chong E, Ho E, Baldevarona-Llego J, Chan M, Wu L, Tay L, et al. Frailty in hospitalized older adults: comparing different frailty measures in predicting short- and long-term patient outcomes. J Am Med Dir Assoc 2018;19:450-7.e3.
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Table 4. Conceptual Models of Frailty Identification and Measurement in the Reviewed Articles (Cont'd)

Index Reference*	Reviewed Articles	Frailty Components	Operationalisation, Scoring, and Categories of Frailty
	Vaingankar, et al (2017)***	• Weight loss • Weakness • Exhaustion • Slowness • Low physical activity	• Weight loss: ≥4.5 kg in the last 3 months • Weakness (dominant hand grip strength: lowest 20% by sex, BMI • Exhaustion (self-report): being "worn out or exhausted" • Slowness (5-metre string gait speed): slowest 20% by height and sex • Physical activities (self-report): "not very physically active"; "not at all physically active" • Cutoff: frail, ≥3; prefrail, 1 to 2; non-frail, 0 (no. of parameters) • Categories: frail, prefrail, non-frail
	Wei, et al (2017)†††	• Shrinking • Slowness • Weakness • Exhaustion • Low activity	Modifications to Fried's criteria: • Slowness (gait tests): walked 6 metres back and forth; POMA gait score (0 to 12); <9 denotes slowness • Weakness: lowest quintile of performance based on the POMA • Exhaustion: "Not at all" response to question from SF-12: "Do you have a lot of energy?" • Low activity (physical activity): self-report of "none" for participation in any physical activity • Cutoff: score 1 = for each component present; frail = 3 to 5 points; prefrail = 1 to 2; robust = 0 • Categories: frail, prefrail, robust
Fried (2001)[l]	Chong MS, et al	• Grip strength • Timed walk	• Grip strength (hand dynamometer): <26 kg (males), <18kg (females) • Timed walk (15-ft walk time): <0.8 m/s
Buchman (2007)‡‡‡	Chong MS, et al (2014);§§§ Chong MS, et al (2015)[ll]	• Body composition • Fatigue	• Body composition (BMI): Not specified • Fatigue: Endorsing either item: I felt that everything I did was an effort; I could not get "going" • Cutoff: frail ≥2; non-frail <2 • Categories: frail, non-frail
Morley (2012)¶¶¶	Ng, et al (2014)[#]	FRAIL • Fatigue • Resistance • Ambulation • Illness • Loss of weight	• Fatigue (energy): none of the time • Resistance (aerobic activity): limited a lot • Ambulation (climb stairs): limited a lot • Illness: having ≥5 illnesses • Loss of weight: lost 10 pounds in the past 6 months • Cutoff: score sub-item (0 or 1); frail, ≥3; prefrail, 1 or 2 • Categories: frail, prefrail
	Tan QL, et al (2018)[###]	• FRAIL	Modifications to FRAIL scale: • Frailty was measured using the FRAIL scale questionnaire • Cutoff: score 1 = for each component present; frail = 3 to 5 points; prefrail = 1 to 2; robust = 0 • Categories: frail, prefrail, robust
	Chong E, et al (2018)****	• FRAIL	Modifications to FRAIL scale: • Health state at least 2 weeks prior to any acute illness and/or functional decline or best overall health status over the last 6 months in the absence of acute illness and/or functional decline • Cutoff: frailty ≥3 • Categories: frail, non-frail

AD: Alzheimer's disease; BMI: Body mass index (measured as weight/height); FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; IADL: Instrumental activities of daily living; MCI: Mild cognitive impairment; MFC: Modified Fried Criteria; MLTA: Minnesota Leisure Time Activity; MMSE: Mini Mental State Examination; POMA: Performance Oriented Mobility Assessment

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Index Reference*	Reviewed Articles	Frailty Components	Operationalisation, Scoring, and Categories of Frailty
Physical Frailty – Frailty Index or Index of Deficit Accumulation			
Lunney (2002)††††	Yash Pal, et al (2017)‡‡‡‡	• Chronic frailty	• Patient demographics, comorbidities, premorbid functional status, clinical presentation, previous resuscitation status documentation or discussion, details of death (time, cause of death) from electronic medical records database, which would be available to an emergency physician in clinical practice
Rolfson (2006)§§§§	Tan LF, et al (2018)‖‖‖‖	• Edmonton Frail Scale	• Frailty was measured using the Edmonton Frail Scale and sarcopenia using Sarcopenia-Frailty scale (SARC-F) • Categories: robust, sarcopenic, frail, sarcopenic and frail
Rockwood (2007)¶¶¶¶	Merchant, et al (2016)####	• Function • Strength • Gait characteristics	• Grip strength (<26 kg); 6-minute walk; slow walking speed (<1.0 m/s), and/or • slow time-up-and-go (>10 seconds) • Joint and limb segment: kinematics using 6-camera motion analysis • Cutoff: (Canadian Study for Health and Ageing, CSHA): CFS categories CSHA1 = very fit; CSHA2 = without active disease but less fit than CSHA1; CSHA3 = well, with treated and well controlled comorbidity; CSHA4 = apparently vulnerable, not dependent but complain of being "slowed" and have disease symptoms • Modified CSHA: CSHA1 and 2 = healthy; CSHA3 = intermediate-risk; and CSHA4 = vulnerable • Categories: healthy, intermediate risk, vulnerable
	Chew, et al (2017)****	• CGA†	• 20-item frailty index based on specified criteria in the literature • Cutoff: frailty index ≥0.25 denotes frailty • Categories: frail, non-frail
	Ge, et al (2018)†††††	• CGA†	• Trained nurse assigns the category based on frailty factors (1 to 7) • Clinical Frailty Scale (CFS): F1 (1 to 3), F2 (4), F3 (5), F4 (6 to 7) • Categories: very fit (F1), vulnerable (F2), mildly frail (F3), moderately frail (F4)
Frailty Phenotype versus Frailty Index			
Fried (2001);‖ Hilmer (2009)‡‡‡‡‡	Kua, et al (2016)§§§§§	• Modified Fried Criteria (MFC) • Edmonton Frail Scale	• Slowness (MFC, modified criteria for slowness as hip-fracture patients cannot be tested for gait speed): "positive" if response is positive to any of the questions: "2 weeks ago, were you able to (a) walk up and down stairs to the second floor without help and (b) walk 1 km without help" • Cutoff: ≥3 of the criteria present; MFC, frail = 1 to 5, non-frail = 0 • Categories: frail, non-frail • Edmonton: cognitive impairment, IADL, recent burden of illness, health, depression, weight loss, medication issues, incontinence, inadequate social support, mobility difficulties • Cutoff: severe = 12 to 18; moderate = 10 to 11; mild = 8 to 9; apparent = 6 to 7; non-frail = 0 to 5; frail >7; non-frail ≤7 • Categories: severe frailty, moderate frailty, apparent frailty, non-frail; frail, non-frail
Jones (2004)‖‖‖‖	Chong E, et al (2017);¶¶¶¶ Chong E, et al (2018)#####	• CGA†	• 37-item frailty index based on a comprehensive geriatric assessment • Cutoff: score ≥0.25 (i.e., at least 10 of 37 deficits) • Categories: frail, non-frail

AD: Alzheimer's disease; BMI: Body mass index (measured as weight/height); FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; IADL: Instrumental activities of daily living; MCI: Mild cognitive impairment; MFC: Modified Fried Criteria; MLTA: Minnesota Leisure Time Activity; MMSE: Mini Mental State Examination; POMA: Performance Oriented Mobility Assessment

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Table 4. Conceptual Models of Frailty Identification and Measurement in the Reviewed Articles (Cont'd)

Index Reference*	Reviewed Articles	Frailty Components	Operationalisation, Scoring, and Categories of Frailty
Rockwood (2005)[******]	Chong E, et al (2017);[¶¶¶¶¶] Chong E, et al (2018)[#####]	• CGA†	• 9-point scale: assessor makes a judgement on the degree of frailty • Cutoff: CFS score of 5 to 9 = frail (range 1 to 9) • Categories: frail, non-frail
Gobbens (2010)[††††††]	Chong E, et al (2017);[¶¶¶¶¶] Chong E, et al (2018)[#####]	• Physical • Psychological • Social	• Questionnaire capturing the multidimensional construct of frailty • Tilburg Frailty Index: score ≥5 was diagnostic of frailty (range 0 to 15) • Categories: frail, non-frail
Morley (2012)[¶¶¶]	Chong E, et al (2017); [¶¶¶¶¶] Chong E, et al (2018)[#####]	FRAIL • Fatigue • Resistance • Ambulation • Illness • Loss of Weight	• Health state at least 2 weeks prior to any acute illness and/or functional decline or best overall health status over the last 6 months in the absence of acute illness and/or functional decline • Cutoff: frailty ≥3 parameters • Categories: frail, non-frail
		Combination of Conceptual Models	
Frailty Phenotype + Frailty Index			
Fried (2001);[l] Mitnitski (2002)[‡‡‡‡‡‡]	Lu, et al (2016)[§§§§§§]	• Phenotype: weight loss, weakness, exhaustion, slowness, low physical activity • Index: CGA†	• Phenotype – (a) unintentional weight loss: BMI of <18.5 kg/m² or weight loss of ≥4.5 kg in the past 6 months; (b) dominant knee extension: lowest quintile of a gender- and BMI-adjusted average value from 3 trials; (c) exhaustion: <10/15 on the vitality domain; (d) slowness: <9 in 6-minute fast gait speed test; (e) time (hours) spent daily doing light, moderate and vigorous activities: total time spent per week • Cutoff: score 1 = for each component present; frail = 3 to 5 points; prefrail = 1 to 2; robust = 0 Categories: frail, prefrail, robust • Index – a continuous variable denoting the number of cumulative deficits out of 45 multisystem risk factors • Cutoff: higher value denotes higher risk for frailty (0 to 1)
Physical Frailty + Cognitive Frailty			
Fried (2001);[l] Buchman (2007)[‡‡‡*]	Chong MS, et al (2015);[lllllll] Tay, et al (2016)[¶¶¶¶¶¶]	• Grip strength • Timed walk • Body composition • Fatigue	• Grip strength (hydraulic dynamometer): <26 kg (males), <18 kg (females) • Gait speed (15-ft walk time): <0.8 m/s • Body composition (BMI): Not specified • Fatigue: endorsing either item, "I felt that everything I did was an effort"; "I could not get going" • Cutoff: frail ≥2; non-frail <2 • Categories: frail, non-frail • Also assessed frailty progression/transitions

AD: Alzheimer's disease; BMI: Body mass index (measured as weight/height); FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; IADL: Instrumental activities of daily living; MCI: Mild cognitive impairment; MFC: Modified Fried Criteria; MLTA: Minnesota Leisure Time Activity; MMSE: Mini Mental State Examination; POMA: Performance Oriented Mobility Assessment

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†Based on a comprehensive geriatric assessment (CGA) where items comprised medical comorbidities, premorbid functional performance in activities of daily living before onset of the acute illness, presence of sensory, and swallowing impairment, laboratory markers, etc.

‡Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85-94.

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Fried (2001);[l] Feng (2012)[######]	Feng, et al (2017a);[*******] Feng, et al (2017b);[†††††††] Chye, et al (2018)[‡‡‡‡‡‡‡]	• Shrinking • Slowness • Weakness • Exhaustion • Low activity	Modifications to Fried's criteria: • Slowness (gait tests): walked 6 metres back and forth; POMA gait score (0 to 12); <9 denotes slowness • Weakness (POMA): lowest quintile of performance • Exhaustion (SF-12): responds "Not at all" to "Do you have a lot of energy?" • Physical activity (self-report): participation in physical activity, "none" • Cutoff: score 1 = for each component present; frail = 3 to 5 points; prefrail = 1 to 2; robust = 0 • Categories: frail, prefrail, robust
	Feng, et al (2017a);[†††††††] Chye, et al (2018)[‡‡‡‡‡‡‡]	• Cognitive impairment	• Presence of both physical frailty and cognitive impairment (excluding concurrent dementia) assessed using the MMSE • MMSE: 30 total points, higher score indicates better cognition • Cutoff: Cognitive impairment ≤23; cognitive prefrailty = presence of both physical prefrailty and cognitive impairment, both excluding concurrent dementia or other dementia • Categories: cognitively frail, cognitively prefrail
	Feng, et al (2017b)[†††††††]	• Cognitive impairment	• Modification: mild or greater degrees of cognitive impairment; Chinese MMSE <26 • Categories: no impairment, mild impairment, greater impairment
Morley (2012)[¶¶]	Merchant, et al (2017)[§§§§§§§]	FRAIL • Fatigue • Resistance • Ambulation • Illness • Loss of Weight	Modifications to the FRAIL scale: • Fatigue (energy): none of the time • Resistance (aerobic activity): limited a lot • Ambulation (climb stairs): limited a lot • Illness: having ≥5 illnesses • Loss of weight: lost 10 pounds in the past 6 months • Cutoff: score sub-item (0 or 1); frail = 3 or more; prefrail = 1 or 2 • Categories: frail, prefrail
		• Cognitive impairment	• Modification: cognitive frailty = MMSE score <24 • Categories: cognitively frail, not cognitively frail

AD: Alzheimer's disease; BMI: Body mass index (measured as weight/height); FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; IADL: Instrumental activities of daily living; MCI: Mild cognitive impairment; MFC: Modified Fried Criteria; MLTA: Minnesota Leisure Time Activity; MMSE: Mini Mental State Examination; POMA: Performance Oriented Mobility Assessment

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Index Reference*	Reviewed Articles	Frailty Components	Operationalisation, Scoring, and Categories of Frailty
Physical Frailty + Social Frailty			
Fried (2001);[l] Bunt (2017)[llllllll]	Teo, et al (2017)[¶¶¶¶¶¶¶]	• Shrinking • Slowness • Weakness • Exhaustion • Low activity	• Weight loss: BMI of 18.5 kg/m² and/or unintentional weight loss ≥10 pounds in the last 6 months • Slowness (6-minute fast gait speed test): lowest quintile values stratified for gender and height • Weakness (leg muscle strength using dominant knee extension): lowest quintiles • Exhaustion: "Did you feel worn out/tired/have a lot of energy"; total score <10 (range 3 to 15) • Low activity: average minutes per day spent on physical activities; lowest quintile are classified as low activity • Cutoff: 1 = present, 0 = absent; total score 0 to 5; frail = 3 to 5; prefrail = 1 to 2; robust = 0 • Categories: frail, prefrail, robust
		• Sociodemographic factors	• Living alone: "Who do you live with?" (alone) • No education: "What is your education level?" (Nil) • Absence of a confidant: "Do you have someone to confide in?" (none) • Infrequent contact: none or no more than once a year visits; none or no more than once a year calls from family, friends, or loved ones; none to a very little extent of help when they require it • Infrequent social activities: rarely or do not at all participate in all categories of social activities • Financial difficulties: limited to a great extent to pay for needed medical service • Socioeconomic deprivation: lived in 1-to-2-room flats (housing type) • Cutoff: high = 2 to 7 total; low = 1 total; Nil = 0 • Categories: Social Frailty Index – high, low, Nil

AD: Alzheimer's disease; BMI: Body mass index (measured as weight/height); FRAIL: Fatigue, Resistance, Ambulation, Illnesses & Loss of Weight; IADL: Instrumental activities of daily living; MCI: Mild cognitive impairment; MFC: Modified Fried Criteria; MLTA: Minnesota Leisure Time Activity; MMSE: Mini Mental State Examination; POMA: Performance Oriented Mobility Assessment

*The Index Reference refers to the original papers cited in the articles.

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of sociodemographic indicators where a total score >1 indicates a higher index of social frailty.[22]

Finally, the common physical frailty categories in relevant publications classified older adults into 3 categories: "frail, prefrail, and robust/non-frail". Other papers used dichotomous categories of frailty, such as "frail or non-frail", "frail or prefrail", and "frailty positive or negative".

Discussion

Although the majority of articles in our review examined the physical frailty domain, recent investigations on cognitive and social frailty suggest an important conceptual development in frailty identification research for Singapore. The composite evidence from our review informs immediate next steps in frailty identification research and practice, which primarily relate to streamlining our conceptual understanding of frailty and its measurement as well as addressing the need for implementing optimal measures for its identification.[12] We now discuss the implications of our review findings for research, practice, and policy along with a few insights on important steps moving forward.

Implications for Frailty Research

Our findings on the key conceptual approaches to defining and identifying frailty are consistent with those in the international literature.[6,10] Briefly, the frailty phenotype[7] identifies frailty based on the presence of a set of measurable indicators; whereas the deficit accumulation approach[9] suggests that frailty exists in a spectrum where individuals with more health deficits have a greater risk for adverse outcomes. In 2010, an international study[47] proposed an integral conceptual model of frailty—from which an integral definition of frailty was developed with experts. Their resulting definition identified nutrition, mobility, physical activity, strength, endurance, balance, cognition, sensory functions, mood, coping, social relations and social support as the essential components of frailty. This definition clearly goes beyond the physical domain of frailty—encompassing the cognitive and psychosocial aspects as well.

Notwithstanding the rich knowledge base of frailty identification and the proposed integral definition in previous works, our review of relevant research in Singapore, confirms the lack of consensus on the component elements of frailty and their operationalisation, which has also been reported in previous international studies.[6,10,12] We conjecture that the underlying purpose of measurement[6] and the availability of reliably measured data for analysis[1] can partly explain the observed variations in the component elements examined in eligible articles. Nevertheless, the lack of consistency in frailty components cannot be overstated. Efforts to address the apparent lack of consensus on what constitutes frailty will require a standard frailty definition that specifies a set of component elements and a guide for systematic deviations to the standard definitions, if needed. Standardising the construction of frailty can facilitate the efficient operationalisation of its components as appropriate for research and clinical purposes, which can subsequently allow for greater comparability of measurements across different investigations.

Further research is encouraged to demonstrate the utility of each component element considered in defining frailty.[47] For example, researchers from Duke-NUS Medical School reported that a set of 12 items, which only covers physical frailty variables, has the same ability as a set of 29 items consisting of physical, psychological and social frailty variables to predict a composite of adverse health outcomes among community-dwelling older Singaporeans; after adding age and gender to the 12 physical frailty items, they developed a 14-item Frailty Assessment Measure (FAM).[48] A clear argument from this example weighs into the added benefit of including social and psychological components in the definition of frailty (vs focusing on physical frailty).

Implications for Clinical Practice

The latest AP-CPGMF strongly recommended routine screening for frailty among older adults aged ≥75 years or those individuals with unintentional weight loss.[12] Identifying frailty clearly requires adopting a standard definition and operationalisation of its component elements; however, this assertion raises a related question on the need for a standard measure or scale. Current guidelines recommend using a validated tool for identifying and measuring frailty (vs reliance on crude subjective assessments of visual appearance). The need for selecting the tool that best matches clinical goals is also emphasised.[12]

Conveniently, a pool of validated measurement tools is currently available (Table 4) to provide researchers, clinicians, and/or administrators with a range of measures from which they can select the most appropriate one for their respective purpose. Clinicians are likely to use measures that are easy to integrate in their clinical practice and have demonstrated sound predictive ability to detect functional decline. Whereas administrators, given their intrinsically different purpose for measurement, may consider using other measures based on readily available data from the database of a relevant government agency.[6,10]

Irrespective of the specific goals of measurement, it is essential to select a tool that accurately identifies frailty and predicts relevant patient outcomes. However, beyond testing the psychometric properties of a measurement tool, it is also important to consider its feasibility (i.e., ease of use; fit with the goals of measurement and the resources available). Although most of the available tools have been described as appropriate for clinical settings and have been

regularly used in the region for its predictive value in relation to important health outcomes (e.g., mortality, disability, healthcare utilisation), practical aspects of using these measures largely influence decisions in actual measurements in the clinical setting.[12] Some of the practical considerations include labour and time requirements for administration, training requirements for use, and the need for assessors with highly developed clinical judgement.

Detailed assessment of the outcomes examined in the eligible papers is beyond the scope of our review. Nevertheless, we noted a number of papers that considered the predictive validity of specific frailty measures in detecting adverse health outcomes.[17,19,21,29,30,32,33,46,49] Such papers are especially relevant for clinicians and administrators who are interested in identifying patients at risk for negative outcomes. Measures with low positive predictive value result in an undesirable number of false-positives that may translate to channelling already limited resources into a frailty management plan that will not benefit patients, mainly because they are non-frail to begin with and may have better benefit from prevention programmes. Nevertheless, such measures with high negative predictive values can still be useful in ruling out frailty and reassuring that providers recommend care plans that do not harm an older patient subjected to an unnecessary intervention.[10,50] Awareness of clinically important characteristics of screening tools will not only facilitate the sound interpretation of frailty measures but also better support the implications of measurements for research, policy, and practice.

Lastly, identifying older adult populations who undergo frailty transitions can help in targeting groups who may be more responsive to specific interventions than others in terms of reversing their condition.[25] Despite evidence that certain older adult groups can transition to different frailty states,[25,26] current guidelines[12] mainly focus on screening for individual frailty components (e.g., shrinking, malnutrition, etc.) and the management of older adults who have already been identified to have frailty. Specific recommendations for the management of individuals identified as prefrail may provide further benefits in terms of maximising the opportunity to address reversible frailty states.

Policy Implications

The Singapore Ministry of Health has recognised the lack of agreement in the measures used in systematically identifying frailty and transitions across frailty states. The 2017 National Innovation Challenge (NIC) grant call focused on developing an "appropriate and efficient method" of identifying frailty in older adults to ultimately reduce the risk, delay the onset and/or slow down the progress of physical frailty.[51] The ongoing studies from the NIC initiative will add new insights to relevant discussions on frailty identification and measurement in Singapore. An NIC grant recipient is required to test-bed an evidence-based approach in frailty assessment to ensure the viability of the approach in the community setting and its validity in the local context. This requirement can therefore facilitate a more timely translation of research findings into policy and practice. Stakeholders can then reasonably anticipate new solutions from these projects that can help address the unresolved issues in frailty identification and measurement (e.g., lack consistency in frailty components; need for specific guidelines on selecting appropriate measures).

Reinforcing Frailty Research for Evidence-based Practice and Policy

It is imperative to bring together the foregoing discussion and highlight the importance of reinforcing frailty research for evidence-based practice and policy. Evidence-based guidelines can better target prevention programmes for older adults who are non-frail or prefrail, while focusing on improving management among those identified to have frailty. The latest AP-CPGMF cited the lack of supporting evidence from full systematic reviews in the current recommendations.[12] This scoping review can inform the development of a more rigorous systematic review on the key principles specific to frailty identification and measurement. Furthermore, expert researchers and practitioners in the area of frailty can consider adapting standardised methods for evidence synthesis in the iterative process of guideline development and revision. Achieving a consensus on the definition of frailty and the operationalisation of its components remains a key cog in the wheel that can enable evidence-based practice and policy.

Strengths and Limitations

Our scoping review is the first to summarise the extent of frailty identification research in Singapore. Importantly, this paper engages the local research and medical communities on frailty and related conditions (i.e., sarcopenia). However, we need to consider the findings and implications discussed with a few caveats. Unlike full-scale systematic reviews that aim to present the most comprehensive evidence synthesis in a specific area, the purpose of our review is limited to presenting published research from Singapore in the field of frailty identification in terms of its volume, nature, and characteristics. Although our paper can contribute in informing relevant practice and policy, the relevant implications suggested may be especially limited by the restricted focus on the outcomes investigated and the lack of a standard methodological quality assessment of the papers we included.[13] Moreover, our review is limited to published works in frailty research; this approach essentially excluded available frailty measures that are relevant to clinicians and

researchers, but are still in the publication pipeline (e.g., FAM) as of this writing.

Despite these limitations, the foregoing discourse has substantial contributions to frailty identification and measurement research in Singapore. Presenting the current state of research in the local context uncovers the immediate and long-term needs in this area which future research can address. Given the availability of measurement tools for frailty identification, conducting systematic reviews of measurement properties of available tools in different groups of older adult populations can guide the decision on the optimal measure to be used in specific populations. Such a review will enable the evaluation of the methodological quality of studies that investigate the measurement properties of relevant measurement tools, which can ultimately improve the assessment of synthesised findings. In the same vein, our findings suggest pursuing further primary research on the measurement properties (i.e., validity, reliability, responsiveness) of individual frailty measures, as well as their feasibility and interpretability in specific settings and populations in Singapore. Finally, investigators are encouraged to follow a standard approach in reporting the methodology and findings of their frailty measurement studies to facilitate future evidence synthesis.

Conclusion

In closing, our scoping review provides a broad evidence synthesis of the underpinnings of research on frailty identification and measurement in Singapore. Presenting the available evidence is an essential first step in engaging the local community of researchers and clinicians to move towards improving consistency in frailty measurement. Together, researchers, clinicians, and administrators can enable effective and timely evidence-based practice and policies that can ultimately benefit older adults in Singapore.

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Appendix 1 – Search Strategy

Concept	Key Words	PubMed MeSH	CINAHL Subject Terms	Equivalent Terms
#1 Frailty	frailty or frail or vulnerable or vulnerability	"Frailty"[Mesh]	(MH "Frailty Syndrome")	frail or frailty or vulnerable or vulnerability
		"Frail Elderly"[Mesh]	(MH "Frail Elderly")	"frail elderly"
And				
#2 Older Adults	aged or elderly	"Aged"[Mesh]	(MH "Aged")	aging or ageing or "older adult" or "older adults"
And				
#3 Identification (definition, markers)	risk factors	"Risk Factors"[Mesh]	(MH "Risk Factors")	"risk factor" or "risk factors"
	association	"Association" [Mesh]	None	associated or association
	health status indicators	"Health Status Indicators"[Mesh]	(MH "Health Status Indicators")	"health status indicators"
	markers or biological markers or clinical markers	"Biomarkers"[Mesh] or "Genetic Markers"[Mesh]	(MH "Biological Markers") or (MH "Genetic Markers")	markers or "biological markers" or "clinical markers"
	gait speed	"Walking Speed"[Mesh]	(MH "Gait")	"gait speed" or "walking speed" or "walking pace"
	physical activity	"Exercise"[Mesh]	(MH "Physical Activity")	"physical activity"
	weight loss	"Weight Loss"[Mesh]	(MH "Weight Loss")	"weight loss"
	cognitive impairment	"Cognitive Dysfunction"[Mesh]	None	"cognitive impairment" or "cognitively impaired"
	depressive symptoms	"Depression"[Mesh]	(MH "Depression")	"depressive symptoms" or depression
	exhaustion	None	None	exhaustion
	weakness	None	None	weakness
	hand grip strength	"Hand Strength"[Mesh]	(MH "Grip Strength")	"grip strength"
	deficit or accumulation or cumulative	None	None	deficit or accumulation or cumulative
	identification, assessment, measurement	None	None	identification or identifying or identified or measurement or measuring
And / Or				
#4 Identification (Methods)	health surveys	"Health Surveys"[Mesh]	(MH "Surveys")	questionnaire or questionnaires or survey
	diagnosis	"Diagnosis"[Mesh]	(MH "Diagnosis")	diagnosis
	rating scales or index	None	None	"rating scales" or index
	risk assessment or case finding or geriatric assessment	"Risk Assessment"[Mesh] or "Geriatric Assessment"[Mesh]	(MH "Risk Assessment") or (MH "Geriatric Assessment")	"risk assessment" or "case finding" or "geriatric assessment"
	disability evaluation	"Disability Evaluation"[Mesh]	(MH "Disability Evaluation")	"disability evaluation"
	forecasting	"Forecasting"[Mesh]	(MH "Forecasting")	forecasting
	patient care planning	"Patient Care Planning"[Mesh]	(MH "Patient Care Plan")	"patient care plan" or "patient care planning"
And				
#5 Singapore	Singapore	"Singapore"[Mesh]	(MH "Singapore")	Singapore
			PubMed: (#1 and #2) AND (#3 or #4) and #5	137 records
			CINAHL: (#1 and #2) and (#3 or #4) and #5	28 records
			Combine PubMed2 + CINAHL2	**165 records with 23 duplicates**
			Unique records in PubMed + CINAHL for Title and Abstract Screening	**142 records for title and abstract screening**

Notes: No additional limits/search filters were applied; Last date of search: 8 May 2018 (PubMed and CINAHL); Articles that are not indexed in PubMed on the last date of search are not included in the search results. Key references used in developing the search strategy: Elliott, A., L. Hull, and S.P. Conroy. Age Ageing, 2017. 46(3): p. 509-513; Lee, L., et al. Geriatr Gerontol Int, 2017. 17(10): p. 1358-1377; Drubbel, I., et al. BMC Geriatr, 2014. 14: p. 27; Sternberg, S.A., et al., *The identification of frailty: a systematic literature review.* J Am Geriatr Soc, 2011. 59(11): p. 2129-38