REVIEW

# Nutrition interventions implemented in hospital to lower risk of sarcopenia in older adults: A systematic review of randomised controlled trials

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## Abstract

**Aim:** There is no standardised interventional approach to preventing or treating sarcopenia in older adults in hospital. The aim of this review was to systematically identify and synthesise the effects of nutritional interventions on markers of sarcopenia in hospitalised patients aged 65 years and older.

**Methods:** Four databases were searched using terms for intervention, population and setting. Eligibility screening of title and abstract and then full-text papers was competed in duplicate, independently. The final included papers were assessed for quality, and outcome data extracted independently and in duplicate. Outcome data were synthesised by meta-analysis, where possible, or narratively.

**Results:** Seven hundred and thirty-two articles were screened for eligibility yielding six studies for inclusion. All studies provided oral nutritional support that aimed to increase protein intake ranging from an additional 10 to 40 g/d, each with a unique formulation of amino acids and/or micronutrients; three studies combined nutritional intervention with an enhanced physical activity program. Five studies measured hand grip strength, the mean difference was 1.97 kg (95% CI 0.55-3.39, $P = .006$) greater in the intervention group (n = 166) compared with control group (n = 165). Assessment of muscle mass and activities of daily living were heterogeneous and the changes inconsistent between studies.

**Conclusions:** Few studies inform nutritional management of inpatients with sarcopenia or at risk of sarcopenia. High quality, large intervention trials are

needed urgently to identify the optimal nutrition and physical activity intervention combinations to manage sarcopenia in older hospitalised adults. These studies need to include outcome measures of physical function and muscle quality.

**KEYWORDS**

exercise, geriatric, inpatients, intervention, nutritional supplement, rehabilitation, sarcopenia

# 1 | INTRODUCTION

Sarcopenia is the loss of skeletal muscle mass and strength usually associated with the ageing process.[1] It contributes to functional decline, loss of independence, decreased quality of life and can lead to other chronic health conditions. Commencing as early as the fourth decade of life, sarcopenia can contribute to the loss of 1% to 2% of skeletal muscle mass per year from 50 years of age. In adults aged between 60 and 70 years, the prevalence of sarcopenia is 5% to 13%,[2] with prevalence increasing with age to 11% to 50% in adults 80 years and over.[3] A recent population analysis of 1500 older Portuguese community dwelling adults ($\geq$65 years) identified sarcopenia prevalence of 4.4%.[4] Predictors of sarcopenia were identified as age >75 years and undernutrition or risk of undernutrition. Conversely, there was an inverse association with male gender, being overweight or obese and consuming moderate amounts of alcohol.[4] Higher prevalence rates have been noted for hospitalised patients and those living in aged care facilities.[5,6]

Across a range of international expert working groups, no international consensus definition for sarcopenia has emerged, making it difficult to compare interventions and outcomes of studies exploring sarcopenic populations.[7-9] Experts in Australia have adopted the original definition of the European Working Group on Sarcopenia in Older People.[10] Limited economic analyses have been conducted, however the estimated total direct healthcare cost attributable to hospitalisation of adults with sarcopenia in the United States was US$40.4 billion (from NHANES data 2004) with an average per person cost of US$204 for younger adults and US$375 for older adults.[11,12] The recent inclusion of sarcopenia into the International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, will likely raise the focus of sarcopenia, in its prevention, diagnosis and treatment.[13]

Causal mechanisms of sarcopenia are likely multifactorial. The unintentional weight loss, malnutrition and sarcopenia that develops in older adults may be attributable to poor nutritional intake and decreased exercise.[14-16] Decreases in anabolic hormones, increased inflammation, loss of neuromuscular function and changes in muscle protein balance are other likely contributors.[17,18] The Australia and New Zealand Society for Sarcopenia and Frailty Research recommend that sarcopenia diagnosis is made through the assessment of muscle mass (eg, through dual energy X-ray absorptiometry [DXA] or bioelectrical impedance analysis [BIA]), muscle strength (eg, hand grip dynamometry or chair stand tests) and physical performance tests (eg, gait tests).[10]

Interventions seeking to reduce sarcopenia prevalence have adopted nutritional and exercise approaches including the use of nutritional supplementation in non-hospitalised adults and resistance-based training.[19,20] As stimulators of muscle protein synthesis, these interventions provide a practical approach to maintaining, or increasing, muscle mass and functionality.[21] Protein quality, through the provision of the high biologically available proteins whey and casein, may also stimulate muscle protein synthesis.[22]

With the size of the ageing population growing rapidly, a better understanding of effective preventative strategies for sarcopenia in adults is required.[4] Focusing intervention strategies on preventing the progression of this condition could lower associated costs and the burden on the healthcare system.[6] Gaps exist in the evidence for specific exercise programs, with a wide practice variation in clinical settings reported.[1] A previous systematic review of 17 studies conducted in non-hospital settings found that oral nutrition supplementation can improve muscle mass and strength.[19] Moreover, the positive effects of nutritional supplementation increase when combined with physical activity.[19] Although some large-scale trials are presently underway that consider exercise and nutritional interventions for people with, or at risk of sarcopenia, there is still uncertainty regarding effective interventions to prevent or treat sarcopenia in hospital-based settings.[22,23] It is necessary to assess the effectiveness of nutritional interventions on older adult inpatients because they are at higher risk of inadequate nutritional intake, sarcopenia and functional decline as a result of their acute condition and hospitalisation.[19] This review aims to systematically identify and synthesise the effects of nutritional interventions on markers of sarcopenia in hospitalised patients aged 65 years and older.

# 2 | METHODS

The protocol for this review was defined a priori in August 2018, preceding the commencement of database searching and screening of eligible studies. The PRISMA guidelines for the reporting of systematic reviews was followed.[24] This review protocol was not registered with PROSPERO.

## 2.1 | Eligibility criteria

The research question was developed using the Participant, Intervention, Comparator, Outcomes, Study design (PICOS) format.[25] Original research that reported on adults over the age of 65 years who were hospitalised or in a rehabilitation setting at the commencement of the intervention were eligible. Eligible studies were controlled intervention trials that included a nutritional intervention aimed at improving strength or functional recovery to prevent or slow the progression of sarcopenia. Eligible nutritional interventions were interventions that aimed to provide additional macro- or micronutrient intake above the usual ward diet, for example, additional food items/snacks, fortification of food, oral nutritional support (ONS) products and amino acid supplementation. To be included in the results synthesis, studies needed to report on at least one of the following: a functional outcome (hand grip strength, gait speed); or measurement of lean muscle mass (muscle mass, calf circumference, arm circumference); activities of daily living were extracted as a secondary outcome from studies meeting all other inclusion criteria. Interventions commencing in residential aged care facilities, community dwelling individuals, or animal studies were ineligible. Studies reported in languages other than English were excluded.

## 2.2 | Search strategy

Four electronic databases were searched to identify relevant publications: Ovid MEDLINE, EMBASE, CINAHL and Allied and Complementary Medicine (AMED). A copy of the full search strategy used for Ovid MEDLINE is included as Figure S1. This strategy was replicated across all databases. Searches were undertaken from database inception to 29 August 2018. Reference lists of included studies and/or relevant reviews were hand searched to identify additional studies for inclusion.

## 2.3 | Study selection

Studies were imported into *Endnote* version x8 (Clarivate, Philadelphia, Pennsylvania) where duplicate publications were removed. The remaining studies were transferred into Covidence (Melbourne, Australia) where they were screened for eligibility based on the inclusion criteria. Two authors independently screened titles and abstracts, then full text papers, to exclude papers that did not meet inclusion criteria. Any conflicts were resolved by a third author.

## 2.4 | Data collection and quality assessment

A data extraction template was developed and piloted prior to extracting relevant study information. Details extracted include; study design, study location/setting, sample size and details on participant withdrawal, population characteristics (specified inclusion and exclusion criteria), primary and secondary outcomes, intervention and comparator procedures. The quality of each study was assessed using the Academy of Nutrition & Dietetics' Quality Criteria Checklist for Primary Research, specific for studies in nutrition and dietetics.[26] Studies were independently assessed by two authors, with a rating of negative (weak quality, generalisability, data collection and analysis, likely bias), neutral (neither exceptionally strong nor exceptionally weak quality) or positive (strong quality, generalisability, data collection and analysis, limited bias) assigned to each study.

## 2.5 | Results synthesis

The principal summary measures of interest were between group differences at the end of active intervention for outcomes of hand grip strength, gait speed, muscle mass, calf circumference and arm circumference. Where more than three studies reported on the same outcome (mean and SD) data were synthesised quantitatively by random effects meta-analysis (RevMan V5.3).[27] Authors were contacted to provide additional data to maximise the number of studies that could be included in the meta-analysis. For clarity in the meta-analysis, studies are presented as subgroups based on data presentation as either within group mean difference or end of intervention mean. Conclusions are based on the total mean difference. If outcome measures at the end of the active intervention were not reported then follow up data that was closest to the end of active intervention were used for the results synthesis.

In cases where there were insufficient data for meta-analysis, a narrative synthesis approach was taken and the reported *P*-values used to assess the effectiveness of the intervention. If a statistical comparison between intervention and control group was not reported (ie, only within group differences reported), it was determined that conclusions on intervention effect could not be drawn.

## 3 | RESULTS

A total of 927 articles were retrieved from the database searches. After duplicates were removed, 732 studies were screened for eligibility and of these 45 full text articles were screened. Of these studies, six met the final inclusion criteria (Figure 1).[28-33] Five studies received a positive quality rating and one study[33] was rated as neutral quality as study groups were not equivalent at baseline and the final conclusions discussed cost savings yet this was not a measured outcome in the study. One study was marked as unclear against the statistical approach item as between group tests were not reported.[33] Blinding was difficult in the hospital setting however several studies ensured the outcome assessor was blinded.[29,31-33] Other limitations observed across the included studies were that only one study reported an intention to treat analysis[28] and only one study reported the nutritional composition of the ward diet (control diet).[30]

All studies used an ONS product to implement an enhanced nutritional intervention in addition to usual ward diet. The composition of the oral nutrition support
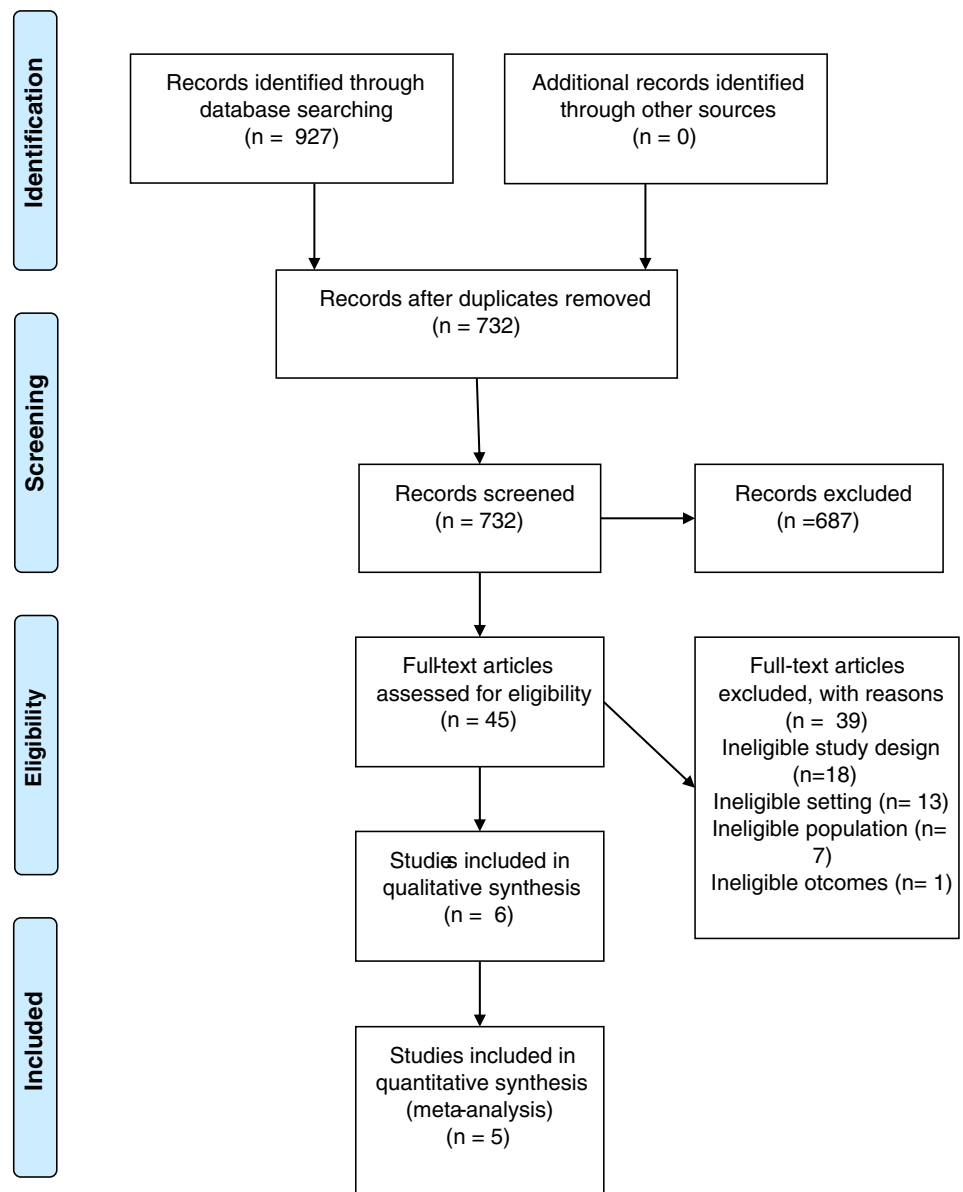


**FIGURE 1** Flow diagram of study selection process following database search for the systematic review of the literature to identify and synthesise the effects of nutritional interventions on markers of sarcopenia in hospitalised patients aged 65 years and older

**TABLE 1** Characteristics of included studies

| Study | Country of origin | Participants, age, mean (SD) | Sample size | Intervention duration mean (SD) | Nutritional composition of ward diet | Intervention | Comparator | Compliance with nutrition intervention |
|---|---|---|---|---|---|---|---|---|
| Flodin et al (2015)[28] | Sweden | Hip fracture patients; 79 (9) years | Baseline: n = 79; 71% female; follow up: n = 67 | 12 months | Not reported | Nutrition: Calcium (1 g) and vitamin D (800 IE) daily for 12 months, plus, oral nutrition support product twice daily (40 g/d protein, 600 kcal/d), for 6 months and risedronate (bisphosphonates) once weekly for 12 months Rehabilitation: Usual care rehabilitation program | Nutrition: Group 1: calcium (1 g) and vitamin D (800 IE) daily for 12 months Group 2: calcium (1 g) and vitamin D (800 IE) daily for 12 months, plus risedronate once weekly for 12 months Rehabilitation: usual care rehabilitation program | 61% consumed only half the prescribed daily dose |
| Niccoli et al (2017)[29] | Canada | Frail geriatric patients; 81.3 (1.0) years | Baseline: n = 53; 68% female; follow up: n = 47 | Length of stay: Intervention: 26.51 (3.65) days; Control: 20.93 (3.02) days | Not reported | Nutrition: Oral supplement of whey protein (24 g/d) added daily to cereal and milk Rehabilitation: Usual care rehabilitation program | Nutrition: Cereal and milk without supplement Rehabilitation: Usual care rehabilitation program | Average intake of supplement was 78% of daily dose |
| Malafarina et al (2017)[30] | Spain | Hip fracture patients; 85.4 (6.3) years | Baseline: n = 107; 74% female; follow up: n = 74 | Length of stay: 42.3 (20.9) days | 1500 kcal/d, 23.3% energy from protein (87.4 g/d), 35.5% fat (59.3 g/d); 41.2% carbohydrate (154.8 g/d) | Nutrition: Oral nutrition support product twice daily (ensure plus 600 kcal/d providing 40 g/d of protein) enriched with calcium β-hydroxy-β-methylbutyrate 0.7 g/100 mL, vitamin D; | Nutrition: Standard diet (1500 kcal/d, protein 87.4 g/d) Rehabilitation: Usual care rehabilitation program | All participants consumed >80% prescribed daily dose |

(Continues)

**TABLE 1** (Continued)

| Study | Country of origin | Participants, age, mean (SD) | Sample size | Intervention duration mean (SD) | Nutritional composition of ward diet | Intervention | Comparator | Compliance with nutrition intervention |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 227 IU/100 mL calcium; 227 mg/100 mL plus standard diet (1500 kcal/d, protein 87.4 g/d) Rehabilitation: Usual care rehabilitation program | | |
| Rondanelli et al (2016)[31] | Italy | Hospitalised rehabilitation patients with sarcopenia Intervention: 80.8 (6.3) years; Control: 80.2 (8.5) years | Baseline: n = 130; 59% female; follow up: n = 130 | 12 weeks | Not reported | Nutrition: Oral supplement once daily (32 g/d) with whey protein 22 g/d + essential amino acids 10.9 g/d (including 4 g/d leucine, and vitamin D 2.5 μg/d) Rehabilitation: Controlled physical activity, age appropriate adapted resistance training 20 min × 5 d/wk | Nutrition: Placebo once daily Rehabilitation: Controlled physical activity, age appropriate adapted resistance training 20 min × 5 d/wk | 100% compliance |
| Yoshimura et al (2016)[32] | Japan | Cerebrovascular, musculoskeletal disorders or disuse syndrome; 79.9 (7.7) years | Baseline: n = 39; 72% female; follow up: n = 36 | Length of stay: mean (SD); 68 ± (22.8) days | Not reported | Nutrition: Oral nutrition support product (Resource PemPal Active) provided 30 min post-resistance exercise once daily containing 200 kcal/d, 10 g/d protein including | Nutrition: Standard diet Rehabilitation: Resistance training specialised for rehabilitation: machine-based exercise 3 d/wk | Not reported |

(Continues)

**TABLE 1** (Continued)

| Study | Country of origin | Participants, age, mean (SD) | Sample size | Intervention duration mean (SD) | Nutritional composition of ward diet | Intervention | Comparator | Compliance with nutrition intervention |
|---|---|---|---|---|---|---|---|---|
| | | | | | | eight branched-chain amino acids (2.5 g/d) and vitamin D (12.5 μg/d) Rehabilitation: Resistance training specialised for rehabilitation: machine-based exercise 3 d/wk plus manual exercises daily | plus manual exercises daily | |
| Hegerova et al (2015)[33] | Czech Republic | Acutely ill patients Intervention: 83.2 (3.8) years Control: 83.6 (3.8) years | Baseline: n = 200% female not reported; follow up n = 200 | Length of stay: 11 ± 7 days with 12-month follow up | Not reported | Nutrition: Oral nutrition support product twice daily (600 kcal/d, 20 g/d protein) Rehabilitation: Intervention-guided by physiotherapist commenced on day 2 of hospitalisation four times a day (2 × 5 min lower leg training; 2 × 15 min therapeutic physical training) for 6 d/wk | Nutrition: Standard diet only. Nutritional support was indicated when patients were unable to eat an adequate diet for >3 days Rehabilitation: Usual care initiated after improvement of the underlying disease 10–15 min for 5 d/wk | Not reported |

**TABLE 2**　Assessment of change in markers of sarcopenia between intervention and control groups

| Study | Outcome (tool) | Intervention | | | Control | | | P-value (between groups) |
|---|---|---|---|---|---|---|---|---|
| | | Baseline | Follow Up | Within group difference | Baseline | Follow up | Within group difference | |
| Flodin et al (2015)[28] | Fat free mass, kg (DXA) | — | — | n = 18, −2.4 (2.5) | — | — | n = 24, −1.3 (3.2) | P = .09 |
| | Appendicular lean mass, kg/m² (DXA) | — | — | −0.2 (0.5) | — | — | 0.0 (0.6) | P = .03; favours control |
| Niccoli et al (2017)[29] | Knee extensor force (peak force lbs) | n = 22, 27.26 (16.6) | n = 22, 33.15 (13.6) | 5.89 (18.8) | n = 25, 34.77 (10.9) | n = 25, 38.18 (11.5) | 3.42 (3.9) | P > .05 |
| | Gait speed (m/s) | 0.52 (0.1) | 0.68 (0.2) | 0.18 (1) | 0.56 (0.3) | 0.74 (0.3) | 0.16 (0.2) | P > .05 |
| | Timed up-and-go (s) | 27.63 (14.8) | 20.75 (9.1) | −6.88 (9.9) | 28.23 (14.1) | 21.83 (10.7) | −6.4 (9.5) | P > .05 |
| Malafarina et al (2017)[30] | Skeletal muscle mass, kg (BIA) | n = 49, 25.5 (9.9) | n = 36, 24.3 (8.6) | — | n = 45, 23.6 (10.0) | n = 38, 22.7 (7.9) | — | P = .368 |
| | Muscle mass, kg (BIA) | 26.3 (7.3) | 26.2 (6.4) | — | 26.4 (7.0) | 25.2 (5.3) | — | P = .031; favours intervention |
| | Appendicular lean mass, kg/m² (BIA) | 5.4 (1.1) | 5.5 (1.2) | — | 5.4 (1.4) | 5.1 (1.4) | — | P = .020; favours intervention |
| | Gait speed | — | 0.4 (0.3) | — | — | 0.4 (0.3) | — | P > .05 |
| | Activities of daily living (Barthel Index) | — | 65 (30-90)[b] | — | — | 65 (40-82.5)[b] | — | P > .05 |
| Rondanelli et al (2016)[31] | Appendicular lean mass, kg/m² (DXA) | — | — | n = 61, 0.21 (0.59) | — | — | n = 69; 0.06 (2.21) | P = .009; favours intervention |
| | Fat free mass, kg (DXA) | — | — | 1.4 (2.3) | — | — | −0.31 (2.5) | P < .001; favours intervention |
| | Activities of daily living (Katz Index) | — | — | 0.54 (59) | — | — | −0.61 (0.76) | P < .001; favours intervention |
| Yoshimura et al (2016)[32] | Activities of daily living (Barthel Index) | n=19 46.1 (23.4) | 71.6 (24.9) | — | n=1740 (14.6) | 61.2 (17.2) | — | P = .041; favours intervention |
| Hegerova et al (2015)[33a] | Lean body mass, kg (BIA) | n = 100, 30.6 (9.1) | 31.9 (8.5)[a] | — | n = 100, 30.9 (10.9) | 27 (6.4)[a] | — | P > .05 |
| | Activities of daily living (Barthel Index) | 93.2 (7.7) | 88.1 (20.3)[a] | — | 91.3 (10) | 83.2 (20)[a] | — | P > .05 |

*Note*: Data are reported as mean (SD), — indicates data are not reported. Sample size, denoted by *n* is provided once per study and applies to all rows of data for each study.

Abbreviations: BIA, bioelectrical impedance analysis; DXA, dual energy X-ray absorptiometry.

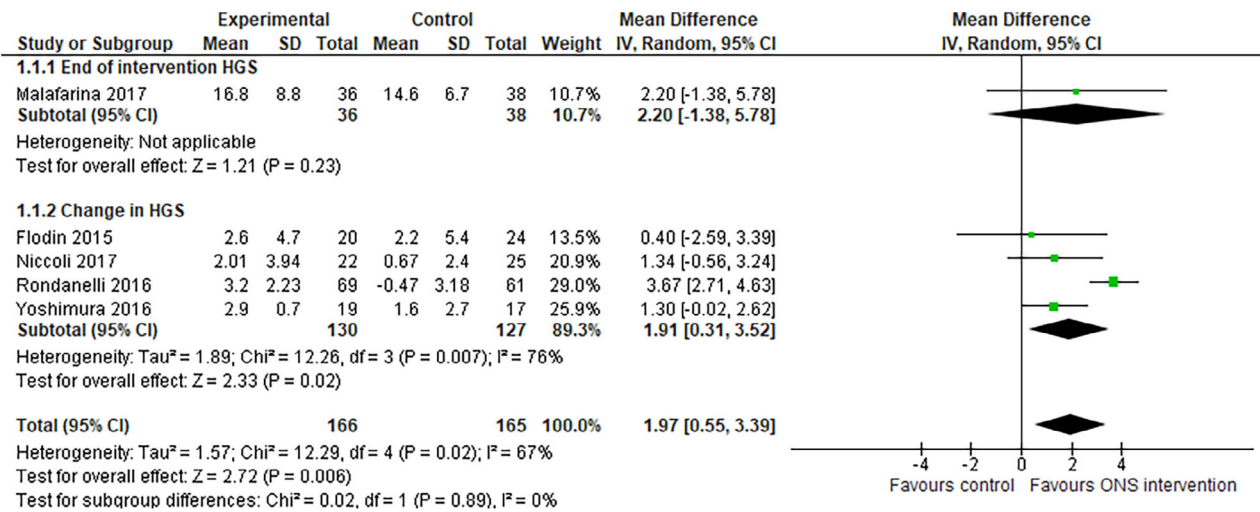[a]Data at 3 months follow up.

[b]Data are median (IQR).

**FIGURE 2** Forrest plot representing the mean difference in hand grip strength between intervention and control conditions (n = 5 studies). Studies are separated into sub-groups based on whether final scores were reported (sub-group 1.1.1, n = 1 study) or if within group change scores were reported (sub-group 1.1.2, n = 4 studies); HGS, hand grip strength; ONS, oral nutrition support products

products used varied across studies, but all contributed protein (ranging from 10 to 40 g/d), energy and other macro- and micro-nutrients (Table 1). The interventions studied were either ONS plus usual rehabilitation programs,[28-30] ONS combined with an enhanced physical activity program compared to the enhanced physical activity alone,[31,32] or ONS combined with enhanced physical activity compared to usual rehabilitation program.[33] The study characteristics are reported in Table 1. Sample size varied across the six studies, ranging from 36 to 200. Four studies intervened for the duration of hospital stay.[29,30,32,33] One study commenced intervention during hospitalisation and continued to provide protein supplements for 6 months and micronutrient supplements for 12 months after discharge.[28] Rondanelli et al[31] examined outcomes after 12 weeks of admission. One study implemented the intervention during the hospitalisation but did not measure outcomes at discharge.[33]

One study described their participants as having sarcopenia at baseline.[31] The intervention periods across studies ranged from 2 weeks to 12 months (Table 1).[28,33] Two studies[28,30] reported on sarcopenia post-intervention as defined by the European Working Group on Sarcopenia in Older People. Malafarina et al[30] found that the nutritional intervention prevented onset of sarcopenia through preservation of lean muscle mass (mean [SD] 5.1 kg/m$^2$ [1.4 vs 5.5 [1.2] kg/m$^2$; $P$ = .02]). Conversely, Flodin et al[28] found that the proportion of people with sarcopenia was not different at any of the follow up time points (21% at baseline, 24.5% at 6 months and 29% at 12 months).

Three studies reported significant improvements on markers of sarcopenia compared with controlled conditions,[30-32] two studies[28,29] found no significant effect of their intervention compared with control groups and one failed to report between group differences[33] (Table 2). The inconsistency of markers measured across studies prevented meta-analysis, with the exception of hand grip strength. The mean difference (n = 5 studies) between intervention (n = 166 participants) and control (n = 165) groups found a small but significantly greater grip strength in participants receiving nutritional intervention (1.97 kg [95% CI 0.55-3.39], $P$ = .006, n = 5 studies, Figure 2). Niccoli et al[29] also measured strength via knee extensor which showed significant improvement within the intervention group , however significant differences were not found between groups (Table 2).

Other markers of sarcopenia risk were not measured consistently across the six studies and assessment tools also varied. Muscle mass was measured in four studies (Table 2), but the method used to determine muscle mass, and the muscle area assessed was inconsistent across the studies precluding synthesis with meta-analysis. Two studies found greater improvement in muscle mass in the intervention compared with control group[30,31] whereas one study[28] found little change in muscle mass in both groups with a small decrease in the intervention group compared with the control (Table 2). Gait speed was reported at discharge in two studies[29,30] and no significant difference between intervention and control groups was found (Table 2). Four studies assessed activities of daily living, with two studies reporting significant improvement[31,32] whereas two

other studies found no significant difference between groups[30,33] (Table 2).

## 3.1 | Compliance and adverse effects

Malafarina et al[30] reported that all of the participants consumed greater than 80% of the prescribed oral nutritional supplement. Flodin et al[28] reported that 61% of participants consumed only half the prescribed intake of protein and energy drink; and similarly Niccoli et al[29] reported the average intake of the whey protein supplement to be only 78%. Rondanelli et al[31] reported that compliance was 100% but did not report how this was measured (Table 1). Furthermore, Yoshimura et al[32] reported the death of six patients during their hospital admission, although this result cannot be directly correlated to the treatment effect as patients had a mean age of 92 years (3.6) with extended lengths of stay in the trauma unit. No other trial reported any adverse effects.

## 4 | DISCUSSION

This review systematically identified and synthesised studies examining the effect of nutritional interventions on measures of sarcopenia in hospitalised patients aged 65 years and above. Ageing is a risk factor for sarcopenia and hospitalised people are at a greater risk due to acute illness leading to increased nutritional requirements and decreased physical function/increased sedentary behaviour.[19,34] To mitigate these factors and slow the progression of sarcopenia in elderly hospitalised patients, early intervention is needed.[23] This review found only six RCTs that have examined nutrition interventions aimed at treating sarcopenia in hospitalised older adults. Three studies investigated the effects of nutritional supplementation combined with a usual care rehabilitation program,[28-30] and three studies investigated nutritional supplementation in combination with an enhanced rehabilitation/resistance exercise program.[31-33] All nutrition interventions provided additional protein (10-40 g/d). The most commonly assessed outcome across studies was hand grip strength. Meta-analysis showed that the mean difference (n = 5) in hand grip strength was 2 kg greater at the end of intervention compared with the control group (ie, usual care). Meta-analysis was not possible for other markers of sarcopenia as they were not consistently measured across studies.

Weak grip strength is an indicator of sarcopenia, with cut points from population data used to interpret risk.[35] Weak grip strength has been linked to poor health outcomes.[36] A 2 kg change in hand grip strength suggests that interventions in hospital to increase nutritional intake may slow the progression of sarcopenia. Previous studies investigating the effects of nutritional supplementation on hand grip strength in elderly community-dwelling people has shown smaller changes in strength,[37] however the baseline measures in the community dwelling participants was greater than the baseline levels of the participants included in this review. The clinical significance of a 2 kg change in hand grip strength on longer term health outcomes is not known. Only two of the included studies had a follow up at 12 months and neither of these studies found a significant difference on sarcopenia markers between the intervention groups and control groups.[28,33]

Systematic reviews investigating sarcopenia prevention and treatment in community dwelling adults and residential aged care facilities suggest a multifaceted approach (eg, enhanced nutrition combined with enhanced physical activity) may be more effective than either alone.[19,38] It is necessary to evaluate the effectiveness of these interventions on the treatment and prevention of sarcopenia in the inpatient setting because of differences in population characteristics and the physical environment compared with the community setting. There may be greater difficulty in measuring markers of sarcopenia using gold standard methods as these need to be available on the hospital site or easily transported to sites. The period available for intervening can be short (due to variable length of stay) and there are additional issues with compliance when interventions are delivered as part of routine hospital care.[39] The studies included in this review demonstrate that a range of factors can be assessed in hospitalised patients, including muscle function via gait speed (n = 2 studies), muscle mass by DXA or BIA (n = 4 studies) and muscle strength by dynamometer or knee-extensor force. This is an important finding as it demonstrates that future studies can assess effectiveness of interventions against the criteria used to define sarcopenia.[1]

This review highlighted a reliance on oral nutritional support products to increase nutritional intake in elderly hospitalised patients, which is consistent with studies in community dwelling older people.[19] The protein source and volume of these products were variable, making specific recommendations regarding optimal nutritional composition of supplementary products difficult. Interventions included in this review had a broad range of additional daily protein dose from 10 to 40 g/d. The lack of consistency reflects the absence of consensus for increasing protein intake in older adults.[5,40] As low protein intake is one of the underlying causes of sarcopenia[5] it is important for future research to determine the effective dose range. The source of protein was not

consistently reported but future research may focus on leucine and its metabolites for improving markers of sarcopenia such as muscle mass or physical function.[5] Only one study used food fortification[29] and no novel menu interventions were tested. Food-based interventions have been shown to provide significant improvements to protein intake in hospitalised adults and should not be discounted in future interventional studies.[41] To advance the field, consistency in the reporting of nutrition formulations being tested is needed, as well as a detailed description of the comparator ward diets.

A limitation of this review is the selection of only English language studies which may have led to papers published in other languages being excluded. The review protocol was not pre-registered, which is a risk of bias and is therefore a limitation of this review. Future research into the prevention of sarcopenia is required for the management of this disease in clinical settings. Currently, there are several large well-designed studies investigating multidisciplinary approaches of a resistance training program in combination with nutritional supplementation, only one is in the hospital setting and is utilising an ONS product to increase nutrition intake.[22,42-44] The findings of these studies will lead to greater clarity across the evidence base, and ideally, a more defined treatment protocol to reduce the loss of lean muscle mass in hospitalised adults.

In conclusion, this review has identified that provision of additional daily protein to people in hospital rehabilitation programs is associated with small but important increases in hand grip strength. There is a dearth of evidence available to inform guidelines for the prevention or treatment of sarcopenia in older hospitalised people. High quality, large intervention trials to identify the optimal nutrition and physical activity intervention combinations for the prevention and treatment of sarcopenia in elderly hospitalised patients are urgently needed. These studies need to include outcome measures of physical function and muscle quality.

## CONFLICT OF INTEREST

J.P. has received funding from Lion Dairy & Drinks to examine the effect of dairy beverages and exercise interventions on skeletal muscle mass, strength and performance outcomes in older adults.

## AUTHOR CONTRIBUTIONS

G.E.R. and C.E.H. conceived the review questions and developed the search strategy. A.B., M.C., Z.K., J.P., L.P. and N.W. completed the database searching, first pass screening and second pass screening quality assessments and drafted sections of the manuscript. G.E.R. independently assessed all papers in the second pass screening and wrote the subsequent drafts of the manuscript. C.E.H. independently completed all data extraction and quality assessments, performed the statistical analysis and reviewed all drafts. J.P. resolved conflicts in the quality assessment, wrote the introduction and critically reviewed all manuscript drafts. All authors are in agreement with the manuscript and declare that the content has not been published elsewhere.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.