Clinical Interventions in Aging

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REVIEW

# Effectiveness of Home-Based Exercise and Nutrition Programs for Senior Adults on Muscle Outcomes: A Scoping Review

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**Abstract:** This scoping review investigates the volume of evidence for home-based exercise and nutrition programs and their effect on muscle quality among senior adults to inform implementation and future research. It aims to answer the research question: What are the evidence, challenges, and needs for research regarding a home-based exercise and nutrition intervention program to improve muscle outcomes in senior adults? This scoping review was conducted following the PRISMA extension for Scoping Review. The following databases were searched: PubMed, Scopus, MEDLINE, CINAHL, EMBASE, and the Cochrane Library. Applied filters were used to help condense the research articles. A total of 13 studies met the inclusion criteria for this scoping review. Most exercise interventions were either resistance or multi-component exercise programs. The nature of the nutrition intervention varied between different supplements, foods, education, or counseling. Muscle outcomes included muscle mass in nine studies, muscle function in all the studies, muscle strength in ten studies, and biochemical analyses in two studies. Two studies found improvements in muscle mass; two studies revealed improvements in all their muscle function tests; and three studies revealed improvements in muscle strength. Muscle biopsy in a study revealed enhanced muscle fibers, but both studies did not reveal any biomarker improvements. The scoping review findings revealed mixed results on the effectiveness of a home-based exercise and nutrition program. However, the current evidence does have many gaps to address before recommending this form of intervention for senior adults as an effective way to prevent and manage sarcopenia. Since this review identified multiple knowledge gaps, strengths, and limitations in this growing field, it can be a starting point to help build future study designs and interventions in this population.

**Keywords:** senior adults, home-based exercise program, nutrition, muscle strength, muscle mass, muscle function

## Introduction

In the 2019 United States 65 years and older population, 24.1 million men and 30 million women were reported as senior adults.[1] The world's senior adult population is anticipated to double from 1 billion to 2.1 billion by 2050.[2] Aging is defined as the "irreversibly progressive decline of physiological function, eventually leading to age-related diseases, such as musculoskeletal disorders".[3] Age-related musculoskeletal disorders can occur because of muscle protein synthesis (MPS) imbalance between anabolic and catabolic pathways.[4]

Muscle mass and strength change throughout a person's lifetime—increasing until young adulthood (up to 40 years old), being maintained in midlife (between 40 to 60 years old), and then decreasing with aging (age 65 years and up).[5] After 60 years, muscle mass can decrease 1.4–2.5% per year,[6] with women losing 0.64–0.7% per year and men losing 0.8–0.98% per year.[7] Muscle strength loss has been reported to be 1.5–5% per year beyond 50 years,[8] with men losing 3–4% per year and women losing 2.5–3% per year.[7]

Fat mass increases as skeletal muscle mass decrease, negatively affecting a person's physical function.[9] The continual worsening of a person's physical function is one of the most critical age-related health issues.[9] Muscle function can decline



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30–50% by 80 years, worsening the decline in inactive senior adults.[3] Consequences of poor physical function can lead to a high incidence of malnutrition, loss of independence, poor quality of life (QOL), morbidity, and mortality.[9] Therefore, senior adults with physical dysfunction can become an economic burden because of the increased need for healthcare resources.[9]

Sarcopenia is the "progressive and generalized skeletal muscle disorder involving accelerated muscle mass, strength, and function loss".[5] Sarcopenia can affect all muscles, including skeletal,[10] smooth,[11] and cardiac.[12] Therefore, sarcopenia is considered among the most common aging-related musculoskeletal disorders.[13] Sarcopenia can increase fall risk,[14] causes cognitive impairment[15] and mobility disorders,[16] lowers QOL,[17] increase the need for long-term care placement,[18] and cause death.[19] In today's research, the prevalence of severe cases of sarcopenia ranged from 0.2% to 45% in women and from 0.2 to 17.1% in men.[20]

Early identification and intervention are essential to preventing or improving the outcomes in people with sarcopenia. There are three stages of sarcopenia diagnosis: 1) probable-low muscle strength, 2) confirmed-low muscle strength and mass, and 3) severe-low muscle strength, mass, and function.[5]

Muscle strength is considered the most reliable measurement of muscle function. Therefore, the New European Working Group on Sarcopenia in Older People (EWGSOP) guidelines use muscle strength as the primary sarcopenia diagnosis stage.[5] When predicting adverse outcomes of sarcopenia, muscle strength is better than mass.[14] Examples of muscle strength measurement are grip strength,[21] isometric torque methods,[22] or chair stand and rise test.[23] Muscle mass can be measured by magnetic resonance imaging, computed tomography, dual-energy X-ray absorptiometry (DXA), or bioelectrical impedance analysis (BIA). Muscle function can be measured by Timed-Up and Go test (TUG), gait speed, and Short Physical Performance Battery (SPPB).[5]

Blood biomarkers could be another way to diagnose sarcopenia and monitor their status. However, there is not a single biomarker that can identify sarcopenia in senior adults.[24] But some biomarkers may provide insight into sarcopenia pathophysiology, which may help identify susceptible individuals. These markers include an inflammatory response (eg, CRP,[25] IL-6,[25,26] and TNF-α[25,26]), hormones (eg, DHEAS,[27] testosterone,[28] IGF-1,[29] and vitamin D[30]), clinical parameters (eg, hemoglobin,[25] albumin,[31] and serum creatinine to cystatin C ratio[32]), products of oxidative stress (eg, advanced glycation end products,[33] protein carbonyls,[34] and oxidized LDL[35]), or antioxidants (eg, carotenoids[36,37] and alpha-tocopherol[37]). Furthermore, comorbidities (eg, cancer, diabetes mellitus, and chronic kidney disease) must be considered when analyzing biomarker levels because they can affect them.[38]

Although many factors contribute to sarcopenia in senior adults, the two crucial factors that can be controlled are inadequate nutrient intake and physical inactivity.[39,40] The American College of Sports Medicine's position states that daily physical activity can help promote healthy aging.[41] Additionally, physical activity interventions can increase muscle strength, endurance, and functional capacity to enhance cognitive status, independence, and QOL.[42,43] Multi-component physical activity programs include strength (eg, resistance), endurance (eg, aerobic), and balance training because they effectively attenuate the adverse effects associated with aging, such as frailty, cognitive dysfunction, and decreased mobility.[9,44]

Resistance training (RT) has been regarded as one of the most successful interventions for sarcopenia to enhance muscle mass, strength, and function in senior adults.[39,40,45] RT is defined as "a high load [~80% one-repetition maximum] performed 2–3 days per week at moderate-to-vigorous intensity".[45] However, high-load RT requires facilities with supervised observation and instructions in most cases.[45] Therefore, it could be difficult for senior adults to perform high-load RT as they may not have these accesses.[45]

In comparison, home-based exercise programs have some benefits, including tailoring exercise to lifestyle preferences and autonomy, variability in timing, easier to maintain than group programs, low cost, and no need for travel.[9] In addition, for inactive senior adults, a home-based exercise program could allow them to adapt quickly and facilitates improvement in physical performance.[42] On the other hand, home-based programs have some limitations, including the lack of social aspect, the strong willpower needed to adhere to and keep consistent with the program, and the lack of equipment to ensure the exercise program, specifically resistance training, provides sufficient intensity.[9] Therefore, there needs to be a consensus on the type of programs that can further enhance senior adults' muscle quality.

Nutrition has also been considered essential in countering sarcopenia.[45] A balanced diet including sufficient macro and micronutrients is required to prevent age-related sarcopenia.[46] Ingestion of dietary protein is required for MPS to prevent muscle breakdown, especially after exercising.[39] Senior adults must consume adequate protein to reduce muscle mass, strength, function loss, and slow sarcopenia.[39] The general recommendation for healthy senior adults is 1.0–1.2

grams per kilogram of body weight per day (g/kg BW/day).[47] However, the Society for Sarcopenia, Cachexia and Wasting Disease[48] recommends at least 1.0–1.5 g protein/kg BW/day combined with regular exercise to prevent and intervene in sarcopenia. Anabolic resistance from age-related impairment response to anabolic stimuli of the muscle[49] is the reason for senior adults' higher protein needs.

Given the rise and prevalence of sarcopenia and the recent growing interest in the field, we conducted a scoping review with the overall aim of reviewing the current research in home-based exercise and nutrition intervention as a strategy to enhance muscle outcomes to help inform future research. This scoping review may provide a basis for planning future studies, identifying current research gaps, and advancing knowledge translation to improve participant outcomes.

## Objectives

The growing amount of senior adults and the consistent rise in sarcopenia have called for research efforts to develop cost-saving, innovative, and effective countermeasures.[50] Furthermore, given the seriousness of sarcopenia, the need for a successful intervention has increased research attention.[51] However, there are limited research studies on interventions with home-based exercise and nutrition programs for senior adults to enhance muscle quality (muscle mass, strength, and function). To the authors' knowledge, this scoping review is the first to explore this study area. Therefore, the following research question was formulated: What are the evidence, challenges, and needs for research regarding a home-based exercise and nutrition intervention program to improve muscle outcomes in senior adults?

The scope of this review will identify, describe, and summarize this question comprehensively. This review is tasked with summarizing the available evidence for 1) interventions that combine home-based exercise and nutrition intervention with senior adults to improve their muscle quality; 2) identifying what outcomes are being used to measure exercise, nutrition, and muscle quality; 3) identify research gaps; and 4) identify the needs for future design, application, and assessment providing the current evidence and their gaps.

# Methods

This scoping review followed the components of the PRISMA extension for Scoping Review (PRISMA-ScR; Table 1)[52] and utilized the Critical Appraisal Skills Programme: Randomized Controlled Trials checklist[53] to critically appraise the included studies by assessing their relevance, trustworthiness, and results systematically. The checklist helped us assess

**Table 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) Checklist

| Section | Item | PRISMA-ScR Checklist Item | Reported On Page# |
|---|---|---|---|
| **Title** | | | |
| Title | 1 | Identify the report as a scoping review. | 1 |
| **Abstract** | | | |
| Structured summary | 2 | Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives. | 1–2 |
| **Introduction** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach. | 5 |
| Objectives | 4 | Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (eg, population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives. | 6 |

(*Continued*)

**Table 1** (Continued).

| Section | Item | PRISMA-ScR Checklist Item | Reported On Page# |
|---|---|---|---|
| **Methods** | | | |
| Protocol and registration | 5 | Indicate whether a review protocol exists; state if and where it can be accessed (eg, a Web address); and if available, provide registration information, including the registration number. | 6 |
| Eligibility criteria | 6 | Specify characteristics of the sources of evidence used as eligibility criteria (eg, years considered, language, and publication status), and provide a rationale. | 7 |
| Information sources* | 7 | Describe all information sources in the search (eg, databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed. | 6–7 |
| Search | 8 | Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated. | 7 |
| Selection of sources of evidence† | 9 | State the process for selecting sources of evidence (ie, screening and eligibility) included in the scoping review. | 7–8 |
| Data charting process‡ | 10 | Describe the methods of charting data from the included sources of evidence (eg, calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators. | 8 |
| Data items | 11 | List and define all variables for which data were sought and any assumptions and simplifications made. | 8 |
| Critical appraisal of individual sources of evidence§ | 12 | If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate). | 6 |
| Synthesis of results | 13 | Describe the methods of handling and summarizing the data that were charted. | 8 |
| **Results** | | | |
| Selection of sources of evidence | 14 | Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram. | 8 |
| Characteristics of sources of evidence | 15 | For each source of evidence, present characteristics for which data were charted and provide the citations. | 8–9 |
| Critical appraisal within sources of evidence | 16 | If done, present data on critical appraisal of included sources of evidence (see item 12). | Table 4; Page 9 |
| Results of individual sources of evidence | 17 | For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives. | Table 2 and Table 3; Page 8–13 |
| Synthesis of results | 18 | Summarize and/or present the charting results as they relate to the review questions and objectives. | Table 2 and Table 3; Page 8–13 |
| **Discussion** | | | |
| Summary of evidence | 19 | Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups. | 13–17 |

(*Continued*)

**Table 1** (Continued).

| Section | Item | PRISMA-ScR Checklist Item | Reported On Page# |
|---|---|---|---|
| Limitations | 20 | Discuss the limitations of the scoping review process. | 14–17 |
| Conclusions | 21 | Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps. | 18 |
| **Funding** | | | |
| Funding | 22 | Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review. | 18 |

**Notes**: *Where sources of evidence (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites. †A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (eg, quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with information sources (see first footnote). ‡The frameworks by Arksey and O'Malley[54] and Levac et al[55] and the JBI guidance[56,57] refer to the process of data extraction in a scoping review as data charting. §The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (eg, quantitative and/or qualitative research, expert opinion, and policy document). From *Annals of Internal Medicine*, Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. 2018;169:467–473. Copyright © 2018 American College of Physicians, Inc.[52]
**Abbreviations**: JBI, Joanna Briggs Institute; PRISMA-ScR, Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

any bias risk and evaluate the publications' quality to see if it is appropriate for this study. A review protocol does not exist. The search was conducted on August 6, 2022. The following databases were searched from 2000–2022 to identify potentially relevant studies: PubMed, Scopus, MEDLINE, CINAHL, EMBASE, and the Cochrane Library.

Keywords, other index terms, and the combination of these terms and appropriate synonyms were used to construct the search strategy. Applied filters were used to help condense the research articles, including academic journal source types, age 65+ years and 80 and over, English, and human trials. The detailed search strategy for databases included four concepts used to structure the search, including senior adults (example keywords: senior adults, older adults, elder, geriatric, elderly people, senior), home-based physical activity (example keywords: home physical activity program, home resistance training program, home exercise program), nutrition (example keywords: home nutrition program, nutrition, diet, supplement), and muscle outcomes (example keywords: muscle quality, muscle mass, muscle strength, muscle growth, blood biomarkers). The scoping review protocol recommends broad search terms to achieve high sensitivity.[58] The terms provided by the database and relevant to the study were used.

An example of an entire search strategy with exact terms used for MEDLINE: TX (elderly or aged or older or elder or geriatric or elderly people or old people or old people or senior) AND TX (home resistance training program OR TX home exercise program) AND TX (nutrition or diet or food or supplements) AND TX (muscle strength or muscle mass or muscle growth or muscle quality or blood biomarkers). Limiters: Aged 65+ years, 80 and over. Source Types: Academic Journals. Language: English

Studies were included if they reported 1) a home-based exercise program with a nutrition component added, 2) the senior adults as the subjects, and 3) muscle outcome, including muscle strength, muscle mass, muscle function, or muscle blood biomarkers. Studies were excluded if 1) the intervention was not home-based, 2) the intervention did not include both nutrition and exercise components, 3) nutrition was considered the control and not a part of the intervention, 4) the subject population was not senior adults, 5) muscle mass, strength, function, or blood biomarker tests were not an outcome, 6) animal study, 7) duplicate study during the initial screening, 8) not English translated, and 9) protocol, abstract, or review.

All articles' citations retrieved by electronic searching were exported to EndNote 20 for organization. The screening process can be seen in Figure 1. Two reviewers (ESG and SG) independently screened trials detailed for eligibility criteria. ESG screened the articles during the first pass. Duplicates, study protocols, abstracts, not English translated, and reviews were removed in first-pass screening. The full text was screened using inclusion and exclusion criteria during the second pass screening. SG confirmed articles met the inclusion criteria after the second pass. Other reviewers could resolve disagreements on study selection and data

**Table 2** Summary of Included Articles

| Reference and Country | Study Design and Groups | Subjects (Gender) | Exercise Intervention | Nutrition Intervention | Outcome Measures |
|---|---|---|---|---|---|
| Nilsson et al (2020)[50] North America | 12 weeks randomized, double-blind, placebo-controlled trial.<br>Two groups: PLA or M5. | 45 sedentary elderly men | • Whole-body elastic band resistance exercise with warm-up and cool-down for 3 day/week on non-consecutive days.<br>• Walk ≥ 5000 steps on exercise days and ≥ 10,000 steps on rest days using an accelerometer.<br>• Resistant bands, handout, and accelerometer provided. | • M5 contained whey and casein protein, creatine, vitamin D3, and omega-3 containing fish-oil.<br>• PLA contained 272 kcal (sunflower oil) and 40 g collagen protein.<br>• Consume 2 tsp. of oil and 1 sachet of M5 or PLA with water (~350 mL) in the morning with breakfast, while maintaining their normal dietary habits. | Muscle Outcome<br>• Muscle mass (DXA)<br>• Muscle function (SPPB, 6-M Gait Speed, TUG, 5-Time Sit to Stand, and 4-Step Stair Climb)<br>• Muscle strength (max grip strength, 1-RM leg press, and isometric knee extension)<br>• Biochemical analyses (blood samples and muscle biopsies)<br>Nutrition Outcome<br>• Food record |
| Tokuda and Hori (2021)[59] Japan | 24 weeks randomized controlled trial.<br>Three groups: resistance exercise intervention group (Ex group), essential amino acid intake after resistance exercise group (Ex+AA group), and the essential AA and tea catechins after resistance exercise group (Ex+AA+TC group). | 78 (10 males; 68 females) healthy older individuals without sarcopenia, diabetes, and kidney disease | • Resistance exercise including bodyweight and resistance elastic band exercise performed 2 days/week with 20-mins warm-up exercise and 40-min resistance exercise.<br>• Pole walking was performed for warm-up exercises.<br>• Resistance bands and pole stick provided. | • AA contained 17.6 kcal and 3000 mg of essential AA (1200 mg leucine, 500 mg lysine, 330 mg valine, 320 mg isoleucine, 280 mg threonine, 200 mg phenylalanine, 100 mg methionine, 50 mg histidine, 20 mg tryptophan).<br>• TC contained 19 kcal and 540 mg of catechins.<br>• Ingested within 30 mins after the end of exercise.<br>• Total protein intake in all groups was adjusted to at least 1.2 g/kg/day by nutritionist and increased during the intervention. | Muscle Outcome<br>• Muscle mass (BIA)<br>• Muscle strength (grip strength, knee extension strength)<br>• Muscle function (gait speed, one-legged stand balance test)<br>Nutrition Outcome<br>• Nutritional survey<br>• Mini-Nutritional Assessment-Short Form |

| | | | | | |
|---|---|---|---|---|---|
| Lee and Lee (2022)[60] Korea | 8 weeks randomized controlled trial. Two groups: MHR or home exercise groups. | 40 (10 males; 30 females) who underwent hip surgery | • Lower extremity strengthening, balance, and mobility function performed 3 days/week for 60 mins.<br>• Rehabilitation leaflet provided. | • Nutritional counseling 1 day/week via 10-mins phone call<br>• Nutrition management via leaflet. | Muscle Outcome<br>• Muscle function (functional reach test and TUG)<br>• Muscle strength (hip flexor, hip abductor, knee flexor, knee extensor, and grip strength)<br>Nutrition Outcome<br>• None |
| Hong et al (2017)[61] Korea | 12 weeks randomized controlled trial.<br>Two groups: tele-exercise group or the control group. | 23 (10 males; 13 females) sedentary elderly individuals | • Video conferencing-based resistance training exercise 3 days/week on non-consecutive days (separated by at least 48 hours) with warm-up (5 mins), main exercise (10–30 mins), and cool-down (5 mins).<br>• Tele-exercise group provided folding chairs, exercise mats, dumbbells (1-kg and 2-kg), and PC operation manuals. | • Nutrition education once every 4 weeks through PC.<br>• Asked to maintain calorie intake as before study. | Muscle Outcome<br>• Muscle mass (DXA and Appendicular Lean Soft Tissue-based formula)<br>• Muscle function (2-min step, back scratch, chair sit-and-reach, and 8-ft TUG tests)<br>• Muscle strength (arm curl and chair stand)<br>Nutrition Outcome<br>• None |
| Wang et al (2022)[62] China | 12 weeks randomized controlled trial.<br>Four groups: control group or three intervention groups: nutrition, exercise, and comprehensive (nutrition plus exercise) groups. | 201 (34 males; 167 females) elderly with sarcopenia | • App evaluated the participant's exercise status and recommended the exercise amount, such as 40–60 mins of moderate-to-high-intensity exercise and resistance training for 30 mins, ≥ 3 days/week. | App provided dietary management information by assessing each participant's diet and provide recommendations for adjustments, focusing on energy and protein intake, and give recommended recipes. | Muscle Outcome<br>• Muscle function (balance test, 4-M timed walking test, and timing sitting and standing tests)<br>• Muscle mass (BIA)<br>Nutrition Outcome<br>• Food frequency questionnaire |

(*Continued*)


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**Table 2** (Continued).

| Reference and Country | Study Design and Groups | Subjects (Gender) | Exercise Intervention | Nutrition Intervention | Outcome Measures |
|---|---|---|---|---|---|
| Miyazaki et al (2022)[63] Japan | 4 weeks single-blind randomized controlled trial. Three groups: a NW group (walking group), an original dance program training group (dance group), and a protein-only group (control group). | 88 (62 males; 26 females) healthy older adults without dementia or sarcopenia | • NW: 30 mins outdoor walking, with a combined 15 mins warm-up and a cool-down indoor session (provided DVD).<br>• Dance: 30 mins with a combined 15 mins warm-up and cool-down session.<br>• Each group performed 3 days/week. | • All groups received protein supplement (~8 g of BCAA) in a baked cake 3 times/week.<br>• Consume before and after training and at 10:00 or 15:00. | Muscle Outcome<br>• Muscle function (10-m gait speed, standing balance test, Five Times Sit-to-Stand Test, heel lift)<br>• Muscle strength (grip strength, toe strength, toe raise test, and angle of active flexion of the dominant shoulder)<br>• Muscle mass (BIA)<br>Nutrition Outcome<br>• Food diary |
| Bonnefoy et al (2012)[46] France | 4-month, open label, randomized trial. Two groups: "prevention" and "control" (no intervention). | 102 (14 males; 88 females) independent older adults at risk of becoming frail | • ~20 mins individualized 13 exercises for mobility, flexibility, strength, balance, and endurance training performed 1 time/day.<br>• Booklet provided | • Hyperprotidine contained 80% milk, 10 g protein including soy and alfalfa protein and 3.49 g of BCAA (2.41 g L-Leucin, 0.51 g L-isoleucine, 0.57 g L-valine), and 44.3 kcal.<br>• 2 doses per day. | Muscle Outcome<br>• Muscle function (walking speed, TUG, 1-minute chair-rise count, and 6-step climb time)<br>• Muscle mass (fat free mass)<br>Nutrition Outcome<br>• Body Max Index<br>• Mini Nutritional Assessment<br>• Dietary Intake |
| Kapan et al (2017)[64] Austria | 12 weeks randomized controlled trial Two groups: PTN or social support group. | 80 (13 males; 67 females) prefrail or frail, malnourished or at risk of malnutrition independent older adults | 10-mins warm-up (mobility and balance exercises) and a 25-mins strength training routine for 2 times/week with a "buddy". | • Nutrition education provided by "buddy."<br>• 1 nutritional topic was discussed out of 8 nutritional-related messages with a focus on fluid, protein, and energy intake. | Muscle Outcome<br>• Muscle function (SPPB)<br>• Muscle strength (grip strength)<br>Nutrition Outcome<br>• None |

| | | | | | |
|---|---|---|---|---|---|
| Naito et al (2019)[65]<br>Japan | 8 week multicenter prospective single-arm study.<br>All participants received the same intervention. | 30 (20 males; 10 females) newly diagnosed advanced pancreatic or non-small-cell lung cancer older adults | • Individualized exercise program combined daily low-intensity resistance training.<br>• Accelerometer provided to determine daily goal steps. | • Individualized nutritional counselling<br>• Inner Power contained BCAA (2500 mg), coenzyme Q10 (30 mg), and L-carnitine (50 mg) and consumed 1 pack/day | Muscle Outcome<br>• Muscle strength (grip strength)<br>• Muscle function (5-time-sit-to-stand test, 6-min walk test, 5-M gait speed)<br>• Muscle mass (computed tomography)<br>Nutrition Outcome<br>• Body weight<br>• Body Mass Index<br>• Mini Nutritional Assessment<br>• 2-day diet diaries or 24-hour recall<br>• Nutrition impact symptoms |
| Johnson et al (2018)[66]<br>Canada | 6-month randomized controlled trial.<br>Four groups: exercise, nutrition, exercise-nutrition, and control. | 134 (23 males; 111 females) independent rural older adults | • 10 progressive weight-bearing exercises and balance training for 3 days/week. | Two 235mL cans/day of Ensure High Calcium, provided 230 kcal, 12 g of protein, and 400 mg of calcium | Muscle Outcome<br>• Muscle function (TUG, 6-min walk test, functional reach)<br>• Muscle strength (Sit-to-Stand test)<br>Nutrition Outcome<br>• None |
| Haider et al (2017)[67]<br>Austria | 12 weeks randomized controlled trial.<br>Two groups: PTN or SoSu group | 80 (13 males; 67 females) prefrail or frail older adults | • Warm-up with mobilization exercises, 2 set of 6 standardized circuit strength exercises 2 days/week with "buddies."<br>• Strength exercises 1 day/week alone<br>• PTN provided elastic resistance band and guidebook. | • Nutritional education with buddy consisted of 8 nutritional issues, mainly on fluid, protein, and energy intake.<br>• During each home visit, 1 nutritional issue was discussed. | Muscle Outcome<br>• Muscle strength (grip strength)<br>• Muscle function (SPPB)<br>• Muscle mass (BIA)<br>Nutrition Outcome<br>• None |
| de Carvalho Bastone et al (2020)[40]<br>Brazil | 3 months randomized, controlled trial.<br>Four groups: resistance training, supplementation, resistance training plus supplementation, and control. | 69 (20 males; 49 females) dynapenic older adults with low protein intake | • Progressive resistance training program done 3 days/week for 60 mins.<br>• Elastic bands, dumbbells, and ankle weights provided. | • Fortifit provided 147 kcal and contained 21.0 g protein (3 g leucine, >10 g EAA), 9.6 g CHO, 3 g fat, vitamins (800 IU vitamin D, 0.77 mg vitamin B6, 3μg vitamin B12) and minerals.<br>• Provided by a research dietician to be consumed daily at night.<br>• Instructed to maintain their regular food intake. | Muscle Outcome<br>• Muscle strength (grip strength)<br>• Muscle function (gait speed, sit-to-stand test, TUG, single-leg-stance test)<br>• Muscle mass (BIA)<br>• Biochemical (insulin resistance using HOMA-IR)<br>Nutrition Outcome<br>• None |

(*Continued*)


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**Table 2** (Continued).

| Reference and Country | Study Design and Groups | Subjects (Gender) | Exercise Intervention | Nutrition Intervention | Outcome Measures |
|---|---|---|---|---|---|
| Hsieh et al (2019)[68] Taiwan | 6 months four-arm, single-blind, randomized controlled trial. Four groups: control, exercise, nutrition, and combination (exercise plus nutrition). | 319 (192 males; 127 females) pre-frail or frail older adults | Strength, flexibility, balance, and endurance training with 3–7 sessions/week, with the time (5–60 mins) per session or repetitions tailored to participants' capabilities. | • Customized dishware (plate, bowl, mug, and a tablespoon) and a colored meal pad was provided.<br>• Nutrition-1 subgroup: 2 supplements were provided 25 g of skim milk powder and 10 g of mixed nuts (cashews, almonds, pumpkin seeds, walnuts, macadamia nuts, and pine nuts) per day.<br>• Nutrition-2 subgroup: half of the participants received 2 supplements per day, including 3 fish oil capsules providing 140 mg of EPA and 95 mg of DHA and a Oxxynea FP providing 200 mg vegetable and fruit concentrate. | Muscle Outcome<br>• Muscle strength [grip strength, lower extremity strength (standing heel-rise)]<br>• Muscle function [gait speed, upper body flexibility (back scratch), lower body flexibility (chair sit-and-reach)]<br>Nutrition Outcome<br>• Dietary recall |

**Abbreviations**: 1-RM, one-repetition maximum; AA, amino acid; BIA, bioelectrical impedance analysis; BCAA, branched chained amino acid; CHO, carbohydrate; DHA, docosahexaenoic acid; DXA, dual energy X-ray absorptiometry; EAA, essential amino acid; EPA, eicosapentaenoic acid; EX, exercise; Ft, feet; G, gram; g/d: gram per day; HOMA-IR, Homeostatic Model Assessment for Insulin Resistance; IU/d, international unit per day; Kcal, kilocalories; M, meter; M5, muscle 5; Mg, milligram; MHR, multicomponent home-based rehabilitation; Mins, minutes; mL, milliliter; NW, Nordic walking; PC, personal computer; PLA, placebo; PTN, physical training and nutrition group; RTS, resistance training supplementation; S, supplementation; SMI, skeletal muscle mass index; SoSu, social support group; SPPB, short physical performance battery; TC, tea catechins; Tsp, teaspoon; TUG, timed up and go.

**Table 3** Muscle Outcome Results

| Reference | Muscle Strength | Muscle Mass | Muscle Function | Biochemical Analysis |
|---|---|---|---|---|
| Nilsson et al (2020)[50] | • Significant improvement in leg press and handgrip for M5 group.<br>• No improvement in knee extensor strength for M5 group. | • Significant improvement in total and appendicular lean mass for M5 group.<br>• Improved muscle-to-body fat ratio for M5 group. | • Significant improvement in 5-Times STS test, with both PLA and M5 groups.<br>• Significant improvement in 4-Step Stair Climb test and 6-M Gait speed for the M5 group.<br>• Improvement in 4-M Gait Speed, 6-M Gait Speed, and 4-Step Stair Climb, but not for TUG, SPPB or 5-Times STS in sarcopenic vs non-sarcopenic individuals. | • Significant improvement in type II muscle fiber for M5 group<br>• No improvement on biomarkers of liver function, inflammation, or lipid profiles. |
| Tokuda and Hori (2021)[59] | Improved grip strength and knee extension strength for Ex+AA+TC, Ex+AA, and Ex. | • Improved SMI for Ex+AA+TC and Ex+AA<br>• No improvement in SMI for Ex group | • Improved gait speed and one-legged stand balance test for Ex+AA+TC<br>• Improved gait speed for Ex+AA group and Ex group | N/A |
| Lee and Lee (2022)[60] | • Significant improvement in knee flexor strength for MHR group.<br>• No improvement in hip flexor, hip abductor, knee extensor, and grip strength between MHG and home exercise groups. | N/A | • Significant improvement in TUG between groups only at week 8.<br>• Significant improvement in balance and mobility functions between groups across the 3 time points (baseline, week 4, and week 8). | N/A |
| Hong et al (2017)[61] | • No improvement in arm curl for groups.<br>• Significant improvement in chair stand between groups. | • Significant improvement in lower limb muscle mass, ALST, and TSM between groups.<br>• No improvement in weight, % fat, or upper limb muscle mass. | • Significant improvement in chair sit-and-reach and 2-min step between groups.<br>• No improvements in back scratch or 8-ft up-and-go between groups. | N/A |
| Wang et al (2022)[62] | N/A | Significant improvement in skeletal muscle mass, skeletal muscle mass/height$^2$ in female, skeletal muscle mass/body weight, skeletal muscle mass/BMI, skeletal muscle mass/body fat % among the 4 groups before and after the intervention. | No improvement in balance test, 4-M regular walking time, and regular sitting and standing times among the 4 groups. | N/A |

(*Continued*)


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**Table 3** (Continued).

| Reference | Muscle Strength | Muscle Mass | Muscle Function | Biochemical Analysis |
|---|---|---|---|---|
| Miyazaki et al (2022)[63] | No improvement in dominant hand grip strength, toe strength, angle of active flexion of the dominant shoulder in the upper limb, or the toe raise test between the 3 groups. | No improvement with weight, muscle mass, fat mass, or phase angle between the 3 groups. | • No improvement in 5 Times STS, stride length, root mean square, gait cycle, or single-leg stance test between the 3 groups.<br>• Significant improvement in max gait speed over 10-M and the angle of the heel lift between the 3 groups. | N/A |
| Bonnefoy et al (2012)[46] | N/A | No improvement in fat free mass in either group. | • Decrease maximum walking time for control group while prevention group was maintained.<br>• No improvement in walking speed, 1-minute chair-rise count, and 6-step climb time in both groups.<br>• Improved get-up-and-go in prevention group while control group was maintained. | N/A |
| Kapan et al (2017)[64] | • No improvement in handgrip strength for FOF and SOSU groups.<br>• Significant improvement in handgrip strength for PTN group. | N/A | Significant improvement in SPPB in PTN group | N/A |
| Naito et al (2019)[65] | Significant improvement in handgrip strength only at T2 point. | No improvement of skeletal muscle mass index. | • No improvement in 6 minutes walking distance and gait speed.<br>• Improvement in five-time STS time at T2 and T3 point. | N/A |
| Johnson et al (2018)[66] | • No improvement in one STS and five STS for all groups. | N/A | • Significant improvement in functional reach test and TUG test for all groups.<br>• Significant improvement in TUG test between the NTR and EX groups and for functional reach test between the EX and NTR-EX group<br>• No improvement in 6-minute walk test, one STS, and five STS for all groups. | |

| | | | | |
|---|---|---|---|---|
| Haider et al (2017)[67] | • Significant improvement in handgrip strength for PTN group.<br>• Significant improvement in lower limb muscle strength between groups.<br>• No improvement in handgrip strength between group | No improvement in lean body mass and appendicular skeletal muscle mass between groups | • Improvement in balance skills and 5-timed chair stands with PTN group<br>• No improvement in gait speed and balance score between groups | |
| de Carvalho Bastone et al (2020)[40] | Significant improvement in handgrip strength between RT group and C group as well as RTS group and C group | No improvement in SMI with all groups. | • Significant improvement in gait speed in the RT group, S group, and RTS group.<br>• Significant improvement in STS test between all groups.<br>• No improvement in one-leg-stance test and the timed up and go test | No improvement in HOMA-IR with all groups |
| Hsieh et al (2019)[68] | Significant improvement in lower extremity strength and handgrip strength with all groups. | N/A | • Significant improvement in upper body and lower body flexibility and 10-M gait speed in exercise, nutrition, and combination intervention groups<br>• No improvement in 10-M gait speed | N/A |

**Abbreviations**: %, percentage; AA, amino acid; ALST, appendicular lean soft tissue; BMI, body mass index; C, control; EX, exercise; FOF, fear of falling; Ft, feet; M, meter; M5, muscle 5; MHR, multicomponent home-based rehabilitation; Mins, minutes; N/A, not applicable; NTR, nutrition; PLA, placebo; PTN, physical training and nutrition; RT, resistant training; RTS, resistant training with supplement; S, supplement; SOSU, social support; STS, sit-to-stand; SMI, skeletal muscle index; SPPB, short physical performance battery; TSM, total body skeletal muscle mass; TC, tea catechins; TUG, time up and go.


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**Table 4** Critical Appraisal Skills Programme: Randomized Controlled Trials Checklist

| Study | Section A: Is the Basic Study Design Valid for a Randomized Controlled Trial? | | | Section B: Was the Study Methodologically Sound? | | |
|---|---|---|---|---|---|---|
| | Did the study address a clearly focused research question? | Was the assignment of participants to interventions randomized? | Were all participants who entered the study accounted for at its conclusion? | Were the participants "blind" to intervention they were given?<br>Were the investigators "blind" to the intervention they were giving to participants?<br>Were the people assessing/analyzing outcome/s "blinded"? | Were the study groups similar at the start of the randomized controlled trial? | Apart from the experimental intervention, did each study group receive the same level of care (that is, were they treated equally)? |
| Nilsson et al (2020)[50] | Yes | Yes | Yes | Yes<br>Yes<br>Yes | Yes | Yes |
| Tokuda and Hori (2021)[59] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |
| Lee and Lee (2022)[60] | Yes | Yes | Yes | Yes<br>No<br>Yes | Yes | Yes |
| Hong et al (2017)[61] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |
| Wang et al (2022)[62] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |
| Miyazaki et al (2022)[63] | Yes | Yes | Yes | No<br>Yes<br>No | Yes | Yes |
| Bonnefoy et al (2012)[46] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| Kapan et al (2017)[64] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |
| Naito et al (2019)[65] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |
| Johnson et al (2018)[66] | Yes | Yes | Yes | No<br>No<br>Yes | Yes | Yes |
| Haider et al (2017)[67] | Yes | Yes | Yes | No<br>No<br>No | Yes | Yes |
| de Carvalho Bastone et al (2020)[40] | Yes | Yes | Yes | No<br>Yes<br>Yes | Yes | Yes |
| Hsieh et al (2019)[68] | Yes | Yes | Yes | Yes<br>No<br>No | Yes | Yes |
| **Study** | **Section C: What are the Results?** | | | **Section D: Will the Results Help Locally?** | | |
| | Were the effects of intervention reported comprehensively? | Was the precision of the estimate of the intervention or treatment effect reported? | Do the benefits of the experimental intervention outweigh the harms and costs? | Can the results be applied to your local population/ in your context? | Would the experimental intervention provide greater value to the people in your care than any of the existing interventions? | |
| Nilsson et al (2020)[50] | Yes | Yes | Yes | Yes | Yes | |
| Tokuda and Hori (2021)[59] | Yes | Yes | Yes | Yes | Yes | |
| Lee and Lee (2022)[60] | Yes | Yes | Yes | Yes | Yes | |
| Hong et al (2017)[61] | Yes | Yes | Yes | Yes | Yes | |

(*Continued*)


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**Table 4** (Continued).

| Study | Section C: What are the Results? | | | Section D: Will the Results Help Locally? | |
|---|---|---|---|---|---|
| Wang et al (2022)[62] | Yes | Yes | Yes | Yes | Yes |
| Miyazaki et al (2022)[63] | Yes | Yes | Yes | Yes | Yes |
| Bonnefoy et al (2012)[46] | Yes | Yes | Yes | Yes | Yes |
| Kapan et al (2017)[64] | Yes | Yes | Yes | Yes | Yes |
| Naito et al (2019)[65] | Yes | Yes | Yes | Yes | Yes |
| Johnson et al (2018)[66] | Yes | Yes | Yes | Yes | Yes |
| Haider et al (2017)[67] | Yes | Yes | Yes | Yes | Yes |
| de Carvalho Bastone et al (2020)[40] | Yes | Yes | Yes | Yes | Yes |
| Hsieh et al (2019)[68] | Yes | Yes | Yes | Yes | Yes |



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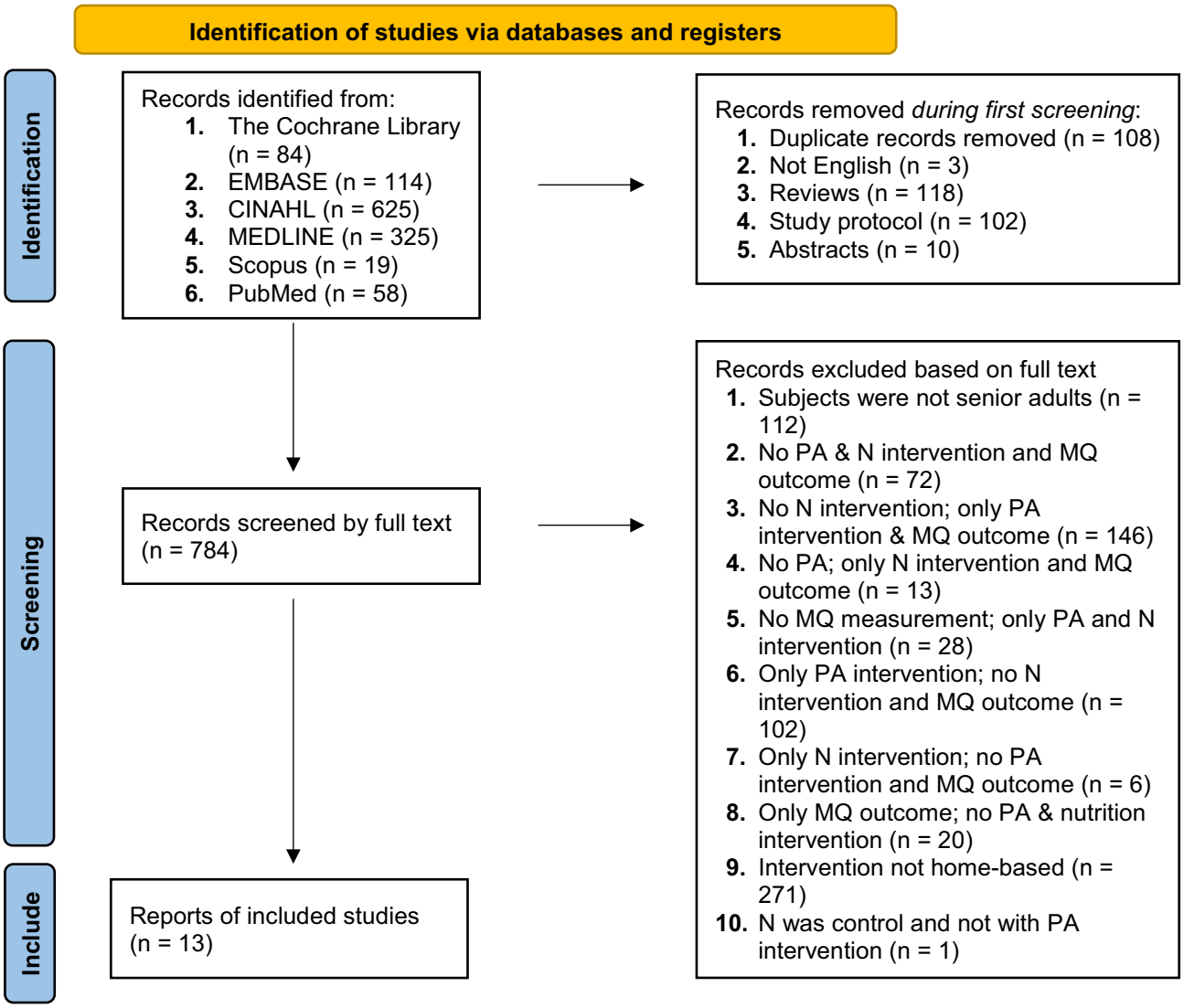


**Figure 1** Flow diagram of literature search. The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (eg, quantitative and/or qualitative research, expert opinion, and policy document). From: *Annals of Internal Medicine*, Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. 2018;169:467–473. Copyright © 2018 American College of Physicians, Inc.[52]
**Abbreviations**: MQ, Muscle Quality; N, Nutrition; PA, physical activity.

extraction if needed. Finally, the two prominent reviewers extracted the studies' key data into a summary table (Table 2) based on the review's sub-objectives. The results were discussed and condensed accordingly.

Only a summary of the articles' study design and groups, country, subjects (number and types of participants involved), exercise intervention (type, duration, and items provided), nutrition intervention (type, duration, items provided, and ingredients), and outcome measurements (muscle and nutrition outcome used) are reported because many included studies were multi-component. The outcome measurement was extracted into four groups (muscle mass, muscle strength, muscle function, and biochemical analyses) seen in Table 3.

# Results

## Search Results

The initial search yielded 1125 articles from the database (Figure 1). After removing the duplicates, reviews, study protocols, abstracts, and articles not translated into English, 784 remained. Of the 784 full-text articles evaluated for

eligibility, 771 were excluded. A total of 13 studies met the inclusion criteria for the scoping review, as seen in Table 2.

## Study Characteristics

The studies' characteristics are seen in Table 2. All but one study of the included studies was reported as randomized controlled trials, while one was a prospective study.[65] All but one study[46] was published within the past five years, demonstrating this area of study is in its novelty. The included studies came from high- and upper-middle-income countries: North America,[50] China,[62] France,[46] Canada,[66] Brazil,[40] Taiwan,[68] Korea,[60,61] Japan,[59,63,65] and Austria.[64,67] The studies ranged in size from 23 participants[61] to 319 participants,[68] with the majority of subjects (9 of the 13 studies) being female (823 females vs 466 males; 64% vs 36%, respectively). The study population varied from healthy individuals,[59,63,66] sedentary individuals,[50,61] those who underwent hip surgery,[60] those who have sarcopenia,[62] prefrail or frail individuals,[46,64,67,68] those newly diagnosed with advanced pancreatic or non-small-cell lung cancer,[65] or dynapenic older adults with low protein intake.[40] The durations varied between 4 weeks[63] to 6 months.[59,66,68] One study did not have a comparison group,[65] six studies included two comparison groups,[46,50,60,61,64,67] two studies included three comparison groups,[59,63] and four studies included four comparison groups.[40,62,66,68] A critical appraisal of the included studies was done using the Critical Appraisal Skills Programme: Randomized Controlled Trials checklist,[53] and the results can be seen in Table 4.

## Exercise Intervention

The exact exercise programs performed, duration, and intensity widely varied among the studies (Table 2). Most studies were either RT[40,50,59,61,62,65,67] or multi-component[46,59,60,64,66,68] exercise programs, while one was strictly aerobics.[63] The RT was more potent towards muscle mass and strength, while the multi-component programs were more effective towards muscle function. Only five studies[50,59,61,63] included a warm-up and cool-down with their intervention, two studies[64,67] had only a warm-up, and the remaining studies[40,46,60,62,65,66,68] did not report involving a warm-up or cool-down. Exercise programs providing warm-up or cool-down did not improve muscle outcomes within the studies. The majority of the studies (9 out of 13) provided participants with equipment for their exercise intervention, including an accelerometer,[50,65] resistance bands,[40,50,59,67] pole sticks for walking,[59] handouts,[46,50,60,67] a DVD,[63] folding chairs,[61] exercise mats,[61] dumbbells,[40,61] ankle weights,[40] or a personal computer (PC).[61] Studies that included resistance bands and handouts showed increased muscle mass and strength, while the other equipment revealed either increased, maintained, or did not affect muscle outcomes.

Participants were asked to exercise for a certain amount of time or perform a specific number of exercises per session. The amount of time ranged from 5[68] to 60 minutes.[40,59,60,62,68] The number of exercises per session varied greatly, with either a set number provided[40,50,59,61,63,64,66,67] or the researchers individualized the session based on the participant's current physical activity level.[46,60,62,65,68] The longer duration and individualized exercise interventions did show improvement in muscle outcomes compared to studies with shorter time and generalized exercise interventions. Each participant was asked to do their sessions a certain number of days per week, either every day,[46] two days/week,[59,64,67] three days/week,[40,50,60,61,63,66] or individualized based on the participant's physical activity level.[62,65,68] The individualized session improved muscle quality over a specific set number of days.

## Nutrition Intervention

The nature of the nutrition intervention varied between different supplements, foods, or nutrition education/counseling (Table 2). Six studies provided only supplements or food in their intervention,[40,46,50,59,63,66] three provided only nutrition education,[61,64,67] two provided only nutrition counseling,[60,62] and two provided both supplement/food and nutritional counseling/education.[65,68] Nutrition education indicated general information, while nutrition counseling provided individualized recommendations.

Regarding supplements and food, there was variation among studies concerning the type of supplement, dose, timing, and frequency of consumption. The supplement's commonly used ingredients contained protein,[50,66,68] amino acids,[40,59,63,65] or both.[46] Four studies provided a multi-nutrient supplement (nutritional powder[40,50,65] or drink[46,66]) for daily consumption. One study[40] provided a combination of food and supplements. The studies providing multi-nutrient supplements and a combination

of food and supplement did show improvement in muscle outcomes rather than consuming protein or amino acid alone. Three studies[40,50,61] reported that participants could maintain their regular dietary habits during the intervention, but it was unclear if the other studies reported the same. Four studies[40,50,59,63] provided specific instructions on when the supplement or food could be consumed; meanwhile, four studies[46,65,66,68] did not provide specific instructions but informed how many times per day to consume them. The studies providing specific instructions revealed improvements in muscle outcomes over those that did not. However, Tokuda and Hori[59] was the only study that provided the participants' protein recommendations of 1.2 g/kg/day and showed improved muscle quality individually but not between groups.

Regarding studies with nutritional counseling or education, 8 of the 13 were provided nutrition education through customized dishware and colored meal pad,[68] a "buddy",[64,67] individualized counseling,[65] an app,[62] PC,[61] or phone call.[60] The app, customized dishware and colored meal pad, and "buddy" showed how participants being involved or having someone accountable for their intervention impacted their muscle outcomes. It should be noted that only seven studies[46,50,59,62,63,65,68] had nutrition outcomes in addition to their muscle outcomes, while the rest had only muscle outcome measurements for their results. The nutrition outcomes data were collected by a type of food diary,[46,50,59,63,65,68] Mini-Nutrition Assessment Short Form,[59] Mini-Nutrition Assessment,[46,65] food frequency questionnaires,[62] body max index,[46,65] body weight,[65] or nutrition impact symptoms.[65] The type of food diary used in the study varied, but it held the exact purpose of obtaining the participants' food intake for a specific time. The studies involving a food diary and food frequency questionnaires revealed improved muscle outcomes.

## Muscle Outcome

Muscle outcome in the 13 included studies included muscle mass in 9 studies,[40,46,50,59,61–63,65,67] muscle function in all the studies, muscle strength in 11 studies,[40,50,59–61,63–68] and biochemical analyses in 2 studies.[40,50] Each assessment method for these outcomes differed across the studies (Table 2). Most studies measured two muscle outcomes,[46,60,62,64,66,68] while the remainder measured three outcomes[59,61,63,65,67] or four outcomes.[40,50] The most popular pairing was muscle strength and function.[46,60,66,68]

## Muscle Mass

The muscle mass was measured by either a DXA,[50,61] BIA,[40,59,62,63,67] appendicular lean soft tissue-based formula,[61] fat-free mass,[46] or CT.[65] The results were mixed between the studies. In 6 studies, the home-based exercise and nutrition intervention did not improve the outcomes of skeletal muscle mass (SMM) index,[40,59,65] lean body mass,[67] appendicular skeletal muscle mass (ASM),[67] and skeletal muscle mass.[46,63] These results could be due to the accuracy of the device used, insufficient protein intake, or the type of exercise intervention being done (aerobic, multi-component, low-intensity RT with an accelerometer, strength exercises, and progressive RT). However, two studies did show improvement in SMM,[50,62] ASM,[50] or muscle-to-body fat ratio[50] compared to the control. The similarity of these studies was that RT for approximately three days/week can help enhance muscle mass. One study[61] had mixed results where lower body muscle mass, ASM, and SMM were improved in the intervention group compared to the control, but not upper body muscle.

## Muscle Function

There were multiple ways muscle function was measured which included SPPB,[50,64,67] gait speed,[40,50,59,63,65,68] TUG,[40,46,50,60,61,66] sit to stand,[40,46,50,62,63,65] stair climb,[46,50] balance test,[40,59,62] functional reach test,[60,66] 2-minute step,[61] back scratch,[61,68] chair sit-and-reach,[61,68] walking test,[46,62,65,66] or heel lift.[63] Two studies[64,68] revealed improvement in all the intervention's muscle function tests compared to the control. The only similarities between the studies were the strength component of the exercise intervention and nutrition education, indicating that these could be ideal interventions for enhancing muscle function. Many studies[40,50,60,61,63,65–67] showed mixed results of muscle function improvements in certain tests but not others. Three studies[46,59,62] revealed no intervention effect in all their tests. The three studies had no similarities because they had different muscle function tests, exercise interventions, and nutrition interventions. Therefore, it is difficult to report what could be the reason why muscle function was not improved.

## Muscle Strength

Muscle strength was measured by either grip strength,[40,50,59,60,63–65,67,68] leg press,[50] knee extension,[50,59,60] knee and hip flexor,[60] hip abductor,[60] arm curl,[61] chair stand,[61,66] toe strength,[63] toe/heel raise,[63,68] or angle of active flexion of the dominant shoulder.[63] Like muscle function, many studies[50,60,61] showed mixed results of muscle strength improvement. Three studies[40,67,68] revealed the intervention having strength improvements compared to the control. All three studies provided the participants with home items to help with their exercise or nutrition intervention, indicating that providing equipment at home for exercise or nutrition could be valuable for enhancing muscle strength. Kapan et al[64] revealed that individuals had improvement in grip strength but did not see a within-group change from control. Naito et al[65] saw improvement in interventions' grip strength only at a one-time point but not with the other time points. Three studies[59,63,66] showed no improvements with the intervention. The only similarity between the three studies was that supplementation (amino acid, tea catechins, or ensure high calcium) was part of their intervention, so it questions if an alternative nutrition intervention like food versus supplementation could be ideal.

## Biochemical Analysis

Only one study[50] performed muscle biopsies during pre-and post-intervention. It revealed muscle fibers improvement after performing whole-body elastic band resistance exercises with warm-up and cool-down for three days/week on non-consecutive days with daily consumption of a multi-nutrient supplement (M5). RT and exercising three days/week have been seen above as effective in enhancing muscle outcomes, further confirming their effectiveness. However, both studies[40,50] did not reveal any biomarkers improvements of liver function, inflammation, lipid profiles, or HOMA-IR with home-based exercise and nutrition intervention. Since recent studies are limited, further testing of common biomarkers to test for muscle mass is needed for home-based exercise and nutrition.

# Discussion

In this scoping review, 13 studies were included with senior adults receiving home-based exercise and nutrition intervention to enhance their muscle quality. The studies were distinct in terms of participants included (nutrition, disease, or frailty status), duration (4 weeks to 6 months), groups (1 to 4 comparison groups), exercise intervention (type and duration), nutrition intervention (education, counseling, and supplementations), and outcomes (muscle, nutrition, and biomarkers). The main finding is that the data needs to be more consistent regarding whether muscle quality can be improved with a home-based exercise and nutrition intervention. In addition, examining the existing research revealed many gaps and further studies are needed to address these. These gaps included lack of participant blinding; lack of research done in low-to-middle-income countries; short study duration; population type and how it could have affected the intervention; and the type, dose, frequency, ingredients, and delivery of the nutrition intervention.

This area of research is novel, with most of the included studies published within the past five years suggesting growing interest in this topic. The growing interest could be because home-based interventions are generally inexpensive, flexible, time-saving, and promote independence.[50] For example, Hsieh et al[68] reported that the cost of their intervention for a home-based exercise and nutrition program was $81–100 for a three-month program. In addition, most of the studies were not blinded, leading to possible biased results. At the same time, it is difficult to blind participants to exercise intervention, but it can be done with nutritional supplements.

The included studies came from high- and upper-middle-income countries, which reveals an evidence gap in low- to middle-income countries to determine if home-based exercise and nutrition interventions are effective in these populations. The durations varied between 4 weeks to 6 months. The short length is likely due to difficulties recruiting and retaining senior adults[69] or concerns about efficacy, protocol adherence, cost, and withdrawal/dropout rates.[50] Since the programs are short-term, it does question the long-term effect of this intervention on muscle quality is largely unknown, especially since there are no follow-up measurements taken long-term. In this review, the longer-duration interventions improved muscle quality, while the shorter-duration interventions did not. It should be noted that the 4-week study was the only aerobic study, and the participants received protein supplements. In contrast, the long-term studies were RT or multi-component exercise training receiving multi-nutrient supplementation, food, or education. Therefore, further

studies are needed to address the effect of this intervention on muscle quality in low- to middle-income countries and long-term studies (1 year or more).

The populations utilized varied from healthy individuals to those with a medical condition. The medical condition could have other factors (eg, medication and standard of care) compromising the study's intervention. For example, participants after hip surgery[60] outcomes showed mixed muscle strength and function results. Participants with newly diagnosed advanced pancreatic or non-small cell lung cancer[65] outcomes revealed either maintenance (muscle mass and function) or improvement (muscle strength and function). Improved muscle quality could occur if the participants received personalized nutrition intervention through a professional nutrition educator (eg, a dietitian). The personalized intervention could help them meet their protein needs and adjust their diet for their conditions. Countries tend to have different medical environments and standards of care.[70] Therefore, the study's result may not apply to different medical conditions in different countries. On the other hand, it could be ideal for the country's standard of care to be included in the study, so the readers know potential outside factors affecting the outcome. The studies that revealed muscle outcome improvements were seen in sedentary, sarcopenic, dyspneic, and prefrail or frail participants. This fact indicates that this study area could have more of an impact on compromised than healthy people. Further studies should be conducted to confirm or deny this fact.

In the six studies that included exercise and only supplementation, the supplements differ in type, dose, frequency, ingredients, and distribution across the studies. Dietary protein requirements are higher in senior adults.[47] Unfortunately, most senior adults do not reach their daily requirements.[71] Therefore, before the study starts, researchers should review their participants to see if they are meeting their recommended protein intake and if their baseline protein intake is sufficient. In the included studies, whether the participants consumed sufficient or insufficient protein before the study is unknown. This data could strengthen the nutrition intervention by personalizing supplementation or food intake to the participant's needs.

Additionally, the recommendations for sarcopenia prevention and intervention for senior adults vary from 1–1.5 g/kg/day combined with regular exercise.[48] Only one study[59] tried to meet this recommendation by adjusting total protein intake to at least 1.2 g/kg/day by a nutritionist at the beginning of the study and increasing the participant's protein intake throughout the intervention. This study showed improved muscle quality individually but not between groups. This study's result could be due to the source or quality of protein being provided to or consumed by the participants. Protein-rich whole foods (eg, lean red meat) are starting to be used in research over protein supplements to promote MPS in senior adults.[72] Only one study[68] provided combined food (skim milk powder and mixed nuts) with different supplementations (fish oil and Oxxynea FP) to reveal muscle strength and function improvement. Therefore, based on these findings, food combined with supplementation or food alone could positively affect muscle quality.

Lastly, the timing of protein intake could be another factor. The International Society of Sports Nutrition (ISSN) position stand recommends post-exercise high protein ingestion (immediately to 2 hours) to stimulate muscle growth.[73] Only two studies[59,63] recommended consuming their supplement after their exercise intervention. However, both studies did not improve muscle quality. The reason could be that either the participant did not consistently follow the instructions or the amount of protein consumed did not meet the participant's needs. Additionally, consuming 20–40 g of high-quality protein doses based on 0.25–0.40 g/kg body is ideal per ISSN.[73] Those two studies provided either 8 g of protein[63] or a protein intake of at least 1.2 g/kg/day.[59] The 8 g of protein did not provide adequate protein post-exercise intervention, while the other study did not report how much protein was provided post-exercise intervention. Therefore, further studies are needed to assess protein intake before the intervention and establish protein type, amount, and timing. Additional benefits for senior adults whose daily protein intakes are sufficient or insufficient based on their baseline intake should be investigated.

Three studies provided only nutrition education with their exercise intervention. The education was given sporadically. One study[61] had education provided once every four weeks through PC, but what was explicitly discussed and who provided the education needed clarification. The other two studies[64,67] had "buddies" provide nutrition education during each session two days/week. All three studies had mixed results regarding muscle quality. They did not reveal if a professional expert (eg, a dietitian) was used in their intervention which could have compromised the education. The researchers employed trained non-professional volunteers as the "buddies" to assist the senior adults and implement the

intervention. Such intervention efforts could have been compromised due to a lack of professional expertise. The "buddy" also felt that their role as the intervention's supervisors was not always positively considered by the senior adult.[46] Therefore, further studies are needed to provide nutrition professional-led or approved education with appropriate training for those who provide the education for home-based exercise and nutrition intervention to see if both could positively affect muscle quality. Further research should also evaluate how an improved training program for the "buddy" impacts senior adults.

Two studies provided only nutrition counseling with their exercise intervention. One study[60] provided nutrition counseling one day/week for 10 minutes and a leaflet for nutrition management. Who provided the counseling was not disclosed, but the researchers did state that their intervention was multi-professionally designed. This study reported mixed results regarding muscle strength and function. The other study[62] delivered nutrition counseling on an app with recommendations based on the participant's diet, and recipes were given. Muscle mass did improve, but not muscle function. Bias tends to be high when participants must report their diet for a food recall, especially in apps.[74] Additionally, the food frequency questionnaire was the nutrition outcome pre- and post-intervention, which can be affected by bias. Therefore, further studies are needed on effective individualized nutrition counseling techniques and interventions to change dietary patterns positively.

Two studies provided both supplement/food and nutritional counseling/education. One study[65] provided individualized nutritional counseling and supplement (Inner Power), but who provided the counseling was not disclosed. The other study[68] provided education through customized dishware and colored meal pad, in addition to having two nutrition subgroups receiving food and supplements. This study was the only one that improved all their outcomes (muscle strength and function) for the exercise and nutrition intervention group. The study revealed that a tailored exercise intervention based on participants' capabilities, visualized and interactive education, and combining food and supplementation could show promising positive effects on home-based exercise and nutrition intervention toward muscle quality. However, further studies are needed to confirm this.

## Conclusion

Thirteen intervention studies were evaluated using home-based exercise training and nutrition intervention to improve muscle quality in senior adults. This study area is in its novelty since all but one study was published within the past five years. The findings revealed mixed results in most studies but highlighted its potential as a strategy for preventing and managing sarcopenia. Resistance training enhanced muscle strength and mass more effectively, while multi-component programs were more effective towards muscle function. Providing equipment, like resistance bands and customized dishware, with handouts or a food diary to use at home amplified muscle outcomes. Longer duration and individualized programs with specific instructions were more effective than shorter, generalized exercise interventions. Providing nutrition education and a combination of food and supplement did show improvement in muscle outcomes instead to consuming protein or amino acid supplements alone. Further testing of biomarkers is needed since recent studies are limited.

However, the current evidence has many gaps (eg, blinding; low-to middle-income countries; short study duration; population type; and the type, dose, frequency, ingredients, and distribution of the nutrition intervention) to be addressed before confidently recommending this intervention to prevent and manage sarcopenia. Nevertheless, since this review addressed multiple knowledge gaps, strengths, and limitations in this growing field, it can be a starting point to help build future designs and interventions.

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## Disclosure

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