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Impact of resistance and high-intensity interval training on body composition, physical function, and temporal dynamics of adaptation in older women with impaired cardiometabolic health: a randomized clinical trial

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Abstract

Purpose Physical inactivity is associated with reduced physical fitness (PF) in older women with impaired cardiometabolic health. Although exercise has been shown to improve PF, interindividual variability in response and adaptation changes over time remain unclear. This study evaluated the effects of eight weeks of resistance training (RT) and high-intensity interval training (HIIT) on body composition, isometric strength, and the 6-minute walk test (6MWT) in older women with impaired cardiometabolic health. Additionally, the study explored the reduction of non-responders (NRs) and adaptation changes over time.

Methods This randomized clinical trial involved 36 older women (64 ± 8.4 years; BMI: 31.8 ± 5.5) with impaired cardiometabolic health, divided into RT-G (n = 12; 62 ± 7 years; BMI: 32.2 ± 4.1), HIIT-G (n = 12; 66 ± 10 years; BMI: 31.2 ± 4.1), and CG (n = 12; 64 ± 9 years; BMI: 31.8 ± 6) groups. RT-G performed elastic band exercises, and HIIT-G performed cycle ergometer intervals. BMI, body fat, lean mass, isometric strength, and 6MWT were measured at baseline and at four and eight weeks. The Student's t-test was applied for normally distributed variables and the Mann–Whitney U test for non-normal variables. Intra- and inter-group differences were analyzed using a two-way repeated measures ANOVA, considering group, time, and their interaction. Post-hoc comparisons were conducted using the Bonferroni test. Individual responses (IR) were calculated using the equation proposed by Hopkins: $SDIR = \sqrt{(SDExp^2 - SDCon^2)}$. The prevalence of responders (Rs) and non-responders (NRs) was expressed as a percentage, and percentage changes from baseline to weeks four and eight were used to evaluate adaptations dynamics.

Results By week eight, isometric strength in RT-G significantly improved from 21.3 ± 4.4 to 24.37 ± 3.99 kg (p = 0.027; 95% CI: 1.8, 4.3 kg; Cohen's d = 0.731) and 6MWT distance in HIIT-G increased from 441.0 ± 48.9 to 480.0 ± 53.0 m. (p = 0.002; 95% CI: 22, 55 m; Cohen's d = 0.757). Both protocols reduced NRs for body fat, lean mass, and 6MWT. Responders showed greater adaptations in the first four weeks, stabilizing by week eight.

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Conclusion RT and HIIT improved PF in older women with impaired cardiometabolic health, reducing NRs in terms of body composition and 6MWT over eight weeks, with similar adaptation changes over time among the responders. These findings highlight the importance of individualized exercise interventions to maximize health benefits.

Trial registration This study was part of a trial registered at ClinicalTrials.gov (ID: NCT06201273). Date: 22/12/2023.

Keywords Resistance training (RT), High-intensity interval training (HIIT), Interindividual response, Temporal dynamics of adaptation, Cardiometabolic risk factors, Physical fitness

Introduction

Physical inactivity (PI) is a significant global public health challenge [1], leading to decreased physical fitness (PF), which is characterized by increased body fat mass, reduced muscle strength and mass, and diminished cardiorespiratory capacity [2, 3]. Furthermore, PI is strongly associated with a heightened risk of developing primary health conditions, such as hypertension (HTN), type 2 diabetes mellitus (T2DM), dyslipidemia, and obesity [4–6]. These cardiometabolic risk factors (CMRFs) tend to accumulate with increasing age [7] and are predominantly managed through pharmacological interventions. Notably, an increase in the number of CMRFs correlates with increased medication use, which is inversely related to PF [8], potentially exacerbating the effects of inactivity.

Physical exercise is known to enhance various aspects of PF, including body composition [9], muscle strength [10], and cardiorespiratory fitness [11], particularly in older adults [12]. Despite these well-documented benefits, time constraints impede widespread regular exercise engagement [13]. Consequently, time-efficient exercise alternatives, such as sessions lasting no more than 10 min and conducted three times per week, could offer practical solutions for individuals with impaired cardiometabolic health, facilitating improvements in PF. Resistance training (RT) using elastic materials [14–16] and high-intensity interval training (HIIT) [17–19] have been shown to significantly improve PF, while also being safe and effective in individuals with impaired cardiometabolic health [20, 21].

In this context, physiological adaptations following a standard exercise regimen exhibit significant interindividual variability, a phenomenon well documented in recent studies [22]. Responses to HIIT and RT differed markedly among individuals with impaired cardiometabolic health. Variability in exercise response for body composition significantly differed between the HIIT and RT protocols, ranging from 21 to 66% and 25% to 47%, respectively [23–26]. The responses varied from 28 to 100% in HIIT for cardiorespiratory fitness and from 24 to 100% for RT [24–26]. Similarly, muscular strength responses ranged from 11 to 45% in HIIT and from 81 to 100% in RT, highlighting the diversity in how individuals react to different exercise modalities [26–29]. Despite the broad spectrum of individual variability, research has consistently demonstrated that exercise elicits cumulative positive effects over time [30]. This finding indicates that nonresponders (NRs) at initial assessments will likely show improvements after eight weeks of consistent intervention [31].

Furthermore, while existing research on RT and aerobic exercise has focused primarily on general postintervention adaptations, there is a need for more clarity regarding the temporal dynamics of adaptation. This term refers to the rate at which biological systems and functions adapt to exercise stimuli over time, such as changes in cardiorespiratory fitness, within a specified period [32, 33]. The lack of focus on temporal dynamics creates a gap in our understanding of how different exercise modalities influence adaptation over time in individuals with CMRFs, particularly among those who exhibit varied responses to these training protocols.

Given the critical importance of tailored exercise prescriptions for individuals with impaired cardiometabolic health [31] and the lack of data on how interindividual variability responds over time to low-volume exercise protocols, such as RT or HIIT, this study was designed to investigate the impact of these protocols on body composition, isometric strength, and 6-min walk test (6MWT) in older adult women with impaired cardiometabolic health. Specifically, this study aimed to evaluate the effects of eight weeks of two low-volume exercise protocols, RT and HIIT, on the outcomes above. Additionally, we sought to compare the efficacy of these exercise modalities in reducing the proportion of NRs between four and eight weeks and to explore the temporal dynamics of adaptations among responders (Rs) and NRs.

We hypothesized that both exercise protocols would similarly reduce the prevalence of NRs from four–eight weeks [34]. We also posited that the temporal dynamics of adaptations would be more significant in the initial stages of the intervention (four weeks) and would stabilize by the end of eight weeks [33]. We expected these temporal dynamics to be more pronounced among the Rs. Furthermore, it was anticipated that the type of stimulus delivered, whether RT or HIIT, would differentially influence the temporal dynamics of adaptation in terms of isometric strength and the 6MWT. However, the specific temporal dynamics related to improvements in body composition and the extent of the differences between Rs and NRs remain unclear. Investigating these dynamics could elucidate methods to modulate internal physiological processes more effectively and optimize performance through individualized exercise prescriptions [33].

Materials and methods

Study design

This was a randomized clinical trial involving older women with impaired cardiometabolic health. These women were invited to participate through no probabilistic convenience sampling during their regularly scheduled health checkups. Before participation, the women were provided with detailed information about the study, including its benefits and potential risks, and were asked to sign an informed consent form. The interventions, which included evaluations and exercise programs, were conducted at the San Sebastián University Health Center in Valdivia, Chile, between June and November 2023.

To be eligible for the study, women were required to meet the following criteria: they were physically inactive, as determined by the International Physical Activity Questionnaire (IPAQ) [35]. They also had to be enrolled in a government-funded cardiovascular health management program. Women who were excluded from the study had uncontrolled chronic diseases, ischemic heart disease or arrhythmia, unresolved acute illnesses, and an inability to provide informed consent or comply with the tests and exercise protocol for any reason.

Sample size calculation

The sample size calculation was performed using G*Power software (version 3.1.9.6), following literature recommendations for studies of this nature and incorporating the following parameters: (1) ANOVA: repeated measures, within-between interaction; (2) type I error: 5%; (3) statistical power: 80%; (4) effect size (ES): 0.25, based on previous studies assessing exercise-induced changes in 6MWT distance as a primary outcome in populations with cardiometabolic risk factors [36]; (5) number of groups: 3; and (6) number of measurements: 3.

With these parameters, the recommended total sample size is 12 participants per group [37]. Assuming a 30% dropout rate, the total population comprised forty-seven participants. After the eligibility process, the participants were assigned to a resistance training group (RT-G), HIIT group (HIIT-G), or control group (CG) via a 1:1:1 random allocation via the online system (https://www.randomizer.org/). Allocation concealment was performed by an investigator not involved in the clinical procedures of the study, who used consecutively numbered, sealed, opaque envelopes. The random sequence generation and allocation concealment method helped control for selection bias.

RT-G and HIIT-G received interventions based on RT with elastic materials and HIIT, respectively, in addition to pharmacological treatment associated with the governmental cardiovascular health management program. CG maintained pharmacological therapy as part of the same governmental program. No pharmacological adjustments were made during the intervention in any of the groups. Although caloric intake, expenditure, and physical activity levels were not objectively measured during the 8-week intervention, the participants were advised to maintain their habitual behaviors before the study.

Sixty-one eligible individuals were identified during study recruitment. Of these, 13 opted not to sign the informed consent form. The forty-eight participants who provided consent were randomly assigned to three distinct groups, with 16 women in each group. Throughout the follow-up period, four participants in the control group were excluded because they did not complete the scheduled evaluations at weeks four and 8. Four participants were excluded from the RT-G because they attended at least 70% of the training sessions. In the HIIT-G, four other participants were excluded because they did not participate in the scheduled reevaluations at weeks four and eight. Finally, analysis was conducted on 12 participants in each group, with the following distributions: RT-G ($n = 12$), HIIT-G ($n = 12$), and CG ($n = 12$). The flow diagram of the study participants, following the CONSORT guidelines, is presented in Fig. 1.

The study was conducted in accordance with the Declaration of Helsinki, adhered to CONSORT guidelines, and received approval from the Ethical Scientific Committee of the Valdivia Health Service Resolution No. 2314327099 (Ord. N 166, 2023). This study was part of a trial registered at ClinicalTrials.gov ID: NCT06201273. Date: 22/12/2023.

Exercise protocols

An RT protocol was implemented for the RT-G and HIIT protocols for the HIIT-G. Each protocol consisted of three weekly sessions for eight weeks. The participants' heart rate and blood pressure were measured before and after each training session to ensure participant safety throughout the study. If recorded values exceeded the established safety limits (SBP > 180 mmHg, DBP > 110 mmHg) [38], the session was immediately suspended. Participants were allowed to resume training in the following session only if their hemodynamic parameters returned to a safe range for exercise. The sessions

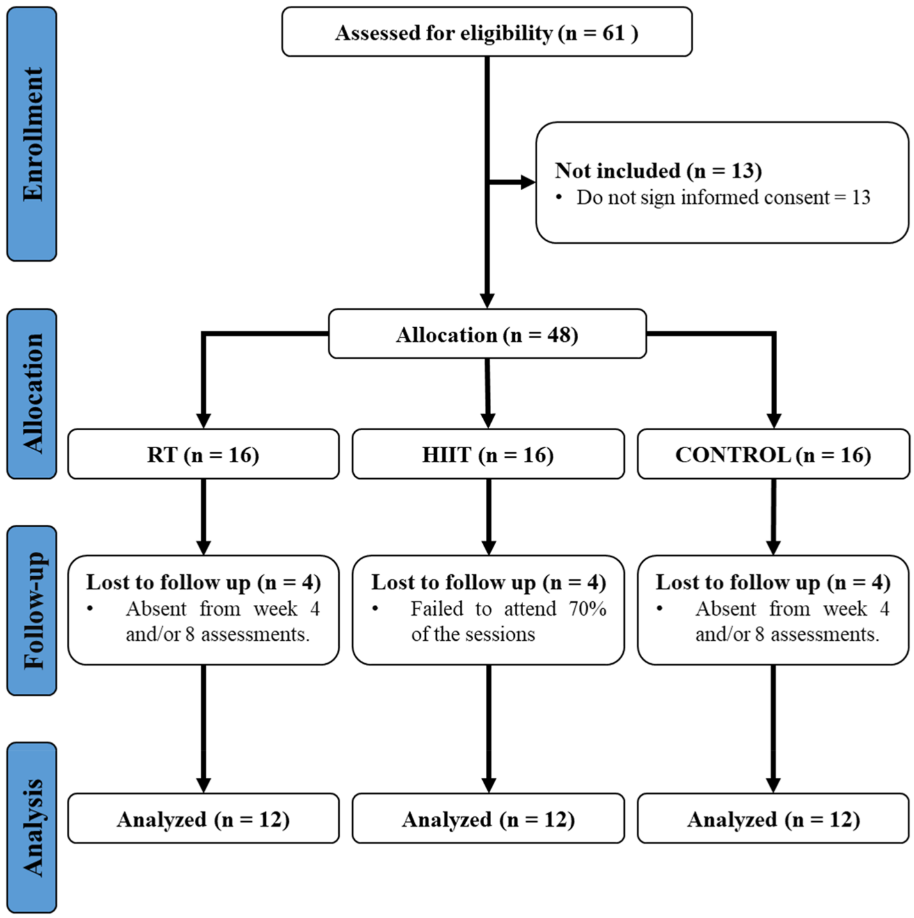

Fig. 1 CONSORT flow diagram

included a) warm-up, b) main exercise, and c) cool-down. Before the commencement of the exercise program, each participant underwent three familiarization sessions: 1) familiarization with cycle ergometers, elastic bands, and instructions during the exercise program; 2) learning the correct execution of exercises; and 3) implementation of RT (two–five sets of exercises) and HIIT (two–five intervals) protocols to understand the configuration of each session. During the warm-up and cool-down periods, all participants performed 5 min on a cycle ergometer at an intensity of 2–3 on the modified Borg scale [39].

Resistance training

RT-G performed concentric and eccentric contractions with TheraBand CLX elastic bands for 1 min at an intensity of 8–10 according to the OMNI resistance exercise scale (OMNI-RES) [40]. A two-minute rest period was observed between the exercises, and each exercise was repeated three times. Specifically, the team conducted biceps curls, seated rows, and wide squats as previously described [29]. The exercise load was modified every two weeks based on the participants' physiological adjustments to the training so that the intensity remained at 8–10 on the OMNI-RES [40]. The resistance of the bands progressively increased in the following order: blue, black, gray, and gold.

HIIT

The HIIT-G protocol consisted of 8–10 intervals per session on a cycle ergometer, performed at an intensity of 8–10 on the modified Borg scale (1–10 points) [41]. Each interval included one minute of cycling, followed by two minutes of active recovery, during which participants pedaled on the cycle ergometer without resistance [42]. To ensure a consistent training stimulus, the number of intervals, exercise duration, and rest periods remained constant throughout the intervention. However, every two weeks, if a participant did not reach an intensity of 8 on the modified Borg scale during the intervals, the cycling load was arbitrarily adjusted using the resistance levels of the ergometer (ranging from 0 to 20). The pedaling resistance was increased accordingly to maintain the target intensity within the 8–10 range on the scale [42].

Primary outcomes

Body composition

Height was assessed using a stadiometer, with a measurement precision of 0.1 cm (SECA Bodymeter 206) [43]. The participants assumed a barefoot, upright stance, aligned their backs, and heeled with the device. The participant's head was maintained in a neutral position, facing forward, to ensure that the line of sight remained parallel to the ground. The horizontal rod of the stadiometer was subsequently lowered until it made gentle contact with the participant's cranial apex, and the measurement was subsequently recorded. Weight, percentage of body fat, and lean mass were measured via a bioimpedance analyzer (TANITA BC-534) [44]. The participants were instructed to abstain from heavy meals and intense exercise before the measurement to ensure that they were adequately hydrated and emptied their bladders. After their shoes and metallic objects were removed, they stepped onto the scale and inputted their data, such as age, sex, and height. The scale processed the measurements once the samples stood still and upright on metal plates [44]. The standard error of measurement (SEM) for body composition assessment using the TANITA BC-534 was 0.46 kg, indicating a reliable but slightly variable precision in body fat and lean mass estimations [44]. Body mass index (BMI) was estimated using the formula kg/m^2.

Isometric strength

Isometric grip strength was assessed by using a dynamometer. (CAMRY EH101, Sensun Weighing Apparatus) [45] via the Southampton protocol [46]. The procedure commenced with the participants seated, their forearms supported by a chair, wrists resting just over the chair armrests in a neutral position, thumbs facing upward, and feet flat on the ground. The participants were instructed to squeeze the dynamometer as hard as possible for as long as possible. Three attempts were made with each hand, and the best attempt was recorded [46]. The SEM for grip strength assessment has been reported to range between 1.59 and 2.15 kg, ensuring a reliable evaluation of isometric handgrip strength [47]. The reference values described for the adult Chilean population were used to classify grip strength [48].

Six-minute walk test

The six-minute walk test was employed to measure a person's walking distance within six minutes along a flat and straight corridor to estimate cardiorespiratory capacity [49]. Before initiating the test, the participants' vital signs were recorded, and they were instructed to ambulate at their own pace, with the option of halting or decreasing the velocity if warranted. The participants were vigilantly monitored throughout the assessment for signs of fatigue or respiratory distress. Upon the conclusion of the 6-min duration, the clock was halted, the total distance traversed was quantified, and vital signs were meticulously documented [49]. The SEM for the six-minute walk test has been reported to be approximately 14 m, indicating a high level of reliability in assessing functional capacity [50]. Reference values described for the adult Chilean population were used to classify the meters covered [51].

Secondary outcomes

Individual response to exercise: Rs and NRs

Individual response (IR) were calculated via the equation proposed by Hopkins [52] given by the square root of the difference between the squares of the standard deviations of the change in values in the experimental (SD_{Exp}) and control (SD_{Con}) groups: $SD_{IR} = \sqrt{(SD_{Exp}{}^2 - SD_{Con}{}^2)}$ [52]. It should be considered that this standard deviation is the extent to which the net average treatment effect typically differs between individuals [52]. Participants were classified as Rs if they exhibited favorable changes in health markers above IR in the measured variables. Conversely, participants were classified as NRs if they did not show changes or if the changes in health markers were favorable but below the IR in the measured variables. The IR was determined between the initial evaluations and those conducted at weeks four and eight (pre vs. week four and week eight, respectively). The four-week assessment served as an early indicator of individual responsiveness, allowing for the identification of potential non-responders at an initial stage of the protocol. This approach is supported by evidence showing that early physiological adaptations—particularly neuromuscular and metabolic changes—can occur within this timeframe [5, 30, 53].

Temporal dynamics of adaptation between Rs and NRs

The temporal dynamics of exercise adaptation, defined as the speed at which organisms adjust their biological systems and physiological functions in response to sustained physical activity, were quantitatively evaluated [33]. This analysis was based on the percentage change between the differences in measurements taken at baseline and those recorded at the end of the fourth and eighth weeks, as in previous studies [33]. According to exercise protocols, this evaluation was applied separately to individuals classified as Rs or NRs.

Statistical analyses

The dependent variables are described using the mean and standard deviation. To ensure the validity of the analyses, we verified the assumptions of normality and homoscedasticity for all the data via the Shapiro–Wilk and Levene tests. To identify baseline differences in dependent variables between groups, we employed the Student's t-test for independent samples for variables with a normal distribution and the Mann–Whitney U test for variables with a nonnormal distribution. Two-way repeated measures analysis of variance (ANOVA) was used to determine intragroup and intergroup differences. The model effects included group (RT-G, HIIT-G, and CG), time (pre-test, post-week four, and post-week eight), and their interaction over time (group × time). The Bonferroni post-hoc test was used to identify specific differences between groups and times. The clinical significance of the interventions was determined by the effect size via Cohen's d (< 0.2, negligible; 0.2–0.49, small; 0.5–0.79, moderate; ≥ 0.8, large) for interactions that showed statistical significance [54]. The IR for each variable was calculated using the equation proposed by Hopkins et al. [52]. The IR are summarized by a standard deviation (SD_{IR}) given by the square root of the difference between the squares of the standard deviations of the change scores in the experimental (SD_{Exp}) and control (SD_{Con}) groups: $SD_{IR} = \sqrt{(SD_{Exp}^2 - - SD_{Con}^2)}$ [52]. The prevalence of participants classified as Rs, or NRs was described as a percentage within the RT-G, HIIT-G, and CG groups. To assess the temporal dynamics of adaptation, the percentage changes in the differential variation from baseline measurements to those recorded at the fourth and eighth weeks were calculated for the Rs and NRs groups, respectively. To ensure optimal bias control, both the assessors responsible for outcome measurements and the researcher conducting the data analysis were blinded to the group assignments. This blinding process minimized potential measurement bias and ensured that all assessments were performed objectively, following strictly standardized procedures across all groups. All the statistical analyses were performed via SPSS software version 26 (SPSS Inc., Chicago, IL, USA).

Results

Baseline measurements

At baseline, no significant differences were observed in anthropometric variables, body composition, isometric strength, 6MWT performance, or medication use. Only a marginal difference in 6MWT was detected between RT-G and HIIT-G (Table 1).

Changes in PF according to group and evaluation time

Body composition

BMI No significant differences were observed between the groups at different time points, nor were there any significant intragroup differences at four and eight weeks (Table 2). Additionally, no significant effects of time ($F = 1.297$, $p = 0.131$) or group ($F = 0.144$, $p = 0.867$) were observed (Table 2).

Body fat No significant differences were detected between the groups at different time points, nor were any significant intragroup differences at four and eight weeks (Table 2). Additionally, no significant effects of time ($F = 1.297$, $p = 0.287$) or group ($F = 0.630$, $p = 0.539$) were observed (Table 2).

Lean mass No significant differences were observed between the groups at different time points, nor were there significant intragroup differences at four and eight weeks (Table 2). Additionally, no significant effects of time ($F = 1.248$, $p = 0.301$) or group ($F = 0.625$, $p = 0.541$) were observed (Table 2).

Isometric strength

Although no statistically significant differences were observed between the groups over time, the HIIT-G group exhibited a clinically relevant difference compared with the control group at week eight, as indicated by a moderate effect size ($d = 0.596$) (Fig. 2, panel d). According to the intragroup analysis, the RT-G demonstrated significant improvements, with moderate effect sizes, in the pre- and postintervention measurements at four weeks ($p = 0.001$, 95% CI: 1.3, 4.1; Cohen's $d = 0.695$) and eight weeks ($p = 0.027$; 95% CI: 1.8, 4.3 kg; Cohen's $d = 0.731$) (Table 2 and Fig. 2, panel d). Furthermore, the analysis revealed a significant time effect on this outcome measure in the RT-G ($F = 4.405$, $p = 0.020$) but not a group effect ($F = 0.710$, $p = 0.347$) (see Table 2).

Six-minute walk test

Significant differences were observed between the RT-G and CG at four ($p = 0.018$; 95% CI: 8.27, 86.73 m; Cohen's $d = 1.039$) and eight weeks ($p = 0.02$; 95% CI: 7.45, 84.55; Cohen's $d = 1.01$), both with large effect sizes (Fig. 2, panel e). Intragroup analysis revealed clinically relevant differences in the RT-G, with moderate effect sizes at four weeks (Cohen's $d = 0.513$) and eight weeks (Cohen's $d = 0.562$). Significant differences were

Table 1 Baseline characteristics of the groups

Outcomes	RT-G	HIIT-G	CG	RT-G vs CG *p* value	HITT-G vs CG *p* value	RT-G vs HIIT-G *p* value
(*n* =)	12	12	12			
Age (years)	62.0 (7.0)	66.0 (10.0)	64.0 (9.0)	0.544	0.648	0.344
Physical fitness						
Anthropometric						
Height (m)	1.52 (0.05)	1.55 (0.09)	1.51 (0.05)	0.511	0.175	0.344
Body mass (kg)	74.7 (9.5)	74.5 (13.8)	72.8 (14.6)	0.699	0.771	0.957
BMI (kg/m^2)	32.2 (4.1)	31.2 (6.7)	31.8 (6.0)	0.853	0.814	0.660
Body composition						
Body fat (%)	40.0 (5.7)	36.2 (9.2)	38.1 (7.6)	0.495	0.583	0.234
Lean mass (%)	57.0 (5.4)	60.7 (8.7)	58.5 (7.7)	0.583	0.520	0.223
Isometric strength						
Handgrip strength (kg)	21.3 (4.4)	23.2 (6.7)	21.9 (4.7)	0.738	0.605	0.429
Endurance performance						
6MWT (m)	478.0 (37.6)	441.0 (48.9)	453.0 (39.2)	0.119	0.512	0.050
CMRFs						
HTN (n)	12	10	10			
T2D (n)	4	5	5			
Dyslipidemia (n)	10	9	12			
Medications						
ARB (n)	9	5	7			
ACEI (n)	3	2	3			
TZD (n)	4	6	8			
CCB (n)	1	3	3			
Beta Blockers (n)	1	2	1			
Metformin (n)	3	5	4			
Sulfonylureas (n)	0	0	1			
Insulin (*n* =)	1	1	2			
Statins (*n* =)	10	12	9			

Data are presented as mean, and (± SD). Groups are described as *RT-G* Resistance training, *HIIT-G* High intensity interval training. Outcomes are described as *HTN* Hypertension, *T2D* Type 2 diabetes, *BMI* Body mass index, *6MWT* 6-min walk test, *CMRFs* Cardiometabolic risk factors. Medications are described as *ARB* Angiotensin Receptor Blockers, *ACEI* Angiotensin-Converting Enzyme Inhibitors, *TZDs* Thiazide Diuretics, *CCBs* Calcium Channel Blockers

observed in the HIIT-G at eight weeks, with a moderate effect size ($p = 0.002$; 95% CI: 22, 55 m; Cohen's d = 0.757) (Table 2, Fig. 2, panel e). Additionally, the analysis indicated a significant effect of time on this outcome measure (F = 7.544, $p = 0.002$) (Table 2).

Individual response to exercise (IR): Rs and NRs

The IR presented in this study by group, outcome measure, and measurement time (weeks four and eight) were as follows: for the RT-G, the IR for BMI (kg/m2) were −0.04 and −0.17, the body fat percentages were −1.61 and −1.08, the lean mass percentages were 1.62 and 0.92, the isometric strength (kg) was 2.08 and 3.15, and the 6MWT (m) were 36.09 and 28.69, respectively. For the HIIT-G, the IR for BMI (kg/m2) were −0.51 and −0.40, body fat (%) was −1.77 and −1.48, lean mass (%) was 1.83 and 1.26, isometric strength (kg) was 2.85 and 4.84, and 6MWT (m) were 24.89 and 19.56, respectively. For the CG, the lowest IR values were used to detect a positive response for each variable.

Regarding the prevalence of Rs in the RT-G (Table 3), 50% ($n = 6$) of the participants had Rs at both weeks four and eight for BMI. In terms of body fat percentage, the Rs increased from 25% ($n = 3$) at week eight to 50% ($n = 6$) at week eight. Lean mass increased Rs from 8% ($n = 1$) at week four to 58% ($n = 7$) at week eight. The isometric strength was 75% ($n = 9$) at week four and decreased to 50% ($n = 6$) at week eight. Finally, in the 6MWT, Rs increased from 25% ($n = 3$) at week four to 33% ($n = 4$) at week eight.

Table 2 Changes during the intervention in body composition, isometric strength, and 6MWT variables

Outcome	Intervention	Pre	Week 4	Week 8	Pre vs Week 4 (Δ, 95% CI, *p*-value, ES)	Pre vs Week 8 (Δ, 95% CI, *p*-value, ES)	Time effect F value (*p*-value)	Group effect F value (*p*-value)	Interaction F value (*p*-value)
BMI (kg/m^2)	RT-G	32.2 ± 4.1	32.1 ± 4.0	32.0 ± 4.1	−0.1 (−0.3, 0.1), $p = 0.327$, ES = 0.026	−0.2 (−0.5, 0.1), $p = 0.359$, ES = 0.044	1.297 (0.131)	0.144 (0.867)	2.410 (0.007)
	HIIT-G	31.2 ± 6.7	30.9 ± 6.9	30.9 ± 6.8	−0.3 (−0.6, 0.0), $p = 0.123$, ES = 0.044	−0.3 (−0.6, 0.0), $p = 0.194$, ES = 0.047			
	CG	31.0 ± 6.0	31.9 ± 6.0	32.4 ± 5.9	0.1 (−0.2, 0.4), $p = 0.395$, ES = 0.015	0.6 (0.2, 1.0), $p = 0.012$, ES = 0.098			
Body fat (%)	RT-G	40.0 ± 5.7	39.3 ± 5.3	38.7 ± 6.2	−0.7 (−1.5, 0.1), $p = 0.086$, ES = 0.121	−1.3 (−2.5, −0.1), $p = 0.060$, ES = 0.216	1.297 (0.287)	0.630 (0.539)	2.410 (0.012)
	HIIT-G	36.2 ± 9.2	36.0 ± 9.0	35.4 ± 8.3	−0.2 (−1.2, 0.8), $p = 0.511$, ES = 0.021	−0.8 (−2.0, 0.4), $p = 0.268$, ES = 0.090			
	CG	38.1 ± 7.6	37.7 ± 9.2	38.8 ± 8.8	−0.4 (−1.3, 0.5), $p = 0.570$, ES = 0.040	0.7 (−0.5, 1.9), $p = 0.210$, ES = 0.085			
Lean mass (%)	RT-G	57.0 ± 5.4	57.6 ± 5.1	58.2 ± 5.8	0.6 (0.1, 1.1), $p = 0.114$, ES = 0.109	1.2 (0.3, 2.1), $p = 0.053$, ES = 0.214	1.248 (0.301)	0.625 (0.541)	2.640 (0.008)
	HIIT-G	60.7 ± 8.7	60.7 ± 8.6	61.3 ± 7.9	0.0 (−0.8, 0.8), $p = 0.827$, ES = 0.006	0.6 (−0.5, 1.7), $p = 0.320$, ES = 0.076			
	CG	58.5 ± 7.7	59.0 ± 9.3	57.9 ± 8.8	0.5 (−0.5, 1.5), $p = 0.425$, ES = 0.056	−0.6 (−1.4, 0.2), $p = 0.277$, ES = 0.067			
Handgrip (kg)	RT-G	21.3 ± 4.4	**24.09 ± 3.59**[a]	**24.37 ± 3.99**[b]	2.79 (1.3, 4.1), $p = 0.001$, ES = 0.695	3.07 (1.8, 4.3), $p = 0.027$, ES = 0.731	4.405 (0.020)	0.347 (0.710)	2.319 (0.028)
	HIIT-G	23.2 ± 6.7	23.08 ± 5.32	25.78 ± 4.75	−0.12 (−1.3, 1.1), $p = 0.946$, ES = 0.014	2.58 (1.0, 4.1), $p = 0.132$, ES = 0.450			
	CG	21.9 ± 4.7	22.65 ± 5.9	22.75 ± 5.4	0.75 (−0.8, 2.3), $p = 0.434$, ES = 0.134	0.85 (−0.3, 2.0), $p = 0.321$, ES = 0.162			
6MWT (m)	RT-G	478 ± 37.6	499 ± 42.0	**502 ± 47.0**[b]	21.0 (7, 35), $p = 0.149$, ES = 0.513	24.0 (10, 38), $p = 0.061$, ES = 0.562	7.544 (0.002)	3.217 (0.053)	2.013 (0.044)
	HIIT-G	441 ± 48.9	457 ± 51.0	**480 ± 53.0**[b]	16.0 (5, 27), $p = 0.157$, ES = 0.327	39.0 (22, 55), $p = 0.002$, ES = 0.757			
	CG	453 ± 39.2	447 ± 57.0	456 ± 44.0	−6.0 (−20, 8), $p = 0.460$, ES = 0.127	3.0 (−8, 14), $p = 0.750$, ES = 0.062			

Data are presented as mean ± standard deviation (SD). The groups are defined as follows: *RT-G* (Resistance Training Group), *HIIT-G* (High-Intensity Interval Training Group), and CG (Control Group). The measured outcomes include *BMI* (Body Mass Index) and *6MWT* (6-Minute Walk Test). Time points are described as Pre (baseline, before the intervention), Week 4 (after four weeks of intervention), and Week 8 (after eight weeks of intervention). Δ (Delta) represents the absolute change between two time points (e.g., Pre vs. Week 4 or Pre vs. Week 8); 95% CI (Confidence Interval) denotes the 95% confidence interval; ES (Effect Size) quantifies the magnitude of the observed change. (a) Indicates significant differences between Pre and Week 4. (b) Indicates significant differences between Pre and Week 8. Statistically significant differences are highlighted in bold

In the HIIT-G (for details, see Table 3), 25% ($n = 3$) of the participants had Rs at week four, which increased to 50% ($n = 6$) at week eight for BMI. In terms of body fat percentage, the Rs increased from 8% ($n = 1$) at week four to 42% ($n = 5$) at week eight. For lean mass, 100% ($n = 12$) of NRs were observed at week four; however, 42% of Rs were observed at week eight. The isometric strength was 17% ($n = 2$) of the Rs at week four,

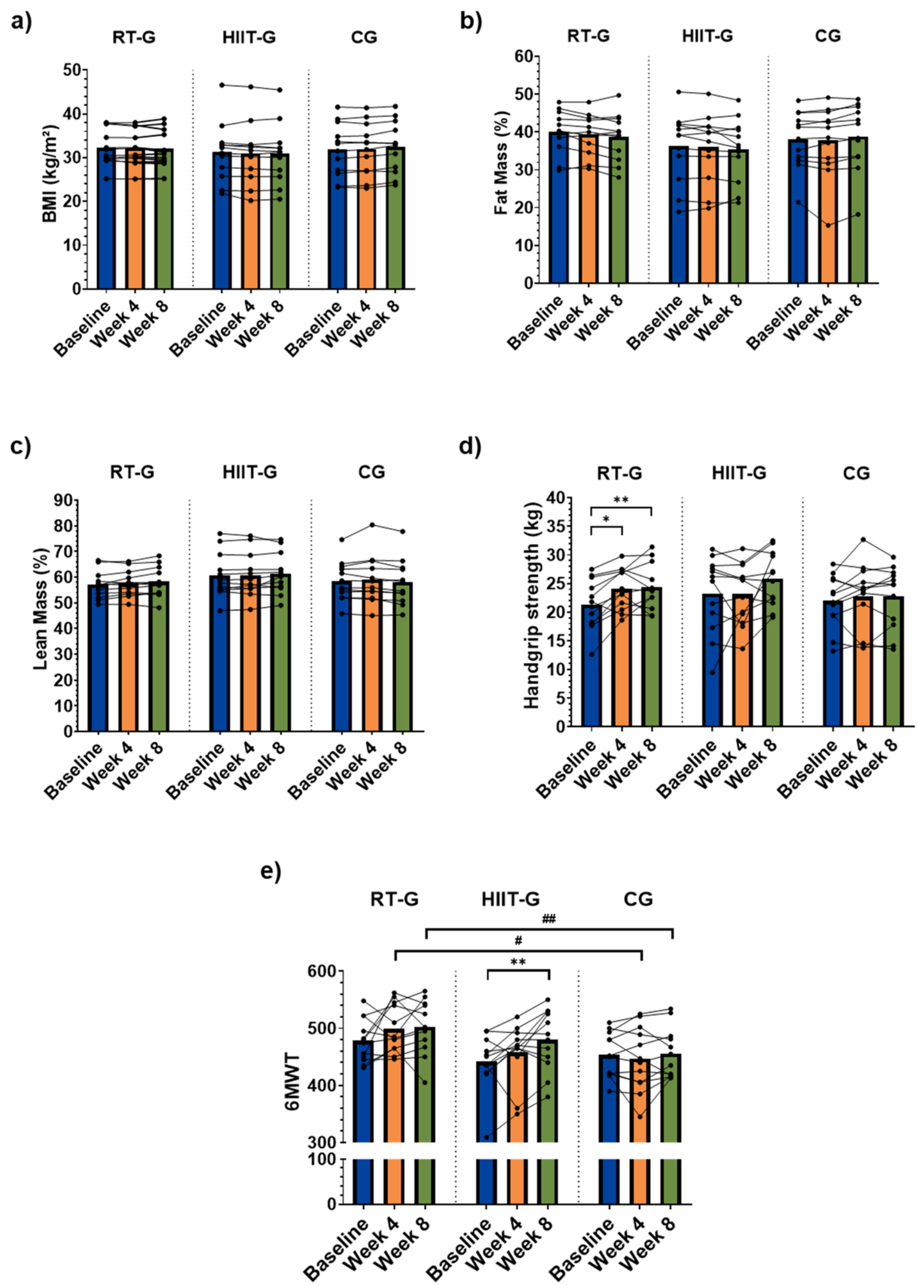

Fig. 2 Comparison of the effects of different exercise modalities at baseline, week 4, and week 8 on BMI (panel **a**), fat mass (panel **b**), lean mass (panel **c**), handgrip strength (panel **d**), and the 6MWT (panel **e**). Significant differences ($p < 0.05$) are indicated as follows: (*) between baseline and week 4, (**) between baseline and week 8, (#) between RT-G and CG at week 4, and (##) between RT-G and CG at week 8. RT-G: Resistance training group; HIIT-G: high-intensity interval training group; CG: control group; BMI: body mass index; 6MWT: 6-min walk test

increasing to 25% ($n = 3$) at week eight. Finally, for the 6MWT, the proportion of Rs increased from 58% ($n = 7$) in week four to 75% ($n = 9$) in week eight.

In the CG (for details, see Table 3), 42% ($n = 5$) of the participants had Rs at week four, which decreased to 17% ($n = 2$) at week eight for BMI. In terms of body fat percentage, one Rs (8%) was observed at weeks 4 and 8. For lean mass, 17% ($n = 2$) of the Rs were observed at weeks four and eight. The isometric strength was 25% ($n = 3$) of the Rs at week four, which decreased to 17% ($n = 2$) at week eight. Finally, for the 6MWT, the proportion of Rs increased from 8% ($n = 1$) in week four to 25% ($n = 3$) in week eight.

Table 3 Temporal dynamics of adaptation based on training modality, evaluation time, and response

Outcome	Response	Groups																	
		RT-G						HIIT-G						CG					
		Week 4			Week 8			Week 4			Week 8			Week 4			Week 8		
		(*n* =)	Δ	%	(*n* =)	Δ	%	(*n* =)	Δ	%	(*n* =)	Δ	%	(*n* =)	Δ	%	(*n* =)	Δ	%
BMI (kg/m^2)	Rs	6	−0.8	−1.2	6	−0.67	−2.1	3	−0.91	−3.2	6	−0.89	−2.8	5	−0.27	−0.8	2	−0.4	−1.3
	NRs	6	0.17	0.5	6	0.31	1.0	9	−0.09	−0.3	6	0.27	0.9	7	0.35	1.1	10	0.8	2.4
Body fat (%)	Rs	3	NA	−2.2	7	NA	−2.7	1	NA	−1.8	5	NA	−2.9	1	NA	−6.1	1	NA	−3.2
	NRs	9	NA	−0.2	5	NA	0.7	11	NA	0.0	7	NA	0.7	11	NA	0.18	11	NA	1.1
Lean mass (%)	Rs	1	NA	2.8	7	NA	2.5	0	NA	NA	5	NA	2.4	2	NA	4.0	2	NA	2.2
	NRs	11	NA	0.4	5	NA	−0.6	12	NA	0.1	7	NA	−0.7	10	NA	−0.2	10	NA	−1.1
Handgrip strength (kg)	Rs	9	3.72	18.5	6	6.43	33.6	2	6.45	48.1	3	9.10	66.1	3	4.03	16.7	2	4.15	18.3
	NRs	3	−0.03	−0.1	6	−0.32	−1.3	10	−1.39	−5.5	9	0.44	1.7	9	−0.39	−1.8	10	0.15	0.6
6MWT (m)	Rs	3	83.33	17.7	4	70.75	15.2	7	40	9.4	9	54.93	12.6	1	32	6.4	3	33.33	7.4
	NRs	9	−0.56	−0.1	8	0.50	0.1	5	−16.6	−3.6	3	−9.90	−2.2	11	−9.64	−2.1	9	−7.67	−1.6

Data are presented as absolute delta (Δ) changes at weeks 4 and 8, and as percentage delta (%) changes at weeks 4 and 8. Groups are described as *RT-G* Resistance training group, *HIIT-G* High intensity interval training group and *CG* Control group. Outcomes are described as *BMI* Body mass index, *6MWT* 6-min walk test. Exercise responses are described as *Rs* Responders, *NRs* No responders

Temporal dynamics of adaptation in Rs and NRs

In the RT-G (Table 3), Rs showed a reduction in BMI of −1.2% at week four and −2.1% at week eight, whereas NRs increased by 0.5% and 1.0%, respectively. Body fat in Rs decreased by −2.2% at week four and −2.7% at week eight, whereas NRs showed a minimal change of −0.2% at week four and an increase of 0.7% at week eight. In terms of lean mass, Rs increased by 2.8% at week four and 2.5% at week eight, whereas NRs increased by 0.4% at week four and decreased by −0.6% at week eight. The isometric strength in Rs increased by 18.5% at week four and 33.6% at week eight, whereas NRs showed minimal changes of −0.1% at week four and −1.3% at week eight. In the 6MWT, Rs improved by 17.7% at week four and 15.2% at week eight compared to NRs, which showed a slight decline of −0.1% at week four and an increase of 0.1% at week eight.

Regarding BMI in the HIIT-G group (Table 3), Rs decreased by −3.2% at week four and −2.8% at week eight, whereas NRs exhibited minor changes of −0.3% and 0.9%, respectively. In terms of fat mass, Rs decreased by −1.8% at week four and −2.9% at week eight, whereas NRs did not change at week four and slightly increased by 0.7% at week eight. There were no changes in lean mass at week four for Rs; however, a 2.4% increase was observed at week eight, whereas NRs showed a slight increase of 0.1% at week four and a decrease of −0.7% at week eight. The isometric strength in Rs increased by 48.1% at week four and 66.1% at week eight, in contrast to NRs, who experienced a decrease of −5.5% at week four and a slight improvement of 1.7% at week eight. In the 6MWT, Rs improved by 9.4% at week four and 12.6% at week eight, whereas NRs decreased by −3.6% at week four and −2.2% at week eight.

In the CG (Table 3), temporal adaptation dynamics showed small positive changes at week 4, stabilized by week 8, and one–three responders were observed. In the NRs, the changes were insignificant at both time points.

No adverse events or unintended effects were observed during the intervention. All participants tolerated the intervention well, and no significant harm was reported in either the intervention or control group.

Discussion

This study aimed to assess the impact of eight weeks of low-volume exercise regimens, specifically RT and HIIT, on body composition, isometric strength, and 6MWT in older women with CMRFs. Furthermore, we compared the efficacy of these exercise modalities in improving these health metrics between weeks four and eight and explored the temporal dynamics of these adaptations over time.

The key findings indicate that the RT and HIIT protocols led to progressive and cumulative improvements in isometric strength and cardiorespiratory capacity, albeit with moderate effect sizes, as shown in Table 2 and Fig. 2. There was noticeable interindividual variability in the exercise response, with a greater percentage of Rs in both protocols by the end of the intervention for body composition and 6MWT (Table 3). Notably, the rate of adaptation peaked in the fourth week and stabilized by the eighth week among the Rs for both RT-G and HIIT-G (Table 3).

The participants presented significantly altered body composition parameters, characterized by an obesity-range BMI, a high fat mass percentage, and a low lean mass percentage, in contrast to healthy Chilean individuals [55], as shown in Table 2. The isometric strength of participants was lower than the average for Chilean women of the same age [48] (RT-G: 21.3 ± 4.4 kg; HIIT-G: 23.2 ± 6.7 kg; national average: 28.6 ± 3.4 kg), as was the distance covered in the 6MWT [51] (RT-G: 478 ± 37.6 m; HIIT-G: 441 ± 48.9 m; national average: 540 ± 60 m). This discrepancy is likely due to the presence of PI at the beginning of the study and their antagonistic relationship with CMRFs and low PF [56].

PI is associated with detrimental metabolic and physiological changes, notably the early development of insulin resistance at the muscular level and a shift in muscle fibers from oxidative to glycolytic. This shift reduces lipid utilization as an energy substrate, resulting in the accumulation of unoxidized lipids in central and peripheral fatty tissues and organs as ectopic fat. Such accumulation increases sympathetic activity and the inflammatory response, which are linked to the deterioration of PF and the progression of CMRFs [57].

Effects of RT and HIIT

Chen et al. [58] and Fritz et al. [16] reported significant increases in muscle strength following twelve and eight weeks of strength training with elastic bands in individuals with impaired cardiometabolic health, which aligns with the findings of our study (Table 2 and Fig. 2). Additionally, studies by Lock et al. [18] and Mello et al. [59] reported improvements in cardiorespiratory capacity through HIIT protocols lasting eight weeks in inactive women over 45 years of age and individuals with impaired cardiometabolic health. Our findings corroborate these observations, suggesting that low-volume strength training with elastic bands and HIIT offers safe and effective alternatives for improving muscle strength and 6MWT in older adults with impaired cardiometabolic health(Table 2 and Fig. 2).

Moreover, previous research has highlighted the extensive benefits of RT and HIIT beyond improvements in cardiorespiratory fitness and muscle strength. Both training modalities have been shown to elicit favorable changes in anthropometric characteristics, promote fat mass reduction, and enhance lean mass in individuals with metabolic dysregulation [60]. Additionally, recent studies suggest that RT and HIIT exert positive effects on psychological health by lowering stress-related biomarkers and enhancing perceived well-being [61, 62], further reinforcing their role as comprehensive exercise strategies. These findings underscore the versatility of RT and HIIT in targeting multiple health parameters in populations at cardiometabolic risk.

A comprehensive review [30] revealed that exercise-induced changes are progressive and cumulative, with more extended protocols showing greater efficacy. In this context, Zhao et al. [63] reported an increase in grip strength in older sarcopenic individuals following protocols of less than 12 weeks, with a more significant effect observed with a more extended protocol. Similarly, a review [18] revealed that HIIT protocols extending beyond ten weeks substantially improved cardiorespiratory fitness over shorter durations. Despite the favorable outcomes observed after eight weeks of training in our study, future research should explore longer durations to maximize the beneficial effects of exercise over time and assess potential ceiling effects in individuals with impaired cardiometabolic health.

Interestingly, we noted improvements in the 6MWT in the RT-G and enhancements in isometric strength in the HIIT-G (Table 2). Previous studies have shown that strength training can improve mitochondrial function [64] and increase aerobic capacity, as measured by the VO2 max [65]. In contrast, aerobic exercise is associated with modest muscle hypertrophy [66] and neuromuscular adaptations [67] in healthy individuals. This suggests that strength and aerobic exercises are not physiologically mutually exclusive but offer complementary benefits, where specific adaptations may be more pronounced in response to one type of exercise [30]. These findings support the notion that individuals with cardiovascular risk factors can benefit from engaging in physical exercise regardless of the chosen modality, highlighting the versatility and importance of tailored exercise programs in managing and improving health outcomes in this population.

In addition to RT and HIIT, multicomponent exercise programs, which integrate aerobic and resistance, have demonstrated significant improvements in physical function, body composition, and metabolic health outcomes in individuals with metabolic dysregulation. Al-Mhanna et al. [68] and Batrakoulis [20] et al. reported that a combined aerobic and resistance training protocol was effective in enhancing overall physical performance in individuals with impaired cardiometabolic health similar to those in this study. While our study focused on low-volume RT and HIIT, which are time-efficient strategies, future research should explore how these modalities compare to or complement multicomponent exercise approaches in individuals with cardiometabolic conditions.

Interindividual variability in response to exercise

Interindividual variability in response to exercise was substantial and influenced by the group, outcome measures, and measurement timing. This variability presents a significant challenge for the prescription of personalized training programs. Physical stress induced by exercise is multifaceted, and substantial interindividual variability has been observed in intensity markers in response to standardized workloads. Consequently, the accuracy of the relative intensities in achieving the desired training stimulus may be questioned [69]. However, to minimize bias in exercise prescription, it was ensured that individuals reached high work intensities in each session (Borg 8–10 in HIIT and OMNI-RES 8–10 in RT).

Body composition outcome measures revealed that BMI improved in 50% of participants at week eight in both groups. Similar patterns were observed for fat mass (RT-G, 50%; HIIT-G, 42%) and lean mass (RT-G, 58%; HIIT-G, 42%). Although no statistically significant or clinically relevant changes were noted, individual analyses revealed that approximately 50% of participants benefited from these outcome measures. Alvarez et al. [29] reported a 25% prevalence of Rs for BMI. Improvements in the RT group were observed after the 12-week protocol, with a 21% response rate in the HIIT group. Bonafiglia et al. [26] observed a 30% response rate for weight reduction with strength exercise and a 42% response rate with aerobic exercise. The differential response rates for fat mass reduction in a similar 12-week protocol were 29.5% and 66% for RT and HIIT, respectively [27]. For lean mass gain, 47% of the participants in the RT group were classified as Rs, whereas NRs were noted in the HIIT group [27].

Statistically significant differences and clinically relevant improvements in isometric strength were reported in the RT-G at the end of the protocol. However, the individual response rate decreased from 75% at week four to 50% at week eight. This reduction may be due to increased individual response thresholds from week four (2.08 kg) to week eight (3.15 kg). Strength training is known to lead to significant gains through enhancements in neuromuscular efficiency and the ability of the nervous system to recruit motor units, typically peaking at four weeks and maturing by 8–12 weeks, which may eventually lead to a plateau in improvement rates [33].

In a nine-week thrice-weekly strength-training protocol, 81% of the participants achieved gains in quadriceps strength [70], a proportion that was greater than that observed in our study. This discrepancy could be attributed to the specific characteristics of our study population, which comprised older adults with chronic conditions, as opposed to the young, healthy men in the referenced study, who are anticipated to exhibit a more pronounced response to a strength-training protocol [71]. In the HIIT-G, NRs were noted at week four; however, 42% of the participants showed improvements in isometric strength by week eight. Alvarez et al. [28], in a similar but longer intervention (16 weeks), reported an Rs of 45.4%. Contrasting results were reported in two different 12-week HIIT protocols by Alvarez et al. [27, 29], where the Rs did not exceed 11%. Notably, the number of Rs in all studies was less than 50%, which could be explained by the nonspecific nature of HIIT training for muscle strength gain [72] or the need for a greater training volume to achieve a more substantial response.

Regarding improvements in the 6MWT, the RT-G group presented an increase in the percentage of Rs from 25 to 33%. These findings contrast with those of Alvarez et al. [29], who reported a 100% response rate after 12 weeks of strength training. Conversely, in the HIIT-G, the percentage of Rs increased from 58 to 75%, aligning more closely with the findings of Alvarez et al. [29] who reported 100% Rs after 12 weeks of HIIT and 86% after a 16-week protocol [28]. The notably higher response rates in Alvarez's study are likely due to the longer duration of the exercise protocols, which has been recognized as a crucial factor in enhancing response rates to exercise [73].

These findings underscore that the number of Rs for various outcome measures generally increases with exercise protocol duration. This observation is supported by prior research [34, 73], which indicated that higher training intensities and prolonged protocol durations lead to increased Rs. Additionally, exercise modality plays a significant role in determining the final percentage of Rs [72, 74]. This effect is attributed to the nature of the stimulus delivered: HIIT directly targets enhancements in cardiorespiratory capacity, whereas strength training predominantly increases isometric strength in this population [30].

Temporal dynamics of adaptation

In the RT-G group, Rs slightly reduced BMI, decreasing by 1.2% at week four and 2.1% at week eight. Similarly, the HIIT-G score decreased by 3.2% and 2.8% at the same time points. These results align with those of a systematic review by Wewege et al. [75], which reported no significant effects of physical exercise on body mass across various studies. However, the HIIT-G in our study showed a modest trend toward more substantial changes in BMI, although these changes were not clinically significant [76].

For body fat percentage, both RT-G and HIIT-G showed reductions of approximately 2% at week four and 2.8% at week eight, aligning with but slightly exceeding the reductions reported in a review by O'Donoghue et al. [9], which reported decreases of 1.27% and 1.47%, respectively, in protocols involving vigorous aerobic exercise and low-load resistance training over more than eight weeks. Notably, O'Donoghue's review distinguished between Rs and NRs.

Lean mass adaptations in Rs at eight weeks were similar in RT-G and HIIT-G, with 2.5% and 2.4% increases, respectively. Although these changes are not clinically significant, they may reduce the risk of cardiometabolic disease.

Our findings contrast with a review by Bellicha et al. [60], which reported significant reductions in body and fat mass following HIIT and RT protocols of longer durations (more than eight weeks). Additionally, following a 12-week resistance training protocol with elastic bands, Liao et al. [77] demonstrated a significant increase in lean mass in women with sarcopenic obesity. Extending exercise protocols beyond eight weeks may be necessary to elicit significant changes in these outcomes.

In summary, although changes in body composition through physical exercise alone are challenging [78], our findings underscore the potential of interdisciplinary interventions. The incorporation of nutritional management, psychological support, and pharmacological treatment alongside physical exercise may provide a more effective strategy for improving body composition [79]. Future studies should consider these interdisciplinary approaches to maximize the health benefits of exercise interventions.

In RT-G, Rs increased in isometric strength from 18.5% at week four to 33.6% at week eight. Similarly, HIIT-G showed a more pronounced increase, from 48.1% to 66.1%. The notable increase in isometric strength among the Rs in the HIIT-G can be attributed to the small number of Rs ($n = 2$) and their initially low strength levels at the start of the intervention, as indicated in Table 3. Notably, the minimal clinically relevant difference in grip strength was reported to be 6.5 kg [80], which was achieved by week eight (Table 3). These findings suggest that these interventions effectively increased grip strength among Rs.

The temporal dynamics of adaptation for the 6MWT varied between the protocols. The RT-G improved by 17.7% at week four but slightly decreased to 15.2% at week eight. In contrast, the HIIT-G experienced a cumulative increase from 9.4% to 12.6% over the same period. Despite varying patterns of change, both protocols surpassed the minimal clinically relevant difference of 30.5 m by week four [81] (Table 3). This finding indicates that a four-week duration is sufficient to observe significant improvements in the 6MWT among the exercise Rs.

Overall, Rs displayed a more rapid rate of change by week four, which stabilized by week eight across both RT-G and HIIT-G, as illustrated in Table 3. This pattern mirrors the temporal dynamics of adaptation reported by Lambrianides et al. [33] as early as week four in the 6MWT and by week eight in muscle strength for both protocols, underscoring the potential of these interventions to improve critical components of physical fitness among Rs swiftly.

Conversely, the NRs group exhibited minimal or adverse changes in specific fitness parameters (Table 3), underscoring the need for personalized training programs. Early tailoring of interventions is crucial to optimize individual outcomes and improve the effectiveness of fitness programs for this subgroup.

Strengths and limitations

The strengths of this study lie in: (1) its accounting for individual variability in exercise response, an essential aspect of personalizing training programs; (2) its innovative approach to documenting the temporal dynamics of exercise adaptation, which moves beyond the traditional reporting of overall intervention effects; and (3) its significant practical implications, as the findings offer valuable insights for creating physical training programs, particularly for those with impaired cardiometabolic health.

The limitations of this study are (1) its restricted sample size and geographic specificity, which may limit the generalizability of the results to broader or more diverse populations; (2) the relatively short duration of the study, which lasted only eight weeks; more extended intervention periods could provide insights into the sustainability of improvements and reveal additional long-term changes in physical capacities; (3) the lack of control over diet and other lifestyle factors, beyond the recommendations given to participants at the beginning of the study; (4) the instruments employed to assess body composition in this study are not considered gold standard methods; however, these tools have been previously validated in scientific literature [44, 49], supporting their accuracy and reliability within the scope of the present research; [5] the limitations associated with using the Hopkins Eq. [52] to determine individual responses, which is based on the assumption that the combined effect of random variation and within-participant variation is equal between the intervention and control groups. Even with random assignment to the control and intervention groups, the inability to calculate within-participant variation in each group opens the possibility that its influence may differ [82]. Therefore, the results must be interpreted with caution to avoid undue generalizations.

Conclusion

This study proves that RT and HIIT can significantly improve physical fitness among older women with impaired cardiometabolic health over eight weeks. Specifically, the RT-G demonstrated consistent and progressive enhancements in isometric strength, whereas the HIIT-G exhibited improvements in distance covered in 6MWT.

Notable across both groups was the considerable variability in individual responses to the interventions; however, there was a marked decrease in the prevalence of NRs concerning body fat, lean mass, and 6MWT. This decrease underscores the potential for tailored exercise protocols to mitigate initial non-responsiveness by adapting the intensity and type of exercise to an individual's needs.

Among Rs, both exercise modalities showed a pattern of rapid improvement during the initial four weeks, which tended to stabilize according to the conclusion of the eight-week regimen. Importantly, these changes reached clinical significance in isometric strength measures and in the distance covered in the 6MWT, suggesting that such interventions can yield tangible benefits in relatively short periods.

These findings highlight the importance of customizing exercise interventions to maximize physiological responses and secure substantial health benefits for older adults with impaired cardiometabolic health. Future studies should explore longer duration protocols and personalization to enhance these effects and reduce the proportion of NRs.

Abbreviations

6MWT	6-minute walk test
BMI	Body mass index
CG	Control group
CMRFs	Cardiometabolic risk factors
HIIT	High-intensity interval training
HIIT-G	High-intensity interval training group
HTN	Hypertension
IR	Individual response
NRs	Non-responders
PF	Physical fitness
PI	Physical inactivity
Rs	Responders
RT	Resistance training
RT-G	Resistance training group
T2DM	Type 2 diabetes mellitus

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Authors' contributions
JC-M, MR, SB, CN, AND CA designed the present study. JC-M, SB, CN, and FG collected the data; assistance was provided to facilitate data collection; and JC, SM, and CA analyzed the data. JC-M, CA, and MI undertook the data interpretation. Writing—original draft: JC-M. Writing—review & editing: JC-M, MR, SB, CN, SM, FG, CA, and MI. All authors approved the final version of the manuscript.

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Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethical Scientific Committee of the Valdivia Health Service Resolution No. 2314327099 (Ord. N° 166, 2023). Informed consent was obtained from all participants, ensuring their full understanding of the study's objectives, procedures, potential benefits, and associated risks.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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