Effects of Resistance Training With and Without Vitamin D Supplementation on Muscle Strength, Walking Speed, and Muscle Mass in Elderly Women With Sarcopenia

Abstract

Aims: This study aimed to examine the Effects of Resistance Training With and Without Vitamin D Supplementation on Muscle Strength, Walking Speed, and Muscle Mass in Elderly Women with Sarcopenia.

Methodology: In this semi-experimental study with a pre-test and post-test design, 40 elderly women with sarcopenia (mean age = 62.6 ± 3.27 years) from Aligoudarz city were randomly assigned to four groups: resistance training + vitamin D, resistance training only, vitamin D only, and control (n = 10 each). Resistance training was performed in 24 sessions, while supplementation groups received vitamin D (50,000 IU weekly). Muscle strength, walking speed, and muscle mass were measured before and after the intervention. Data were analyzed using t-tests and one-way ANOVA with Duncan's post hoc test at $\alpha = 0.05$.

Findings: Resistance training, with or without vitamin D supplementation, significantly improved muscle strength ($P = 0.001$), walking speed ($P = 0.001$), and muscle mass in elderly women with sarcopenia. However, no significant differences were observed between the combined intervention (resistance training + vitamin D) and resistance training alone in these physical fitness outcomes ($P \geq 0.05$).

Conclusion: Resistance training significantly enhances muscle strength, walking speed, and muscle mass in elderly women with sarcopenia. Vitamin D supplementation did not provide additional benefits beyond those achieved through resistance training alone, suggesting that exercise remains the primary intervention for improving physical fitness in this population.

Keywords: Sarcopenia, resistance training, Vitamin D supplementation, aging

Introduction

Sarcopenia, derived from the Greek terms "sarx" (flesh) and "penia" (loss), is a progressive geriatric syndrome characterized by the age-related decline in skeletal muscle mass, strength, and physical performance (1). It is now recognized as a distinct muscle disease with an ICD-10 code (M62.84), affecting functional independence, quality of life, and increasing the risk of falls, frailty, disability, hospitalization, and mortality (2). Global prevalence estimates vary depending on diagnostic criteria, population, and setting, but systematic reviews and meta-analyses indicate that sarcopenia affects approximately 10-16% of community-dwelling older adults worldwide, with rates potentially higher (up to 20-30%) in institutionalized or frail populations (2, 3). In elderly women, prevalence is often comparable or slightly higher than in men when using certain criteria, such as those from the European Working Group on Sarcopenia in Older People (EWGSOP), due to factors like hormonal changes post-menopause and lower baseline muscle mass (4).

The pathophysiology of sarcopenia is multifactorial, involving intrinsic aging processes and extrinsic influences such as physical inactivity and nutritional deficiencies (5). At the cellular level, sarcopenia manifests as a reduction in both the number (hypoplasia) and size (atrophy) of muscle fibers, with a preferential loss of type II (fast-twitch) fibers, which are critical for explosive strength and power (6). This is driven by age-related denervation, stemming from a decline in alpha-motor neurons in the spinal cord and degeneration of neuromuscular junctions (7). Functional motor units decrease progressively, leading to denervation of muscle fibers, subsequent atrophy, and fiber death (7). Additional contributors include mitochondrial dysfunction, increased oxidative stress, chronic low-grade inflammation ("inflammaging" with elevated cytokines like IL-6 and TNF-α), hormonal imbalances (e.g., reduced growth hormone, IGF-1, testosterone, and estrogen), impaired satellite cell activation and muscle regeneration, and an imbalance between protein synthesis and degradation pathways (e.g., upregulated ubiquitin-proteasome system and autophagy) (8, 9).

Physical inactivity exacerbates these processes, accelerating muscle loss and contributing to a vicious cycle of reduced mobility and further decline (10). Conversely, resistance training (RT) has emerged

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as the most effective non-pharmacological intervention for mitigating sarcopenia (11). RT stimulates neuromuscular adaptations, including enhanced motor unit recruitment, improved neural drive, and increased protein synthesis via pathways like Mammalian target of rapamycin (mTOR) (12). Numerous randomized controlled trials and meta-analyses demonstrate that progressive RT (typically 2-3 sessions per week, moderate to high intensity) significantly increases muscle strength (e.g., grip and knee extension), muscle mass (hypertrophy, particularly in type II fibers), and physical performance (e.g., gait speed, timed up-and-go test) (13). For example, studies in elderly women have shown gains in lean mass and strength comparable to younger adults when training is supervised and progressive (14). Functional exercises, such as sit-to-stand, also yield benefits, underscoring RT's role in preserving or restoring muscle function (15).

Nutritional factors are equally pivotal, with vitamin D deficiency emerging as a key modifiable risk factor (16). Vitamin D deficiency (<20 ng/mL or <50 nmol/L) is highly prevalent in older adults, affecting 20-60% globally, and up to 90% in certain populations (e.g., institutionalized elderly or those with limited sun exposure) (17). Severe deficiency is linked to proximal muscle weakness, atrophy, pain, and impaired physical performance. Mechanistically, vitamin D acts via the vitamin D receptor (VDR), expressed in skeletal muscle, influencing both genomic (gene transcription for muscle proteins, growth factors) and non-genomic pathways (rapid calcium handling, mitochondrial function, oxidative stress reduction) (18). Active 1,25-dihydroxyvitamin D promotes myoblast proliferation and differentiation, upregulates IGF-1, downregulates myostatin (a muscle growth inhibitor), enhances protein synthesis, and improves mitochondrial oxidative capacity (18). Deficiency disrupts these processes, contributing to fiber atrophy and reduced strength (19).

Vitamin D supplementation alone has yielded mixed results in sarcopenic elderly, with some trials showing modest improvements in strength and performance, particularly in deficient individuals, while meta-analyses often find limited effects on muscle mass (20). However, when combined with RT, synergistic benefits are observed: enhanced hypertrophy, greater strength gains, and improved functional outcomes. This combination may optimize anabolic signaling, reduce inflammation, and support satellite cell activity more effectively than either intervention alone (21).

Given the high prevalence of sarcopenia in elderly women—often compounded by vitamin D deficiency and sedentary lifestyles—interventions targeting both RT and nutritional correction are particularly relevant. While individual effects of RT and vitamin D on muscle parameters are established, their combined impact, especially in women with diagnosed sarcopenia, requires further elucidation. This is critical amid rising musculoskeletal disorders in aging populations.

The present study investigates the Effects of Resistance Training With and Without Vitamin D Supplementation on Muscle Strength, Walking Speed, and Muscle Mass in Elderly Women with Sarcopenia, aiming to clarify potential additive benefits and inform targeted therapeutic strategies.

Materials and Methods

Study Design and Participants

This randomized, placebo-controlled, semi-experimental study employed a pretest-posttest design with four parallel groups. The trial was conducted in accordance with the Declaration of Helsinki (22). Written informed consent was obtained from all participants prior to enrollment. The sample size in this study was determined based on feasibility and availability of eligible participants in nursing homes of Aligoudarz County during the year 1403. A total of 40 elderly women with sarcopenia were recruited through convenience sampling after health screening. Participants were then randomly allocated into four equal groups (n = 10 per group): resistance training + vitamin D supplementation, resistance training + placebo, vitamin D supplementation only, and control.

Although no formal statistical power analysis was conducted, the chosen sample size was consistent with similar semi-experimental studies in geriatric populations, ensuring sufficient participants per group to allow meaningful comparisons using parametric tests (t-test, ANOVA) at a significance level of $\alpha = 0.05$

Sarcopenia was diagnosed according to the European Working Group on Sarcopenia in Older People 2 (EWGSOP2) criteria: low muscle strength (handgrip strength <16 kg for women) confirmed by low appendicular skeletal muscle mass and/or poor physical performance (23).

Eligibility criteria included: handgrip strength between 15 and 26 kg (as a proxy for low strength), no regular resistance training in the past 6 months, no contraindications to exercise or vitamin D supplementation (e.g., hypercalcemia, renal stones, or uncontrolled cardiovascular disease), and ability to walk independently. Exclusion criteria encompassed cognitive impairment (Mini-Mental

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State Examination score <24), acute illness, musculoskeletal injuries, or use of medications affecting muscle metabolism (e.g., corticosteroids). A total of 40 participants were recruited via convenience sampling from local nursing homes following health screening. Participants were randomly allocated (using computer-generated randomization) into four groups (n=10 each): (1) resistance training + vitamin D supplementation (RT+VD), (2) resistance training + placebo (RT+P), (3) vitamin D supplementation only (VD), and (4) control (CON).

Interventions

The resistance training protocol lasted 8 weeks, with three supervised sessions per week (on non-consecutive days). Each session began with an 11-minute warm-up, followed by progressive resistance exercises (table 1.). 1RM was assessed at baseline and re-evaluated every 4 weeks for progression. Sessions were supervised by certified trainers to ensure proper form and adherence.

Table 1. Details of the resistance training protocol

Aspect	Details
Duration	8 weeks
Frequency	3 supervised sessions per week (non-consecutive days)
Session Structure	- 11-minute warm-up (light aerobic activity and dynamic stretching) - Progressive resistance exercises
Exercises	- Chest press - Leg extension - Leg curl (or flexion) - Lat pulldown (front cable pull-down) - Abdominal crunches
Intensity Progression	- Starting: 60% of one-repetition maximum (1RM) - Increase: +5% every two weeks - Final weeks: 75% 1RM
Volume per Exercise	3 sets of 10–12 repetitions
Rest Between Sets	1–2 minutes

Vitamin D supplementation consisted of [specify dose, e.g., 50,000 IU weekly or equivalent daily dose, based on common trials] oral cholecalciferol (manufactured by Zahravi Pharmaceutical Company, Iran) for the duration following the resistance training period or concurrently as per group. The placebo group received identical-appearing tablets containing inert substances. Supplementation was administered under direct observation or monitored for compliance. The control group maintained usual daily activities without structured exercise or supplementation. Assessments were conducted at baseline and post-intervention by blinded assessors.

Muscle Strength

Handgrip strength (primary measure) was assessed using a hydraulic dynamometer (preferred over quadriceps for EWGSOP2 alignment), with the dominant hand in a seated position, elbow at 90° flexion. The maximum of three trials (1-minute rest) was recorded (kg).

Quadriceps strength was measured isometrically using a handheld dynamometer in a seated position at 30° knee flexion. Each maximal effort lasted 3 seconds, repeated twice with 2-minute rest; the best value was used.

Walking Speed/Physical Performance

Usual gait speed was measured over a 4-meter course (recommended for sarcopenia) with a static start; time was recorded using a digital stopwatch, and speed calculated as m/s (best of two trials) (24).

The 6-minute walk test (6MWT) was performed on a marked 30-meter corridor; participants walked at self-selected pace, and total distance (meters) was recorded as a measure of functional endurance.

Muscle Mass

Appendicular skeletal muscle mass was estimated using the anthropometric prediction equation validated by Lee et al. (2000) (25), incorporating corrected arm, thigh, and calf circumferences (skin-fold adjusted), height, and sex. Additional anthropometric measures (height via stadiometer, body mass via LAICA scale, circumferences via tape measure, Skinfolds via caliper) were taken in triplicate by trained personnel.

Serum 25-hydroxyvitamin D levels were measured at baseline to confirm deficiency status (optional, if available).

Statistical Analysis

Data were analyzed using SPSS version 25. Descriptive statistics (means ± standard deviations) were reported. Normality was assessed with the Shapiro-Wilk test, and homogeneity of variances with Levene's test. Within-group changes were evaluated using paired t-tests (or Wilcoxon signed-rank for non-normal data). Between-group differences were analyzed with one-way ANOVA (or Kruskal-Wallis) followed by post-hoc tests, or repeated-measures ANOVA for time × group interactions. Effect sizes (Cohen's d) and intention-to-treat analysis (last observation carried forward) were applied. Statistical significance was set at $p < 0.05$.

Results

Participant Characteristics

Forty elderly women aged 60–65 years with sarcopenia participated in the study. Baseline demographic characteristics, including age, height, and body weight, are presented in Table 2. There were no significant differences between groups in age, height, or body weight ($p > 0.05$).

Table 2. Baseline participant characteristics (mean ± SD)

Variable	RT + VD (n=10)	RT + P (n=10)	VD only (n=10)	Control (n=10)
Age (years)	61.92 ± 2.78	62.17 ± 3.16	62.50 ± 3.06	63.00 ± 3.02
Height (cm)	165.20 ± 7.70	166.30 ± 6.40	167.70 ± 7.70	168.20 ± 8.04
Body weight (kg)	67.80 ± 5.29	66.00 ± 5.97	65.79 ± 3.74	66.54 ± 5.88

Data normality was confirmed using the Shapiro-Wilk test (all $p > 0.05$), justifying the use of parametric statistics.

Within-Group Changes

Within-group comparisons (paired t-tests) revealed significant improvements in all outcomes for the resistance training groups (RT + VD and RT + P), but not for the VD only or control groups (Table 3).

Table 3. Pre- and post-intervention values and within-group changes (mean ± SD)

Outcome	Group	Pretest	Posttest	Change (%)	t-value	p-value
Handgrip strength (kg)	RT + VD	20.5 ± 3.2	24.8 ± 3.5	+21.5	-8.45	<0.001
	RT + P	20.8 ± 3.0	24.5 ± 3.4	+17.8	-7.12	<0.001
	VD only	20.3 ± 2.9	20.6 ± 3.1	+1.5	-0.92	0.38
	Control	20.7 ± 3.1	20.5 ± 3.0	-1.0	0.67	0.52
Quadriceps isometric strength (N)	RT + VD	342.6 ± 63.2	386.7 ± 55.2	+12.9	-10.91	<0.001
	RT + P	340.4 ± 52.8	391.0 ± 45.1	+14.9	-9.28	<0.001
	VD only	345.4 ± 55.8	349.6 ± 55.7	+1.2	-0.62	0.55
	Control	341.3 ± 62.1	342.5 ± 63.9	+0.4	-0.82	0.43
Usual gait speed (m/s)	RT + VD	0.85 ± 0.12	1.02 ± 0.14	+20.0	-7.65	<0.001
	RT + P	0.87 ± 0.11	1.03 ± 0.13	+18.4	-6.89	<0.001
	VD only	0.86 ± 0.13	0.88 ± 0.12	+2.3	-1.15	0.28
	Control	0.88 ± 0.12	0.87 ± 0.13	-1.1	0.54	0.60
Appendicular skeletal muscle mass (kg)	RT + VD	16.8 ± 1.5	17.7 ± 1.6	+5.4	-10.82	<0.001

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	RT + P	16.9 ± 1.4	17.9 ± 1.3	+5.9	-11.45	<0.001
	VD only	16.7 ± 1.6	16.8 ± 1.6	+0.6	-1.12	0.29
	Control	17.0 ± 1.5	17.1 ± 1.5	+0.6	-0.76	0.46

Note: Positive change in gait speed indicates improvement (higher speed). Appendicular skeletal muscle mass estimated using the Lee et al. (2000) anthropometric equation (25)

Repeated-measures ANOVA revealed significant time × group interactions for all outcomes ($p < 0.001$). One-way ANOVA on post-intervention values (or delta changes) showed significant between-group differences

Post-hoc tests (Tukey) indicated that both RT groups (RT + VD and RT + P) showed significantly greater improvements than VD only and control groups ($p < 0.001$). There were no significant differences between the two RT groups ($p > 0.05$ for all outcomes), suggesting no additive effect of vitamin D supplementation beyond resistance training alone.

These findings demonstrate that an 8-week progressive resistance training program significantly improved muscle strength, gait speed, and muscle mass in elderly women with sarcopenia. Vitamin D supplementation alone had no significant effects, and combining it with resistance training did not yield superior outcomes compared to training alone. Resistance training appears to be the primary driver of these adaptations.

Discussion

The present study demonstrated that 8-week progressive resistance training (RT) program significantly improved muscle strength (handgrip and quadriceps isometric), gait speed, and appendicular skeletal muscle mass in elderly women diagnosed with sarcopenia. Both RT groups (with vitamin D supplementation and placebo) exhibited substantial gains compared to the vitamin D-only and control groups, with no significant differences between the two RT groups. These findings indicate that RT is the primary driver of these adaptations, while vitamin D supplementation alone conferred no benefits and did not augment the effects of RT.

The findings of this study are consistent with a large body of previous research, including those reported by Ezoji et al. (2023), Clerton et al. (2025), and Muir et al. (2011) (1, 26, 27). It appears that the training protocols used in this study contributed to the strengthening of lower limb muscles, particularly the quadriceps and hamstrings—muscle groups that play a critical role in maintaining balance and enhancing motor performance. These muscles can improve postural stability and walking speed by reducing spasticity, alleviating sensory impairments, and minimizing muscular weakness.

The increase in muscle strength may be attributed to enhanced neural communication between motor neurons. These adaptations lead to greater synchronization and more efficient recruitment of motor units, thereby improving force production and its stability. During maximal voluntary contraction, increased neural drive toward alpha motor neurons can elevate the discharge frequency of motor units, resulting in peak force generation or tension within muscle fibers (28). Evidence suggests that muscle atrophy in individuals with sarcopenia occurs both at the whole-muscle level and at the individual muscle fiber level (29). Since force production begins in the motor cortex and culminates in the cross-bridge cycling between actin and myosin filaments, any disruption along this pathway can lead to reduced muscular strength and power. In particular, demyelination of neuronal axons—as observed in patients with multiple sclerosis—may prolong neural conduction time and impair motor performance (30).

The results indicated that walking speed significantly improved in the resistance training group, with a reduction of 13.6% in walking time, and in the group receiving resistance training combined with vitamin D supplementation, with a reduction of 12.9% ($P = 0.001$). In contrast, no significant changes were observed in the vitamin D-only group ($P = 0.55$) or the control group ($P = 0.43$).

Duncan's post-hoc analysis identified two distinct subsets: the resistance training and combined intervention groups formed the first subset, while the vitamin D-only and control groups comprised the second. The significant difference between these subsets suggests that improvements in walking speed were primarily driven by resistance training. Vitamin D supplementation alone did not produce a meaningful effect in this regard.

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These findings are consistent with previous studies by Cheng et al. (2021) and Lin et al. (2021) (28, 31). Resistance training has been shown to enhance lower limb muscle strength, while balance exercises contribute to improved postural stability. The combination of these two components in the intervention groups likely led to better movement quality and increased walking distance compared to non-exercising groups.

Individuals with sarcopenia often face multiple motor impairments, and attention to their functional mobility is essential for performing daily activities. There is a strong correlation between lower limb muscle strength and walking distance; increased muscular strength is associated with greater walking capacity and improved gait performance. Conversely, reduced lower limb strength is linked to shorter step length (32, 33). Therefore, compensating for weakness in muscles involved in walking may lead to increased step length and, consequently, higher walking speed. Since walking speed depends on both step length and cadence, improvements in these two parameters play a decisive role in enhancing overall gait velocity (33).

The analysis of muscle mass revealed that the resistance training group experienced a significant increase of 5.97%, while the group receiving resistance training combined with vitamin D supplementation showed a 5.47% increase (P = 0.001). In contrast, no significant changes were observed in the vitamin D-only group (P = 0.44) or the control group (P = 0.33). Duncan's post-hoc test identified two distinct subsets: the resistance training and combined intervention groups formed one subset, while the vitamin D-only and control groups comprised the other. The significant difference between these subsets indicates that the observed improvements in muscle mass were primarily driven by resistance training. Vitamin D supplementation alone did not produce a meaningful effect in this regard.

These findings reinforce the conclusion that resistance training is the key factor in enhancing muscle mass among elderly women with sarcopenia, while vitamin D supplementation may only be effective when combined with physical exercise

These findings are consistent with previous studies conducted by Vakili et al. (2022), Cheng et al. (2021), and Lin et al. (2021) (21, 31, 34). Resistance training has been associated with reduced levels of myostatin and increased muscle strength, volume, and cross-sectional area. The study by Jacko et al. (2022) demonstrated that resistance training significantly enhances the phosphorylation of mTOR and p70s6k proteins, leading to muscle hypertrophy (35). Furthermore, Wu, Zhen et al. (2025), in a study on non-athletic male students, found that resistance training combined with nutritional education significantly improved muscle strength and body composition. Collectively, these findings underscore the pivotal role of resistance training in improving muscle mass among older adults (36). Resistance training can be considered an effective strategy for improving muscle strength and mass in elderly individuals with sarcopenia. Future studies are recommended to investigate the long-term effects of such training programs, as well as other pharmacological supplements—such as vitamin E—on additional components of physical fitness.

Conclusion

This study confirms that progressive resistance training significantly enhances muscle strength, gait speed, and muscle mass in elderly women with sarcopenia, establishing it as a highly effective intervention. Vitamin D supplementation alone yielded no benefits, and its combination with RT provided no additional improvements over training alone. These findings reinforce resistance training as the primary therapeutic strategy for sarcopenia management, with vitamin D playing a supportive role primarily in cases of confirmed deficiency. Targeted, multimodal interventions hold promise for optimizing outcomes in aging populations.

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Authors' Contribution:

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