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Effect of Low-Intensity High-Repetition Versus High-Intensity Low-Repetition Elastic Band Resistance Training on Functional Physical Fitness and Myokine Levels in Older Adults

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Abstract: This study investigates the effects of low-intensity high-repetition (LI-HR) and high-intensity low-repetition (HI-LR) resistance training (RT) on functional fitness and myokines in older adults. A total of 30 participants (mean age ~76 years) were randomized into control (n = 10), LI-HR (n = 10), or HI-LR (n = 10) groups. Participants in LI-HR and HI-LR groups performed elastic band-based RT three times per week for 12 weeks. Pre- and post-intervention assessments included functional fitness (relative grip strength, sit-to-stand, 4 m walk, timed up-and-go (TUG)), ankle muscle strength, lower extremity power, and myokine levels (IL-6, IGF-1, SPARC, BDNF). Both experimental groups showed significant IL-6 reduction (LI-HR: $p = 0.033$; HI-LR: $p = 0.015$) and IGF-1 increase (LI-HR: $p = 0.003$; HI-LR: $p < 0.001$). SPARC increased significantly only in the HI-LR group ($p = 0.021$). Functional improvements were noted in TUG for both groups, while the 4 m walk improved significantly in the HI-LR group ($p < 0.001$). Body fat percentage increased in both LI-HR ($p = 0.003$) and HI-LR ($p = 0.047$). In conclusion, both LI-HR and HI-LR RT effectively enhance functional fitness and key myokines, with LI-HR emerging as a promising, accessible option for older adults.

Keywords: low and high intensity; low and high repetition; resistance training; functional physical fitness; myokines

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1. Introduction

Aging affects numerous systems in the human body; further, the concomitant decrease in muscle mass and muscle strength significantly affects the quality of life and independence of older adults [1]. Recent studies have demonstrated the role of skeletal muscle not only as a motor organ, but also as an endocrine organ that secretes various physiological substances (myokines) crucially involved in muscle growth, regeneration, metabolic regulation, and overall health [2,3].

Among the representative myokines, secreted protein acidic and rich in cysteine (SPARC) regulates muscle and fat development during the aging process. SPARC, which is secreted by skeletal muscles, facilitates muscle regeneration and growth while inhibiting fat accumulation [4]. Insulin-like growth factor 1 (IGF-1) strongly activates SPARC expression in muscle cells via the phosphatidylinositol 4,5-bisphosphate 3-kinase (PI3K) signaling pathway [5]. These myokines are crucial for preventing or improving age-related sarcopenia.

Other myokines, including interleukin 6 (IL-6) and brain-derived neurotrophic factor (BDNF), also influence muscle health, metabolic processes, and cognitive function [6–8]. For

example, IL-6 rapidly increases after exercise and is involved in immune and inflammatory responses, while BDNF contributes to neuroplasticity and improves cognition.

Secretion of the aforementioned myokines is promoted during exercise, especially resistance training (RT). However, the effects of RT on myokine levels and functional fitness in elderly individuals remain unclear. Specifically, the comparative efficacy between low-intensity high-repetition (LI-HR) and high-intensity low-repetition (HI-LR) resistance exercises in elderly individuals remains unclear. Some studies have suggested that HI-LR RT is better for increased muscle strength and muscle mass [9–11], while others have suggested that LI-HR RT is better for improvements in muscle function and daily life activities [12–14]. Contrastingly, other studies have reported no significant differences between the two approaches [15–17].

Despite these prior studies and public interest in the elderly population, the comparative efficacy of LI-HR and HI-LR RT is still unclear, especially the effect of such exercise intensity control on biomarkers such as myokines. Accordingly, this study aimed to compare the effects of LI-HR and HI-LR resistance exercises on functional fitness and myokine levels (IL-6, IGF-1, SPARC, and BDNF) in elderly individuals. In addition, we aimed to provide a better training approach to certain aspects, such as muscle strength and muscle mass in older persons, identify the optimal RT protocol for improving the overall quality of life, and provide a scientific basis for the prevention and management of age-related sarcopenia.

2. Materials and Methods

2.1. Study Design and Participants

This is a quasi-experimental intervention study with group of adults over 65 years old in Incheon, South Korea. We only included participants who did not live in a nursing home facility and lacked serious illness, disability, or physical activity-related problems. The required sample size was calculated to be 31 participants, with an effect size (f) of 0.35, an α level of 0.05, and a power (1-ß) of 0.80, yielding an actual power of 80.4% (G*Power 3.1.9.7, Heinrich-Heine-University Düsseldorf, Germany). To account for potential dropouts, 36 participants were eventually included. Included participants were classified into three groups: control (CON), low-intensity high-repetition (LI-HR), and high-intensity low-repetition (HI-LR) using computer-generated random numbers. Two subjects in the CON group dropped out due to frequent absences and one each in the LI-HR and HI-LR groups due to musculoskeletal pain during the experiment. Thus, 30 people participated in the study. Figure 1 shows the overall schematic. The inclusion criteria were as follows: (i) male and female, aged 65 years, (ii) systolic blood pressure $\leq$ 139 mmHg and diastolic blood pressure $\leq$ 89 mmHg, (iii) ability to ambulate independently, no history of severe cardiovascular disease, chronic kidney disease, or stroke within the past year, and (iv) not engaged in regular aerobic and resistance exercise within the past six months. In addition, overall food intake was not controlled, but diet was restricted from 8 p.m. to 6 a.m. the following morning. All participants, including caregivers or family members, were informed of the purpose, design, benefits, and risks of injury. Subsequently, they voluntarily provided informed consent for participation.

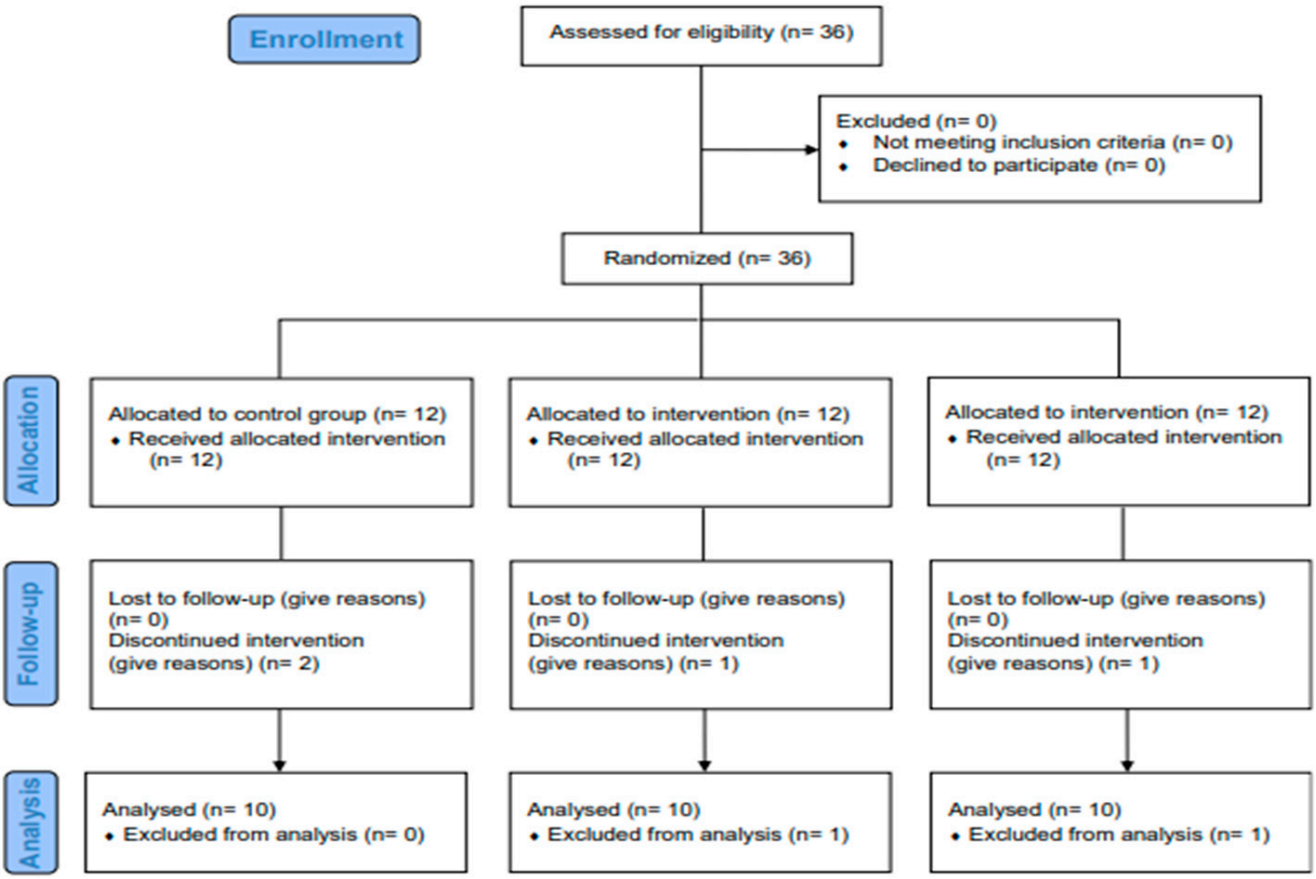

Figure 1. CONSORT flow diagram.

2.2. Resistance Training Protocol

Regarding the exercise program, participants performed resistance exercises thrice a week for 12 weeks using elastic bands (Theraband, Akron, OH, USA) based on the Resistance Exercise Program for the Elderly in American College of Sports Medicine, with each session lasting ≈ 60 min [18]. The program comprised a warm-up period (10 min), main exercise (45 min), and a cool-down period (5 min) (Table 1). Participants were instructed individually and consistently supervised by two physical education professionals to perform resistance exercises safely and easily. Depending on the age of the participants, the exercise program was classified into the sitting position (10–12 exercises) or standing position (3–6 exercises). All participants selected a band according to their respective strengths and set the exercise intensity based on the grip width (OMNI-RES scale) prior to the exercise program (high intensity maximum 15 repeatable grip width, moderate intensity +25% high intensity, low intensity +50% high intensity). Moreover, weeks 1–4, 5–8, and 9–12 comprised low-intensity (OIMNI-RES 3–4), moderate-intensity (OIMNI-RES 5–6), and high-intensity (OIMNI-RES 7–8) resistance exercises [19]. Movement without a band was monitored using the same scale. All exercises were performed at a 1:2 (concentration–eccentricity) ratio (Table 1).

Table 1. Resistance training protocol.

Type	Week	Exercise Protocol	Volume	Intensity	Frequency
Warm-up (10 min)	1–12	Dynamic stretching	Freedom	Freedom	3 times /week
Main Exercise (45 min)	1–4	Sitting: Ankle pump, Leg extension, SAQ, Hamstring curl, Row, Protraction, External rotation, Kick back, Biceps curl, Wrist twist, Hand grip	25 reps, 3 set	LI-HR: OMNI-RES 3–4	
		Standing: Hip adduction and abduction, Stand and sit	12 reps, 3 set	HI-LR: OMNI-RES 6–7	
	5–8	Sitting: Leg extension, Hamstring curl, Chest press, Row, Shoulder press, External & internal rotation, Biceps curl, Kick back, Wrist twist, Hand grip,	20 reps, 3 set	LI-HR: OMNI-RES 4–5	
		Standing: Calf raise, Hip flexion and extension, Hip abduction and abduction, Stand and sit, Half squat, Lunge,	10 reps, 3 set	HI-LR: OMNI-RES 7–8	
	9–12	Sitting: Leg extension, Hamstring curl, Chest press, Row, External rotation, Shoulder press, Kick back, Biceps curl, Wrist twist, Hand grip	15 reps, 3 set	LI-HR: OMNI-RES 5–6	
		Standing: Calf raise, Hip extension and abduction, Half squat, Lunge, Crap Walking	8 reps, 3 set	HI-LR: OMNI-RES 8–9	
Cool-down (5 min)	1–12	Static stretching	Freedom	Freedom	

2.3. Body Composition

Body composition was measured after fasting for ≥10 h on the measurement day, with the participants having abstained from exercise, alcohol, and caffeine. They wore very light clothing and underwent measurements while lying on a bed using the bioimpedance method (BWA 2.0, InBody, Seoul, Republic of Korea). The following data were collected: body weight (kg), body fat content (kg), body fat percentage (%), and skeletal muscle mass (kg).

2.4. Functional Physical Fitness

Relative grip strength (RGS) was measured for 5 s with maximum force, where the handle was held with both hands and one arm was kept straight and at a 15° angle. Both hands were measured alternately twice, and the maximum value (in 0.1 kg) was calculated as follows: grip strength (kg)/body weight (kg) × 100 [20].

During the sit-to-stand (STS), the participants sat in a height adjustment chair with their arms crossed in an X-shape in front of their chest. Subsequently, they were asked to repeatedly stand and sit five times as prompted by signals. Measurements were recorded at 0.01 s intervals [21].

The 4 m walking test is an assessment of the daily walking speed. Participants walked from a starting point to a finish line as prompted by a signal, with measurements being recorded at 0.01 s intervals [22].

In the timed up-and-go (TUG) test, participants sat on a chair, stood, moved to a cone placed 3 m in front, and returned to sit. Measurements were recorded up to the first decimal place in seconds [20].

2.5. Muscle Strength and Power

Muscle strength was measured through isometric contraction of the ankle using the method described by Li et al. [23], with slight modifications. Briefly, the microFET®2 device (Hoggan Scientific, LLC, Salt Lake City, UT, USA) was placed in close contact with the feet soles and instep. Subsequently, participants pushed the soles or applied force towards the direction of the instep for ≈5 s, as prompted by a signal. Resistance was provided to prevent recoil and knee bending. Measurements were recorded to the first decimal place in kg units. Muscle power was calculated using the following validated formula [21]:

$$(relative)STSpower = \frac{Body\ weight\ (\mathrm{kg}) \times 0.9 \times \mathrm{g} \times [Height\ (\mathrm{m}) \times 0.5 - Chair\ height(\mathrm{m})]}{\left[\frac{(five)STS\ time}{n\ of\ STS\ repetitions}\right] \times 0.5}$$

2.6. Myokines

For measurement of myokine levels, blood samples were obtained through the forearm veins after participants fasted for 10 h. Blood samples were immediately centrifuged at 3000× *g* rpm for 15 min using a DSC-200A-2 system (DGI Systems, Taoyuan, Taiwan) and stored at −80 °C until analysis. IL-6, IGF-1, SPARC, and BDNF levels were measured using commercial human ELISA kits obtained from Minneapolis R&D Systems (Minneapolis, MN, USA). For IL-6 analysis, a high-sensitivity Quantikin ELISA kit was used, with absorbance being measured at 490 nm and calibrated at 650 nm. Prior to analysis, IGF-1 samples underwent pretreatment to release IGF-1 from binding proteins. SPARC levels were determined using 50 microliters of the test sample, while BDNF samples were diluted 20-fold before analysis. Absorbance measurements for IGF-1, SPARC, and BDNF were measured at 450 nm and calibrated at 540 nm. Each sample was analyzed in duplicate, with the mean values being used for statistical analysis.

2.7. Statistical Analysis

All statistical analyses were performed using SPSS Ver. 27.0 (IBM Corp., Armonk, NY, USA). Each variable was presented as the mean ± standard deviation using descriptive statistics. The Shapiro–Wilk test confirmed normal data distribution of all variables ($p > 0.05$). Generalized estimating equations (GEE) were used to analyze the effect of time period, group, and time period × group on body composition, functional physical fitness, muscle strength and power, and myokine levels for the repeated measures design while controlling for covariates. The resulting interactions were analyzed using a one-way analysis of variance (ANONA) followed by Bonferroni's post hoc test for between groups and a paired t-test for time periods. Partial eta squared (partial η^2) values were calculated using repeated measures ANOVA for time and group to describe the effects sizes (ES) for each outcome variable. The partial η^2 is the sum of the between-group variance divided by the sum of the error squares, and the ES was calculated by fitting the partial η^2 to G*Power 3.1.9.7 ver. ES values of 0.01, 0.06, and 0.14 were considered small, medium, and large effects, respectively. Statistical significance was set at $p < 0.05$.

3. Results

This study included 30 participants. Table 2 presents the participants' characteristics. The presented variables did not show significant among-group differences.

Table 2. Demographic characteristics.

Characteristics	CON (n = 10)	LI-HR (n = 10)	HI-LR (n = 10)	*p*-Value
Age (yrs.)	77.5 ± 4.3	76.4 ± 5.4	75.8 ± 6.2	0.776
Height (cm)	154.5 ± 10.3	155.6 ± 7.3	156.4 ± 9.7	0.894
BW (kg)	60.9 ± 8.4	62.2 ± 5.5	59.0 ± 6.2	0.568
BMI (kg/m^2)	25.5 ± 2.5	25.8 ± 2.2	24.2 ± 2.3	0.572
BF (%)	34.3 ± 6.0	34.2 ± 5.9	31.8 ± 4.1	0.517
SMM (kg)	21.8 ± 4.3	22.2 ± 2.6	20.4 ± 3.0	0.475
ASM (kg/m^2)	7.3 ± 1.1	7.1 ± 1.1	6.7 ± 2.1	0.730
SBP (mmHg)	135.6 ± 24.7	134.2 ± 16.3	130.5 ± 16.2	0.837
DBP (mmHg)	75.2 ± 13.6	75.0 ± 7.9	72.8 ± 13.9	0.887
CC (cm)	33.3 ± 2.3	35.6 ± 1.3	34.7 ± 4.4	0.230
GS_M (kg)	22.2 ± 5.0	21.8 ± 4.7	20.5 ± 4.7	0.725
HbA1C (%)	6.2 ± 1.1	6.4 ± 1.1	5.8 ± 0.6	0.362
AGEs (AU)	3.6 ± 1.4	3.0 ± 0.7	3.2 ± 0.7	0.387

mean ± SD. BW, body weight; BMI, body mass index; BF, body fat; SMM, skeletal muscle mass; ASM, appendicular skeletal muscle mass; SBP, systolic blood pressure; DBP, diastolic blood pressure; CC, calf circumference; GS_M, grip strength max; HbA1C, hemoglobin A1c; AGEs, advanced glycation end-products.

3.1. Changes in Body Composition

Table 3 shows the results of the GEE for differences in body composition between groups and time periods. Body weight (BW), body mass index (BMI), and skeletal muscle mass (SMM) did not differ between groups and time periods for all three groups. However, body fat percentage (BF) showed an interaction effect (Wald χ^2 = 8.95, p = 0.011). Post hoc analyses showed that LI-HR and HI-LR were significantly reduced post compared to pre (p = 0.003 and 0.047, respectively).

Table 3. Results of generalized estimating equation (GEE) model for body composition.

	Group	Pre	Post	Wald χ^2	ES	*p*-Value
BW (kg)	CON	60.9 ± 8.4	62.1 ± 9.8	2.03	0.26	T: 0.155
	LI-HR	62.2 ± 5.5	63.1 ± 5.6	4.97	0.22	G: 0.083
	HI-LR	59.0 ± 6.2	59.1 ± 6.3	1.18	0.18	T × G: 0.553
BMI (kg/m^2)	CON	25.5 ± 2.5	26.0 ± 3.5	2.38	0.42	T: 0.123
	LI-HR	25.8 ± 2.2	26.1 ± 2.5	4.15	0.21	G = 0.126
	HI-LR	24.2 ± 2.3	24.2 ± 2.5	1.23	0.14	T × G: 0.540
BF (%)	CON	34.3 ± 6.0	35.0 ± 5.4	3.35	0.33	T: 0.067
	LI-HR	34.2 ± 5.9	33.3 ± 5.6 **	3.02	0.31	G: 0.221
	HI-LR	31.8 ± 4.1	30.0 ± 5.6 *	8.95	0.52	T × G: 0.011
SMM (kg)	CON	21.8 ± 4.3	22.0 ± 4.3	3.87	0.36	T: 0.049
	LI-HR	22.2 ± 2.6	22.9 ± 2.6	7.83	0.23	G: 0.020
	HI-LR	20.4 ± 3.0	21.3 ± 2.5	0.67	0.16	T × G: 0.716

mean ± SD. ES, effect size. * p < 0.05, ** p < 0.01, * versus Pre. BW, body weight; BMI, body mass index; BF, body fat; SMM, skeletal muscle mass.

3.2. Changes in Functional Physical Fitness

Table 4 presents the results of the difference in change in functional fitness. No interaction was observed between RGS and STS. However, there was an interaction for the 4 m walk (Wald χ^2 = 10.31, p = 0.006) and a main effect of time (Wald χ^2 = 11.54,

$p < 0.001$). Post hoc analyses showed a significant decrease in the HI-LR group from pre to post ($p < 0.001$). In addition, an interaction was found for TUG (Wald $\chi^2 = 7.98$, $p = 0.019$), and a main effect of time was also observed (Wald $\chi^2 = 11.92$, $p < 0.001$). Post hoc analyses showed that LI-HR and HI-LR were significantly reduced post compared to pre ($p = 0.018$ and 0.006, respectively).

Table 4. Results of generalized estimating equation (GEE) model for functional physical fitness.

	Group	Pre	Post	Wald χ^2	ES	*p*-Value
RGS (%)	CON	33.6 ± 6.2	33.6 ± 5.6	1.03 0.70 0.39	0.18 0.11 0.13	T: 0.310 G: 0.705 T × G: 0.823
	LI-HR	32.3 ± 4.5	32.9 ± 4.0			
	HI-LR	33.6 ± 6.1	34.2 ± 6.9			
STS (s)	CON	14.2 ± 3.9	13.8 ± 3.8	9.99 0.89 3.41	0.75 0.05 0.39	T: 0.002 G: 0.957 T × G: 0.182
	LI-HR	15.7 ± 4.3	13.1 ± 4.0			
	HI-LR	15.0 ± 3.8	12.9 ± 3.0			
4 m walk (s)	CON	5.9 ± 1.1	5.8 ± 0.9	11.54 0.90 10.31	0.62 0.18 0.45	T: < 0.001 G: 0.637 T × G: 0.006
	LI-HR	6.4 ± 1.9	6.0 ± 1.8			
	HI-LR	6.1 ± 1.0	5.3 ± 1.0 ***			
TUG (s)	CON	9.9 ± 2.7	10.0 ± 2.6	11.92 0.92 7.98	0.63 0.15 0.50	T: < 0.001 G: 0.631 T × G: 0.019
	LI-HR	9.6 ± 1.7	8.8 ± 1.6 *			
	HI-LR	10.2 ± 2.5	9.1 ± 2.0 **			

mean ± SD. ES, effect size. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, * versus Pre. RGS, relative grip strength; STS, sit-to-stand; TUG, timed up-and-go.

3.3. Muscle Strength and Power

Muscle strength was measured using the dominant plantarflexion (PF) and dorsiflexion (DF) of the ankle (Table 5). The results showed no interaction, and only a main effect of time was observed for DF (Wald $\chi^2 = 18.00$, $p < 0.001$). In addition, only the main effect according to the time was observed in STSpower, which represents muscle power (Wald $\chi^2 = 9.87$, $p = 0.002$).

Table 5. Results of generalized estimating equation (GEE) model for muscle strength and power.

	Group	Pre	Post	Wald χ^2	ES	*p*-Value
PF (kg)	CON	11.9 ± 2.8	12.1 ± 1.3	2.27 0.82 0.79	0.27 0.12 0.11	T: 0.132 G: 0.665 T × G: 0.674
	LI-HR	11.2 ± 2.7	11.8 ± 2.5			
	HI-LR	11.1 ± 3.0	9.4 ± 1.6			
DF (kg)	CON	9.4 ± 1.8	9.6 ± 1.2	18.00 0.59 3.79	0.77 0.14 0.39	T: < 0.001 G: 0.744 T × G: 0.151
	LI-HR	9.0 ± 1.5	9.8 ± 1.8			
	HI-LR	9.4 ± 1.6	10.4 ± 1.6			
STSpower (W/kg)	CON	1.9 ± 0.8	1.9 ± 0.9	9.87 0.15 2.47	0.57 0.03 0.14	T: 0.002 G: 0.929 T × G: 0.291
	LI-HR	1.7 ± 0.6	2.0 ± 0.6			
	HI-LR	1.8 ± 0.6	2.0 ± 0.5			

mean ± SD. ES, effect size. PF, plantar flexion; DF, dorsi flexion; STSpower, sit-to-stand power.

3.4. Changes in Myokines

Figure 2 shows the results for the differences in myokine changes. IL-6 showed an interaction effect (Wald $\chi^2 = 9.96$, $p = 0.007$) and a main effect by time (Wald $\chi^2 = 4.72$, $p = 0.030$). Post hoc analysis showed that IL-6 in LI-HR and HI-LR were significantly reduced in post compared to pre ($p = 0.033$, $p = 0.015$). IGF-1 showed an interaction effect

(Wald $\chi^2 = 8.38$, $p = 0.015$), a main effect by time (Wald $\chi^2 = 13.55$, $p < 0.001$) and a group effect (Wald $\chi^2 = 10.67$, $p = 0.005$). Post hoc analyses showed that IGF-1 in the LI-HR and HI-LR groups each increased significantly post compared to pre ($p = 0.003$, $p < 0.001$). These two groups also showed a significant difference in post compared to CON ($p = 0.012$, $p < 0.001$) (Figure 2b). SPARC also showed an interaction effect (Wald $\chi^2 = 6.14$, $p = 0.046$) and a main effect of time (Wald $\chi^2 = 5.09$, $p = 0.024$). Post hoc analysis revealed that HI-LR was increased significantly post compared to pre ($p = 0.021$). BDNF showed only a main effect of time with no interaction effect (Wald $\chi^2 = 5.84$, $p = 0.016$). The LI-HR and HI-LR groups showed a trend toward an increase of 22.3% and 10.7%, respectively.

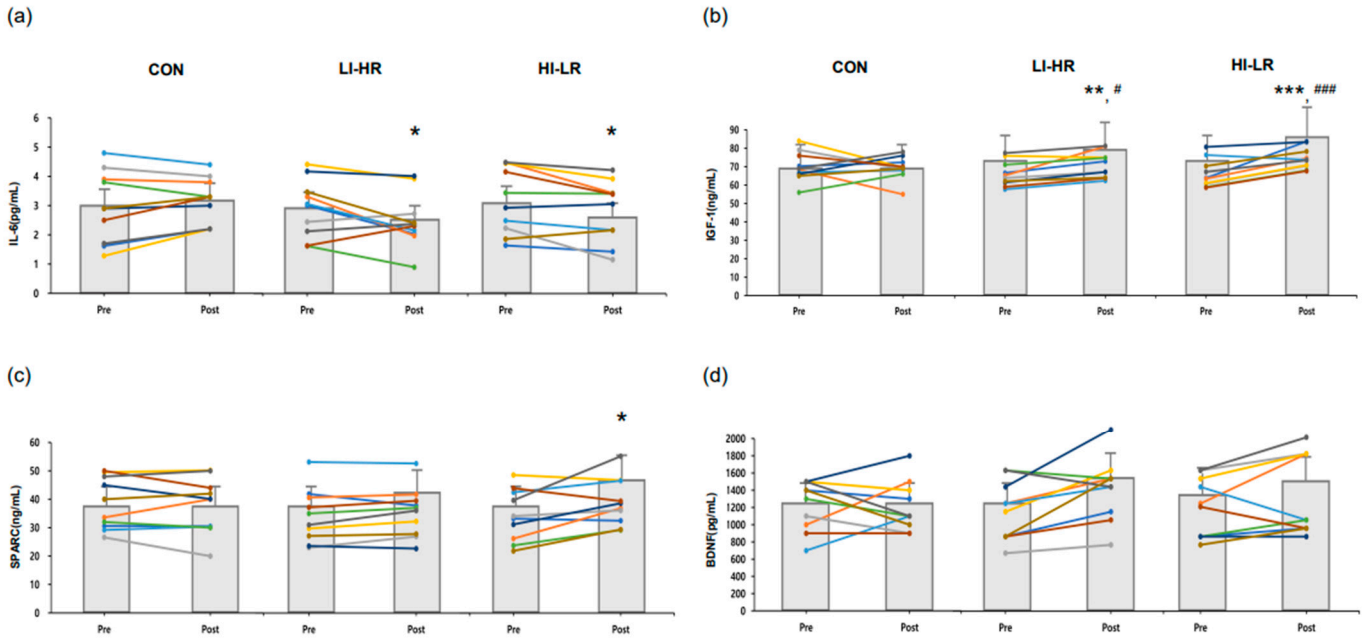

Figure 2. Difference in myokines between groups and time by generalized estimating equation (GEE) model. Difference and changes of IL-6 (**a**), IGF-1 (**b**), SPARC (**c**), BDNF (**d**). *, **, *** Significantly different compared to Pre (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$), #, ### significant difference from CON (# $p < 0.05$, ### $p < 0.05$).

4. Discussion

This study analyzed the effects of LI-HR and HI-LR resistance exercises in older adults over a 12-week intervention period, which focused on functional fitness, myokine levels, and muscle adaptations. The average attendance rate of participants was 92%, with no injuries or adverse events being observed. RT involved 10–25 reps per session, which is consistent with findings reported by Cavalcante [24], who showed that combining machine and free weights (15 reps) reduced body and abdominal fat in older adults over a 12-week intervention period. A higher training volume may enhance fat reduction given that RT increases energy expenditure through post-exercise oxygen consumption [25]. However, sedentary individuals may counteract this by increasing energy intake [26]; accordingly, further research is warranted to elucidate the effect of RT on total energy expenditure. Nonetheless, combined exercises are more effective in reducing body fat than single-exercise approaches (e.g., aerobic or resistance training) [27].

Regarding functional physical fitness, the HI-LR group showed greater improvements in muscle strength (e.g., STS test), which can reduce the risk of falling and enhance exercise performance. Contrastingly, the LI-HR group showed significant improvements in dynamic balance and gait speed (e.g., TUG test), which facilitate daily tasks requiring sustained effort. This is consistent with the specificity of the exercise regimens since HI-LR targets fast-twitch

fibers for power, while LI-HR focuses on slow-twitch fibers for endurance. Furthermore, we assessed the isometric strength of the ankle and relative muscle power using the STS test. The results showed the main effects of dorsiflexion strength and STSpower over time in the LI-HR and HI-LR groups, with a tendency to increase in Post (dorsi flexion: 8.9%, 10.6%; STSpower: 17.6%, 11.1%). This is consistent with the clinically relevant thresholds of 0.33 and 0.42 W/kg-1 for women and men, respectively, suggested by Alcazar et al. [28]. Izquierdo et al. [29] argued that to improve frailty and physical function in older adults, high-intensity RT should be included, if possible. High-intensity exercises are very effective in improving strength and power in a short period of time; however, it carries a higher risk of injury, especially to joints and connective tissue that may already be compromised by age-related degenerative changes. It may even have the negative effect of reducing strength. In this study, the LI-HR and HI-LR groups showed similar functional improvements. LI-HR training is generally safer because it places less mechanical stress on the body and provides significant benefits in endurance, functional fitness, and health. Therefore, a balanced approach combines LI-HR and HI-LR to minimize injury risk while providing physiological benefits such as increased muscle mass and strength, improved endurance, and neuroplasticity may be the most effective strategy.

In older adults, RT can help regulate the levels of myokines such as IL-6, IGF-1, SPARC, and BDNF, which promote muscle growth, regeneration, anti-inflammation effects, and neuroplasticity. In the present study, both experimental groups showed a significant decrease in IL-6 levels, suggesting that RT plays a role in reducing chronic inflammation. Elevated IL-6 is associated with extreme fatigue, rapid weight loss, and sarcopenia in the elderly. IL-6 and tumor necrotic factor-α activate the Janus kinase signal transducer and activator of transcription pathway, which is associated with inflammation, cancer development, and muscle mass atrophy [30]. IL-6 also blocks myocyte development, causing microstructural myofibrillar degradation and replacing muscle mass with collagen and fat [30]. This pathway is maintained by free fatty acids produced through lipolysis, which stimulate the release of the ubiquitin ligases Atrogin-1 and MuRF1 [31]. In the present study, IL-6 levels were significantly reduced in both experimental groups ($p = 0.033$, $p = 0.015$), suggesting that RT may help reduce chronic inflammation and its negative effects on muscle tissue.

Previous research has shown that high-intensity RT (80% 1 RM) further amplifies IGF-1 secretion [32]. Both groups showed increased IGF-1 levels, which is important for muscle repair and hypertrophy, especially in aging. Muscle protein synthesis (MPS) is generally shown to decrease in older adults. Rashidi et al. [33] performed low-intensity high-repetition (30% of 1 RM, 20 reps) and high-intensity low-repetition (80% of 1 RM, 8 reps) resistance exercise three times per week for eight weeks in older female adults, and they found that only the low-intensity high-repetition group had a significant increase in IGF-1 at postmortem ($p = 0.06$), which differs from our study's findings. These conflicting results are thought to have important implications for intensity settings for RT in the elderly: MPS is slowed in the elderly compared to the young, but an acute increase in Akt-mTORC1 signaling increases MPS to prevent skeletal muscle degradation [34]. Therefore, higher volume (6 sets > 3 sets) of RT may increase type II muscle fiber mobilization and restore the MPS response to a more youthful state. High repetitions, such as LI-HR, can induce metabolic stress through sustained contractions, which can stimulate anabolic hormones such as IGF-1 and growth hormone. Therefore, LI-HR can be a relatively efficient alternative for older adults who cannot perform high-intensity RT.

SPARC is essential for extracellular matrix remodeling and mitochondrial biogenesis, which are crucial processes for muscle metabolism during aging. SPARC expression is strongly associated with IGF-1. Melouane [35] reported that myokine, SPARC, and

peroxisome proliferator-activated receptor γ coactivator-1 alpha expression was induced in myoblasts after 48 h of electrical pulse stimulation, which is a suitable model of exercise in vitro. This suggests that exercise-induced SPARC is crucially involved in muscle integration through extracellular matrix remodeling and mitochondrial biogenesis [36]. Specifically, exercise-induced SPARC has been shown to regulate extracellular matrix remodeling through the integrin-linked kinase, glycogen synthase kinase 3 beta, [37], transforming growth factor beta 1 (TGF β1) and Smad family member 3 (Smad3) pathways [38]. Therefore, the TGF β1-Smad3-atrogin 1 pathway inhibits the degradation of myogenic transcription factors, including MyoD and myogenin, and promotes muscle differentiation [39]. A previous study showed that growth hormone administration to aged mice ameliorated low intramuscular SPARC expression. This can be attributed to growth hormone/IGF-1 strongly inducing SPARC via the PI3K-dependent signaling pathway. Recent studies have demonstrated a strong association between SPARC and IGF-1, indicating its positive impact on muscle metabolism in aging.

Previous animal studies indicated that exercise increases hippocampal BDNF expression and neuroregeneration. For example, Russo-Neustadt et al. reported increased BDNF mRNA expression in the hippocampus after 20 days of voluntary wheel running [40], while Rasmussen et al. reported that treadmill running increased BDNF expression in mice, with repeated exercise amplifying this effect [41]. Acute or chronic exercises increase circulating BDNF in humans. Exercise increases BDNF in the periphery, muscle, and brain, and the longer the exercise duration, the greater the increase [42]. Exercise also increases BDNF production in skeletal muscle, particularly in satellite cells, and can cross the blood–brain barrier into the brain [43,44]. To date, increased BDNF has been reported to be a distinct effect of aerobic exercise in relation to other exercise. As such, although aerobic exercise is more associated with neuroprotective and developmental mechanisms, recent studies have shown that RT also contributes to the maintenance, development, and recovery of brain activity through specific neurochemical adaptations induced by training [45,46]. In this regard, Arazi et al. [47] compared the acute effects of RT in men with an average age of 60.8 years, divided into a Strength group (90% of 1 RM, 10 reps, 2 circuits) and an endurance group (65–70% of maximal heart rate, 3 × 10 min with 120 s intervals). The results showed that IGF-1 and BDNF in these two groups differed significantly from that in the control group and each significantly increased post hoc within the groups ($p = 0.003$). Furthermore, no difference was observed between the two groups, suggesting that the strength and endurance interventions increased IGF-1 and BDNF effectively. In contrast, no significant difference was observed in BDNF levels between the two groups, which tended to increase in both experimental groups post, with 22.3 and 10.7%, in the LI-HR and HI-LR groups, respectively. This suggests that even moderate- or low-intensity RT (with high repetitions) may increase circulating BDNF levels. Although the effect of RT on skeletal muscles has been established, its impact on the brain remains unclear. Unlike aerobic exercise, RT involves different forms and intensities of muscle contractions that stimulate signal transduction pathways, which regulates gene expression through calcium-mediated mechanisms [48]. Further studies are warranted to elucidate the effects of RT on the brain.

5. Conclusions

Our findings demonstrate that LI-HR and HI-LR training for 12 weeks had comparable effects. Notably, LI-HR can increase the potential to upregulate functional physical fitness, muscle strength and power, and essential myokines such as IGF-1 and BDNF. Taken together, our findings demonstrate safe and appropriate exercises for muscle function and metabolic control in vulnerable individuals, including women, older adults, and individuals with physical disabilities. Further large-scale studies that include acute and

detraining time points, as well as adjust for nutritional intake, are warranted. Furthermore, we suggest the following for practical application based on this research. First, the research could be communicated in an easy-to-understand manner using illustrations, infographics, and short videos. Second, community partnerships (local communities, senior centers, and public health centers) could be leveraged to encourage participation in the study and share the results for greater uptake.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app15020757/s1.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data generated or analyzed in this study are included in this study and Supplementary Materials. However, not all of it has been made publicly available as it may compromise the privacy of participants. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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