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Comparison of Repetition-Based Progressive-Overload Strategies in Resistance Training: Rest-Pause Versus Drop Sets

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ABSTRACT

Rest-pause (RP) and drop sets (DS) are widely used as intensification strategies during resistance training. However, their incorporation within a repetition-based progressive-overload (PO) model and their effects under supervised conditions are not well established. We compared progressive-overload rest-pause (PO-RP) with progressive-overload drop-set (PO-DS) training, assessing changes in body composition and maximal strength in resistance-trained adults. Twenty-three participants (20 men and 3 women; 29.1 [5.9] years; 25.0 [3.1] kg/m²) were randomized to either PO-RP ($n = 12$) or PO-DS ($n = 11$). After a 1-week familiarization phase, both groups trained twice weekly for 8 weeks under supervision while following a prescribed nutritional protocol. Pre/post measures of body composition were assessed by DXA, and maximal strength was evaluated by the one-repetition maximum (1-RM) bench press. Adiposity-related outcomes (total and upper-body fat mass, and total and upper-body fat-free adipose tissue) remained essentially unchanged in both protocols (all group \times time $p > 0.05$). Lean soft tissue mass increased in PO-DS ($\Delta = 1.4$ kg; 95% CI, 0.8–2.2; $p < 0.001$; $g = 0.1$) and PO-RP ($\Delta = 1.2$ kg; 95% CI, 0.8–2.0; $p < 0.001$; $g = 0.1$), with no between-protocol difference in change (group \times time $p = 0.688$). Bench press 1-RM increased in both protocols (PO-DS: $\Delta = 12.3$ kg; 95% CI, 9.6–14.0; $p < 0.001$; $g = 0.7$; PO-RP: $\Delta = 9.5$ kg; 95% CI, 7.3–11.2; $p < 0.001$; $g = 0.4$), without a statistically significant group \times time effect ($p = 0.086$). Under supervised training and a standardized nutritional protocol, PO-RP and PO-DS produced comparable adaptations. Adiposity-related outcomes remained stable, fat-free compartment measures increased, and maximal strength improved, with no statistically significant between-protocol differences in change. Future research should determine whether these adaptations are maintained over longer interventions and whether responses differ across populations with different characteristics, including women, older adults, clinical populations, or individuals with different training experience. Further studies incorporating larger samples, direct assessments of muscle hypertrophy, additional strength outcomes, and mechanistic measures of fatigue and recovery may help refine the application of advanced resistance-training strategies in evidence-based exercise programs.

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1 | Introduction

Resistance training (RT) is widely recognized as an effective intervention for increasing skeletal muscle mass and maximal strength in trained and untrained individuals. Its efficacy for promoting muscular adaptations has been consistently demonstrated across a wide range of populations, making it a central component of exercise prescription in both performance and health-oriented contexts [1].

A fundamental principle underlying RT-induced adaptations is progressive overload, which describes the gradual increase in training stress over time to elicit continued physiological adaptations [2]. In RT research, this principle has often been operationalized through increases in external load or total training volume across training periods [2]. However, classical models of RT programming have long acknowledged that training adaptations can be promoted through the manipulation of multiple variables, including load, volume (i.e., number of sets and repetitions), training intensity, rest intervals (density), frequency, and exercise selection, as well as through different periodization strategies such as linear and nonlinear (undulating) models [3].

In this context, progression through increases in the number of repetitions performed at a fixed relative intensity has emerged as a viable alternative when load-based progression becomes constrained. Several studies have shown that repetition-based progression can elicit similar hypertrophic and strength adaptations to traditional load progression, provided that training is performed close to failure and the training effort is comparable [4, 5]. These findings support the notion that different overload strategies may lead to similar outcomes when the overall training stimulus is adequate.

Among the strategies used to extend repetition-based progression, drop sets (DS) and rest-pause (RP) techniques have been commonly employed in RT practice. DS involve sequential reductions in load following momentary muscular failure, while RP methods incorporate brief recovery periods at the end of sets, typically when muscle failure is reached, allowing for additional repetitions with the same load. Both techniques have been used in strength training settings to increase training density and prolong exposure to high levels of effort [6, 7]. Although the underlying mechanisms have yet to be determined, it has been speculated that DS may potentially contribute to muscle hypertrophy by increasing metabolic stress and total repetition volume [6, 7]. Similar mechanistic explanations have been proposed as a rationale for RP-induced enhancements in hypertrophic adaptations.

Although DS and RP have shown the potential to elicit hypertrophy in previous studies, the available evidence differs by method and study design [7, 8]. DS and RP techniques have predominantly been investigated in short-term training protocols in which these methods are applied continuously throughout the entire intervention period, from beginning to end, as the primary training strategy. In contrast, in the present study, these techniques were not applied systematically across all sessions, but were instead incorporated within a structured progression model. Specifically, they were introduced only when participants were no longer able to increase the number of repetitions with the fixed prescribed load while maintaining proper technique.

This limitation is particularly relevant in trained individuals, for whom linear progression in repetitions or load becomes increasingly difficult over time. Recent studies highlighting the absence of a simple linear dose–response relationship between volume progression and hypertrophy further emphasize the need to explore alternative progression strategies that preserve an effective stimulus [9–11]. Nevertheless, when DS and RP were compared, muscle hypertrophy was similar when total training volume (i.e., volume load calculated as sets \times repetitions \times load) was equalized, even relative to traditional sets [12].

The present study aimed to compare the effects of two repetition-based progressive overload strategies, DS and RP, implemented within a structured RT program, on body composition and maximal strength in resistance-trained adults under controlled nutritional conditions. Although both methods have demonstrated hypertrophic efficacy conceivably through increased metabolic stress and training volume, they have mainly been studied as standalone strategies rather than as tools integrated within a progressive overload framework. Therefore, this study sought to examine their practical application once conventional repetition progression could no longer be sustained. We hypothesized that DS and RP would induce similar improvements in lean soft tissue mass, fat-free mass adjusted for fat-free adipose tissue (FFM_{adj}) and maximal strength when training volume and nutritional intake were controlled.

2 | Methods

2.1 | Trial Design

Participants were randomly assigned (www.randomizer.org) to one of two intervention groups: (1) progressive overload through repetitions with DS (PO-DS, $n = 11$), and (2) progressive overload through repetitions with RP (PO-RP, $n = 12$). In both conditions, progressive overload was based on increasing the number of repetitions; when participants reached their repetition limit in an exercise, either DS or RP were implemented according to group allocation. All participants completed a 1-week familiarization phase immediately prior to starting the 9-week supervised RT period, which comprised 8 weeks of protocol application and one individualized recovery week.

During the first week of familiarization, participants visited the laboratory four days a week, received their nutritional protocol and had it explained, and were tested for one-repetition maximum (1-RM) bench press strength as well as DXA-derived estimates of body composition. These measurements were reassessed post-intervention. Participants were instructed to refrain from strenuous exercise for 24 to 48 h and to avoid caffeine, alcohol, and other stimulants for at least 24 h before testing. Food intake and hydration were maintained as usual, avoiding heavy meals before the assessment. All tests were performed at the same time of day. For bone densitometry (DXA), participants arrived fasting, urinated before the assessment, and wore light, metal-free clothing. It is worth noting that the laboratory's environmental conditions are maintained between 20°C and 24°C.

In addition, the 1-RM for the remaining six exercises was also determined during this first week and used to calculate the 80% RM for the seven exercises employed in the protocol.

2.2 | Participants

A total of twenty-seven volunteers were deemed eligible to participate in this study. A total of 23 participants (PO-DS = 10 men and 1 woman; PO-RP = 10 men and 2 women) aged 18 to 35 years ultimately participated as a convenience sample, all with at least one year of continuous resistance-training experience (training experience: 1.5 [0.5] years; age: 29.1 [5.7] years; height: 175.7 [9.5] cm; body mass: 77.8 [12.9] kg; body mass index: 25.1 [3.1] kg/m²; baseline relative bench press strength: 1.13 [0.15] kg·kg⁻¹). In addition, participants trained an average of 4.09 [0.73] days per week, with each session lasting 1.23 [0.23] h. Participants were informed about the potential risks of the study and provided written informed consent prior to enrollment. The experimental procedures were reviewed and approved by the Ethics Committee of the University of Málaga (approval code: 52-2025-H), in accordance with the ethical standards set forth in the Declaration of Helsinki [13].

2.3 | Intervention Procedures

2.3.1 | Exercise Protocol

Before beginning the structured training program, participants completed a one-week familiarization phase. During this period, they received instruction on proper exercise technique, practiced performing sets to momentary muscular failure, were introduced to the PO-DS (20% load reduction after momentary muscular failure) and PO-RP (30-s rest-pause interval after momentary muscular failure) strategies, and had their training loads adjusted and recorded to establish baseline reference values. Thereafter, participants completed a 9-week supervised RT period comprising 8 weeks of resistance training with their assigned protocol and one individualized recovery week. All sessions were overseen by two researchers to ensure protocol adherence and correct exercise execution. The weight training machines used were from Gervasport, Madrid, Spain. A recovery week was implemented according to individual training response that commenced when participants were unable to increase repetitions in most exercises or when they reported excessive fatigue; during this period, the absolute load being used in each exercise was reduced by 30% and sets were not performed to failure. Participants began the recovery week at different time points: most between the fourth and fifth week, one at the end of the third week, and two during the sixth week.

Training was performed twice per week with at least 72 h between sessions. The program targeted the upper body musculature with three sets performed per exercise. The absolute training load corresponded to 80% of baseline one-repetition maximum (1-RM) in both groups and was maintained throughout the 8-week intervention, except during the recovery week. The 1-RM assessment conducted to standardize the 80% 1-RM training loads was performed for all exercises in the study during the first week of familiarization over four non-consecutive days. Pushing and pulling exercises were interspersed on each of the days. Seven upper-body exercises were performed in the following order: bench press, lat pull-down,

military press, pec deck, barbell row, triceps pulley, and biceps curl. A 2-min rest interval was established between sets and exercises, with a controlled movement tempo of approximately 1 s concentric and 1 s eccentric. Participants were instructed to complete the prescribed repetitions and, when possible, perform additional repetitions while maintaining proper technique; DS and RP were applied to all seven exercises according to group allocation, but only under the progression conditions described for the last and penultimate sets.

2.3.1.1 | Progressive-Overload Drop-Set (PO-DS) Protocol. In the PO-DS protocol, participants performed all sets of each exercise to momentary muscular failure using the predetermined load established during the familiarization week (80% 1-RM), with only fully completed repetitions recorded. Initially, progression was achieved by increasing the number of repetitions performed with this fixed load across training sessions. When participants were no longer able to further increase the number of repetitions completed before reaching failure in the final sets of the exercises, the drop-set strategy was introduced as the first progression. Specifically, after reaching failure in the last set, the external load was immediately reduced by 20%, allowing participants to continue performing additional repetitions until failure was reached again. When no further repetition progression could be achieved with this configuration, a second progression was introduced by applying the same drop-set strategy to the penultimate set of each exercise, thereby further increasing total training volume.

2.3.1.2 | Progressive-Overload Rest-Pause (PO-RP) Protocol. In the PO-RP protocol, participants performed all sets of each exercise to momentary muscular failure using the predetermined load established during the familiarization week (80% 1-RM), with only fully completed repetitions recorded. Initially, progression was achieved by increasing the number of repetitions performed with this fixed load across training sessions. When participants were no longer able to further increase the number of repetitions completed before reaching failure in the final sets of the exercises, the rest-pause strategy was introduced as the first progression. At this stage, after reaching failure in the last set, participants performed a 30-s intra-set rest period and then resumed the exercise using the same external load, completing additional repetitions until failure was reached again. Subsequently, when no further repetition progression could be achieved with this configuration, a second progression was introduced by applying the same rest-pause strategy to the penultimate set of each exercise, thereby further increasing total training volume. The overall study timeline and supervised training structure are illustrated in Figure 1.

2.3.2 | Nutritional Protocols

Participants received a standardized dietary plan prescribing an energy intake equivalent to 39 kcal·kg⁻¹ of fat-free mass (FFM), in accordance with previous research from our laboratory [14]. The macronutrient distribution was set at 2.2 g·kg⁻¹ body mass·day⁻¹ of protein and 1 g·kg⁻¹·day⁻¹ of fat, favoring monounsaturated and polyunsaturated lipid sources; carbohydrate intake was individualized based on the remaining energy allotment after protein and fat targets were established to achieve the target caloric intake.

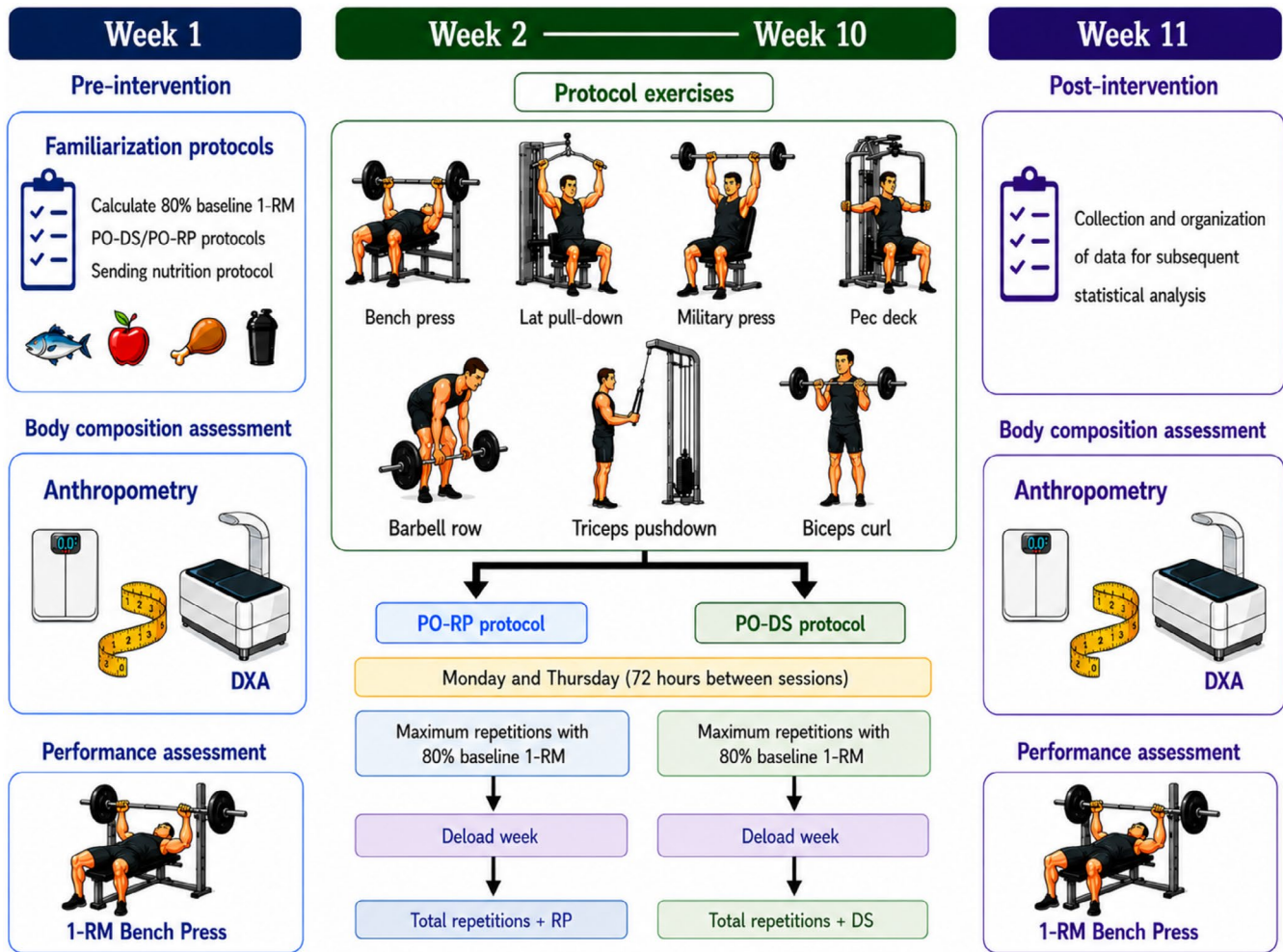


FIGURE 1 | Study timeline and supervised upper-body resistance-training protocol (PO-DS vs. PO-RP). Diagram of the 1-week familiarization, the supervised intervention performed twice weekly (72h between sessions) at 80% 1-RM with a deload week, and the pre/post assessments (DXA, anthropometry, and 1-RM bench press). Both groups completed the same exercise selection and nutritional protocol; progression differed only by the technique used within the progressive-overload (PO) model: Drop sets (PO-DS) or rest-pause (PO-RP). AI (ChatGPT) has been used to improve the aesthetics of the image.

Participants were instructed to distribute their intake across five daily meals, adapted to their usual eating patterns. A physician specialized in sports nutrition supervised dietary prescriptions, offering individualized meal plans with flexible alternatives to support adherence. Nutrium software (Braga, Portugal) was used to support supervision and individual adjustments throughout the intervention. The available prescribed nutritional plans are summarized in Table S1.

2.4 | Measurements

2.4.1 | Body Composition

Body mass was measured with a digital scale to the nearest 50 g (Tanita RD-545, Tokyo, Japan). A fixed stadiometer was used to measure the stature (SECA 220, Hamburg, Germany).

Total and regional body composition was evaluated using dual-energy X-ray absorptiometry (DXA). Participants were instructed to arrive for testing in a fasted state, having abstained from food or caloric beverages for at least 8h; water

consumption was allowed during this period. They were also instructed to avoid any intense physical activity for at least 12h prior to the assessment and to void their bladder immediately before scanning. For female participants, DXA measurements were scheduled seven days after the onset of menstruation in both pre- and post-intervention assessments to reduce potential body mass fluctuations related to hormonal changes and fluid retention [15].

All scans were conducted by a certified radiological technician. Bone and soft tissue analysis, including border detection and regional segmentation, was performed using automated software (APEX 5.6.0.7, Hologic Horizon A, Waltham, MA). Participants wore minimal athletic clothing and removed all items that could interfere with the scan, such as jewelry and garments containing metal. The densitometer was calibrated daily using the standard block provided by the manufacturer. The coefficient of variation was below 2% for all whole-body and regional measures, including bone mineral density (g/cm^2), bone mineral content, fat mass (FM), lean mass, and total body mass. Phantom calibration was performed daily prior to scanning following the manufacturer's guidelines.

Assuming that adipose tissue contains ~85% fat, fat-free adipose tissue (FFAT) was estimated from DXA-derived fat mass (FM) as follows: $FFAT = (FM/0.85) \times 0.15$ [16]. Fat-free mass excluding FFAT was then calculated as $FFMadj = FFM - FFAT$, following the approach previously reported by our group [17]. When regional outcomes were analyzed, the same procedure was applied to the upper-body compartments to derive UB FFAT and UB FFMadj.

2.4.2 | Volume Load

Training volume was calculated as the product of sets, repetitions, and the corresponding load lifted (sets \times repetitions \times load). The initial load was set at 80% of each participant's 1-RM, determined during the familiarization week, and progression was achieved by increasing the number of repetitions according to the assigned protocol. In the PO-RP group, additional repetitions performed after short intra-set rest periods were calculated using the same absolute load, as the external load was maintained throughout the set. In contrast, in the PO-DS group, repetitions performed after reaching muscular failure were calculated using the reduced load applied during the drop-set phase. Therefore, weekly volume-load calculations accounted for the specific number of repetitions completed and the actual external load used in each protocol.

2.4.3 | Maximum Repetition

The assessment of maximal strength was performed via the determination of the 1-RM in the bench press exercise, following standardized procedures used in previous investigations conducted in our laboratory [18]. Participants adopted a five-point body contact position, with the head, upper back, and buttocks in continuous contact with the bench and both feet flat on the floor. Each attempt was executed with full elbow extension to be considered valid, and the bar had to gently touch the chest on the descent. After a specific warm-up, loads were progressively increased until the 1-RM was achieved. A standardized rest interval of 7 min was provided between maximal attempts to minimize the effects of fatigue. Participants performed progressive attempts until concentric failure was reached, typically within 3–5 attempts and never exceeding five attempts, consistent with NSCA muscular-strength testing procedures [19]. The same 1-RM testing procedures were applied to the remaining six exercises used for load prescription, with a 7-min rest interval between maximal attempts with technical validation by experienced investigators. To ensure positional consistency across attempts, foot placement was standardized by marking the floor with adhesive tape. All testing sessions were supervised by experienced investigators from the laboratory, who reached a consensus regarding technical execution and the validity of each attempt.

2.5 | Statistical Analysis

Continuous variables are presented as mean \pm standard deviation. Normality was evaluated exploratorily using the Shapiro–Wilk test to characterize the distributional properties of the data. Pre–post change (Δ) within each group was examined from an estimation perspective [20], emphasizing

effect magnitude and precision; paired Hedges' g (g) relative to baseline was computed with 95% CIs derived from bias-corrected and accelerated (BCa) bootstrap resampling (5000 resamples), and permutation-based p -values were obtained from two-sided permutation t -tests (5000 label shuffles); effect sizes (ES) were interpreted following Cohen's [21], operationalized as trivial < 0.20 , small 0.20–0.49, medium 0.50–0.79, and large ≥ 0.8 . The study used a convenience sample and no a priori power analysis was conducted before recruitment. To contextualize the group \times time comparisons given the final sample size, a sensitivity analysis was conducted in G*Power 3.1.9.2 (F tests, ANOVA: repeated measures, within–between interaction), with two groups, two measurements, $\alpha = 0.05$, power = 0.80, $n = 23$, and $\epsilon = 1$. The minimum detectable effect sizes varied according to the assumed correlation between repeated measures: $f = 0.31$ for $\rho = 0.5$, $f = 0.24$ for $\rho = 0.7$, and $f = 0.14$ for $\rho = 0.9$, corresponding approximately to $\eta p^2 = 0.09$, 0.05, and 0.02, respectively. Complementarily, a mixed repeated-measures ANOVA was used to model between-group differences in change, reporting Group and Group \times Time effects (p -values and ηp^2), as within-group pre–post change was already estimated using the procedures described above. For all p -values (permutation and ANOVA), the significance level was set at two-sided $\alpha = 0.05$. Analyses were conducted in IBM SPSS Statistics v27.0 (IBM Corp., Armonk, NY) and Python v3.12.11 (Python Software Foundation), using `dabest-python` v2025.03.27.

3 | Results

The CONSORT diagram (Figure 2) provides a flowchart of the data collection process. Twenty-seven individuals were assessed for eligibility; four declined to participate, and 23 were randomized to PO-DS ($n = 11$) or PO-RP ($n = 12$). All randomized participants completed the intervention and were included in the analysis. At entry, the groups were comparable in age, BMI, and relative bench press strength: the unpaired mean difference in age was 0.903 years (95% CI, -3.65 to 5.19 ; $p = 0.720$), BMI showed no between-group difference (1.17 kg/m^2 ; 95% CI, -0.85 to 4.03 ; $p = 0.393$), and relative bench press strength also showed no between-group difference ($-0.06 \text{ kg}\cdot\text{kg}^{-1}$; 95% CI, -0.17 to 0.07 ; $p = 0.391$).

With respect to body composition, adiposity-related outcomes (total FM [Figure 3], upper-body FM, total FFAT, and upper-body FFAT) showed minimal changes in both groups, with trivial effect sizes and no evidence of differential modification by protocol type (time \times group interactions non-significant; ηp^2 close to zero); adiposity therefore remained stable over the intervention period (Table 1).

Conversely, fat-free compartment variables increased in both groups, with trivial-to-small effect sizes and no statistically significant between-group differences in change for LSTM, UB LSTM, FFMadj, and UB FFMadj (all time \times group $p > 0.50$; Figure 3 and Table 1).

Regarding maximal strength, bench press 1-RM increased in both groups, with numerically larger gains in PO-DS than PO-RP. The between-protocol difference in change did not reach

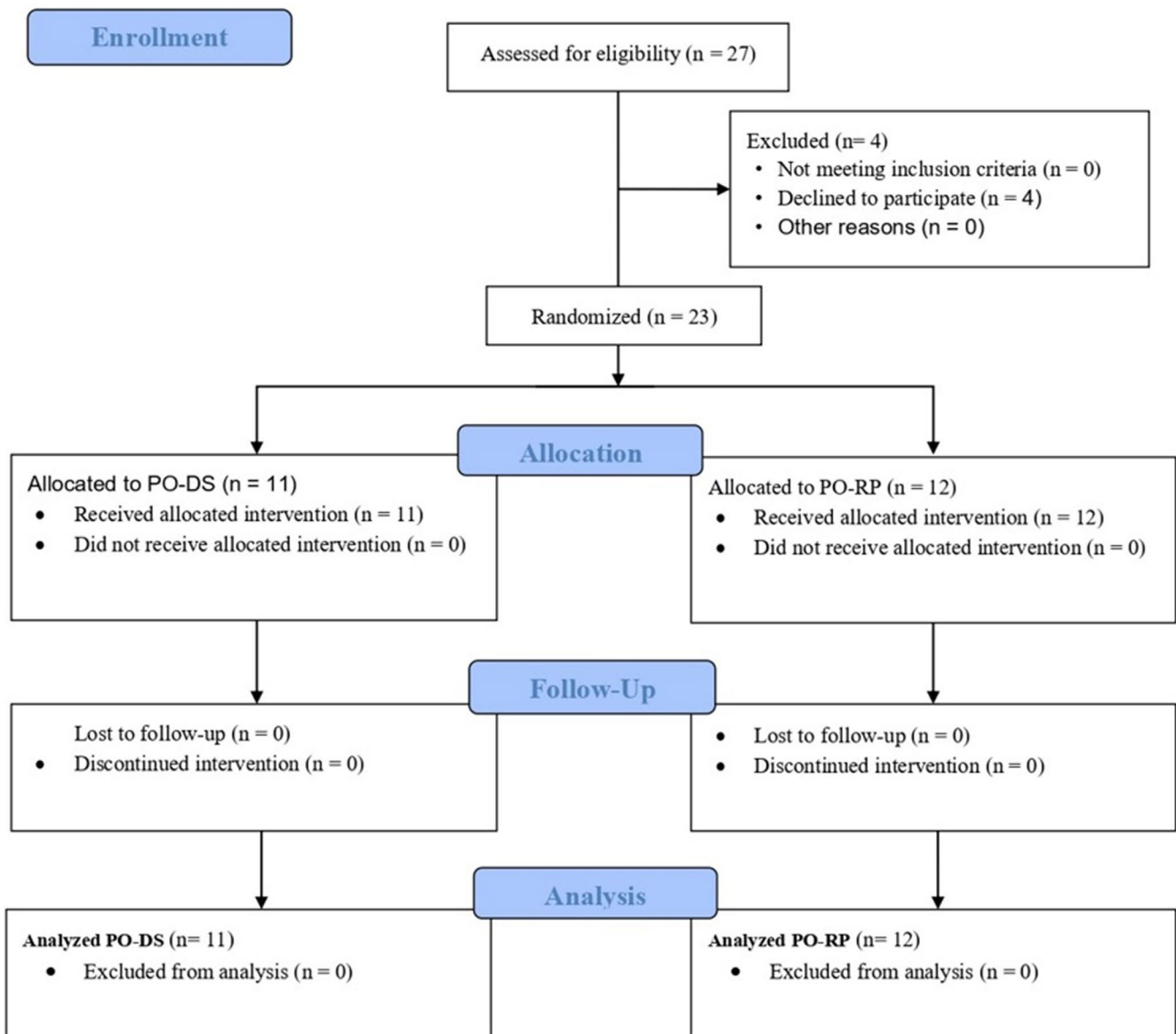


FIGURE 2 | Consolidated standards of reporting trials (CONSORT) flow diagram.

statistical significance (time \times group: $p=0.086$; $\eta p^2=0.134$), as shown in Table 1.

3.1 | Volume Load

The comparison of weekly training volume between the PO-DS and PO-RP groups showed no meaningful differences between conditions. As illustrated in Figure 4, the distribution of weekly values was similar across groups, and the unpaired mean difference (PO-DS—PO-RP) centered near zero with a 95% confidence interval that crossed the null value. This indicates that weekly training volume was comparable between protocols.

4 | Discussion

The present study compared two overload progression strategies based on increasing the number of repetitions through

intensification methods (*rest-pause* and *drop sets*). Based on our initial hypothesis, the main findings indicate that both approaches induced comparable improvements in LSTM, FFMadj, and maximal strength, without meaningful changes in adiposity-related outcomes. These results suggest that, when an effective mechanical stimulus is maintained, the specific method used to accumulate additional repetitions—whether through brief rest-pause intervals following momentary muscular failure or through load reductions after failure—were not associated with clear protocol-specific differences in short-term adaptations.

Adiposity-related variables remained stable in both groups, which is consistent with the absence of a targeted weight loss intervention and the relatively low total training volume. This pattern aligns with previous literature indicating that RT alone tends to preserve rather than markedly reduce FM when not combined with a structured caloric restriction [22]. Moreover, the present findings suggest that different repetition-based

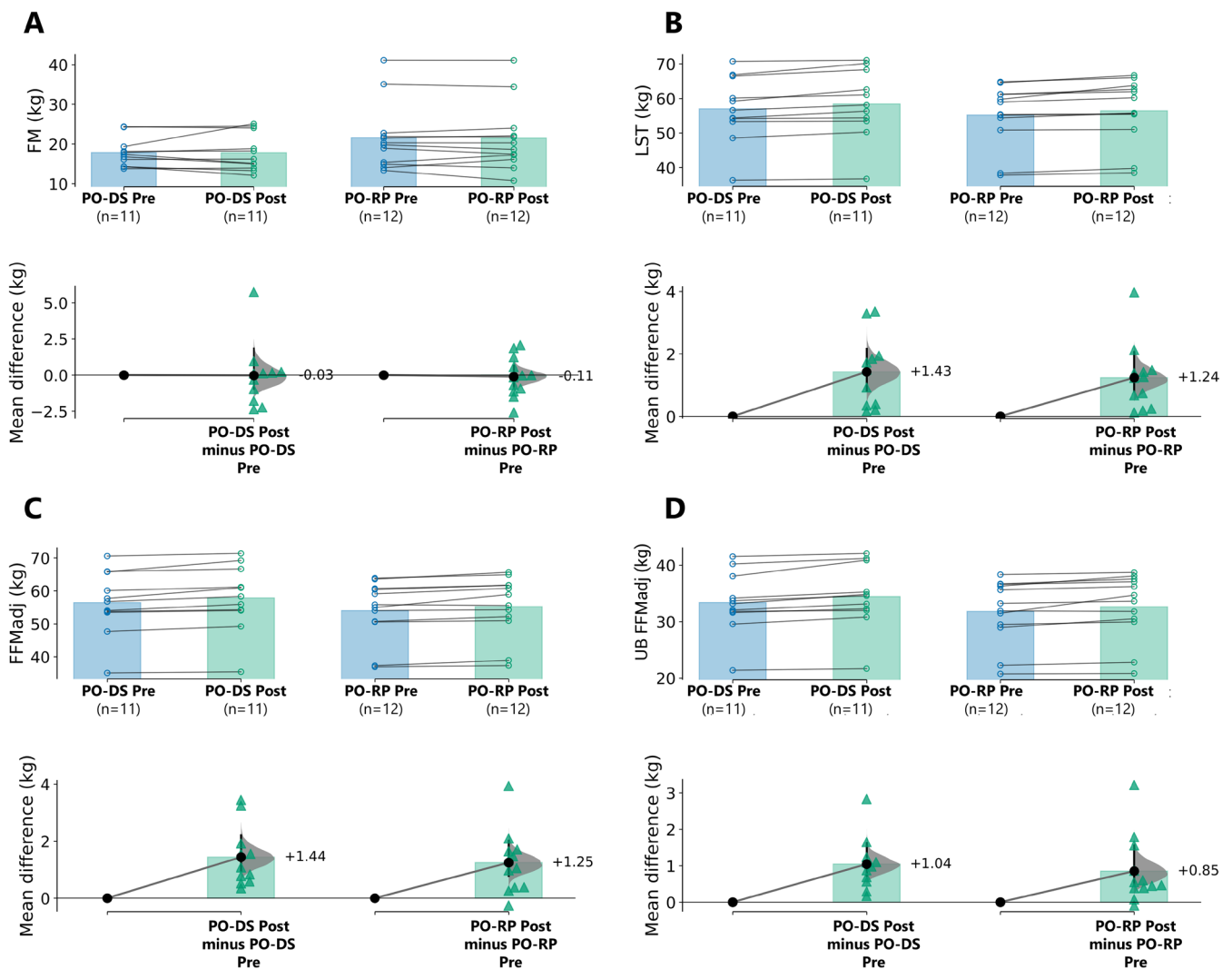


FIGURE 3 | Cumming estimation plots of primary DXA-derived body-composition outcomes. (A) Fat mass (FM); (B) lean soft tissue (LST); (C) fat-free mass adjusted for fat-free adipose tissue ($FFM_{adj} = FFM - FFAT$); (D) upper-body FFM_{adj} (UB FFM_{adj}). For each intervention arm (PO-DS and PO-RP), individual pre and post values are shown on the upper axes, with paired observations connected by lines; the lower axes display the paired mean difference (Post – Pre) as a bootstrap sampling distribution; the mean difference is indicated by the dot, and the 95% confidence interval by the ends of the vertical error bar.

progression strategies do not differentially affect body fat partitioning during short-term RT programs.

Within this conceptual framework, the use of repetition-based progression strategies, such as RP and DS, becomes particularly relevant. Both techniques allow for an increase in the total number of repetitions performed with a given initial load or within a single set, either through brief rest-pause intervals after momentary muscular failure (RP) or through successive reductions in load after failure (DS). From a mechanistic perspective, these approaches facilitate the accumulation of repetitions performed close to task failure, thereby prolonging exposure to high levels of mechanical tension provided that training intensity does not fall below thresholds generally considered effective, commonly cited at approximately 30% of 1-RM [23].

Importantly, unlike previous studies in which RP or DS were applied continuously throughout the entire intervention period as standalone training methods, the present study incorporated

these strategies only when participants were unable to continue progressing through conventional repetition increases. Therefore, RP and DS were implemented as progression tools within a structured overload model rather than as the primary training stimulus itself.

It is important to note that, in the present study, the application of these intensification strategies was limited in duration, which restricts the ability to draw firm conclusions regarding their differential effects or their potential advantages over longer timeframes. Nevertheless, from an applied standpoint, it is plausible that the primary value of RP and DS emerges over the medium to long term, particularly when traditional repetition progression within continuous sets becomes impractical. In such scenarios, these strategies may allow for continued increases in the number of stimulating repetitions without necessitating additional sets or compromising the mechanical stimulus, which is particularly relevant in training programs with lower set volumes or time-constrained environments.

TABLE 1 | Body composition and maximal strength outcomes at pre- and post-intervention for both training groups.

	PO-DS					PO-RP					Time × Group				
	Pre	Post	Δ	ES	p	Pre	Post	Δ	ES	p	p	p	η ²	p	η ²
FM, kg	17.9 ± 3.6	17.8 ± 4.7	-0.0 (-0.9, 1.8)	-0.0 (-0.3, 0.4)	0.980	21.6 ± 8.5	21.5 ± 8.5	-0.1 (-0.8, 0.7)	-0.0 (-0.1, 0.1)	0.789	0.918	0.001	0.206	0.075	
UB FM, kg	9.3 ± 1.8	9.2 ± 2.3	-0.1 (-0.7, 0.9)	-0.0 (-0.4, 0.5)	0.849	12.0 ± 6.0	11.8 ± 5.9	-0.2 (-0.6, 0.3)	-0.0 (-0.1, 0.1)	0.463	0.834	0.002	0.168	0.089	
FFAT, kg	3.2 ± 0.6	3.1 ± 0.8	-0.0 (-0.2, 0.3)	-0.0 (-0.3, 0.5)	0.978	3.8 ± 1.5	3.8 ± 1.5	-0.0 (-0.1, 0.1)	-0.0 (-0.1, 0.1)	0.806	0.918	0.001	0.206	0.075	
UB FFAT, kg	1.6 ± 0.3	1.6 ± 0.4	-0.0 (-0.1, 0.2)	-0.0 (-0.4, 0.5)	0.842	2.1 ± 1.1	2.1 ± 1.0	-0.0 (-0.1, 0.1)	-0.0 (-0.1, 0.1)	0.445	0.834	0.002	0.168	0.089	
LSTM, kg	57.0 ± 9.6	58.4 ± 10.0	1.4 (0.8, 2.2)	0.1 (0.0, 0.3)	<0.001	55.2 ± 9.0	56.4 ± 9.4	1.2 (0.8, 2.0)	0.1 (0.1, 0.3)	<0.001	0.688	0.008	0.291	0.052	
UB LSTM, kg	34.3 ± 5.5	35.3 ± 5.8	1.0 (0.6, 1.5)	0.2 (0.1, 0.3)	0.001	33.2 ± 5.7	34.0 ± 6.0	0.8 (0.5, 1.5)	0.1 (0.1, 0.3)	<0.001	0.55	0.017	0.62	0.012	
FFMadj, kg	56.4 ± 9.7	57.9 ± 10.1	1.4 (0.9, 2.2)	0.1 (0.1, 0.3)	<0.001	54.0 ± 9.0	55.2 ± 9.3	1.2 (0.8, 2.0)	0.1 (0.1, 0.3)	0.001	0.675	0.009	0.83	0.009	
UB FFMadj, kg	33.4 ± 5.5	34.4 ± 5.8	1.0 (0.7, 1.6)	0.2 (0.1, 0.3)	<0.001	31.8 ± 5.7	32.6 ± 5.9	0.9 (0.5, 1.6)	0.1 (0.1, 0.3)	<0.001	0.591	0.014	0.487	0.023	
1-RM, kg	89.2 ± 15.9	101.5 ± 17.8	12.3 (9.6, 14.0)	0.7 (0.3, 2.5)	<0.001	86.9 ± 20.2	96.4 ± 22.0	9.5 (7.3, 11.2)	0.4 (0.2, 1.7)	<0.001	0.086	0.134	0.652	0.010	

Note: Values are mean ± SD; Δ denotes the change (post-pre); Δ and paired Hedges' g are reported with 95% bootstrap CIs (5000 resamples); permutation p values were obtained from 5000 label reshuffles.

Abbreviations: 1-RM, one-repetition maximum (bench press); ES, effect size (paired Hedges' g); FFAT, fat-free adipose tissue; FFMadj, fat-free mass adjusted for FFAT; FM, fat mass; LSTM, lean soft tissue mass; PO-DS, drop sets; PO-RP, rest-pause; UB FFAT, upper-body fat-free adipose tissue; UB FFMadj, upper-body fat-free mass adjusted for FFAT; UB FM, upper-body fat mass; UB LSTM, upper-body lean soft tissue mass; η², partial eta-squared.

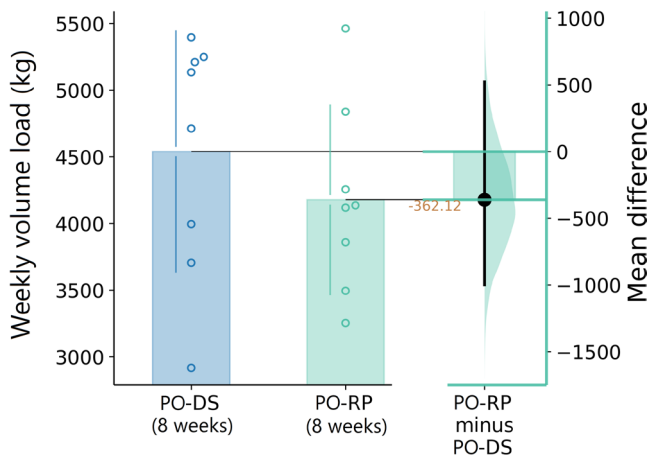


FIGURE 4 | Weekly training-volume comparison between PO-DS and PO-RP. Gardner-Altman estimation plot for weekly training volume. Each dot represents one training week within each group (PO-DS and PO-RP). Groups are displayed on the left axes; the unpaired mean difference (PO-RP minus PO-DS) is shown on the right as a bootstrap sampling distribution. The mean difference is indicated by the dot and the 95% confidence interval by the ends of the vertical error bar.

This interpretation is consistent with the conceptual framework proposed by Hammert et al., who highlighted that skeletal muscle hypertrophy can be achieved through multiple combinations of training variables and that effective progression does not necessarily require linear increases in total repetition volume or load [2]. Similarly, findings from Plotkin et al. [5] and Chaves et al. [4] support the notion that different overload progression strategies can lead to comparable adaptations, provided that the overall stimulus is sufficient. In this context, RP and DS may be viewed as complementary tools to sustain effective overload when other progression pathways are limited.

Regarding maximal strength, both protocols increased bench press 1-RM by 9.5 to 12.3 kg, broadly consistent with our hypothesis that both progression models would produce comparable strength adaptations when training volume was comparable and a prescribed nutritional protocol was used. These improvements may reflect neural and technical adaptations, together with the accumulation of high-effort repetitions close to failure, which may have helped maintain a sufficient strength stimulus despite the use of fixed absolute loads derived from baseline 1-RM. The concurrent increases in LSTM and FFMadj observed in both groups may also have contributed to these strength gains, although the present design does not allow the ability to separate the relative contribution of neural or technical adaptations and DXA-derived fat-free compartment changes.

These findings are consistent with previous research comparing load- and repetition-based progression strategies, which have reported comparable improvements in maximal strength despite differing overload models. For instance, Chaves et al. [4] observed similar increases in 1-RM when progression was achieved through load or repetition manipulation. Likewise, Plotkin et al. [5] reported equivalent gains in dynamic strength between these strategies, with between-group differences deemed practically trivial. Collectively, this evidence suggests that when training is performed at high effort, the specific mode

of progression may be less critical for maximal strength development in trained individuals.

In our study, weekly volume load was similar between PO-DS and PO-RP, which aligns with research comparing load- versus repetition-based progression strategies that also report no statistical differences in accumulated volume load or the resulting adaptations. Specifically, Chaves et al. showed that progression via load or repetitions did not appreciably differ in accumulated volume load ($53\,703 \pm 17\,390$ kg vs. $52\,528 \pm 18\,283$ kg; $p=0.346$) [4]. Consistent findings were reported by Plotkin et al., who observed equivalent increases in lower-body dynamic strength when comparing load- versus repetition-based progression, with mean improvements of ~ 20 kg in both groups and an adjusted difference of $+2.0$ kg in favor of the load-based condition (90% CI: -2.4 to 7.8), deemed to lack practical relevance [5]. However, Hammert et al. concluded that total volume (sets \times repetitions \times load) is not necessarily a sensitive indicator of hypertrophic stimulus nor a causal metric of muscle growth, which may help explain the similarity observed in our data [2]. Taken together, these findings suggest that different progression strategies can induce similar improvements in maximal strength and volume load in protocols where the number of repetitions is progressively increased.

The study has several limitations that must be acknowledged. First, the interventional duration was relatively short, precluding the ability to determine changes over longer time periods. Second, participants were recruited as a convenience sample, and no a priori power analysis was conducted before recruitment; the sensitivity analysis based on the final sample size showed that the minimum detectable group \times time effect sizes depended on the assumed pre-post correlation; therefore, smaller between-protocol differences cannot be ruled out. This is particularly relevant for the bench press 1-RM comparison ($\eta^2=0.134$; $p=0.086$), where a between-protocol difference in strength adaptation remains possible with the present sample. Third, although participants were provided with a prescribed individualized nutritional protocol using Nutrium software, actual energy and macronutrient intake were not analyzed or reported as group-level dietary exposure variables. Nutritional intake should therefore be interpreted as prescribed and supervised, rather than as a quantified dietary exposure. Fourth, DXA provides an estimate of fat-free mass, which represents all non-fat tissue in the body; thus, it is a gross proxy for muscle hypertrophy and may not accurately reflect true changes in muscle mass [24]. Fifth, although DXA provides regional estimates at the limb level, it cannot determine muscle-specific hypertrophy, muscle architecture, or site-specific changes within individual muscles [25]; therefore, changes in upper-body LSTM and FFMadj should be interpreted as regional fat-free compartment estimates rather than direct measures of muscle hypertrophy. Sixth, the absolute loads were derived from 80% of baseline 1-RM and were not readjusted during the intervention, except during the recovery week. Consequently, any increase in strength during the study would reduce the relative intensity represented by those fixed loads. Finally, the findings are specific to young adults with at least one year of continuous resistance-training experience. The sample was predominantly male, and sex-stratified analyses were not performed because only three female participants were included; therefore, the findings should not be interpreted

as sex-specific responses to PO-RP or PO-DS. Training status should not be classified solely from training experience. The present study reports relative bench press strength, training frequency, and session duration, but did not collect technical proficiency, previous training volume, detraining time, or strength level across exercises in sufficient detail to place participants on the beginner–intermediate–advanced–highly advanced continuum proposed by Santos Junior et al. Whether RP and DS sustain repetition progression beyond 8 weeks, how they accumulate fatigue across mesocycles, and how individuals differ in their hypertrophic adaptations to each strategy remain open questions for longer interventions [26].

5 | Conclusions

The present findings indicate that, in an RT context, two repetition-based overload progression strategies, RP and DS, produce comparable adaptations in fat-free mass and maximal strength, without affecting adiposity. The strategic use of these methodologies may represent a potential avenue for maintaining progressive overload over the medium to long term, a hypothesis that warrants further investigation in longer-duration studies.

6 | Perspective

Future work should determine whether repetition-based progressive-overload strategies using rest-pause or drop sets remain effective beyond short training cycles and whether their usefulness depends on sex, age, training status, clinical condition, or sport-specific demands. Stronger designs should combine larger samples with direct imaging of muscle hypertrophy, strength outcomes beyond the bench press, and closer monitoring of proximity to failure, fatigue, recovery, and dietary intake. This would help define when these set-configuration strategies are useful as progression tools, rather than as intensification methods applied uniformly across an intervention.

Author Contributions

S.V.-M., A.G.-P., and J.B.-P. conceived and designed the experiments. J.B.-P. served as lab coordinator and project manager for the study coordination. S.V.-M., M.G.-S., and J.B.-P. assisted in data collection. A.G.-P. controlled the nutritional protocol. J.L.P. analyzed the data. S.V.-M., M.G.-S., A.G.-P., J.L.P., D.A.B., L.C., B.J.S., and J.B.-P., assisted in analysis, and manuscript review. S.V.-M. and J.L.P. wrote the first draft. S.V.-M., J.L.P., M.G.-S., L.C., B.J.S., A.G.-P., D.A.B., and J.B.-P. assisted in the statistics advice, discussion analysis, and manuscript preparation. All authors read and approved the final manuscript.

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The authors have nothing to report.

Conflicts of Interest

D.A.B. has conducted academic-sponsored research in sport and exercise sciences, serves as an NSCA Latam board member, and has received honoraria for speaking on exercise sciences at international conferences and private courses. B.J.S. formerly served on the scientific advisory board for Tonal Corporation, a manufacturer of fitness equipment. The remaining authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in RIUMA at <https://riuma.uma.es/home>.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Available prescribed nutritional plan by intervention group.