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Original Article

Evaluation the Outcome of Resistance Training and Its Relationship with Grip Strength in Pre-Sarcopenic Elderly Individuals

Chuntao Lai [a # *], Peizhen Xian [b #], Shuixian Li [a], Zhongying Su [c], Chunlian He [d *]

[a] *Department of Rheumatology and Immunology, Wuzhou Workers' Hospital, Wuzhou, Guangxi, 543000, China,* [b] *Department of Gastrointestinal Surgery, Wuzhou Municipal Workers' Hospital, Wuzhou, Guangxi, 543000, China,* [c] *Department of Nursing, Wuzhou Workers' Hospital, Wuzhou, Guangxi, 543000, China,* [d] *Cardiovascular Zone 1, Wuzhou Workers' Hospital, Wuzhou, Guangxi, 543000, China*

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SUMMARY

Pre-sarcopenia, characterized by low muscle mass but largely preserved physical function, is a critical period for intervention. Seventy-seven older adults were assigned to 12-month resistance training (n = 40) or control (n = 37). Lean mass, fat mass, handgrip strength, and gait velocity were measured at baseline, 3, 6, and 12 months. By 12 months, the training group gained 1.2 kg total lean mass (95% CI: 0.8–1.6) with an 8.4% arm lean mass increase. Handgrip strength rose 2.1 kg (95% CI: 1.3–2.9) and correlated with arm lean mass (r = 0.68). Clinically meaningful gains (≥ 2.0 kg grip or ≥ 1.0 kg lean mass) occurred in 65% of trainees versus 22% of controls (p < 0.001). Gait velocity improved more in the training group (0.17 vs. -0.08 m/s). These findings highlight resistance training's role in preventing muscle decline and highlight handgrip strength as an accessible marker of improvement.

1. Introduction

Pre-sarcopenia is characterized by low muscle mass without major deficits in strength or function, according to the European Working Group on Sarcopenia in Older People (EWGSOP) and Asian Working Group for Sarcopenia (AWGS).[1] In a worldwide meta-analysis of 692,056 individuals aged ≥ 60, its prevalence ranges from 10% to 27%.[2] Clinically, early muscle loss can impair independence, increase fall risk, and progress to full sarcopenia.[3] Chronic diseases, malnutrition, and inactivity are key risk factors.[3,4] Addressing them through lifestyle and targeted interventions can mitigate adverse outcomes.[3]

Resistance training is crucial for managing sarcopenia and pre-sarcopenia in older adults, boosting muscle strength, mass, and performance, thus mitigating sarcopenia's adverse effects.[5,6] Both moderate and high-intensity protocols enhance muscle quality and strength.[7] Combining resistance training with nutritional support improves recovery from acute diseases.[8] A systematic review found it can reduce inflammatory markers like interleukin-6.[9] These findings highlight resistance training's role in preventing and managing sarcopenia/pre-sarcopenia. However, there's a gap in studies focusing on early or pre-sarcopenic stages, where interventions could yield the greatest preventative benefits.

Handgrip strength is a vital muscle function indicator correlated with forearm/hand mass and predictive of frailty and mobility decline.[10,11] A meta-analysis shows moderate sensitivity (72%) and specificity (70%) for mobility limitations.[11] Low grip strength also predicts higher all-cause mortality hazard ratios.[12,13] Clinically, it is simple, cost-effective, and recommended for routine geriatric assessments, serving as a practical marker of muscle function.[14]

Longitudinal studies on pre-sarcopenic older adults are limited. AWGS 2019 suggests SARC-F and calf circumference for screening, but current research used direct lean mass and grip measures for detailed insights.[15,16] Resistance training enhances grip strength and skeletal muscle mass index, varying by intensity/method.[15,17] While simpler screening is recommended, comprehensive assessments provide crucial data for effective interventions.

This study evaluates a 12-month resistance training program's effects on total, arm, leg, and appendicular muscle mass in older pre-sarcopenic adults. Additionally, it examines how changes in handgrip strength correlate with muscle mass alterations, highlighting grip strength's clinical relevance for monitoring intervention efficacy.

2. Methods

2.1. Participants

A total of 77 adults aged 60–80 with independent mobility were recruited from Wuzhou Workers' Hospital (July 2022–July 2023) and randomized into control or training groups (Random Allocation Software v2.0), using gender-stratified blocks of four. Allocation was concealed in sealed, opaque envelopes opened post-baseline. Assessments occurred at baseline, 3, 6, and 12 months. Patients were included if they were identified as having pre-sarcopenia. Patients were excluded if they had any of the following conditions: (a) uncontrolled hypertension; (b) joint contractures or internal metal implants such as total joint arthroplasty; (c) cardiovascular or pulmo-

* Corresponding author. No. 1, South Third Lane, Highland Road, Wuzhou, Guangxi, 543000, China.
E-mail address: 113878274@qq.com (C.t. Lai)
hechunlian000@163.com (C.l. He)
[#] Contributed equally to this work and share first authorship.

nary diseases; or (d) neurological impairment. All patients provided written informed consent. The study was approved by the Ethics Committee of Wuzhou Workers' Hospital (EC-2022-KY-013).

2.2. Sample size calculation

We estimated sample size to detect a 1.0 kg between-group lean mass difference (SD = 1.2) at $\alpha = 0.05$ and power = 0.80, requiring about 28 per group. Accounting for a 20% dropout, we aimed for 35 per group (70 total). Ultimately, 77 participants were recruited to ensure adequate power for the hypothesized changes.

2.3. Pre-sarcopenia definition

Following EWGSOP 2010 criteria,[1] participants with ALMI < 7.0 kg/m^2 (men) or < 5.67 kg/m^2 (women), but normal grip strength and gait speed, were classified as pre-sarcopenic.

2.4. Intervention

Participants were randomly assigned to control or training groups. Controls maintained usual activities without formal exercise or diet interventions. The training group performed thrice-weekly supervised sessions focusing on major muscle groups. Phase 1 introduced equipment, technique, and gradual intensity. Phase 2 used a single-set protocol for optimal volume. Phase 3 added dynamic, explosive movements. Phase 4 incorporated advanced techniques (e.g., supersets) to maximize muscle engagement. Certified trainers ensured safety and quality throughout.

Adherence to resistance training was calculated by the percentage of attended training sessions out of the total prescribed (three times per week). Participants were considered 'adherent' if they attended $\geq$ 75% of sessions.

The primary outcome of interest was the change in total lean mass over the 12-month period. Secondary outcomes included changes in arm and leg lean mass, handgrip strength, gait velocity, and total fat mass.

2.5. Muscle mass assessment

The detailed body composition (fat, muscle, etc.) were measured by a body composition analyzer. Participants were fast for at least 12 hours and refrained from physical exercise for 24 hours prior to analysis.

2.6. Muscular strength measurement

Muscle quality (muscle quality for the upper extremity was calculated using the ratio of handgrip strength to arm lean mass, and lower-extremity muscle quality was similarly defined as maximal quadriceps isometric strength divided by leg lean mass.

Upper extremity MQ:

$$MQ_{upper} = \frac{\text{Handgrip Strength (kg)}}{\text{Arm Lean Mass (kg)}}$$

Lower extremity MQ:

$$MQ_{lower} = \frac{\text{Maximal Quadriceps Isomertic Strength (N)}}{\text{Leg Lean Mass (kg)}}$$

2.7. Gait speed

Gait speed was determined by the time it took for the patient to walk 10 meters on a track at a self-determined pace. The speed was calculated in meters per second, providing a quantitative measure of the patient's basic locomotive function.

2.8. Statistical analysis

Values are presented as mean $\pm$ standard deviation or count (percentage). Chi-square tests analyzed categorical variables, and independent t-tests assessed continuous variables at baseline. Repeated-measures ANOVA with Bonferroni correction evaluated differences over time, adjusting for sex and baseline muscle mass. Sensitivity analyses omitting these covariates confirmed stable results for lean mass and grip strength changes. Pearson correlations examined relationships between grip strength and body composition. All participants with baseline data were included in intention-to-treat analyses, while per-protocol analyses were limited to those completing $\geq$ 75% of training sessions and follow-ups. All tests were two-tailed at $p < 0.05$, performed in SPSS (version 26.0).

3. Result

3.1. Patient demographic characteristics

Of the 77 participants randomized, 40 were assigned to the training group and 37 to the control group (Figure 1). Few dropped

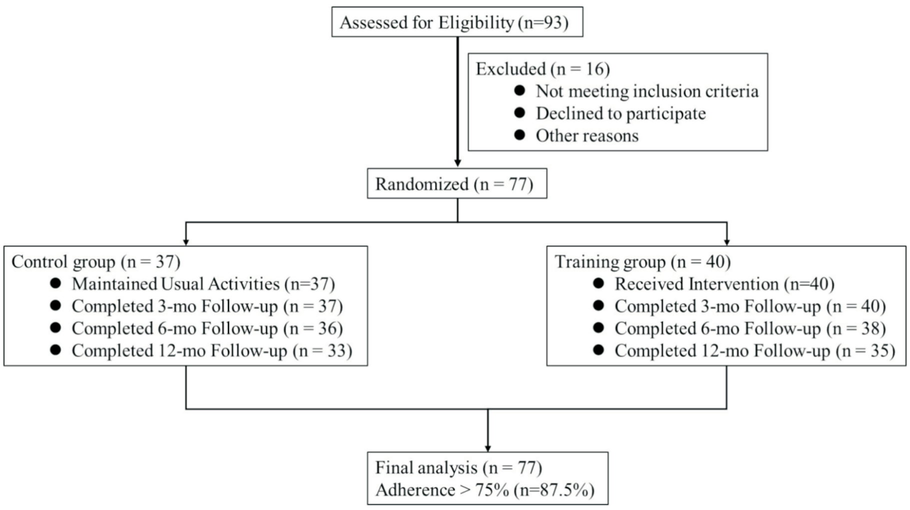

Figure 1. Flowchart of participants enrollment.

out due to health or personal issues, with imputation for missing data. Baseline demographics, anthropometric measures, body composition, and exercise frequency were similar, ensuring well-balanced groups for evaluating 12-month changes in muscle mass, strength, and functional outcomes (Table 1).

3.2. Resistance training improves body composition and muscle function in pre-sarcopenic elderly

Over 12 months, the training group reduced fat mass from 22.15 to 21.14 kg (-4.6%, between group Cohen's d = 0.55, p = 0.0039, Table 2), increased lean mass from 46.00 to 47.23 kg (+2.7%, between group Cohen's d = 0.46, p = 0.0262, Table 2), gained 2.10 kg grip strength (+7.5), and improved gait speed by 0.17 m/s (Figure 2 and Table 2), surpassing clinically meaningful thresholds. Controls showed negligible changes, confirming moderate improvements with resistance training.

3.3. Correlation between grip strength and muscle metrics in pre-sarcopenic elderly

At baseline, handgrip strength correlated with total lean mass (r = 0.46–0.50) and arm lean mass (r ≈ 0.61–0.65); at 12 months, these rose to r = 0.507 and r = 0.61–0.65, respectively (Table 3). Negative associations with fat mass (r ≈ -0.41 to -0.50) persisted, highlighting grip strength's role as a practical marker for beneficial body composition changes.

3.4. Correlation of changes in grip strength and muscle mass in the training group over time

Improvements in handgrip strength were negatively correlated with reductions in total fat mass, from r = -0.442 at 3 months to r = -0.507 at 12 months (Table 4). In contrast, positive correlations emerged between increases in handgrip strength and gains in total lean mass (r = 0.532 at 3 months, to r = 0.597 at 12 months, Table 4). Arm lean mass exhibited the highest positive correlations, reaching r = 0.683 by 12 months (Table 4). Similarly, increases in the appendicular lean mass index were associated with larger handgrip strength gains.

Several published guidelines and empirical studies support that 1.5 to 2 kg increase in handgrip strength was identified as a minimal clinically important difference in geriatric populations.[18] Similarly, gaining 1.0 kg of total lean mass and an improvement of 0.1 m/s in gait velocity are often considered significant.[19,20] Thus, we applied these thresholds to conduct a clinically meaningful

Table 2
Changes of body composition after resistance training program.

	Baseline	12 mo
Total fat mass (kg)		
Control	23.85 ± 4.75	23.81 ± 4.69
Training	22.15 ± 3.50	21.14 ± 2.96
p	0.0760	0.0039
95% CI		2.67 (-3.77, -1.57)
Cohen's d		0.55
Total lean mass (kg)		
Control	46.45 ± 2.10	46.14 ± 2.10
Training	46.00 ± 2.20	47.23 ± 2.11
p	0.3626	0.0262
95% CI		1.09 (0.32, 1.86)
Cohen's d		0.46
Arm lean mass (kg)		
Control	4.35 ± 0.32	4.24 ± 0.15
Training	4.41 ± 0.16	4.78 ± 0.07
p	0.296	< 0.0001
95% CI		0.54 (0.30, 0.78)
Cohen's d		0.62
Leg lean mass (kg)		
Control	14.11 ± 1.28	13.89 ± 1.34
Training	13.96 ± 1.74	14.50 ± 1.27
p	0.6701	0.0447
95% CI		0.61 (0.02, 1.20)
Cohen's d		0.40
Appendicular lean mass index		
Control	6.40 ± 0.45	6.26 ± 0.42
Training	6.35 ± 0.53	6.65 ± 0.34
p	0.6582	< 0.0001
95% CI		0.39 (0.24, 0.54)
Cohen's d		0.55
Handgrip-strength (kg)		
Control	28.74 ± 2.74	28.65 ± 2.41
Training	27.92 ± 2.82	30.02 ± 2.46
p	0.2003	0.0164
95% CI		2.19 (0.42, 3.96)
Cohen's d		0.43
Habitual gait velocity (m/s)		
Control	1.73 ± 0.24	1.62 ± 0.19
Training	1.70 ± 0.17	1.87 ± 0.28
p	0.5261	< 0.0001
95% CI		0.25 (0.14, 0.36)
Cohen's d		0.60

Table 1
Patient demographic characteristics.

	Control (n = 37)	Training (n = 40)	*p*
Age (years), mean ± SD	68.65 ± 6.10	66.98 ± 4.60	0.266
Sex, n (%)			0.840
Male	16 (43.2%)	18 (45.0%)	
Female	21 (56.8%)	22 (55.0%)	
Height (cm)	151.78 ± 5.75	152.85 ± 5.90	0.534
Weight (kg)	67.05 ± 8.25	63.90 ± 8.60	0.139
Body mass index (kg/m^2)	29.25 ± 3.60	27.35 ± 3.70	0.067
Body composition			
Total fat mass (kg), mean ± SD	23.85 ± 4.75	22.15 ± 3.50	0.145
Total lean mass (kg), mean ± SD	46.45 ± 2.10	46.00 ± 2.20	0.709
Arm lean mass (kg), mean ± SD	4.35 ± 0.32	4.41 ± 0.16	0.413
Leg lean mass (kg), mean ± SD	14.11 ± 1.28	13.96 ± 1.74	0.370
Appendicular lean mass index (kg/m^2), mean ± SD	6.40 ± 0.45	6.35 ± 0.53	0.107
Handgrip-strength (kg), mean ± SD	28.74 ± 2.74	27.92 ± 2.82	0.315
Exercise ≥ 1 per week, n (%)	5 (13.51%)	6 (15.00%)	0.447
Habitual gait velocity (m/s), mean ± SD	1.73 ± 0.24	1.70 ± 0.17	0.635

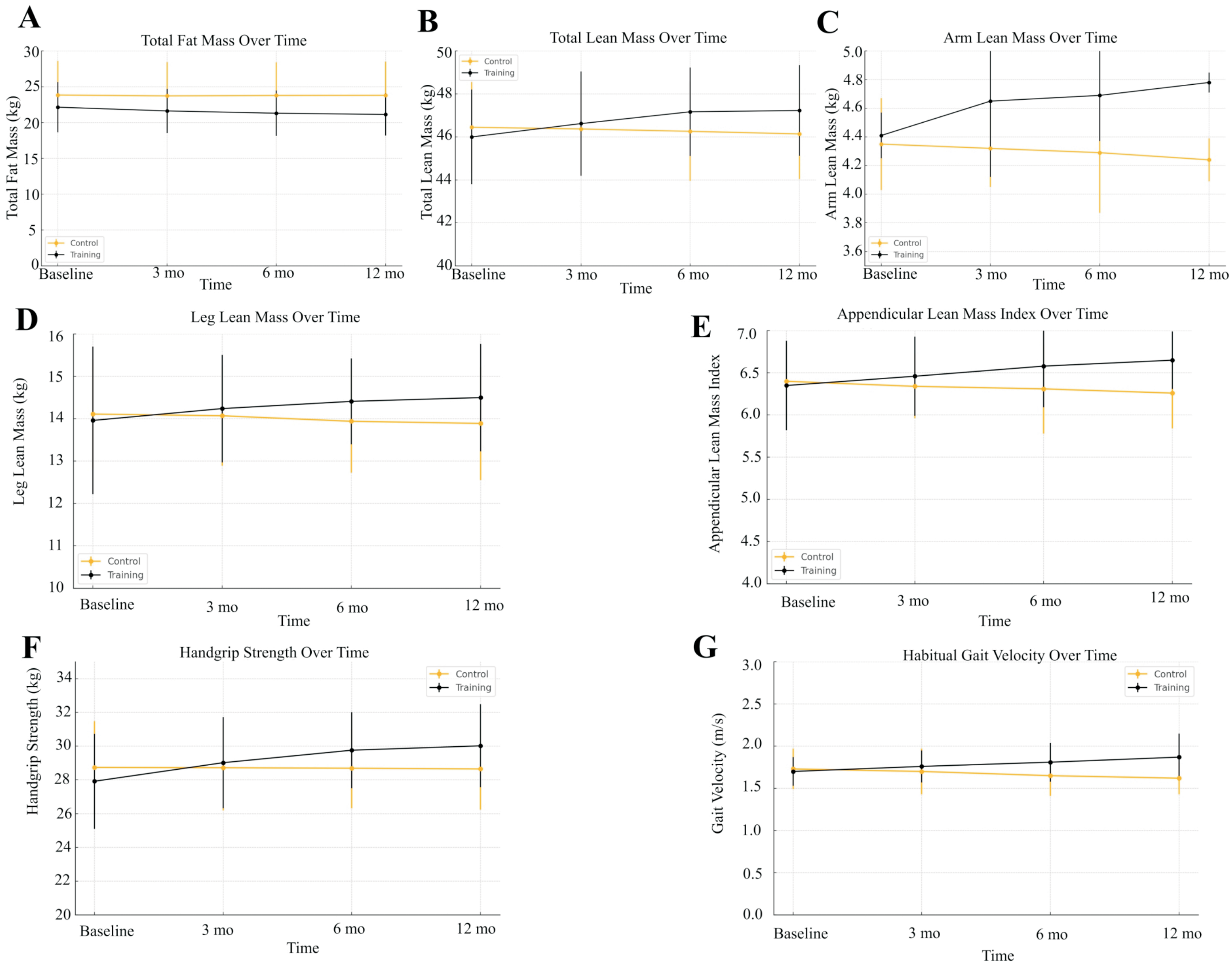

Figure 2. Total fat mass (A), total lean mass (B), arm lean mass (C), leg lean mass (D), appendicular lean mass index (E), handgrip strength (F), habitual gait velocity (G) changes in the control and training group over time

Table 3
Correlation of grip strength with muscle mass.

	Baseline [*r*, (*p*)]	3 months [*r*, (*p*)]	6 months [*r*, (*p*)]	12 months [*r*, (*p*)]
Total fat mass				
Control	-0.448 (0.0024)	-0.412 (0.0147)	-0.475 (0.0068)	-0.405 (0.0094)
Training	-0.503 (0.0031)	-0.473 (0.0084)	-0.473 (0.0065)	-0.422 (0.0121)
Total	-0.482 (0.0014)	-0.459 (0.0045)	-0.474 (0.0037)	-0.419 (0.0048)
Total lean mass				
Control	0.458 (0.0030)	0.432 (0.0140)	0.465 (0.0049)	0.462 (0.0082)
Training	0.476 (0.0022)	0.459 (0.0091)	0.484 (0.0060)	0.507 (0.0018)
Total	0.469 (0.0015)	0.445 (0.0040)	0.478 (0.0031)	0.494 (0.0025)
Arm lean mass				
Control	0.587 (0.0005)	0.651 (0.000082)	0.617 (0.0003)	0.631 (0.00005)
Training	0.650 (0.000084)	0.616 (0.0003)	0.639 (0.0002)	0.608 (0.00002)
Total	0.623 (0.00095)	0.635 (0.000076)	0.626 (0.000071)	0.616 (0.00004)
Leg lean mass				
Control	0.475 (0.0052)	0.487 (0.0043)	0.400 (0.0220)	0.467 (0.0070)
Training	0.410 (0.0180)	0.452 (0.0081)	0.424 (0.0149)	0.516 (0.0026)
Total	0.457 (0.0073)	0.468 (0.0069)	0.412 (0.0187)	0.476 (0.0059)
Appendicular lean mass index				
Control	0.517 (0.0022)	0.532 (0.0015)	0.554 (0.0010)	0.522 (0.0009)
Training	0.525 (0.0018)	0.551 (0.00008)	0.535 (0.0014)	0.619 (0.00006)
Total	0.521 (0.0020)	0.541 (0.0012)	0.547 (0.0011)	0.569 (0.00004)

r: Pearson correlation coefficient.

change analysis (Table 5). By 12 months, 65.0% of participants in the training group, compared to 10.8% in the control group achieved an increase of at least 2.0 kg in handgrip strength (Table 5). Similarly, 55% of the training group and 14% in the control group gained ≥ 1 kg lean mass, and 38% vs. 8% increased gait ≥ 0.1 m/s ($p = 0.0027$) (Table 5).

Table 4
Correlation of delta grip strength with muscle in the training group.

	Δ3 mo [*r* (*p*)]	Δ6 mo [*r* (*p*)]	Δ12 mo [*r* (*p*)]
Total fat mass (kg)	-0.442 (0.0034)	-0.493 (0.0054)	-0.507 (0.0027)
Total lean mass (kg)	0.532 (0.0053)	0.585 (0.0074)	0.597 (0.0003)
Arm lean mass (kg)	0.661 (0.00005)	0.657 (0.00004)	0.683 (0.0004)
Leg lean mass (kg)	0.527 (0.0005)	0.538 (0.0014)	0.551 (0.00003)
Appendicular lean mass index	0.563 (0.0029)	0.579 (0.0002)	0.581 (0.0005)

r: Pearson correlation coefficient. *p*: *p* value.

Table 5
Proportion of participants achieving clinically meaningful improvements at 12 months.

Outcome	CMC threshold	Control, n (%)	Training, n (%)	p-value
Handgrip strength	Increase ≥ 2.0 kg	4 (10.8%)	26 (65.0%)	0.0012
Total lean mass (kg)	Increase ≥ 1.0 kg	5 (13.5%)	22 (55.0%)	0.0053
Gait velocity (m/s)	Increase ≥ 0.1 m/s	3 (8.1%)	15 (37.5%)	0.0027

4. Discussion

Our findings reveal significant increases in total, arm, leg, and appendicular lean mass in patients receiving resistance training, alongside marked handgrip strength improvements correlating with muscle mass gains. These results suggested that resistance training substantially augments muscle strength and mass, and the strong association between grip strength and lean mass underscores handgrip strength's practicality as a monitoring tool in clinical or home settings.

We observed clinically meaningful changes in body composition and function. The training group exceeded the commonly recognized threshold of ≥ 1.0 kg lean mass gain, achieving an average of 1.23 kg,[1,21,22] alongside a fat mass reduction of 1.01 kg, while controls showed negligible fat change. Handgrip strength improvements of ≥ 2.0 kg, considered functionally significant,[23] were also achieved. Gait speed gains of ≥ 0.1 m/s, which reduce fall risk and improve mobility,[21,24] further underscore the training's benefits. The strong positive correlation between grip strength and arm lean mass aligns with established anatomical and functional links,[8] while negative correlations with fat mass highlight the importance of managing adiposity to optimize muscle function.[25]

We adopted EWGSOP 2010 criteria for pre-sarcopenia, whereas AWGS 2019 sets slightly lower cutoffs for Asian populations.[1,26,27] These adjustments could potentially reclassify a subset of participants in the current study, leading to a marginally higher prevalence of low muscle mass under AWGS definitions. Studies comparing these criteria demonstrate that while both frameworks are effective for identifying individuals at risk, the stricter EWGSOP definitions may miss some cases in populations with smaller body frames. Such differences may classify more individuals as having low muscle mass, especially near borderline thresholds.[28,29] Nonetheless, our core conclusion endures: resistance training improves muscle mass and functional outcomes, aligning with global research on sarcopenia interventions.[7,30] Thus, although AWGS 2019 could alter classification rates, the overall efficacy of resistance training remains valid regardless of diagnostic framework.

Mechanistically, gains in grip strength and upper-limb muscle mass arise from neuromuscular adaptations — heightened motor unit recruitment and muscle fiber hypertrophy.[31,32] Targeted upper-limb exercises especially benefit forearm and hand muscles, explaining the tight link between arm lean mass and grip strength. Excess adiposity can dampen these gains by increasing movement costs and reducing muscle quality.[33,34] Emphasizing both lean mass development and fat management appears vital for maximizing strength and functional improvements in older adults.

Baseline fitness and adherence strongly influence training outcomes. Individuals with higher initial fitness may show smaller proportional gains, reflecting a ceiling effect.[35] Although variability existed, our pre-sarcopenic cohort, subjected to progressively intensified exercise, generally benefited from resistance training. Moreover, high adherence rates likely contributed to the robust gains observed.[36] Long-term improvements in grip strength and gait velocity may reduce falls and mobility decline.[37]

The limitations of our current study include a relatively small, single-center sample, potentially constraining generalizability. Our use of bioelectrical impedance, while practical, may yield measurement differences from dual-energy X-ray absorptiometry. The 12-month follow-up does not clarify whether improvements in lean mass and grip strength persist or translate into reduced fall incidence over time. Evolving diagnostic criteria, such as discrepancies between EWGSOP and AWGS guidelines, could also shift pre-sarcopenia classification. Future research addressing these aspects could enhance precision and applicability in older adult populations.

In conclusion, resistance training effectively increases muscle mass and strength in pre-sarcopenic older adults. The strong correlation between grip strength and lean mass supports using handgrip strength as a simple, cost-effective measure for monitoring intervention outcomes. These findings advocate implementing resistance training in healthcare and community settings to prevent or delay sarcopenia onset, potentially reducing healthcare costs and enhancing quality of life for aging populations.

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Conflict of interest

The authors have no conflicts of interest to declare.

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