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Research Article

Exercise Mediated Reinnervation of Skeletal Muscles in Geriatric Patients - A Literature Review

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Abstract

Background: Sarcopenia, characterized by age-related loss of skeletal muscle mass and strength, is a growing concern affecting mobility, independence, and overall health in older adults. This review integrates findings from ten recent scholarly articles, including systematic reviews and mechanistic studies, to evaluate the impact of physical exercise, particularly resistance training, on mitigating the effects of sarcopenia.

Objective: The objective was to examine the role of various exercise interventions in maintaining or improving muscle physiology, neuromuscular integrity, and overall functional performance in aging populations.

Method: The studies reviewed employed diverse methodologies such as randomized controlled trials, biomechanical modeling, and neuromuscular junction assessments. These explored how different forms of physical activity—including multicomponent, resistance, aerobic, and balance training—affect muscle mass, strength, metabolism, motor unit remodeling, and neuromuscular junction stability.

Results: Results indicate that multicomponent exercise programs, especially those incorporating resistance training, are most effective in improving muscle strength, mass, and physical function. Resistance training alone significantly benefits muscle protein synthesis, mitochondrial function, and calcium signaling, while also stimulating neuromuscular remodeling and reinnervation.

Conclusion: The evidence strongly supports structured, consistent exercise—particularly resistance-based protocols—as a primary non-pharmacological intervention for sarcopenia. Integrating such interventions into elderly care routines can substantially delay or reverse age-related muscular and functional decline, promoting healthy aging and improved quality of life.

Keywords: Calcium Signaling; Exercise Intervention; Neuromuscular Remodeling; Sarcopenia; Exercise-Mediated Reinnervation; Aging Skeletal Muscle; Sarcopenia and Exercise; Geriatric Exercise Rehabilitation

Introduction

Age-related muscle loss, or sarcopenia, is defined by the progressive decline of skeletal muscle mass and function [1]. It's accompanied by several interrelated physiological changes, including mitochondrial dysfunction, chronic low-grade inflammation, reduced satellite (stem) cell numbers, and denervation of muscle fibres—particularly fast-twitch fibres—which leads to fibre atrophy and impaired muscle performance [2,3]. These alterations contribute directly to decreased strength, endurance, and physical independence among older individuals [4].

The neuromuscular system exhibits adaptive reinnervation: surviving motor neurons extend collateral branches to denervated fibres, re-establishing neuromuscular junctions (NMJs). This results in larger, slower motor units and clustering of slow-twitch fibres—a hallmark of aging muscle [3,5]. Central to sarcopenia is the progressive denervation of muscle fibres—a phenomenon amplified by motor neuron death or impairment [6]. This loss reduces muscle fibre innervation, compromising contractile function. However, the body possesses a compensatory mechanism: surviving

neurons sprout new axonal branches that reinnervate denervated fibres, forming enlarged motor units and thus partially preserving muscle fibre count and function [3,7].

Exercise can significantly amplify this reinnervation, enhancing NMJ integrity and mitigating sarcopenic progression [8]. Both resistance and endurance training are shown to bolster reinnervation, preserve muscle architecture, and delay functional decline [6,8,9]. Emerging evidence indicates that regular exercise can significantly enhance this reinnervation process in older adults. Both endurance and resistance training stimulate collateral axonal sprouting and promote re-establishment of neuromuscular junctions (NMJs), stabilizing muscle architecture and delaying functional decline [8,10]. Importantly, this neural plasticity complements the well-established benefits of exercise on mitochondrial health, muscle protein synthesis, and satellite cell activity [2,9]. Thus**,** exercise-mediated reinnervation presents a valuable strategy to counteract sarcopenia, preserve neuromuscular function, and support healthy aging in older adults [4,8].

Aerobic training

The following aerobic training protocol is structured to be safe, progressive, and effective for elderly sarcopenia patients, aiming to promote reinnervation and functional improvement.

Participant criteria

Inclusion

- Age ≥ 65 years
- Diagnosed with sarcopenia (based on EWGSOP2: low muscle strength and muscle mass)
- Ability to walk with or without assistive devices
- Medically cleared for moderate physical activity

Exclusion

- Uncontrolled cardiovascular or pulmonary disease
- Recent musculoskeletal injuries
- Severe cognitive impairment impeding instructions

Exercise mode and frequency

- **Exercise Type:** Aerobic
- **Preferred:** Brisk walking (indoors or outdoors)
- **Alternatives (if balance or joint issues):** Stationary recumbent cycling, Arm-leg ergometry (NuStep), Aquatic walking or water aerobics.

Frequency

4 to 5 sessions per week.

Session Duration:

- Begin with 20 minutes per session
- Progress to 40 minutes per session over 4–6 weeks

Intensity guidelines

- Target Intensity
- Moderate intensity (40–60% Heart Rate Reserve)
- (RPE) Scale
- **Monitoring Tools:** Heart rate monitor, Pulse oximeter (especially in cardiac or pulmonary-compromised patients)

Progression strategy

Progression is essential to promote adaptation while avoiding fatigue or injury.

Weeks 1–2

- 20–25 min per session at low-moderate intensity
- Prioritize establishing a consistent routine

Weeks 3–4

- Increase to 30–35 min per session
- Maintain moderate intensity
- Introduce mild intervals (e.g., 1 min brisk walk every 5 mins)

Weeks 5–6 onwards

- Target 40 min/session with intervals or terrain variation
- Increase pace gradually or include short inclines for challenge.

Objective of the Study

- To assess the effectiveness of structured exercise interventions in promoting reinnervation of skeletal muscle in geriatric patients.
- To examine the impact of exercise-mediated reinnervation on quality of life and independence in daily activities among older adults.

Materials and Methods

Study design

Literature review.

Search engines

- Pubmed
- Google Scholar
- ScienceDirect
- ResearchGate

Search year

2010 to 2025.

Inclusion criteria

- Studies published in english between 2010 to 2025
- Full text articles.

Exclusion criteria

- Articles not in English
- Studies with incomplete data or unclear outcome measures
- Studies which are not in full text articles

Study population

The targeted population includes more than 65 years of age.

Study type

- Randomized Controlled Trials (RCTs)
- Systematic and Narrative Reviews
- Cross-sectional and Longitudinal Studies
- Cohort studies

Result

The results from various published studies clearly highlight that exercise plays a significant role in promoting the reinnervation of skeletal muscle in geriatric patients. Research has shown that aging is associated with a progressive loss of motor neurons, particularly affecting type II (fast-twitch) muscle fibers. However, regular physical activity—especially long-term, high-level exercise—can induce compensatory reinnervation, where denervated fibers are reinnervated by neighbouring slow-type motor neurons. This adaptive process leads to the formation of type I fibres groupings, which help preserve muscle mass and function. In a study by Mosole., *et al*. (2022), elderly individuals who engaged in lifelong exercise showed a significantly higher proportion of slow-type fibre groupings and a reduced number of small, denervated fibres compared to sedentary counterparts. This structural preservation was accompanied by better muscle strength and reduced functional decline.

Literature Review

Author and Year	Study Design	No. of Participants	Methodology	Key Findings
Shen., *et al*. (2023)	Systematic Review and Network Meta-Analysis	7,809	Analyzed 83 RCTs comparing resistance, aerobic, balance, and multicomponent exercises for sarcopenia management in older adults.	Multicomponent exercises, especially those including resistance training, were most effective in improving muscle mass, strength, and physical performance.
Jones., *et al*. (2022)	Narrative Review	Not specified	Reviewed the effects of aging on motor unit remodeling and the influence of exercise on this process.	Exercise, especially resistance training, enhances reinnervation and helps preserve muscle function in older adults.
Distefano and Goodpaster (2018)	Narrative Review	Not specified	Explored how aging and exercise affect skeletal muscle structure, metabolism, and mitochondrial function.	Regular resistance and endurance training mitigate age-related muscle changes and improve mitochondrial health.
Coletti., *et al*. (2022)	Review Article	Not specified	Focused on how exercise influences collateral reinnervation and neuromuscular stability in aging muscle.	Structured exercise promotes neuromuscular junction stability and counteracts muscle atrophy and weakness.
Distefano and Goodpaster (2018)	Narrative Review	Not specified	Investigated the interplay between aging, sarcopenia, and exercise's effect on muscle regeneration and metabolism.	Exercise enhances insulin sensitivity, mitochondrial function, and supports healthy aging.
Jones., *et al*. (2022)	Review Article	Not specified	Examined how exercise supports motor unit remodeling in aged populations using animal and human data.	Physical activity stimulates adaptive remodeling of motor units; deeper study of molecular mechanisms needed.
Loumeaud., *et al*. (2024)	Systematic Review	Not specified	Used biomechanical modeling to analyze age-related changes in muscle structure and mechanical properties.	Aging reduces muscle elasticity; exercise helps preserve muscle architecture and function.
Dong and Maturana (2025)	Review Article	Not specified	Studied calcium channel changes in aging skeletal muscle and the modulatory effects of exercise.	Exercise improves calcium homeostasis and delays muscle contractile dysfunction in older adults.
Wang., *et al*. (2025)	Review Article	Not specified	Reviewed NMJ degradation in sarcopenia and the protective effects of resistance exercise.	Exercise supports NMJ repair and neuromuscular function, offering a strategy to manage sarcopenia.
Xu., *et al*. (2024)	Review Article	Not specified	Investigated resistance training as a countermeasure to disuse-induced atrophy in elderly individuals.	Resistance training prevents atrophy and promotes protein synthesis and muscle regeneration.

Table 1

Discussion

The findings from studies on exercise-mediated reinnervation in elderly individuals underscore the adaptive potential of the neuromuscular system, even in advanced age. Aging naturally leads to a decline in motor neurons, resulting in denervation of muscle fibers—particularly type II (fast-twitch) fibers. However, evidence indicates that consistent physical activity, particularly endurance and resistance training, promotes reinnervation by surviving motor neurons, often resulting in the transformation of denervated fibers into type I (slow-twitch) fiber groupings. This reorganization not only preserves muscle structure but also supports functional muscle performance, helping to mitigate the effects of sarcopenia and age-related decline.

The study related literature provide compelling data that lifelong high-level physical activity leads to increased type I fiber-type grouping and decreased presence of atrophic, denervated fibers. These physiological changes were associated with preserved muscle strength and reduced physical decline, demonstrating the long-term benefits of habitual exercise. Importantly, the observation of hybrid muscle fibers (co-expressing slow and fast myosin) in active older adult points to dynamic ongoing reinnervation, not just the static preservation of muscle mass.

Similarly, short-term interventions such as resistance training have shown measurable benefits. In studies involving older obese adults, resistance training significantly reduced markers of denervation (e.g., NCAM-positive fibers), and these reductions were strongly correlated with improved lower-limb strength. These results suggest that even in previously sedentary older adults, neuromuscular plasticity remains viable, and meaningful functional recovery is possible with structured exercise programs.

Despite these encouraging results, certain limitations should be considered. Most data come from observational or small interventional studies, and variability in training protocols, participant age ranges, and baseline fitness levels makes it challenging to generalize findings. Moreover, although improvements in reinnervation and muscle function are evident, the long-term sustainability of these benefits post-intervention requires further investigation. There is also a need to identify the optimal type, duration, and intensity of exercise that most effectively promotes reinnervation in different subsets of elderly populations.

The discussion reinforces the critical role of physical activity—particularly endurance and resistance training—in promoting reinnervation of skeletal muscle in aging individuals. Whether through long-term participation in sport or short-term exercise interventions, elderly patients can experience measurable neuromuscular benefits. These findings strongly advocate for the inclusion of targeted exercise programs in geriatric rehabilitation and preventive care to combat sarcopenia and support healthy aging.

5-month resistance training program in obese older adults resulted in a marked reduction in NCAM-positive fibres—indicative of decreased denervation—and these changes were closely correlated with improvements in lower limb strength (Snijders., *et al*. 2015). While satellite cell activation and fiber regrouping were not significantly altered, the neuromuscular improvements underline the efficacy of resistance training in muscle reinnervation. Mechanistic studies further support these clinical findings by indicating that exercise stimulates neurotrophic factor release, preserves neuromuscular junctions, and activates molecular pathways crucial for nerve-muscle communication. Overall, these results confirm that both chronic and short-term exercise regimens are effective in promoting reinnervation, improving muscle integrity, and counteracting sarcopenia in the elderly population.

Conclusion

Incorporating aerobic training into the treatment plan for geriatric patients offers both neuromuscular and systemic benefits. It not only enhances cardiovascular health but also supports reinnervation of skeletal muscles, helping preserve strength, mobility, and independence in aging individuals. As supported by published research, structured aerobic protocols should be an essential component of rehabilitation and preventive care strategies for older adults at risk of sarcopenia and functional decline.

To conclude, exercise goes beyond improving muscle mass in the elderly; it plays a key role in re-establishing nerve-muscle communication, maintaining mobility, and preventing functional decline. These findings reinforce the importance of integrating structured physical activity into geriatric rehabilitation programs as a non-invasive, cost-effective strategy to combat sarcopenia and support healthy aging.

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