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Meta-analysis

Post-discharge consequences of protein-energy malnutrition, sarcopenia, and frailty in older adults admitted to rehabilitation: A systematic review

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SUMMARY

Background & aims: Malnutrition, sarcopenia, and frailty are three prevalent wasting conditions among older rehabilitation patients that lead to multiple health-related negative outcomes. This systematic review and meta-analysis aimed to determine the post-discharge consequences of malnutrition, sarcopenia, and frailty in older adults admitted to inpatient rehabilitation.

Methods: MEDLINE, Embase, Web of Science, and CINAHL databases were searched on 20 April, 2021 for longitudinal studies in older adults (≥65 years) admitted for inpatient rehabilitation. This systematic review included and synthesised studies that 1) measured malnutrition, sarcopenia, and/or frailty using a validated assessment tool or guideline; and 2) reported the association with post-discharge mortality, physical function, quality of life, or discharge location. The Academy of Nutrition & Dietetics Quality Criteria Checklist and GRADE criteria were used to assess risk of bias and evidence certainty. Where possible, data were pooled using Revman.

Results: Twenty-six observational studies (n = 9709 participants in total) with similarly aged populations were included. Eight, seven, and eleven studies assessed malnutrition, sarcopenia, and frailty, respectively. Follow-up periods ranged from immediate to 7 years post-rehabilitation. Malnutrition was associated with discharge to a higher level of care (GRADE: very low), and worse quality of life (GRADE: very low) and physical function (GRADE: very low). Sarcopenia was associated with worse physical function (GRADE: very low) and lower rate of home discharge (OR: 0.14; 95%CI: 0.09–0.20; I^2:30%; GRADE: low). Frailty was associated with increased mortality (GRADE: very low), hospital readmission (GRADE: very low), and decreased home discharge (GRADE: very low).

Conclusion: Wasting conditions in older adults during rehabilitation admission may be associated with poorer quality of life, lower rates of home discharge, and higher rates of health service use, physical dysfunction, and mortality following discharge. Further research is needed to investigate the comparative and combined impacts, as well as the overlap of malnutrition, sarcopenia, and frailty during and after rehabilitation to guide priority screening and intervention.

1. Introduction

Globally, the ageing population is growing due to continuous improvements in public health. However, with longer life expectancy, the prevalence of physical and/or cognitive dysfunction has increased [1]. Older adults are at high risk of conditions

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characterized or caused by muscle and/or fat wasting (herein referred to as wasting conditions) [2] including protein-energy malnutrition (PEM), sarcopenia, and frailty [3,4]. There is no global consensus on the definition, but PEM can be characterised by inadequate intake or uptake of protein and energy and varying degrees of disease-related inflammation that leads to altered body composition with reduced fat free mass, reduced physiological function and increased risk of poorer clinical outcomes [5,6]. Sarcopenia is the loss of lean tissue due to age-related muscle atrophy and suboptimal protein intake, characterised by the loss of muscle strength and performance [7]. Frailty is a clinical state where an individual has higher vulnerability for developing increased dependency and/or mortality when exposed to a stressor [8]. Each of these wasting conditions are not only interdependently related [2,3,9], but also share similar characteristics in terms of their aetiology and parameters for assessment, such as weight loss, muscle loss and/or reduced functional capacity [2,10]. Collectively and individually, they contribute to poorer patient outcomes in terms of physical function, quality of life, mortality, falls, and higher reliance on healthcare, home care, and family care [11–17].

The prevalence of malnutrition, sarcopenia, and frailty have been reported as 13–60%, 37–69%, and 12–84% respectively among older patients across different settings, including inpatient rehabilitation [3,18–20]. Inpatient rehabilitation programs provide multidisciplinary treatment for patients – with dietetic treatments including interventions such as dietary education, oral nutrition supplements and enteral nutrition [21]. Though inpatient rehabilitation programs aim to improve independence in managing personal care and activities of daily living, wasting conditions undermine this goal through increasing the risk of physical dysfunction [22]. A 2013 systematic review exploring the post-discharge consequences of PEM found that, compared with well-nourished older rehabilitation patients, PEM increased the risk of post-discharge mortality, institutionalisation, hospitalisation, physical dysfunction, and lower quality of life [12]. As well as requiring an update, there is a need for systematic reviews on PEM to also explore the impact of sarcopenia and frailty on patient-centred outcomes, as these wasting conditions have a significant diagnostic overlap and similarly high prevalence in rehabilitation (Fig. 1) [2,10]. Understanding the negative consequences of these three wasting conditions may help to prioritise screening and diagnostic efforts in inpatient rehabilitation setting towards the condition which has the strongest association with negative health outcomes. Although previous systematic reviews have examined PEM, sarcopenia, and frailty, none have explored the post-discharge consequences of these wasting conditions in rehabilitation [11,12,23].

In order to inform evidence-based practice in rehabilitation clinical screening, assessment, and triaging of interventions, this

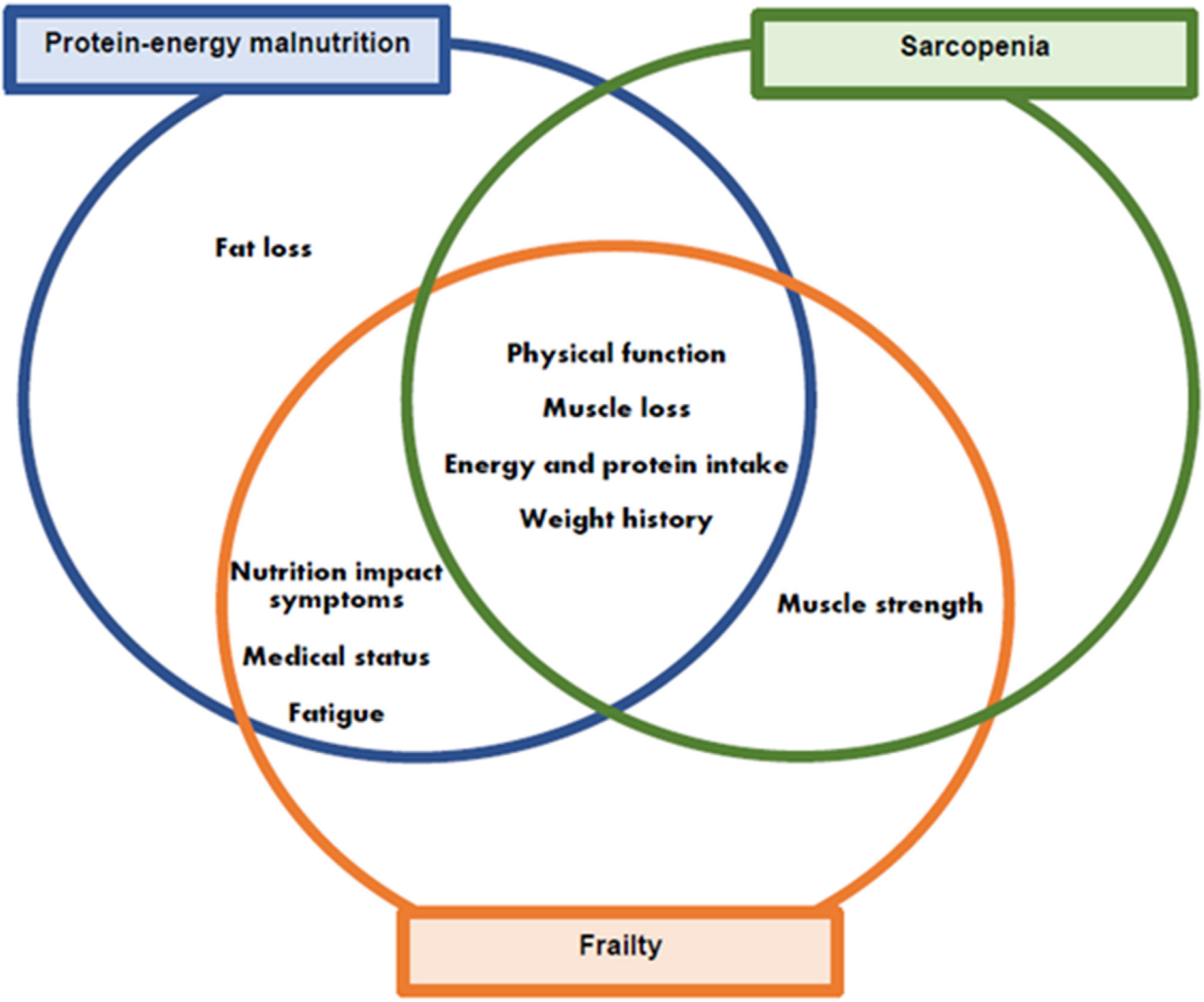

Fig. 1. Overlap between Protein-energy malnutrition, Sarcopenia, and Frailty Assessment.

study aims to determine the association of wasting conditions (malnutrition, sarcopenia, and frailty) among older adults admitted in rehabilitation, on various outcomes (nutrition status, sarcopenia, fraitly status, institutionalisation, discharge location, functional status, quality of life and mortality) following discharge from rehabilitation.

2. Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) [24] checklist for observational studies and was registered in the International Prospective Register of Systematic Reviews (PROSPERO identifier: CRD42020173809) (Table S1).

2.1. Search strategy and study selection

Published studies were searched for in electronic databases MEDLINE (via PubMed), Embase (via Elsevier), CINAHL (via EBSCO), and Web of Science for publications until February 2020, followed up by an updated search until April 2021, using a combination of keywords and controlled vocabulary (Table S2). A 'snowball' search of citations in the included studies complemented the systematic search.

Titles and abstracts were independently screened by two investigators (XF and [NC or EL]). Full text publications of potentially eligible studies were retrieved and independently screened by two investigators for eligibility (NC and [EL and XF]). Disagreements were resolved by consensus or a third investigator (SM or BvdM). Study selection was performed using Covidence software [Covidence systematic review software, Veritas Health Innovation: Melbourne, Australia].

Eligibility was assessed according to the Population, Intervention/Exposure, Comparator, Outcome (PICO) framework. Studies were included if (P) participants (mean age $\geq$65 years) who were admitted to inpatient rehabilitation or sub-acute care then discharged (home, residential aged care, or other discharge destination such as acute care), and (I) who were assessed during inpatient admission for PEM, sarcopenia, or frailty using validated tools or guidelines, and (O) if one or more of the following post-discharge health outcomes were measured post-discharge and according to the exposure status (that is, well-nourished versus malnourished, non-frail versus frail, non-sarcopenic versus sarcopenic). Prospective or retrospective cohort studies, case series, case control studies, or the control group of an intervention study (analysed as a prospective cohort study) were included. Studies in any language were eligible if they could be translated to Chinese or English.

Studies were excluded if discharge location was not reported, or the whole sample had a single health condition or treatment (e.g. cystic fibrosis; haemodialysis or peritoneal dialysis; or enteral or parenteral nutrition), or were receiving drug and/or alcohol rehabilitation or ambulatory rehabilitation.

2.2. Outcomes

Post-discharge outcomes considered in this review comprised nutrition status, sarcopenia status, frailty status, physical function, quality of life, and cognitive function if these outcomes were measured by a validated tool. Outcomes also included incidence of hospitalisation (general, emergency, intensive care unit, rehabilitation), institutionalisation (admission to residential home, long term care, nursing home), discharge location, falls, pressure ulcers, and mortality.

2.3. Data extraction and quality assessment

Data were extracted from eligible studies into standardised tables by one investigator (NC), and accuracy was checked by a second investigator (SM, KL, BvdM, EL, or XF). Two investigators (NC and XF, EL, or KL) independently assessed study quality and risk of bias using the Academy of Nutrition & Dietetics Quality Criteria Checklist (QCC) [25], and conflicts were resolved by consensus. The QCC considered: selection of subjects; comparability of subjects; outcomes; and then rated studies as having positive (+), negative (−), or neutral quality (ϕ).

For each outcome, the certainty of evidence was assessed according to the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) based on the following parameters: risk of bias; consistency; directness; and precision [26]. GRADE ratings commenced as 'low certainty' in the body of evidence, as evidence was based on observational studies. Certainty was then upgraded to 'moderate' or 'high', or downgraded to 'very low', depending on the parameters.

2.4. Meta-analysis

Outcome data were pooled using Review Manager (version 5.4. The Cochrane Collaboration, 2020) [27], where adequate data were reported or could be calculated. All pooled categorical outcomes were assessed using the random-effects Mantel-Haenszel model. The association between wasting conditions and outcomes were expressed as odds ratios (OR) with 95% confidence intervals (CI) for categorical outcomes (incidence of home discharge based on wasting conditions status). The I^2 statistic was used to evaluate statistical inconsistency/heterogeneity, where a value of >50% was considered substantial heterogeneity [28]. $P < 0.05$ was considered as statistically significant.

3. Results

3.1. Search results

Of the 9694 records identified in the search strategy, 341 were selected for full text screening, and 26 were included after snowball searching (Fig. 2). The main reason for ineligibility was clinical setting (128 studies), with most studies occurring in acute care or community settings. Of the 26 studies, eight studies were conducted in Australia [29–36], four in Spain [37–40], five in Japan [41–45]; two each in the USA [46,47], Switzerland [48,49], Finland [50,51]; and one each in Canada [52], Italy [53], and United Kingdom [54] (Table 1). Mean ages ranged between 66 and 85 years, and sample sizes ranged between n = 57 and n = 2188 participants (n = 9709 participants in total). Post-rehabilitation outcomes were measured from immediately after discharge to 7 years post-discharge (Table 2). Twelve studies were rated as positive quality and fourteen were rated as neutral quality (Table 3 and S3).

3.2. Consequences of protein-energy malnutrition

Of the nine studies measuring the post-discharge consequences of PEM, PEM was assessed via the Mini Nutritional Assessment (n = 5) [30–32,35,49], the Subjective Global Assessment (n = 2) [46,52], the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (n = 1) [29], and the Global Leadership Initiative for Malnutrition [39] (Table 4). Nutrition assessment was conducted within four days of admission across studies, except for four studies where timing of nutrition assessment was not reported [35,39,49,52].

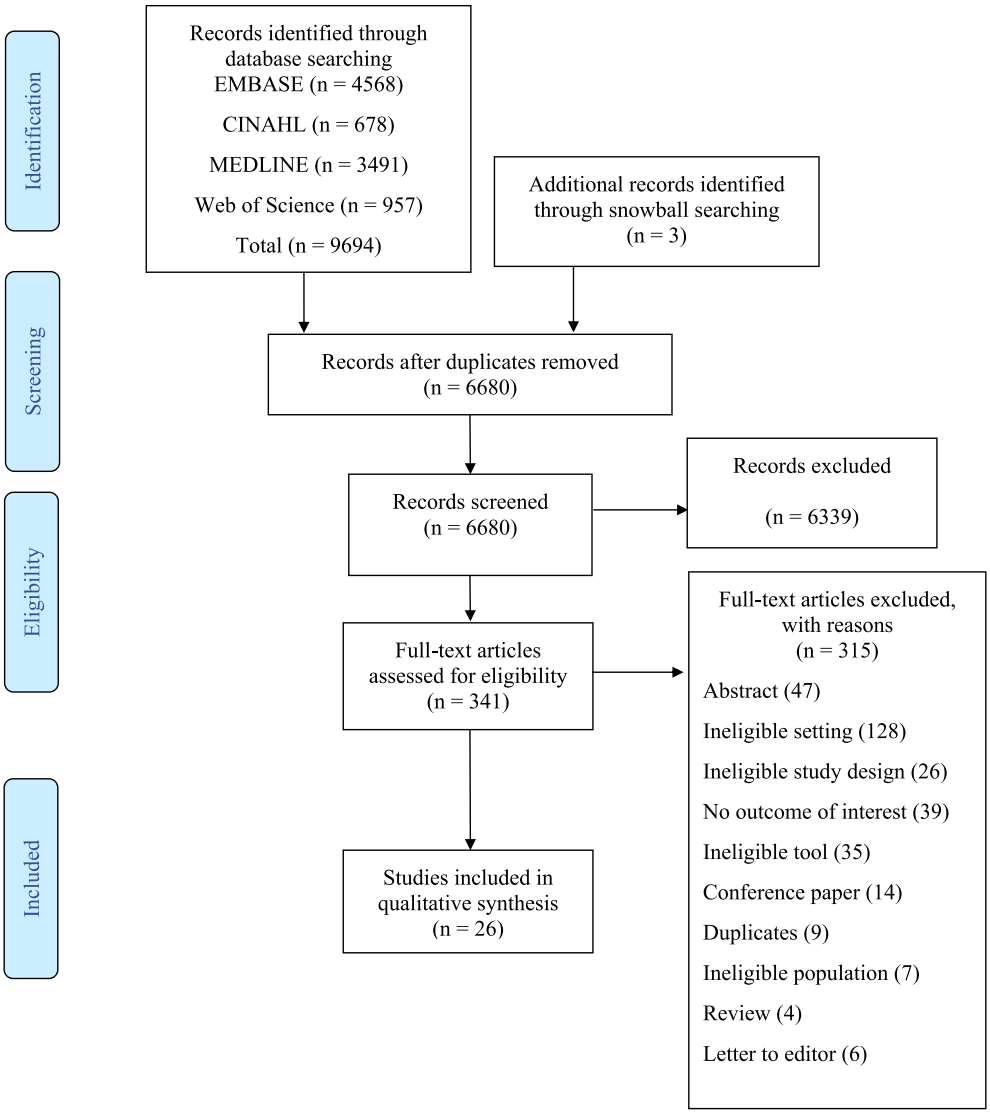

Fig. 2. PRISMA flowchart of the search results and the included studies.

Of the five studies reporting mortality outcomes (GRADE: very low), three found malnourished patients had a higher rate of post-discharge mortality [30,39,52]; one showed a trend towards an increased rate of mortality in malnourished patients [29]; and another showed no effect [46]. Furthermore, two studies each found that increased mortality rates were associated with higher percentage of weight loss, lower BMI, and lower sex-specific fat free mass [39,46]. Among five studies that measured hospital readmission (GRADE: very low), Visvanathan et al. found that malnourished older adults had a higher rate of admission to an acute care facility upon discharge [32]; Marshall et al. found that malnourished patients had a significantly longer length of stay (LOS) during hospital readmission ($p = 0.032$) [29]; but Dávalos-Yerovi et al. did not find a statistically significant association with hospital readmission (OR: 1.89; 95%CI:0.9–4.1; $p = 0.116$) nor rehospitalisation LOS (OR: 1.65; 95%CI: 0.7–3.8; $p = 0.23$) for malnourished patients [39]. Five studies reported significantly increased rates of admission to a higher level of care for malnourished patients (n = 2154 subjects; GRADE: very low) [29–32,35].

Only Neumann et al. reported quality of life and physical function, as evaluated by assessment of a quality of life instrument and modified Barthel index respectively, and identified significantly poorer quality of life (mean difference: 5; $p = 0.001$; GRADE: very low) and physical function (mean difference: 11; $p = 0.002$; GRADE: very low) in malnourished older adults than in their well-nourished counterparts at 90 days post-discharge (Table 4 and S4) [31].

3.3. Consequences of sarcopenia

Three of seven studies assessed sarcopenia according to the definition of the European Working Group on Sarcopenia in Older People (EWGSOP) [37,38,42], three studies determined sarcopenia based on Asian Working Group for Sarcopenia [41,43,44], and one study assessed sarcopenia using the definition of the Foundation for National Institutes of Health Sarcopenia Project (FNIH) [53]. Sarcopenia assessments were all conducted within seven days of admission, except for two studies [37,43] which did not report timing of assessment.

Mortality was measured in two studies, where only Malafarina et al. found a significant association, reporting that patients with sarcopenia were 1.67 times more likely to die than non-sarcopenic older adults (HR: 1.67; 95%CI:1.11–2.51; $p = 0.014$; GRADE: very low) (Table 4 and S4) [37]. Physical function assessed by Barthel

Table 1
Characteristics of identified studies.

Citation	Study design	Setting	Study sample	Study quality[a] (+, ϕ, −) [21]
Protein Energy Malnutrition				
Charlton et al., 2012 [30]	Retrospective cohort study	Two rehabilitation hospitals. Unknown number of beds. NSW, Australia	n = 469 Mean age: 80.2 ± 7.1 y Data collected: 2006–2009	+
Dávalos-Yerovi et al., 2021 [39]	Prospective cohort study	Pulmonary rehabilitation unit of a university hospital. Unknown number of beds. Barcelona, Spain	n = 167 Mean age: 66.5 ± 9 y Females: n = 32 (20%) Data collected: 2015–2018	+
Duerksen et al. 2000 [52]	Prospective cohort study	Four centers of geriatric and rehabilitation units. Unknown number of beds. Winnipeg, Canada	n = 87 Mean age: 80–82 y Females: n = 62 (71.3%) Data collected: unknown	ϕ
Marshall et al. 2016 [29]	Prospective cohort study	Two public general rehabilitation units 24 and 31 beds. NSW, Australia	n = 57 Mean age: 79.1 ± 7.3 y Females: n = 28 (49.0%) Data collected: 2013–2014	ϕ
Lambert et al., 2020 [35]	Retrospective cohort study	Three rehabilitation wards within local health district. 20-22 beds. NSW, Australia	n = 1430 Median age (IQR): 79 (74–84) y Females: n = 819 (57.3%) Data collected: 2010–2013	ϕ
Neumann et al. 2005 [31]	Prospective cohort study	Rehabilitation unit of general hospital. 55 beds. SA, Australia	n = 133 Mean age: 81 ± 6.0 y Females: n = 75 (56.0%) Data collected: 2003	ϕ
Sullivan et al. 1991 [46]	Prospective cohort study	Geriatric rehabilitation unit of Veterans Administration Hospital. 20 beds. Arkansas, USA	n = 110 Mean age: 78 ± 9.0 y Data collected: 1987–1988	+
Visvanathan et al. 2004 [32]	Prospective cohort study	Medical, orthopaedic and geriatric wards at a rehabilitation center. Unknown number of beds. SA, Australia	n = 65 Mean age (range): 76–79 y Females: n = 44 (67.7%) Data collected: 2002–2003	ϕ
Sarcopenia				
Landi et al. 2017 [53]	Prospective cohort study	Geriatric rehabilitation unit of the 'A. Gemelli' Hospital. Unknown number of beds. Rome, Italy	n = 127 Mean age: 81.3 ± 4.8 y Females: n = 82 (64.6%) Data collected: 2015–2016	+
Malafarina et al. 2019 [37]	Prospective cohort study	Post-acute rehabilitation units of 2 hospitals. Hospital San Juan de Dios Hospital Viamed Valvanera. Unknown number of beds. Pamplona & Logroño, Spain	n = 187 Mean age: 85.2 ± 6.3 y Females: n = 138 (73.8%) Data collected: 2012–2019	+
Matsushita et al. 2019 [42]	Retrospective cohort study	Convalescent rehabilitation wards. Unknown bed number. Nagasaki, Japan	n = 267 Mean age: 72.5 ± 13.2 y Females: n = 117 (43.8%) Data collected: 2017–2018	+
Nishioka et al., 2020 [43]	Retrospective cohort study	Convalescent rehabilitation wards of rural private hospital. Unknown number of beds. Nagasaki, Japan	n = 408 Mean age: 73.1 ± 12.5 y Females: n = 170 (41.7%) Data collected: 2017–2019	ϕ
Sanchez-Rodriguez et al. 2014 [38]	Prospective cohort study	Subacute geriatric care unit at Hospital de l´Esperança. Unknown number of beds. Barcelona. Spain	n = 99 Mean age: 84.6 ± 6.6 y Females: n = 64 (64.6%) Data collected: 2012	ϕ
Yoshimura et al. 2019 [41]	Retrospective cohort study	Rehabilitation hospital. 225 beds. Kumamoto, Japan	n = 795 Mean age: 74.9 ± 13.2 y Females: n = 471 (59.2%) Data collected: 2014–2016	+
Yoshimura et al., 2020 [44]	Retrospective cohort study	Post-acute care hospital. 135 beds. Kumamoto, Japan	n = 917 Mean age: 74.7 ± 13.5 y Females: n = 536 (58.5%) Data collected: 2014–2016	+
Frailty				
Aida et al., 2020 [45]	Retrospective cohort study	Cardiovascular Center, Kitasato University Hospital. Unknown number of beds. Sagamihara, Japan	n = 895 Median age (IQR): 76 (71–81) y Females: n = 354 (39.6%) Data collected: 2015–2017	+
Arjunan et al. 2019 [33]	Prospective cohort study	Three geriatric rehabilitation wards of a tertiary hospital. Unknown number of beds. QLD, Australia	n = 258 Mean age: 79 ± 8 y Females: n = 139 (54%) Data collected: 2015	ϕ

Table 1 (*continued*)

Citation	Study design	Setting	Study sample	Study quality[a] (+, ϕ, −) [21]
Fompeyrine et al., 2020 [48]	Prospective cohort study	Post-acute care units of three municipal nursing homes. Unknown number of beds. Zurich, Switzerland	n = 140 Mean age: 84 ± 8.6 y Females: n = 88 (62.9%) Data collected: 2016-unkown	ϕ
Haley et al. 2013 [34]	Prospective cohort study	Two subacute age care wards of rehabilitation hospital. Unknown number of beds. VIC, Australia	n = 86 Mean age: 81.3 ± 7.7 y Females: n = 44 (51.2%) Data collected: 2011-unknown	+
Kerminen et al., 2020 [50]	Retrospective cohort study	Two geriatric post-acute hospitals. 190-230 beds. Tampere, Finland	n = 2188 Mean age: 84 ± 76.3 y Females: n = 1499 (68.5%) Data collected: 2013–2016	ϕ
Kerminen et al., 2021 [51]	Retrospective cohort study	Community-dwelling elderly discharged from two post-acute geriatric hospitals. 190-230 beds. Tampere, Finland	n = 1167 Mean age: 84.5 ± 6.2 y Females: n = 827 (70.9%) Data collected: 2013–2016	ϕ
Low et al., 2021 [36]	Retrospective cohort study	One general rehab and two geriatric evaluation and management wards in a public tertiary teaching hospital. Unknown number of beds. VIC, Australia	n = 844 Median age (IQR): 86 (81–90) y Females: n = 590 (69.9%) Data collected: 2010–2018	+
Madruga-Flores et al., 2021 [40]	Prospective cohort study	Geriatric functional recovery unit of the Hospital Central Cruz Roja. Unknown number of beds. Madrid, Spain	n = 74 Median age (IQR): 82 (77–86) y Females: n = 36 (48.5%) Data collected: 2019	ϕ
Schuijt et al., 2021 [47]	Retrospective cohort study	Level one trauma center with an orthogeriatric co-management service. Unknown number of beds. Boston, United States	n = 296 Median age (IQR): 84 (79–89) y Female: 223 (71.2%) Data collected: 2014–2018	+
Singh et al. 2012 [54]	Prospective cohort study	Acute geriatric medicine rehabilitation unit of a university hospital. Unknown number of beds. Cardiff, UK	n = 265 Mean age: 82.6 ± 8.6 y Females: n = 159 (60%) Data collected: 2008–2010	ϕ
Thomas et al., 2020 [49]	Prospective cohort study	Four post-acute care units designated for temporary stays. Unknown number of beds. Zurich, Switzerland	n = 140 Mean age: 84.1 ± 8.6 y Females: n = 88 (62.9%) Data collected: 2016	ϕ

+ , positive; ϕ, neutral; − , negative; y, year.
[a] Study quality assessed by Quality criteria checklist of the Academy of Nutrition and Dietetics.

index was found to be poorer in older adults with sarcopenia as identified by FNIH (p = 0.02) [53] and EWGSOP (p = 0.007) [38] (GRADE: very low), where the mean difference of Barthel index in sarcopenic and non-sarcopenic group were between 10.4 and 15.8. Further, patients with sarcopenia were 3.44 times more likely to not fully recover in physical function as measured by FNIH (p value not available) [53] and had less functional gain by EWGSOP (p = 0.017) than their counterparts without sarcopenia (Table 4 and S4) [38].

Discharge location was the sole variable measured by four studies [41–44]. Two studies reported data from the study by Miyai et al. [55]. In a meta-analysis including three studies from four eligible cohort datasets, sarcopenia was associated with lower odds of home discharge (OR: 0.14; 95%CI: 0.09–0.20; I^2:30%; GRADE: low) (Fig. 3).

3.4. Consequences of frailty

Five studies assessed frailty using the derived Frailty Index; however, frailty indexes across studies were derived from different variables [33,47,50,51,54]. Two studies each assessed frailty by Fried Frailty Phenotype [48,49] and Clinical Frailty Scale [36,40]. Haley et al. [34] and Aida et al. [45] measured frailty by the Edmonton Frail Scale and Simplified Frailty Scale respectively. Frailty was assessed within seven days of admission, except for eight studies where the timing of assessment was unreported [33,36,40,45,49–51,54].

Mortality was measured in four studies [45,47,48,54], all of which found frailer older adults to have a statistically significant higher risk of mortality (GRADE: very low). Three studies reported a statistically significant higher risk of rehospitalisation among frailer older adults (OR: 1.34 to 1.89; HR: 3.27; GRADE: very low) [45,47,51]. Of the six studies investigating the rate of discharge to a higher level of care [33,34,47,49,50,54], five found a positive association between frailty and rate of discharge to a higher level of care [33,47,49,50,54], except for Haley et al. [34] (GRADE: very low) (Table 4 and S4). Three studies reported frailty to be significantly associated with a lower risk of home discharge or returning to previous address prior to admission (OR: 0.1 [95%CI: 0.06–.0.4] to 0.074 [95%CI: 0.581–0.946]; GARDE: very low) [36,40,47].

4. Discussion

The results of this systematic review suggest that older adults with a wasting condition may have poorer outcomes following rehabilitation discharge. In the majority of the retrieved studies, PEM, sarcopenia, and frailty were found to be associated with negative post-discharge outcomes including higher rates of mortality, health service admission, and discharge to a higher level of care. PEM and sarcopenia were associated with physical dysfunction; frailty was associated with lower rate of home discharge; PEM was further associated with worse quality of life. Meta-analysis of three studies showed that sarcopenia was associated with 86% decreased odds of home discharge, indicating higher risk for loss of

Table 2
Summary of outcome measurements.

Citation	Outcomes					
	Mortality	Rehospitalisation	Rehospitalisation LOS[a]	Discharge location	Quality of life	Physical function
Protein Energy Malnutrition						
Charlton et al., 2012 [30]	✓	✓		✓		
Dávalos-Yerovi et al., 2021 [39]	✓	✓	✓			
Duerksen et al., 2000 [52]	✓	✓				
Marshall et al., 2016 [29]	✓	✓	✓	✓		
Lambert et al., 2020 [35]				✓		
Neumann et al., 2005 [31]				✓	✓	✓
Sullivan et al., 1991 [46]	✓					
Thomas et al., 2020 [49]				✓		
Visvanathan et al., 2004 [32]		✓		✓		
Total number of studies (n)	5	5	2	6	1	1
Sarcopenia						
Landi et al., 2017 [53]						✓
Malafarina et al., 2019 [37]	✓					
Matsushita et al., 2019 [42]				✓		
Nishioka et al., 2020 [43]				✓		
Sanchez-Rodriguez et al., 2014 [38]	✓					✓
Yoshimura et al., 2019 [41]				✓		
Yoshimura et al., 2020 [44]				✓		
Total number of studies (n)	2	0	0	4	0	2
Frailty						
Aida et al., 2020 [45]	✓	✓				
Arjunan et al., 2019 [33]				✓		
Fompeyrine et al., 2020 [48]	✓					
Haley et al., 2013 [34]				✓		
Kerminen et al., 2020 [50]				✓		
Kerminen et al., 2021 [51]		✓				
Low et al., 2021 [36]				✓		
Madruga-Flores et al., 2021 [40]				✓		
Schuijt et al., 2021 [47]	✓	✓		✓		
Singh et al., 2012 [54]	✓			✓		
Thomas et al., 2020 [49]				✓		
Total number of studies (n)	4	3	0	8	0	0

[a] LOS, length of stay.

independence. According to GRADE, there was a very low to low certainty that the pooled effect estimate represented the true effect due to clinical heterogeneity and/or imprecision. Although this study also aimed to update the evidence of the 2013 systematic review exploring the post-discharge consequences of PEM, a lack of eligible new studies prevents stronger conclusions from being drawn since then to strengthen the level of evidence, and highlights the need for further research and funding in the rehabilitation setting [12].

PEM, sarcopenia, and frailty are three distinct geriatric wasting conditions, but they are known to share similar characteristics in terms of their aetiology and definition [9], and share overlapping diagnostic criteria in terms of physical function and functional performance (Fig. 1) [2,56–58]. Previous studies found that nutritional status is positively associated with physical function as assessed by Barthel Index and Short Physical Performance Battery during rehabilitation [59,60]. The poorer physical performance among those with poorer nutritional status can be indicative that PEM-related muscle-wasting and weight loss may be one of the main parameters that influence the physical function of those who have frailty and sarcopenia [9,61]. However, interestingly, of all the included studies, only three assessed physical function based on nutrition and sarcopenia status [31,38,53].

Two studies in this review reported body weight change as one of the nutritional status indicators [39,46]. Weight loss remains an important hallmark of nutrition status [63], but body composition is also highly relevant in clinical settings, as low muscle mass, especially in combination with high fat mass loss, is associated with worse prognosis [64–66]. Apart from the positive association between PEM-related weight loss and adverse clinical events, inconsistency in the relationship between PEM and mortality were identified by this review, which was likely due to limited timeframes of follow-up and underpowered sample sizes.

Previously, a meta-analysis completed by Xu et al. investigating the association between sarcopenia and mortality demonstrated a higher risk of mortality among sarcopenic older adults across the community, hospitals, and aged care settings [67]. Corresponding to the findings of the current review, only two studies reported mortality based on sarcopenia status. The study included in this review by Sánchez-Rodríguez failed to find a significant association between mortality and sarcopenia [38]; however, this study was likely underpowered due to a small sample size. In contrast, Malafarina et al. comprised a larger sample size and found a significant difference in mortality between sarcopenic and non-sarcopenic older adults [37].

The findings of this review exploring the association between frailty and post-discharge outcomes align with those reported for PEM and sarcopenia, having a positive association with mortality and healthcare use, which is consistent with the findings of a meta-analysis completed by Cunha et al. in hospital settings [23]. Although there were inconsistent findings in the association between frailty and discharge to a higher level of care in this review, a possible explanation may be because the Edmonton Frail Scale has insufficient predictive validity compared to frailty index [34,68].

Earlier studies have shown that rehabilitation interventions that focus on nutrition and physical exercise may improve nutritional status and functional status among older adults with wasting conditions during admission - however, whilst inadequate energy and protein intake is always an aetiological factor in PEM, it may not be so in sarcopenia and frailty [42,69–72]. Whilst nutrition

Table 3
Risk of bias assessments for the n = 26 studies which examined the post-discharge consequences of malnutrition, sarcopenia, and frailty.

Study		Validity Question [a]										Overall Quality Rating
		1	2	3	4	5	6	7	8	9	10	
Protein Energy Malnutrition	Charlton et al., 2012											Positive
	Dávalos-Yerovi et al. 2021											Positive
	Duerken et al., 2000											Neutral
	Marshall et al., 2016											Neutral
	Lambert et al. 2020											Neutral
	Neumann et al., 2005											Neutral
	Sullivan et al., 1991											Positive
	Visvanathan et al., 2004											Neutral
Sarcopenia	Landi et al., 2017											Positive
	Malafarina et al., 2019											Positive
	Matsushita et al., 2019											Positive
	Nishioka et al. 2020											Neutral
	Sanchez-Rodriguez et al., 2014											Neutral
	Yoshirmura et al., 2019											Positive
	Yoshimura et al. 2020											Positive
Frailty	Aida et al. 2020											Positive
	Arjunan et al., 2019											Neutral
	Fompeyrine et al. 2020											Neutral
	Haley et al., 2014											Positive
	Kerminen et al. 2020											Neutral
	Kerminen et al. 2021											Neutral
	Low et al. 2021											Positive
	Madruga-Flores et al. 2021											Neutral
	Schuijt et al. 2021											Positive
	Singh et al., 2012											Neutral
	Thomas et al. 2020											Neutral

Green indicates 'Yes'; Red indicates 'No'; Orange indicates 'Unclear or N/A'.

[a] Validity questions according to the Academy of Nutrition & Dietetics Quality Criteria Checklist (21):

1. Was the research question clearly stated?
2. Was the selection of study subjects/patients free from bias?
3. Were study groups comparable?
4. Was method of handling withdrawals described?
5. Was blinding used to prevent introduction of bias?
6. Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?
7. Were outcomes clearly defined and the measurements valid and reliable?
8. Was the statistical analysis appropriate for the study design and type of outcome indicators?
9. Are conclusions supported by results with biases and limitations taken into consideration?
10. Is bias due to study's funding or sponsorship unlikely?

Table 4
Outcomes of identified studies.

Citation	Baseline outcomes	Timepoint & Outcomes measurement	Post-discharge outcomes
Protein Energy Malnutrition			
Charlton et al., 2012 [30]	MNA was completed within 72 h of admission. Baseline: MNA score (median, IQR): 20 (16–22.5) • Well-nourished (MNA≥24): 17.3% • At risk of malnutrition (MNA = 17.1 –23.9): 53.1% • Malnutrition (MNA≤17): 29.6%	Up to 26 months post discharge: • Discharge location • Rehospitalisation • Mortality Follow-up (mean ± SD): 18.97 ± 3.84 months.	**Discharge location:** Discharge to a higher level of care than prior to admission (%) • Well-nourished: 4.9 • Malnourished: 33.1 ($p < 0.001$) Discharge to nursing homes and hostels are associated with malnutrition Hostel (n, %): • Well-nourished: 5 (6.5) • Malnourished: 27 (12.4) Nursing Home (n, %): • Well-nourished: 1 (1.3) • Malnourished: 23 (18.5) **Rehospitalisation (n, %):** 291 (62%) of patients recorded at least one readmission • No association with MNA ($r = -0.04$, $p = 0.45$) **Mortality:** Malnourished HR: 3.41 (95%CI:1.07–10.87, $p = 0.038$)
Dávalos-Yerovi et al., 2021 [39]	Global Leadership Initiative for Malnutrition was completed at unknown timepoint of admission. Baseline (n, %): • Well-nourished: 92 (55.1) • Malnourished: 75 (44.9)	2 y from unknown timepoint: • Rehospitalisation • Rehospitalisation LOS • Mortality	**Rehospitalisation:** Adjusted for Age: • OR: 2.9 (95%CI:1.4–6.0, $p = 0.004$) Adjusted for age and obstruction severity: • OR: 1.89 (95%CI: 0.9–4.1, $p = 0.116$) **Rehospitalisation LOS (>10 days):** Adjusted for Age: • OR: 2.6 (95%CI: 1.2–5.6, $p = 0.01$) Adjusted for age and obstruction severity: • OR: 1.65 (95%CI: 0.7–3.8, $p = 0.23$) **Mortality:** Adjusted for Age: • HR: 2.8 (95%CI: 1.0–8.1, $p = 0.05$) Adjusted for age and obstruction severity: • HR: 2.27 (95%CI: 0.8–6.8, $p = 0.140$)
Duerksen et al. 2000 [52]	SGA was completed at an unknown point of admission. Of the interobserver agreement only 64 subjects were included in analysis. Baseline (n, %): • Well-nourished: 47 (73.4) • Mild-moderately malnourished: 13 (20.3) • Severely malnourished:4 (6.3)	6 months from unknown timepoint: • Rehospitalisation • Number of institutional days • Mortality	**Number of readmission/6 months and institutionalisation LOS (mean ± SD):** • Well-nourished: 0.2 ± 0.1 admissions, 62 ± 9 days • Mild-moderately malnourished: 0.1 ± 0.1 admissions, 62.2 ± 17 days • Severely malnourished: 0.0 admission, 59.8 ± 33 days Number of hospital readmission and LOS did not correlate with clinical assessment of nutrition status **Mortality (n, %)**: n = 12/64 (19) • Well-nourished: 8/47 (17) • Mild-moderately malnourished: 1/13 (8) • Severely malnourished:3/4 (75) Risk of mortality of severely malnourished: • RR: 16 ($p < 0.0001$) comparing to well-nourished and mild-moderately malnourished groups
Marshall et al. 2016 [29]	ICD10AM was completed within median of 2 d after admission. Baseline (n, %): • Well-nourished: 31 (54.4)	12 weeks post rehabilitation discharge: • Discharge location • Rehospitalisation • Rehospitalisation LOS	**Discharge location** (n, %): Home: • Well-nourished: 27 (87.1)

Table 4 (*continued*)

Citation	Baseline outcomes	Timepoint & Outcomes measurement	Post-discharge outcomes
	• Mild PEM: 4 [7] • Moderate PEM: 16 (28.1) • Unspecified severe PEM: 6 (10.5)	• Mortality	• Malnourished: 17 (65.4) ($p = 0.052$) Other locations (RACF, hospital, staying with family/friends): • Well-nourished: 4 (12.9) • Malnourished: 9 (34.6) Admitted to RACF: • Well-nourished: 4 (12.9) • Malnourished: 7 (26.9) **Rehospitalisation Incidence (median and IQR):** • Well-nourished: 2.0 (1.0–2.0) • Malnourished: 1.0 (1.0–2.0) **Rehospitalisation LOS, days (median and IQR):** • Well-nourished: 4.0 (1.0–14.75) • Malnourished: 10.0 (7.0–36.0) ($p = 0.032$) **Mortality (n, %)** • Well-nourished: 0 • Malnourished: 3 (11.5) ($p = 0.052$)
Lambert et al., 2020 [35]	MNA was completed at unknown timepoint of admission. Baseline (n, %): • Well-nourished: 372 (26.1) • At risk of malnutrition: 763 (53) • Malnourished: 294 (20.6)	Immediate post discharge: • Discharge location	**Discharge location:** Admission to higher level of care: • Malnourished OR: 2.9 (95%CI: 1.02–8.3) ($p < 0.05$)
Neumann et al. 2005 [31]	MNA was completed within 4 d of admission. Baseline (n, %): • Well-nourished: 62 (47) • Risk of/malnutrition: 71 (53)	90 d from baseline: • Discharge location • Physical function • Quality of life	**Discharge location:** Admission to higher level of care: • Risk of malnutrition RR: 2.29 (95%CI 1.09–4.80) ($p < 0.05$) **Physical function via Modified Barthel index:** Poorer physical function associated with risk of and malnutrition (mean ± SD) • Well-nourished: 96 ± 7 • Risk/malnutrition: 85 ± 19 ($p = 0.002$) **Quality of life via AQol:** Poorer quality of life associated with malnutrition and at risk of malnutrition (mean ± SD). • Low risk of malnutrition: 12 ± 5 • Risk/malnutrition17 ± 6 ($p = 0.001$)
Sullivan et al. 1991 [46]	SGA was completed within 3 d of admission. SGA results not reported	1 y post discharge: • Mortality	**Mortality:** no association with malnutrition (no data available)
Thomas et al., 2020 [49]	MNA measured at unknown timepoint of admission. Baseline (mean ± SD) • MNA score: 8.7 ± 2.7	Immediate post discharge: • Discharge location	**Discharge location:** MNA score (mean ± SD): • Home: 9.6 ± 2.6 • Institutionalisation: 7.9 ± 2.6 ($p = 0.001$)
Visvanathan et al. 2004 [32]	MNA was completed within 2 d of admission. Baseline (n, %): • Well-nourished:16 (24.6) • At risk of malnutrition: 30 (46.1) • Malnutrition: 19 (29.2)	Immediate post discharge: • Discharge location • Rehospitalisation	**Discharge location:** Admission to higher level of care associated with risk of malnutrition (%) • Well-nourished: 8.1 • Risk of/malnutrition: 17.9 **Hospitalisation:** Admission to acute care facility directly upon rehabilitation discharge (n, %) • Well-nourished: 5 (13.5) • Malnourished: 9 (32.1) **Total poor discharge outcome (Institutionalisation + Hospitalisation) (n, %)** • Well-nourished: 8 (21.6) • Risk of/malnutrition: 14 (50) ($p = 0.017$)

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Table 4 (*continued*)

Citation	Baseline outcomes	Timepoint & Outcomes measurement	Post-discharge outcomes
Sarcopenia			
Landi et al., 2017 [53]	Assessment was completed according to FNIH within 48 h of admission. Baseline (n, %): • Sarcopenic: 43 (33.9) • Non-sarcopenic: 84 [66] Barthel index (mean ± SD) • Sarcopenic: 28.0 ± 14.7 • Non-sarcopenic: 31.3 ± 12.3 (p = 0.28)	3 months post discharge: • Physical function	**Physical function via Barthel index (mean):** • Sarcopenic: 80.5 • Non-sarcopenic: 90.9 (p = 0.02): Sarcopenic patients had increased risk of not achieving a full functional recovery • Adjusted OR: 3.44 (95%CI: 1.08–11.74)
Malafarina et al. 2019 [37]	Assessment was completed according to EWGSOP at unknown point of admission and 48 h before discharge. Baseline (n, %): • Sarcopenic: 58 [31] • Non-sarcopenic: 129 [69] At discharge (n, %): Sarcopenic: 95 (50.8) • Incident sarcopenia: 54 (56.8) • Chronic sarcopenia: 41 (43.2) Non Sarcopenic: 92 (49.2) • Reverted sarcopenia:17 (18.5) • No sarcopenia: 75 (81.5)	7 y post discharge: • Mortality Mean follow up: 3.9 ± 2.1 y	**Mortality (n, %):** 114 (61) deceased (71.9% female; 28.1% male, p = 0.468) • Sarcopenic: 69 (60.5) • Non-sarcopenic: 45 (39.5) (p = 0.001) • Sarcopenia via EWGSOP HR: 1.67 (95%CI 1.11–2.51; p = 0.014) • Hand grip strength HR: 1.76 (95%CI 1.08–2.88; p = 0.024) Deceased patients were older than alive patients, years (mean ± SD): • Deceased: 86 ± 6 • Alive: 83 ± 6.1 (p = 0.0001) Mortality by group: • Chronic sarcopenia HR 1.60 (95%CI:0.93–2.76; p = 0.087) • Incident sarcopenia HR 1.59 (95%CI: 0.97–2.63; p = 0.065) • Reverted sarcopenia group HR 0.98 (95%CI: 0.45–2.21; p = 0.960); not associated to risk of mortality
Matsushita et al. 2019 [42]	Assessment was completed according to EWGSOP within 7 d of admission. Baseline (n, %): • Sarcopenic: 129 (48) • Non-sarcopenic: 138 (52)	Immediate post discharge: • Discharge location	**Discharge location:** Home (n, %): • Sarcopenic: 90 (69.8) • Non-sarcopenic: 128 (92.8) (p = 0.001) Long term care facilities/hospital: • Sarcopenic: 39 (30.2) • Non-sarcopenic: 10 (7.2) (p = 0.001)
Nishioka et al., 2020 [43]	Assessment according to AWGS and calf circumference-based sarcopenia measurement at unknown timepoint of admission Baseline (n, %): AWGS: • Sarcopenic: 225 (69) • Non sarcopenic: 103 (31) Calf circumference-based sarcopenia: • Sarcopenic: 174 (53) • Non sarcopenic: 154 (47)	Immediate post discharge: • Discharge location	**Discharge location:** Home (n, %) based on calf circumference-based sarcopenia Male: • Sarcopenic: 54 (57) • Non-sarcopenic: 90 (89) (p < 0.001) Female • Sarcopenic: 42 (52) • Non-sarcopenic: 45 (85) (p < 0.001)
Sanchez-Rodriguez et al. 2014 [38]	Assessment was completed according to EWGSOP within 3 d of admission. Baseline (n, %): • Sarcopenic: 46 (46.5) • Non-sarcopenic: 53 (53.5) Barthel index (mean ± SD): • Sarcopenic: 24 ± 15.1 • Non-sarcopenic: 28.5 ± 15.2 (p = 0.146)	3 months post discharge: • Physical function • Mortality	**Physical function via Barthel index score (mean ± SD):** • Sarcopenic: 45.5 ± 24.8 • Non-sarcopenic: 61.3 ± 26.6 (p = 0.007) Functional gain in Barthel index score (mean ± SD): • Sarcopenic: 19.9 ± 21.3 • Non-sarcopenic: 32.2 ± 23.9 (p = 0.017) **Mortality (n, %):** • Sarcopenic: 7 (15.2) • Non-sarcopenic: 4 (7.5) (p = 0.196)
Yoshimura et al. 2019 [41]	Assessment was completed according to AWGS within 72 h of admission Baseline (n, %): For participants with stroke (n = 276) • Sarcopenic: 144 (35.8) • Non-sarcopenic: 132 (33.6)	Immediate post discharge: • Discharge location	**Discharge location:** Home (n, %): For participants with stroke (n = 276) • Sarcopenic: 77 (54.2) • Non-sarcopenic: 119 (90.2) (p < 0.001) • OR: 0.201 (95%CI: 0.067–0.597, p < 0.05)

Table 4 (*continued*)

Citation	Baseline outcomes	Timepoint & Outcomes measurement	Post-discharge outcomes
	For participants with musculoskeletal disease (n = 382): • Sarcopenic: 180 (44.8) • Non-sarcopenic: 202 (51.4) For participants with hospital associated deconditioning (n = 137) • Sarcopenic: 78 (19.4) • Non-sarcopenic: 59 (15) Total: • Sarcopenic: 402 (50.6) • Non-sarcopenic: 393 (49.4)		For participants with musculoskeletal disease (n = 382) • Sarcopenic: 102 (56.7) • Non-sarcopenic: 189 (93.6) (p < 0.001) • OR: 0.242 (95%CI: 0.076–0.772, p < 0.05) For participants with hospital-associated deconditioning (n = 137) • Sarcopenic: 35 (45.5) • Non-sarcopenic: 52 (89.7) (p < 0.001) • OR: 0.121 (95%CI: 0.110–0.347, p < 0.05)
Yoshimura et al., 2020 [44]	Assessment according to AWGS within 72 h of admission Baseline (n, %): Sarcopenia (height -adjusted ASM) • Sarcopenic: 451 (49.2) • Non-sarcopenic: 466 (50.8) Sarcopenia (BMI-adjusted ASM) • Sarcopenic: 481 (52.5) • Non-sarcopenic: 436 (47.5)	Immediate post discharge: • Discharge location	**Discharge location:** Home (OR: 95%CI): Sarcopenia (height-adjusted ASM) • Female: 0.261 (95%CI: 0.024–0.561, p < 0.001) • Male: 0.425 (95%CI: 0.160–0.925, p = 0.045) Sarcopenia (BMI-adjusted ASM) • Female: 0.196 (95%CI: 0.091–0.424, p < 0.001) • Male: 0.712 (95%CI: 0.221–1.121, p = 0.163)
Frailty			
Aida et al., 2020 [45]	Japanese version of Cardiovascular Healthy Study Criteria simplified frailty scale was completed at unknown timepoint of cardiac rehabilitation. Baseline (n, %): • Robust: 101 (11.3) • Pre-frail: 407 (45.5) • Frail: 387 (43.2)	Up to 463 d post discharge: • Rehospitalisation • Mortality Median follow-up: 289 (range 128–463) d	**Rehospitalisation and mortality (HR; 95%CI):** • Pre-frail: 2.19 (1.00–4.79, p = 0.049) • Frail: 3.27 (1.49–7.21, p = 0.003) Based on number of components of frailty: • 1: 1.52 (0.64–3.58, p = 0.332) • 2: 2.88 (1.29–6.45, p = 0.01) • 3: 3.07 (1.37–6.90, p = 0.007) • 4: 3.80 (1.67–8.67, p = 0.002) • 5: 3.94 (1.40–9.94, p = 0.008)
Arjunan et al. 2019 [33]	Derived Frailty index was completed at an unknown timepoint of admission. Baseline (mean ± SD): • Frailty index: 0.42 ± 0.13	Immediate post discharge: • Discharge location	**Discharge location (n, %):** Discharge to higher care • 109 (42%) • Frailty index (mean ± SD): 0.44 ± 0.11 • Frailty index odd ratios: 1.38 (95%CI: 1.11–1.70) Frailty index at 0.4 cut point was specific in predicting poor discharge outcome (inpatient mortality and higher-level care)
Fompeyrine et al., 2020 [48]	Fried frailty phenotype was completed within 1 week upon admission. Baseline (n, %): • Robust: 6 (4.3) • Pre-frail: 52 (37.1) • Frail: 76 (54.3)	3 months and 12 months post discharge: • Mortality	**Mortality (n, %):** 3 months • Robust: 0 (0) • Pre-frail: 2 (3.8) • Frail: 9 (11.8) (p = 0.20) 12 months • Robust: 0 (0) • Pre-frail: 6 (11.5) • Frail: 24 (31.6) (p = 0.01) Fried frailty phenotype odd ratios: 4.19 (95%CI: 1.53–11.47, p = 0.0096) Each point increment of frailty score at post-acute care admission was associated with a decreasing one-year survival (p = 0.014)
Haley et al., 2013 [34]	Frailty measured by Edmonton Frail Scale within 1 week of admission. Baseline (mean ± SD): • Edmonton Frail Scale score: 8.65 ± 2.12	Immediate post discharge: • Discharge location	**Discharge location (n, %):** Residential care: 47 (54.7) • Mean EFS score: 8.31 ± 2.25 Community: 28 (37.3) • Mean EFS score: 8.95 ± 1.99 No significant difference between EFS score based on discharge location (t = −1.32, p = 0.19) Frailty did not significantly increase risk of discharge to residential care

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Table 4 (*continued*)

Citation	Baseline outcomes	Timepoint & Outcomes measurement	Post-discharge outcomes
Kerminen et al., 2020 [50]	Derived Frailty index from interRAI-PAC was completed at unknown point of admission. Baseline (mean ± SD): • Frailty index: 0.34 ± 0.15	Immediate post discharge: • Discharge location	**Discharge location:** Emergency department admission: OR: 1.24 (95%CI: 1.11–1.37) per 0.1 increment in Frailty index
Kerminen et al., 2021 [51]	Derived Frailty index from interRAI-PAC was completed at unknown point of admission. Baseline (n, %): • Robust (<0.2): 362 (31) • Pre-frail (0.2–0.4): 571 (48.9) • Frail (>0.4): 234 (20.1)	90 d post discharge: • Rehospitalisation	**Rehospitalisation (n, %):** • Robust: 84 (23.2) • Pre-frail: 175 (30.6) • Frail: 85 (36.3) Rehospitalisation OR: • Pre-frail: 1.46 (95%CI: 1.08–1.98) • Frail: 1.89 (95%CI: 1.32–2.71)
Low et al., 2021 [36]	Clinical Frailty Scale was completed at unknown timepoint upon admission. Baseline (n, %): • Robust (1-3): 196 (23.2) • Vulnerable (4): 55 (6.5) • Mildly frail (5): 282 (33.1) • Moderately frail (6): 158 (18.7) • Severe frail (7): 153 (18.1)	Immediate post discharge: • Discharge location	**Discharge location:** Returned to community dwelling (OR): • Vulnerable (4): 0.2 (95%CI: 0.1–0.7, $p = 0.01$) • Mildly frail (5): 0.1 (95%CI: 0.06–.0.4, $p < 0.001$) • Moderately frail (6): 0.2 (95%CI: 0.1–0.7, $p = 0.009$) • Severe frail (7): 0.2 (95%CI: 0.05–0.7, $p = 0.01$)
Madruga-Flores et al., 2021 [40]	Clinical Frailty Scale was completed at unknown timepoint upon admission Baseline (%): • Robust (1-3): 25.5 • Vulnerable (4): 13.5 • Mild-moderate frail (5,6): 32 • Severe frail (7): 8	Immediate post discharge: • Discharge location	**Discharge location:** Rate of discharge to previous address prior to admission: OR: 0.65 (95%CI: 0.44–0.96)
Schuijt et al., 2021 [47]	Frailty index was calculated upon admission of emergency department prior to post-acute care admission Baseline (Median, IQR): • Skilled nursing facility: 0.36 (0.25–0.47) • Inpatient rehabilitation facility: 0.28 (0.21–0.38)	90 d post discharge: • Discharge location • Rehospitalisation • Mortality	**Discharge location:** Discharge destination based on frailty index (median, IQR): • Home: 0.26 (0.19–0.37) • Home with services: 0.31 (0.22–0.41) • Skilled nursing facility: 0.38 (0.29–0.42) • Hospital readmission: 0.49 (0.28–0.59) ($p < 0.001$) Rate of discharge to skilled nursing facility: OR: 1.440 (95%CI: 1.185–1.751, $p < 0.001$) per 0.1 point increment Rate of home discharge: OR: 0.741 (95%CI: 0.581–0.946, $p = 0.016$) per 0.1 point increment **Rehospitalisation:** OR: 1.338 (95%CI: 0.992–1.805, $p = 0.056$) per 0.1-point increment **Mortality:** OR: 1.69 (95%CI: 1.263–2.263, $p < 0.001$) per 0.1-point increment
Singh et al., 2012 [54]	Derived Frailty index was completed at an unknown timepoint of admission. Baseline (mean ± SD): • Frailty index: 0.34 ± 0.09	1 y post completion of recruitment: • At discharge poor outcomes: new care home placement or inpatient mortality • Mortality	**Discharge outcomes (mean ± SD):** Discharge to original residence with 28 days: • Frailty index score: 0.29 ± 0.09 Discharge to original residence, but more than 28 days of LOS: • Frailty index score: 0.37 ± 0.07 Inpatient mortality or new care home placement: • Frailty index score: 0.40 ± 0.73 Frailty index was strongly associated with worsening patient outcomes ($p < 0.001$) 78% participants were discharged to their own home **Mortality** HR: 1.63 (95%CI: 1.29–2.06, $p < 0.001$) per unit increase in Frailty index
Thomas et al., 2020 [49]	Fried frailty phenotype at unknown timepoint of admission. Baseline (n, %):	Immediate post discharge: • Discharge location	**Discharge location:** Home (n,%)

Table 4 (*continued*)

Citation	Baseline outcomes	Timepoint & Outcomes measurement	Post-discharge outcomes
	• Robust: 27 (19.3) • Pre-frail: 31 (22.1) • Frail: 77 (55)		• Frail: 31 (43.1) • Non-frail: 38 (52.8) Institutionalisation (n, %) • Frail: 46 (67.6) • Non-frail: 20 (29.5) (p = 0.003) Rate of institutionalisation: Frail at admission • OR: 2.97 (95%CI: 1.04–9.42, p = 0.04) Frail at discharge • OR: 3.99 (95%CI: 1.55–10.29, p = 0.004)

Abbreviations: Aqol, Assessment of Quality of Life Instrument; CI, confidence interval; d, days; EWGSOP, The European Working Group on Sarcopenia in Older People; FNIH, Foundation for National Institutes of Health Sarcopenia Project; h, hours; HR, hazard ratio; ICD10AM, International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification; IQR, interquartile range; LOS, length of stay; MNA, Mini Nutritional Assessment; OR, odd ratio; PEM, protein energy malnutrition; RACF, residential age facility; RR, relative risk; SD, standard deviation; SGA, Subject Global Assessment; y, years.

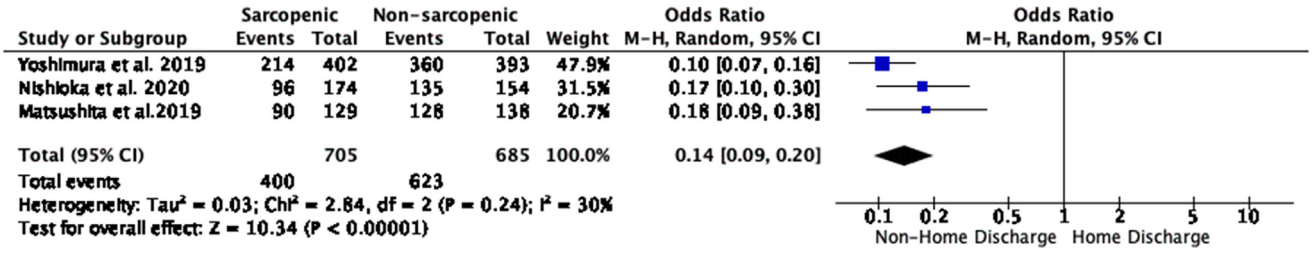

Fig. 3. Odds ratio of home discharge for sarcopenic older adults after inpatient post-acute care.

interventions to improve the long-term intake of protein and energy are effective for PEM [73], the essentiality of this intervention component is less well understood in sarcopenia and frailty [74,75]. Further research is required to determine not only the diagnostic and prognostic overlap between PEM, sarcopenia, and frailty, but also the optimal interventions for these conditions and whether there is overlap in interventions for these conditions.

4.1. Limitations

This review found no original study that repeated any diagnostic assessments for wasting syndromes post-rehabilitation, thereby limiting the interpretation of findings. Understanding of post-discharge consequences of the wasting syndromes was also limited by no studies measuring other outcomes of interest including falls, pressure ulcers, or cognitive function. All but one study measured only a single wasting condition [49], thereby limiting understanding of the diagnostic and prognostic overlap of these conditions.

It was not possible to perform meta-analyses on multiple post-discharge outcomes due to clinical heterogeneity within the included studies, where studies differed in terms of length of follow-up, outcomes of interest and statistical risk analysis methodology. The majority of the included studies did not specify the type of care or intervention provided during rehabilitation admission. As the exposure to interventions was unknown for most studies, this could have led to a bias in determining the impact of wasting conditions on clinical outcomes. Confidence in the body of evidence using GRADE was downgraded due to the observational nature of all included studies. However, as prospective cohort studies are the highest level of evidence for prognostic research questions [76], the GRADE assessments may be underestimating confidence.

4.2. Implications for future practice and research

Although there is insufficient evidence to provide recommendations on clinical assessment and interventional priorities for these wasting conditions, this review has identified a research gap in terms of the assessment and follow-up of wasting conditions. Observational and differential diagnostic research are needed to investigate these geriatric wasting conditions to develop effective screening tools to screen for all three geriatric conditions. This is required to inform evidence-based clinical prioritisation and optimisation of multidisciplinary models of care to improve the trajectory of these geriatric conditions during rehabilitation and post-discharge. It is important for rehabilitation clinicians to assess for and be aware of these wasting conditions, in order to optimise the intervention and treatment that patients receive, to improve the trajectory of these conditions both during rehabilitation admission and post-discharge.

Future research should aim to assess all wasting conditions according to validated tools or guidelines (e.g. SGA/GLIM for PEM; EWGSOP for sarcopenia; Edmonton Frail Scale for frailty) and should aim to also assess a diverse array of clinically-relevant post-discharge outcomes.

5. Conclusions

PEM, sarcopenia, and frailty were found to be associated with higher rates of post-discharge mortality, health service use, and discharge to higher level of care. PEM and sarcopenia were associated with physical dysfunction; sarcopenia and frailty were associated with lower rate of discharge home or returning to previous address. PEM was further associated with worse quality of life.

This review revealed the lack of research investigating post-rehabilitation consequences of multiple wasting conditions among older adults. Therefore, further observational, diagnostic, and interventional research is required to clarify the consequences of multiple wasting conditions to inform optimal interventions and models of care for patients.

Statement of authorship

Hei Chun Nicholas Chan: Formal analysis, Investigation, Data Curation, Writing - Original Draft Xinzhu Fei: Validation, Investigation, Writing - Review & Editing Eden Leung: Validation, Investigation, Writing - Review & Editing Keanne Langston: Conceptualisation, Validation, Investigation, Writing - Review & Editing Skye Marshall: Conceptualisation, Validation, Writing - Review & Editing Barbara S van der Meij: Supervision, Validation, Writing - Review & Editing.

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Declaration of competing interest

The authors have no conflicts of interests to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2023.01.023.

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