INFOGRAPHIC

Exercise training as a cornerstone intervention for sarcopenia: a review

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Purpose of review
A loss of muscle mass and strength with aging may reflect a generalized and progressive disease known as sarcopenia. Mounting evidence shows that sarcopenia is associated with poor health outcomes in older adults. Currently, no specific drugs are approved for the treatment of sarcopenia. In this context, exercise training has emerged as a cornerstone non-pharmacological strategy to disease management. This narrative review synthesizes evidence on the effects of exercise training on muscle strength, muscle mass, and physical performance in sarcopenic older adults published recently (from 2024 onward).

Recent findings
Overall, the literature consistently supports resistance training as the primary exercise modality to combat sarcopenia in older adults with formal diagnosis, with multicomponent programs (i.e., involving aerobic exercises and eventually other exercise types, such as balance) offering additional clinical benefits. Novel approaches, including home-based, technology-assisted, and remotely delivered interventions, combined with traditional exercise modalities further expand the range of feasible strategies.

Summary
Important challenges remain in translating research findings into clinical practice. Continued advances in the definition and operationalization of sarcopenia, alongside well-designed and adequately powered clinical trials, will be essential to refine evidence-based exercise recommendations and to support their effective implementation in real-world settings.

Graphic abstract
http://links.lww.com/COCN/A38

Keywords
aging, exercise, sarcopenia

INTRODUCTION

The term sarcopenia – derived from the Greek words sarx (flesh) and penia (poverty) – was introduced in the 1980s by Dr Irwin Rosenberg to describe age-related loss of skeletal muscle mass [1]. Sarcopenia has since emerged as a recognized progressive musculoskeletal disease marked by the decline of muscle mass and function associated with aging [2▪]. The disease is common among older adults, in settings ranging from community living (~10%) to hospitalized patients (~23%) and long-term care facilities (~38) [2▪]. Sarcopenia significantly contributes to the loss of functional ability and quality of life, and is associated with an increased risk of adverse outcomes such as mobility and balance impairment, cognitive decline and dementia, falls, frailty, hospitalization, loss of autonomy, and death [2▪].

There are no specific drugs approved to treat sarcopenia [3]. However, many studies have shown the impact of behavioral factors and clinical interventions in counteracting the harmful effects of

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KEY POINTS

- Exercise training as a central behavioral strategy for the management of sarcopenia.
- Evidence supports resistance training as the cornerstone of exercise-based intervention.
- Multicomponent programs appear to provide additional clinical value by addressing the multifactorial nature of sarcopenia.
- Home-based programs, and technology-assisted or remotely delivered interventions are emerging approaches that further expand the range of feasible strategies for tackle sarcopenia in diverse clinical and community settings.

sarcopenia in older adults. In this context, physical activity and exercise are considered essential strategies for both preventing and treating many geriatric syndromes and chronic diseases, including sarcopenia [4▪,5,6▪▪]. Observational studies have found that higher physical activity levels are associated with better muscle health and functional performance [7]. Systematic reviews and randomized trials suggest various exercise modes can improve sarcopenia-related outcomes in healthy older adults with signs of muscle weakness, and mobility and balance impairments) [6▪▪,8]. Accordingly, the central question has shifted from whether exercise is beneficial to how exercise interventions can be optimized for older adults with established sarcopenia diagnosis (e.g., reduced muscle strength and mass).

In recent years, emerging studies have explored novel approaches aimed at enhancing the effectiveness, feasibility, and scalability of exercise-based interventions in this population [4▪,6▪▪,9]. Given the rapid expansion of this literature, a focused synthesis of recent evidence is warranted to highlight contemporary advances and identify future directions for exercise-based strategies specifically targeting older adults with sarcopenia. This mini review aims to presenting the novelties regarding the effectiveness of exercise training on muscle strength, mass and function in sarcopenic patients.

METHODS

Although a systematic review is out of the scope of this narrative review, in order to avoid losing important articles in this field, we performed a search in PubMed on January 2026. Eligibility criteria followed the PICO framework, defining the Population as adults $\geq$65 years with sarcopenia, the Intervention as exercise programs, the Comparator as control conditions (e.g., wait-list, usual care, active controls, etc.), and the Outcomes as muscle strength, muscle mass, and functional performance, with additional health-related outcomes collected when available. Our inclusion criteria were a) randomized controlled studies published in English. Given our aim to provide a synthesis of the "novelty" exercise interventions in this field, we restricted our search to capture relevant hits published in the past 18 months (Supplemental Material, Table 1, http://links.lww.com/COCN/A37). For this purpose, scope and narrative reviews, study protocols, cross-sectional and longitudinal cohorts, acute experiments as well as studies involving animals models were excluded.

We conducted an initial search to identify key terms, followed by a comprehensive database search and reference list screening. The search strategy combined "Exercise," "Sarcopenia," and "Older adults." Study selection was performed in two stages (title/abstract and full-text) by B.R.C. using predefined eligibility criteria. Relevant systematic reviews were also scrutinized (Supplemental Material, Table 2, http://links.lww.com/COCN/A37). Data were extracted using a standardized a form in Excel that capturing study characteristics, interventions, outcomes, and key findings. This approach helped to ensure as much as possible a comprehensive and methodologically rigorous synthesis of the existing literature.

Establishing terminology

The operational definition of sarcopenia has been a topic of intense debate over the past decades. It has culminated in the publication of several consensus statements [2▪,10], recognition as a disease in the International Classification of Diseases, Tenth Revision, with a diagnosis code, and the recent collaborative effort of the Global Leadership Initiative in Sarcopenia (GLIS) to establish a universal definition and operationalization [11▪]. Currently, the term sarcopenia refers to a progressive and generalized skeletal muscle disorder involving the accelerated loss of muscle mass and function that is associated with negative health-related outcomes [10]. In terms of etiology, sarcopenia occurs when age-related processes are the major drivers of muscle loss despite minor comorbidities (primary sarcopenia) or due to specific diseases, disuse, or malnutrition that amplify muscle decline beyond the usual effects of aging (secondary sarcopenia). Physical activity is an umbrella term for any bodily movement produced by skeletal muscles that results in energy expenditure [12]. Exercise training is a specific subset of physical activity characterized by planned, structured, and

repetitive movements [4▪]. The two main types of exercise are: aerobic training and resistance training (RT). Aerobic training includes activities like brisk walking, running, or cycling; generally involving activities that elevate the heart rate for extended periods, leading to increased oxygen consumption and promoting overall cardiometabolic health and functional performance. RT involves exercises with external or body-derived loads, such as weightlifting, resistance/elastic bands, or bodyweight movements. It requires muscles to hold or work against an opposing force, which can stimulate muscle strength, power, hypertrophy, functional performance, and metabolic health. In sarcopenia, while physical activity helps prevent and manage the condition, its effectiveness depends on type, intensity, frequency, and duration.

RESULTS AND DISCUSSION

A total of 2066 records were identified through database searching in the past 18 months. After removing 2020 records that did not meet initial screening criteria, 46 full-text articles were assessed for eligibility. Of these, 37 were excluded for not meeting the inclusion criteria, resulting in 9 studies. Most studies were conducted in China ($n = 5$), followed by Thailand ($n = 2$); The others were delivered in Brazil ($n = 1$) and South Korea ($n = 1$).

Recent advances in exercise-based interventions for the management of sarcopenia

The cornerstone of sarcopenia management lies in effectively stabilizing or mitigating the progressive decline of physical performances by improving muscle strength and mass. Since the groundbreaking work led by Fiatarone *et al.*[13], demonstrated the potential of RT to reverse functional deterioration in very old adults, mounting evidence from systematic reviews have confirmed the benefits of exercise on muscle strength, body composition, functional mobility, as well as sarcopenia consequences (e.g., falls risk, mobility disability, hospitalization, etc.) [4▪]. A recent study by Sanchez and colleagues [6▪▪] of 28 trials involving over 2500 older adults (diagnosed with sarcopenia demonstrated that RT, and gait- and posture-based programs were most used and that exercise overall improved physical performance and muscle strength. RT produced the largest gains, while aerobic and power-based training showed limited effects, with age and sex influencing responses and women showing slightly greater improvements than men.

It is well-recognized that RT-induced benefits can be optimized by the proper manipulation of the variables that make up the training sessions [14]. Weekly frequency of RT is one such variable that plays a prominent role in the structuring of RT programs because it affects the recovery intervals between exercise sessions and, consequently, the volume and intensity of training [14]. Understanding the effects of weekly frequency on different health parameters can simplify prescriptions, enhance benefits, as well as improve adherence to RT programs, particularly among individuals that often carriers of health issues and comorbidities, as example of sarcopenic patients. Recently, Dos Santos *et al.*[14] compared the effects of 12 weeks of RT performed twice vs. three times weekly in 40 community-dwelling older women with sarcopenia. Using a regional definition based on appendicular skeletal muscle mass and strength, both groups completed identical free-weight and machine-based programs [1 set of 10–15 repetitions, with initial loads roughly 60% one repetition maximum (1RM), rest intervals were 1–2 min between sets and 2–3 min between exercises; sessions lasted roughly 60 min]. Both groups increased 1RM total muscular strength, lean muscle mass, and improved muscle quality, with no differences between groups and no changes in total serum IGF-1 and testosterone. This findings suggest that lower weekly frequency of RT can be as effective as a higher frequency in improving muscular outcomes in sarcopenic older women.

In recent years, an increasing number of studies have explored novel exercise-based approaches to address sarcopenia and its adverse consequences in older adults with established disease. Given the multifactorial nature of sarcopenia, interventions integrating two or more components – commonly referred to as multicomponent or multimodal training – have gained prominence due to their potential to enhance clinical outcomes.

One large-scale study stand out for their sample sizes, multicenter designs, extended follow-up, and clinically meaningful outcomes: the SPRINTT [8] project (Sarcopenia and Physical fRailty IN older people: multi-componenT Treatment strategies).

The SPRINTT project was an ambitious initiative conducted across 16 clinical sites in 11 European countries ($n = 1519$). The trial aimed to determine whether a multicomponent intervention – consisting of physical activity (PA) supported by technology and nutritional counseling – could prevent mobility disability in older adults with physical frailty and sarcopenia (defined by low functional status [SPPB score 3–9], low appendicular lean mass, and the ability to walk 400 m independently). Participants in the multicomponent group ($n = 760$) received personalized nutritional counseling and engaged in moderate-intensity PA twice weekly at center

facilities, along with up to four weekly home-based sessions. Control participants (n = 759) received monthly healthy-aging education. Interventions and follow-up lasted up to 36 months. The results showed that among those with SPPB scores of 3–7, the multicomponent intervention reduced the risk of mobility disability by 22% compared with controls. Analyses of sarcopenia-frailty outcomes indicated between-group differences of 0.8 points at 24 months and 1.0 points at 36 months, favoring the multicomponent intervention. Declines in handgrip strength at 24 months were smaller among women in the intervention group than among controls, and women in the intervention group lost 0.24 kg and 0.49 kg less appendicular lean mass than controls at 24 and 36 months, respectively.

Recently, Liu *et al.*[15] evaluated a 12-week graded, home-based resistance program combined with aerobic walking in 86 community-dwelling older adults with sarcopenia. Intervention group performed progressive functional exercises ranging from bodyweight exercises to the addition of external loads for the upper and lower limbs. Participants received initial instruction, training materials, and technique checks prior to progression. The aerobic component consisted of a walking program targeting a predefined step goal. Physical fitness, body composition, and quality of life were assessed at baseline and after completion of the 12-week intervention. The intervention significantly improved muscle strength, balance, flexibility, and cardiorespiratory fitness, while body composition and quality of life were unchanged. These results reinforce the value of multicomponent interventions for preserving mobility and functional performance in sarcopenic older adults.

Our literature search also identified three studies [16–18] that compared the effectiveness of alternative regimes with traditional RT for improving muscle strength, body composition, functional performance, and health-related outcomes. Zhang *et al.* [17] randomized 21 older adults with sarcopenia [Asian Working Group for Sarcopenia (AWGS criteria)] to 12 weeks of low-intensity RT with blood flow restriction (LRT-BFR) or conventional RT. The LRT-BFR protocol consisted of three sets of 30–15–15 repetitions per exercise at 20–30% of 1RM using elastic bands, with limb occlusion pressure set at 50% of individualized LOP via Doppler ultrasound. The conventional RT protocol involved three sets of 15 repetitions at 60% 1RM for weeks 1–4, progressing to three sets of 12 repetitions at 65% 1RM for weeks 5–8, and three sets of 10 repetitions at 70% 1RM for weeks 9–12. Both interventions improved body composition, functional performance, cardiovascular risk markers, blood biomarkers, and quality of life. Conventional RT showed greater gains in lean mass and SPPB scores, but between-group differences were not significant.

In a second study, Zhuang *et al.*[18] compared 12 weeks of whole-body vibration training (WBVT) with RT in 27 older women with sarcopenia. Both groups trained three times per week for 12 weeks. The WBVT group performed 10 sets of 1-min vibrations on a vertical platform (12 Hz, 4 mm) with knees flexed at 30°, while the RT group completed seven progressive elastic-band exercises at 60–70% 1RM. Both groups demonstrated improvements across body composition (e.g., body weight, body mass index, body fat %, and appendicular skeletal muscle mass index measured by BIA), muscle strength (e.g., knee extension strength), physical performance (e.g., gait velocity, chair stand, SPPB), blood biomarkers (e.g., growth hormone, follistatin and creatine kinase) and quality of life (e.g., SF-36). Additionally, between-group analyses revealed superior gains in knee muscle strength and physical quality-of-life scores in the RT group compared with the WBVT group.

The third study was conducted by Wu and colleagues [16] and assessed the efficacy of Baduanjin Exercise (BE) on physical performance 90 patients with sarcopenia. BE is a widely practiced form of traditional Chinese exercise that combines breathing, body movement, meditation and awareness. In this trial, participants were randomly assigned to 24-weeks of traditional RT or BE protocol. Both groups received a short health education session weekly, focusing on nutrition and exercise for sarcopenia management. The BE consisted of 60-minute sessions, three times a week led by a qualified BE coach and included 10 min of warm-up with preparatory movements, 40 min of BE (8 movements), three sets with 1 min rest; and 10 min of cool down. The RT program had the same duration and frequency and included five whole-body resistance exercises (wall squat, wall push-up, forward lunges, reverse triceps push-up, wall supported calf-raise) performed within 3 sets of 10 repetitions and 2 min between sets. The results demonstrated favorable benefits for BE compared to RT on SPPB total score and the lower limb and gait speed component, as well as lean mass and grip strength.

Innovative approaches that combine digital health applications or virtual reality with well-established exercise protocols have also received growing attention as promising strategies for sarcopenia management. An *et al.*[19] examined the effects of a mixed reality-based physical therapy (Mr.PT) platform on quadriceps muscle thickness, balance confidence, activities of daily living, and quality of life (QoL) in older adults with sarcopenia. Thirty

participants aged ≥60 years were assigned to either a conventional therapist-led program or the Mr.PT intervention, which delivered adaptive, interactive functional and cognitive tasks via a head-mounted display with real-time feedback. Sessions lasted 30 min, five times per week for four weeks. The Mr.PT group showed significantly greater improvements in quadriceps thickness and QoL, while both groups improved in balance confidence and daily functioning.

Other studies conducted in Thailand [20,21] and China [22] have similarly reported positive outcomes from combining virtual reality and digital health approaches with traditional exercise modalities. Chitjamnogchai *et al.*[20] demonstrated that 12 weeks of home-based virtual reality aerobic exercise combined with resistance exercise improved cardiorespiratory fitness. Likewise, Yuenyongchaiwat *et al.* [21] showed that home-based virtual reality aerobic exercise combined with resistance training improved muscle mass, muscle strength, and physical performance, while also reducing depressive symptoms in older adults with sarcopenia. In addition, Zhang *et al.* [22] compared a home-based digital rehabilitation program with traditional, therapist-supervised rehabilitation in older adults with sarcopenia. Both groups performed the same RT targeting major upper- and lower-body muscles. The telerehabilitation group received an initial in-person instruction session, then completed the program at home via a smartphone app with individualized protocols, videos, and resistance bands, while the in-person group attended supervised hospital sessions. After four weeks, the remote program effectively improved muscle strength, balance, and instrumental activities of daily living (IADL), with outcomes comparable to supervised rehabilitation..

In general lines, evidence suggests that telerehabilitation and virtual reality-based interventions, when combined with individualized exercise programs, show promise as accessible and potentially effective strategies for sarcopenia management. Their interactive and feedback-driven features may enhance adherence, engagement, and training fidelity, especially among individuals with limited access to supervised rehabilitation or traditional exercise facilities.

Study limitations and knowledge gaps

Exercise training remains a cornerstone strategy for sarcopenia management. However, the interpretability and generalizability of findings are limited by methodological and conceptual shortcomings. Common issues include combining pre-sarcopenia and sarcopenia phenotypes; insufficient control of confounders such as small sample sizes, sex proportion among groups of interest, possible presence of shared comorbidities as well as lifestyle factors (e.g. low protein intake, sedentary lifestyle, etc.) may play a role in cases where intervention shows limited or no improvements; inadequate reporting of training variables, which restrict dose–response interpretation and mechanistic insights; despite current evidence reinforce the potential of multimodal interventions to combat sarcopenia, the nature preclude properly determine the isolated/direct effects of exercise training protocols; trial design limitations, including suboptimal blinding and variability in control groups, raise concerns about internal validity and effect magnitude; it is worthy mentioned that the majority of study included participants with sarcopenia but with health relatively preserved. Participants characteristics (healthy vs. multimorbidity) and settings (community-dwelling vs. Institutionalized) may also play a significant role in training responsiveness; and last, but not least, most trials were originated from Asia, which might have influence on study outcomes given that Asian people have a different body composition and different cut offs for muscle mass may be required to diagnose sarcopenia. Altogether, although exercise interventions yield benefits, robust, evidence-based prescriptions for sarcopenic populations are still lacking.

Current exercise recommendations for management of sarcopenia

Current international guidelines indicate that exercise prescription for older adults with sarcopenia should be anchored in RT (Fig. 1), as it consistently improves muscle strength and physical performance, and, to a lesser extent, muscle mass. RT programs should include appropriate equipment (e.g., machines, free weights, elastic bands), delivery method (e.g., supervised, home-based, remote), target muscle groups, number of exercises, weekly frequency, sets and repetitions, intensity monitoring, rest periods, movement tempo, contraction emphasis, and proper technique, while considering individual tolerance, comorbidities, and functional status. Adherence to training principles such as specificity and progressive overload is essential to ensure safety and meaningful adaptations.

Beyond RT, multicomponent programs integrating aerobic, balance, and functional exercises may offer additional benefits. Muscle power–oriented training, with faster concentric actions at moderate loads, is also recommended due to its association with functional performance and daily activities. Although no sarcopenia-specific RT prescription exists, a gradual, tailored progression is advisable. Future studies are needed to identify the most effective exercise

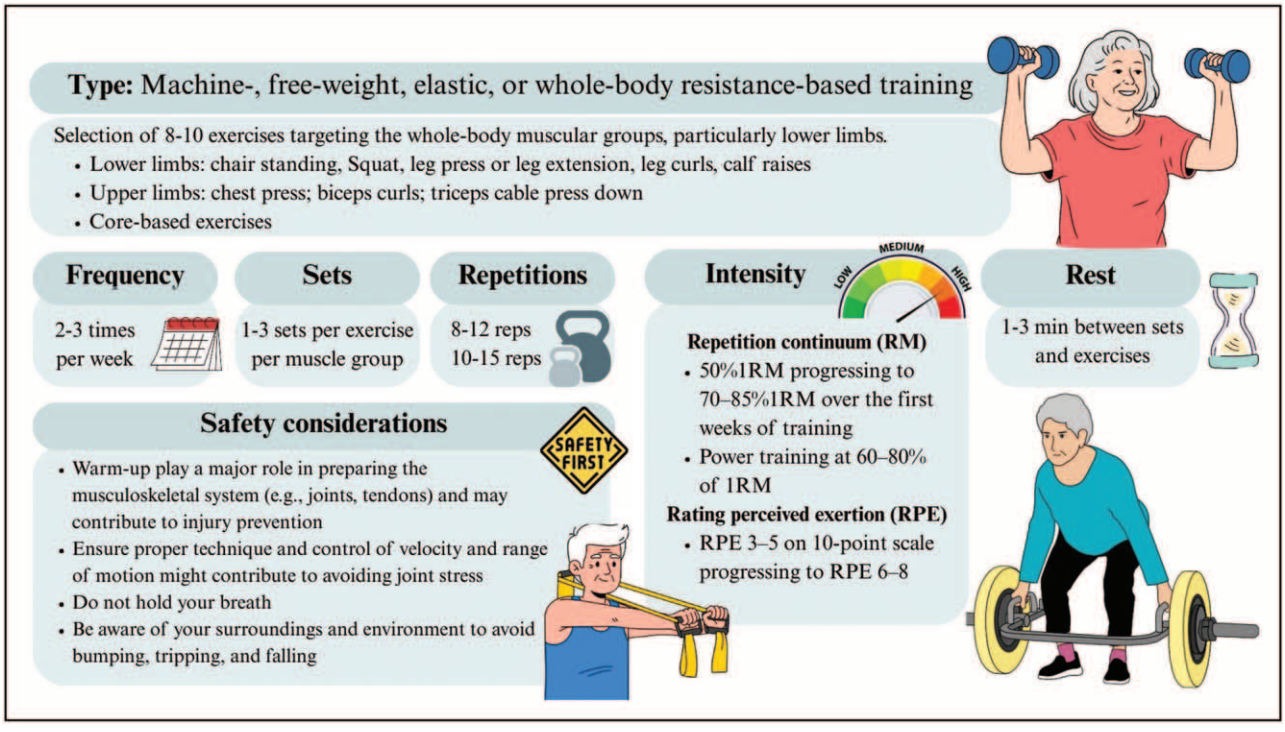

FIGURE 1. Summary of resistance training recommendations for older adults.

prescriptions (e.g., FITT-VP approach) for this population.

CONCLUSIONS AND FUTURE DIRECTIONS

This narrative review examined the role of exercise training as a central behavioral strategy for the management of sarcopenia in older adults. Collectively, the available evidence supports resistance training as the cornerstone of exercise-based interventions, with consistent benefits on muscle strength, physical performance, and, to a lesser extent, muscle mass. Multicomponent exercise programs, particularly those integrating resistance, aerobic, balance, and functional exercises, appear to provide additional clinical value by addressing the multifactorial nature of sarcopenia and its downstream consequences, including mobility limitation and fall risk. Emerging approaches such as home-based programs, and technology-assisted or remotely delivered interventions further expand the range of feasible strategies for diverse clinical and community settings. This preliminary evidence suggests that combining these approaches with exercise may be effective to promote muscle strength and function in sarcopenic older adults, however, more studies are necessary to confirm such findings.

Future research should prioritize adequately powered randomized trials with rigorous methodological standards, transparent reporting of exercise protocols, and integrated approaches that consider biological, nutritional, and contextual factors. Ongoing advances in the definition and operationalization of sarcopenia, particularly through initiatives such as the GLIS, are expected to facilitate greater consistency in study populations and outcomes. Together, these developments will be essential to refine evidence-based, clinically actionable exercise recommendations and to optimize the role of therapeutic exercise in the management of sarcopenia.

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Conflicts of interest

There are no conflicts of interest.

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