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Combined Myo-Reps and Traditional Resistance Training Promotes Greater Muscle Hypertrophy Without Altering Acute Decorin and Interleukin-1β Responses in Resistance-Trained Men

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Abstract

Purpose: This study investigated the acute serum responses of decorin and interleukin-1β (IL-1β) and the effects of 8 weeks of Myo-reps, traditional, and combined resistance training on rectus femoris muscle thickness and lower-body strength in men.

Method: Thirty-six resistance-trained men (26.03 ± 4.22 years; BMI: 24.83 ± 3.05 kg/m²) were randomly assigned to traditional, Myo-reps, or combined training. Participants completed an 8-week program (3 sessions/week) with standardized volume and progressive intensity (75–85% 1RM). Serum decorin and IL-1β were measured before and immediately after the third training session during week 1. Rectus femoris muscle thickness was assessed by ultrasonography, and hack squat one-repetition maximum was measured before and after training. Data were analyzed using paired-samples t-tests and ANCOVA ($p < 0.05$).

Results: No between-group differences were found for serum decorin ($p = 0.81$) or IL-1β ($p = 0.67$). Decorin decreased only in the traditional group ($p = 0.03$), whereas IL-1β remained unchanged in all groups. Rectus femoris muscle thickness increased in the Myo-reps ($p = 0.02$) and combined ($p = 0.001$) groups, but not in the traditional group ($p = 0.07$). Muscle thickness differed between groups ($p = 0.01$), with greater increases in the combined than the traditional group ($p = 0.01$). Hack squat strength improved in all groups ($p = 0.001$), with no between-group differences ($p = 0.51$).

Conclusion: Combined Myo-reps and traditional resistance training produced greater increases in rectus femoris muscle thickness than traditional resistance training alone without altering acute decorin or IL-1β responses. All protocols similarly improved lower-body strength.

Keywords: Muscle hypertrophy; Exercise-induced myokines; Extracellular matrix remodeling; Inflammatory biomarkers; ultrasonography; Strength adaptation.

Introduction

In recent years, the augmentation of skeletal muscle mass has garnered significant interest due to its implications for enhancing physical aesthetics and athletic performance (Lim et al., 2022). Resistance training remains the most efficacious non-pharmacological intervention for augmenting muscle mass and strength (Krzysztofik et al., 2019; Lim et al., 2022). An increase in muscle mass correlates with enhanced force-generating capacity, thereby playing a pivotal role in the preparation of athletes across diverse sports disciplines, particularly in bodybuilding (Krzysztofik et al., 2019). Beyond its functional advantages, maintaining adequate skeletal muscle mass is associated with a reduced risk of cardiovascular diseases, metabolic disorders, and type 2 diabetes, contributing to overall health improvement (Krzysztofik et al., 2019; Schwarz, 2024). In light of these benefits, various strategies have been developed to stimulate muscle hypertrophy and enhance muscular strength through resistance training (Fonseca et al., 2023; Schwarz, 2024).

Among these strategies, traditional resistance training, characterized by a high training volume, is one of the most prevalent approaches (Mangine et al., 2015). However, this method often induces considerable fatigue and diminishes force-producing capacity (Cheng et al., 2020; Wan et al., 2017). Additionally, the requirement for extended rest intervals between sets and sessions renders the protocol time-intensive, which poses a significant barrier to consistent exercise adherence due to time constraints. Consequently, the development of time-efficient training protocols is critical to improving participation rates and motivation (Zhang et al., 2025). Within this framework, the innovative Myo-reps technique, by minimizing superfluous training volume and increasing session density, facilitates muscle hypertrophy and strength gains over a shorter duration, demonstrating comparable or superior efficacy relative to traditional methods (Fonseca et al., 2023; Israetel et al., 2021; Krzysztofik et al., 2019; Schwarz, 2024). The Myo-reps approach is a modified variant of the rest-pause training method, comprising an initial activation set followed by multiple brief mini-sets interspersed with very short rest periods (Israetel et al., 2021; Schwarz, 2024). However, the definition and practical implementation of Myo-reps vary across studies, particularly with respect to the configuration of the activation set, the number of repetitions performed in the subsequent mini-sets, the duration of inter-set rest intervals, and the criteria used to terminate the sets (Bradshaw et al., 2026; Israetel et al., 2021; Schwarz, 2024). Furthermore, combined resistance training involves the integration of two or more distinct training stimuli or methodologies within a single session to elicit enhanced muscular and functional adaptations (Cardozo & de Souza Destro, 2023).

From a physiological standpoint, increased training density, as exemplified by methods like Myo-reps, may result in enhanced metabolite accumulation, augmented cellular swelling, and an extended effective time under tension. These factors, in conjunction with mechanical tension, have the potential to activate anabolic signaling pathways, notably the mammalian target of rapamycin (mTOR) (Schoenfeld, 2020). Nonetheless, the role of metabolic stress as an independent contributor to muscle hypertrophy remains a subject of debate, appearing to function not in isolation but rather through interactions with mechanical tension and neuromuscular responses. Consequently, concurrent evaluation of molecular markers alongside structural adaptations may provide greater insight into this complex interplay (Schoenfeld, 2020).

Multiple factors mediate hypertrophic adaptations induced by metabolic stress, including modifications in myokine secretion (Schoenfeld, 2020). Additionally, variations in adaptations elicited by different training protocols are influenced by the physiological stress imposed during each session and the consequent secretion of specific cytokines (Domin et al., 2021). Repeated exercise induces protein accumulation in response to transient and pulsatile elevations in gene expression (Peake et al., 2015). Therefore, long-term training adaptations represent the cumulative effect of successive training sessions, which collectively elevate the body to a new functional threshold. These alterations in protein content and enzyme activity modify metabolic and hypertrophic responses to exercise, ultimately enhancing athletic performance. Indeed, the extent of cytokine secretion following muscle contraction is significantly affected by exercise intensity, modality, and training volume (Peake et al., 2015). Empirical evidence suggests that resistance training constitutes one of the most potent stimuli for inducing myokine secretion (Cordingley et al., 2023). Among these myokines, decorin is notably upregulated in response to resistance training and facilitates skeletal muscle regeneration and hypertrophy by inhibiting myostatin and promoting promyogenic factors (Cornish et al., 2020; Hoffmann & Weigert, 2017; Lee & Jun, 2019). Conversely, certain cytokines released post-resistance exercise, such as interleukin-1β (IL-1β), exhibit catabolic effects and are implicated in muscle degradation and inflammatory processes (Huang et al., 2017; Li et al., 2009; Webster et al., 2020). Decorin and IL-1β were selected as complementary acute biomarkers of muscle remodeling and inflammation (Domin et al., 2021; Peake et al., 2015; Webster et al., 2020). Decorin is released from skeletal muscle in response to resistance exercise and can bind myostatin, thereby supporting hypertrophic signaling (Domin et al., 2021; Kanzleiter et al., 2014). In contrast, shorter inter-set rest intervals increase the magnitude and duration of the IL-1β response following volume-equated resistance exercise (Senna et al., 2022). Differences among the protocols in mechanical loading, training density, inter-set recovery, and metabolic demand may elicit distinct transient responses in these biomarkers (Peake et al., 2015; Ringleb et al., 2023; Schoenfeld, 2020; Schoenfeld et al., 2016).

Elevated metabolic stress induced by high-density training protocols, such as Myo-reps, may potentiate anabolic signaling pathways through the modulation of myokine secretion and the regulation of inflammatory cytokines (Israetel et al., 2021; Schoenfeld, 2020; Schwarz, 2024). Consequently, these approaches may elicit greater acute molecular responses than conventional resistance training. The combined training paradigm integrates the benefits of traditional resistance training, characterized by high-volume, high-intensity multi-joint exercises, with those of Myo-reps, which employ high-density sets with brief inter-set rest intervals during single-joint exercises. This approach aims to optimize both mechanical loading and metabolic stress; however, empirical evidence supporting its effectiveness remains limited. This methodological inconsistency complicates direct comparisons across studies and underscores the need to evaluate Myo-reps using a clearly defined and consistently implemented protocol. It remains unclear whether combining traditional resistance training with Myo-reps produces greater hypertrophic adaptations than either method alone in resistance-trained men. Clarifying this question may facilitate the development of time-efficient hypertrophy-oriented strategies for trained individuals. Although an increasing number of studies have investigated high-density resistance training methods, no study to date has simultaneously examined the acute responses of decorin and interleukin-1β together with chronic structural and functional adaptations by directly comparing traditional, Myo-reps, and combined resistance training protocols in resistance-trained men. Addressing this gap is important because it remains unclear whether acute myokine and cytokine responses are associated with long-term adaptations, such as muscle hypertrophy and strength gains, or whether these adaptations are primarily driven by other mechanisms, including mechanical tension, cellular swelling, and the activation of anabolic signaling pathways. Therefore, it remains unknown whether different resistance training configurations differentially influence acute decorin and interleukin-1β responses and whether these molecular responses are accompanied by superior structural and functional adaptations. Accordingly, the present study was designed to (1) compare the acute serum responses of decorin and interleukin-1β following Myo-reps, traditional, and combined resistance training and (2) evaluate the effects of an 8-week intervention using these training protocols on rectus femoris muscle thickness and lower-body muscle strength in resistance-trained men. It was hypothesized that the combined resistance training protocol would elicit more favorable acute decorin and interleukin-1β responses and produce greater improvements in rectus femoris muscle thickness and lower-body muscle strength than either Myo-reps or traditional resistance training alone.

Methods

The sample size was determined during the study design phase utilizing the repeated-measures ANOVA interaction model within G*Power software as an approximate method suitable for a three-group design with repeated measurements. A two-tailed test was employed, assuming an effect size of 0.25, a significance level (α) of 0.05, and statistical power (1-β) of 0.80 across three groups. This calculation indicated a minimum total sample size of 36 participants. Specifically, the sample size estimation was conducted using the within–between interaction framework of repeated-measures ANOVA in G*Power version 3.1.9.7 (Xiang et al., 2026). Subsequent to these preliminary arrangements, participants were recruited through purposive sampling from active bodybuilding clubs located in Shiraz. A total of 68 volunteers were initially screened based on predefined inclusion and exclusion criteria. Ultimately, 36 resistance-trained males aged between 20 and 30 years were randomly selected from the eligible pool and enrolled in the study. During an orientation session, the study's objectives, procedures, potential risks, and participants' rights were thoroughly explained. Eligible participants were then randomly assigned to one of three groups (n=12 per group): traditional training, Myo-reps training, and a combined traditional plus Myo-reps training regimen. Efforts were made to ensure balanced distribution of participants with comparable training experience across groups to maintain relative homogeneity regarding training history.

The inclusion criteria encompassed: age between 20 and 30 years; self-reported good physical and mental health confirmed via a health questionnaire; a history of consistent recreational resistance training for a minimum of 6 to 12 months; absence of medications or nutritional supplements known to influence muscle metabolism; and non-smoking status. Exclusion criteria included injury sustained during the study, non-compliance with the training protocol (defined as attendance below 80% of sessions), use of performance-enhancing substances, caffeine consumption, inadequate hydration, and voluntary withdrawal from the study (Tartibian et al., 2024; Tartibian et al., 2022). Compliance with dietary recommendations provided by the research team was mandatory; significant deviations from the prescribed diet constituted grounds for exclusion.

Dietary intake was monitored through self-reported food records, three-day dietary logs, and analysis via the Advanced Nutrition Tracker software (apkpure version 0.2) (Kaiser et al., 2020; Tartibian & Rezaei, 2021). Participants were instructed to maintain a daily caloric intake of approximately 2,500 kcal throughout the intervention period, comprising roughly 350 g of carbohydrates, 40 g of fat, and 150 g of protein. These macronutrient distributions corresponded to approximately 60%, 15%, and 25% of total energy intake from carbohydrates, fats, and proteins, respectively. All participants provided written informed consent prior to enrollment and retained the right to withdraw from the study at any time without penalty. The study protocol adhered to the ethical standards outlined in the Declaration of Helsinki by the World Medical Association and received approval from the Research Ethics Committee of Kharazmi University (Approval No. IR.KHU.REC.1404.055).

Training Protocol

Maximal strength, defined as the one-repetition maximum (1RM), for the selected exercises was evaluated prior to the commencement of the training protocol following the standardized procedure outlined by Barbalho et al. (2018) and established strength assessment guidelines (Barbalho et al., 2018). Initially, participants engaged in 5 minutes of low-intensity walking, followed by performing eight repetitions at 50% of their estimated 1RM. After a one-minute rest interval, they completed three repetitions at 70% of the estimated 1RM. Subsequently, participants rested for three minutes before attempting to determine their actual 1RM within three to five trials, with rest periods of three to five minutes between attempts. The load was incrementally increased by 5% in each successive trial until the participant successfully completed a single repetition. This protocol was similarly applied to assess maximal strength in the hack squat exercise both before and after the intervention.

The resistance training protocol was designed with dual objectives: to examine the acute responses of decorin and interleukin-1 beta (IL-1β) following a single training session, and to evaluate structural muscle adaptations over an eight-week intervention period. Training sessions were conducted thrice weekly (totaling 24 sessions), scheduled between 5:00 and 7:00 p.m. at Azadegan Gym in Shiraz. All sessions were supervised directly by the research team to ensure proper exercise execution, adherence to prescribed training intensities, and compliance with designated rest intervals. Each session commenced with a warm-up consisting of 5 minutes of low-intensity aerobic activity, followed by 5 minutes of dynamic stretching and a specific warm-up targeting the muscles involved in the session. The training regimen employed a three-day split routine across all groups, with distinct muscle groups targeted in each session. The sequence of exercises was consistent across groups. The resistance training program comprised three weekly sessions. The first day focused on lower-body and triceps muscles, incorporating hack squat, leg extension, lying leg curl, standing calf raise, lying barbell triceps extension, and cable triceps pushdown exercises. The second day targeted the chest and shoulder muscles, including barbell bench press, incline barbell bench press, chest fly, Smith machine shoulder press, and dumbbell lateral raise. The third day emphasized back and biceps training, featuring the Hammer Strength row (plate-loaded row machine), seated cable row, lat pulldown, reverse fly, bent-over dumbbell lateral raise, barbell biceps curl, and cable preacher curl.

To ensure consistency in the training stimulus, several variables were standardized across the three groups, including the number of weekly training sessions, the quantity of exercises, relative training intensity (%1RM), movement tempo (2/0/1/0, corresponding to a 2-s eccentric phase, no pause, a 1-s concentric phase, and no pause), full range of motion, session duration (approximately 60 minutes), and exercise sequence. Additionally, all primary sets were executed near voluntary muscular failure, maintaining 0–2 repetitions in reserve (RIR = 0–2), thereby classifying all primary sets as effective. The training load was progressively adjusted throughout the intervention in response to participants' performance to sustain the prescribed relative intensity (%1RM). Standardization of the training stimulus was thus grounded in these predetermined training parameters. Specifically, in the Myo-reps group, each exercise commenced with an activation set at 50% of 1RM, performed until near voluntary muscular failure (RIR = 0–2), followed by main sets conducted according to the Myo-reps protocol, which incorporates brief rest intervals. The principal distinction among the groups pertained to the distribution of sets and the duration of rest intervals between them, structured in accordance with traditional, Myo-reps, and combined training models. A comprehensive overview of the set configurations, number of mini-sets, and rest intervals for each training modality is provided in Table 1.

Table 1. Structure of the Traditional, Myo-Reps, and Combined Resistance Training Protocols.

	RT Variables	**Weeks 1–3**	**Weeks 4–6**	**Weeks 7–8**
TRT	Sets	4	4	4
	Reps (Sets 1)	15	15	15
	Reps (Sets 2–4)	10	10	10
	Inter-set Rest (s)*	60	60	60
	Intensity (% 1RM)	75	80	85
	Weekly Reps/Exercise	45	45	45
	Frequency	3	3	3
	RIR	0–2	0–2	0–2
	Set	4	4	4
	Activation set	1	1	1
	main sets ≠	3	3	3

MRRT	Inter-set Rest (s)	15	10	5
	Mini-set Rest (s)	15	10	5
	Intensity (% 1RM)	75	80	85
	Weekly Reps/Exercise	45	45	45
	Frequency	3	3	3
	RIR	0–2	0–2	0–2

* Rest interval between sets for the hack squat exercise was 120 s. ≠ Each main set consisted of two mini-sets of five repetitions. RIR, repetitions in reserve; 1RM, one-repetition maximum; TRT, traditional resistance training; MRRT, Myo-Reps resistance training.

In the combined training group, a hybrid approach integrating traditional and Myo-reps methods was applied at the exercise level. Specifically, multi-joint exercises were executed using the traditional method during each session, while single-joint exercises were performed employing the Myo-reps technique. For instance, in the first session, leg extension, lying leg curl, and cable triceps pushdown were conducted; the second session included chest fly and dumbbell lateral raise; and the third session comprised lat pulldown, bent-over dumbbell lateral raise, and cable preacher curl, all utilizing the Myo-reps method. The remaining exercises in each session were performed via the traditional method. This training protocol remained consistent throughout the entire 8-week intervention period. The classification of exercises was grounded in their biomechanical properties: multi-joint exercises, characterized by the concurrent engagement of multiple joints and muscle groups in force generation, were assigned to the traditional method, whereas single-joint exercises were designated for the Myo-reps method to enhance training density and capitalize on the specific attributes of the Myo-reps protocol (de França et al., 2015).

Blood Sampling, Biochemical Analyses, and Muscle Thickness Assessment

In this study, blood samples were collected at two time points. At each time point, 5 mL of venous blood was drawn from the antecubital vein of each participant. The first sample was collected 48 h before the pre-test under fasting conditions at Shahid Motahari Clinic in Shiraz. The second sample was obtained immediately after the third resistance training session of the first week, following the completion of one full training cycle in which each muscle group had been trained once. This sample was collected at Azadegan Gym in Shiraz by the medical staff of Shahid Motahari Clinic. Following collection, blood samples were centrifuged at 3,500 rpm for 10 min using a refrigerated centrifuge (ROTINA 380R, Hettich GmbH & Co. KG, Germany), and the serum was separated.

Serum samples were stored at −70°C until analysis, and repeated freeze–thaw cycles were avoided. Serum decorin concentration was determined using a commercially available ELISA kit (ZellBio, Germany; Cat. No. ZB-13702-H9648) with a sensitivity of 4 pg/mL. Serum IL-1β concentration was measured using an ELISA kit (Karmania Pars Gene, Iran; Cat. No. KPG-H Interleukin-1 Beta) with a sensitivity of 2 pg/mL. Both assays were performed according to the manufacturers' instructions, and absorbance was measured at 450 nm. The intra-assay and inter-assay coefficients of variation for the decorin assay were <10% and <12%, respectively.

Rectus femoris muscle thickness was assessed at the midpoint of the muscle using a B-mode ultrasound system (Mindray DC-7, Mindray Bio-Medical Electronics Co., China) equipped with a 12-MHz linear-array transducer, following standardized measurement procedures. All ultrasound assessments were performed by the same experienced examiner to minimize inter-rater variability. The reliability of the measurements was high, with an intraclass correlation coefficient (ICC) of 0.95, a standard error of measurement (SEM) of 1.09 mm, and a coefficient of variation (CV) of <5%.

Statistical Analysis

Descriptive statistics are presented as mean ± standard deviation (SD). Data normality and homogeneity of variances were assessed using the Shapiro–Wilk and Levene's tests, respectively. Baseline differences among the groups were examined using one-way analysis of variance (ANOVA). Following confirmation of the statistical assumptions, between-group differences were analyzed using analysis of covariance (ANCOVA), with baseline values entered as covariates. When significant main effects were observed, Bonferroni-adjusted post hoc comparisons were performed. Within-group changes were assessed using paired-samples t-tests. Effect sizes for ANCOVA were expressed as partial eta squared (ηp^2) and interpreted according to Cohen's guidelines, with values of 0.01, 0.06, and 0.14 representing small, medium, and large effects, respectively. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS (version 26; IBM Corp., Armonk, NY, USA), and figures were generated using GraphPad Prism (GraphPad Software, San Diego, CA, USA).

Results

The anthropometric characteristics of the participants are presented in Table 2. Levene's test confirmed the homogeneity of variances ($p > 0.05$). In addition, one-way ANOVA revealed no significant baseline differences among the three groups in age, height, body mass, or body mass index (all $p > 0.05$).

Table 2. Baseline Anthropometric Characteristics of Participants by Group

Variable	MRRT	TRT	CRT	Levene's Test (*p*)	ANOVA (*p*)
Age (y)	24.90 ± 5.30	26.20 ± 3.69	27.00 ± 3.68	0.374	0.348
Height (cm)	180.30 ± 5.518	183.10 ± 7.23	178.40 ± 4.94	0.094	0.222
Body Weight (kg)	82.54 ± 2.89	83.17 ± 7.73	76.70 ± 5.31	0.576	0.346
BMI (kg/m²)	25.67 ± 2.84	24.74 ± 3.12	24.10 ± 2.21	0.996	0.523

* Significant difference between groups at $p \leq 0.05$. Values are presented as mean ± standard deviation (SD). MRRT, Myo-Reps resistance training; TRT, traditional resistance training; CRT, combined resistance training; BMI, body mass index.

Acute Decorin Response

Levene's test confirmed the assumption of homogeneity of variances for serum decorin levels across the groups (p = 0.76). ANCOVA, with baseline values entered as a covariate, revealed no significant between-group differences in serum decorin concentrations immediately after the third training session of the first week, following the completion of one full training cycle ($F = 0.20$, $p = 0.81$, $\eta p^2 = 0.01$). The effect size was small ($\eta p^2 = 0.01$), indicating that the different set configurations and rest interval strategies used in the three training protocols had only a minimal influence on the acute serum decorin response (Table 3). Within-group analyses using paired-samples *t*-tests showed a significant reduction in serum decorin only in the traditional training group ($p = 0.03$). Although serum decorin concentrations also decreased in the Myo-reps (p = 0.10) and combined (p = 0.06) groups (Table 3, Figure 1).

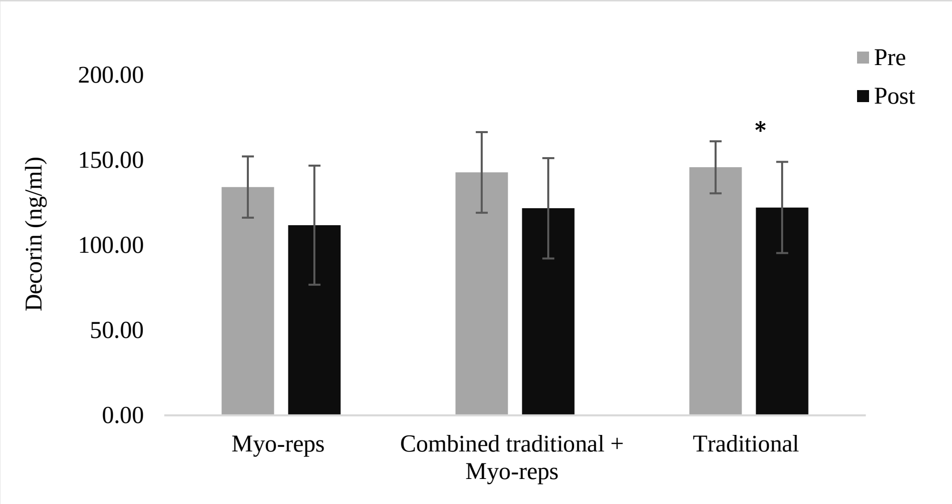

Figure 1. Serum decorin concentrations before and after the training protocol in the study groups. * Significant difference compared with the pre-test within the traditional training group ($p \leq 0.05$).

Acute IL-1β Response

Levene's test confirmed the assumption of homogeneity of variances for serum IL-1β levels across the groups (p = 0.27). ANCOVA, with baseline values entered as a covariate, revealed no significant between-group differences in serum IL-1β concentrations following the third training session of the first week (F = 0.40, p = 0.67, $\eta p^2 = 0.03$). The effect size was small ($\eta p^2 = 0.03$), indicating that the different set configurations and rest interval strategies used in the three training protocols had only a minimal influence on the acute serum IL-1β response (Table 3). Within-group analyses using paired-samples t-tests also showed no significant pre- to post-training changes in the traditional (p = 0.07), Myo-reps (p = 0.10), or combined (p = 0.06) groups. Consistent with the small effect size and the absence of statistically significant between-group differences, these findings suggest that acute serum IL-1β responses in resistance-trained men were not substantially influenced by variations in training structure, including set configuration and rest interval pattern (Table 3, Figure 2).

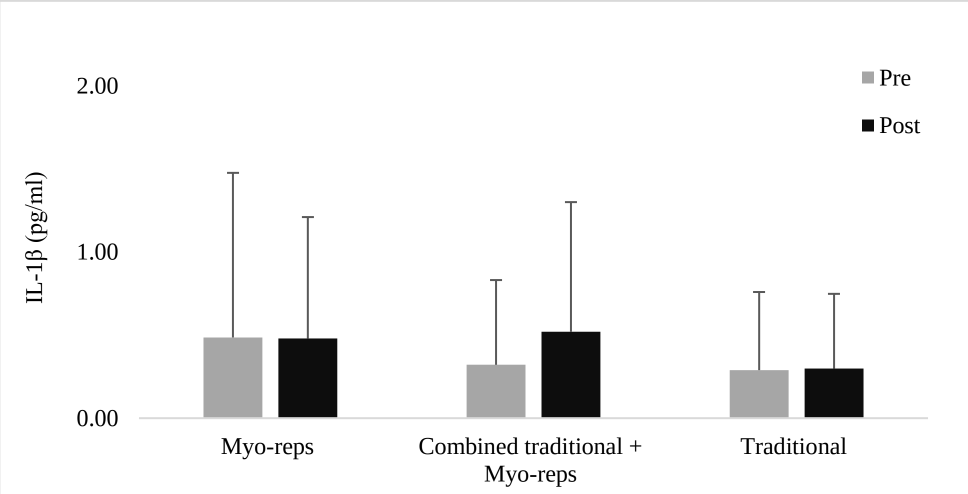

Figure 2. Serum IL-1β concentrations before and after the training protocol in the study groups.

Structural Adaptations (Muscle Hypertrophy)

Levene's test confirmed the assumption of homogeneity of variances for rectus femoris muscle thickness across the groups ($p = 0.15$). Paired-samples *t*-tests showed that rectus femoris muscle thickness increased significantly after the 8-week training intervention in the Myo-reps and combined groups, whereas the increase in the traditional group did not reach statistical significance (traditional: $p = 0.07$; Myo-reps: $p = 0.02$; combined: $p = 0.001$) (Table 3). ANCOVA, with baseline values entered as a covariate, revealed a significant between-group difference in changes in rectus femoris muscle thickness ($F = 4.84$, $p = 0.016$, $\eta p^2 = 0.27$). The effect size was large ($\eta p^2 = 0.27$), indicating that the training protocol substantially influenced the magnitude of muscle hypertrophy (Table 3). Bonferroni-adjusted post hoc comparisons revealed a significant difference between the combined and traditional groups (p = 0.01), whereas no significant differences were observed between the remaining pairwise comparisons. Rectus femoris muscle thickness increased by 12.1% in the combined group, 4.8% in the Myo-reps group, and 2.2% in the traditional group (Table 3, Figure 3).

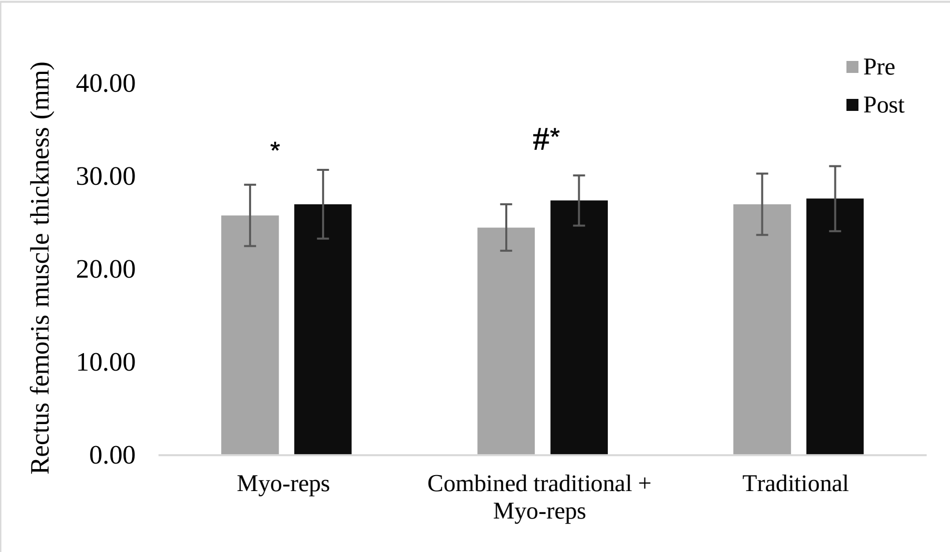

Figure 3. Rectus femoris muscle thickness before and after the training protocol in the study groups. *Significant difference compared with the pre-test within the same group ($p \leq 0.05$). # Significant difference compared with the traditional group ($p \leq 0.05$).

Structural Adaptations (Muscle Strength)

Levene's test confirmed the assumption of homogeneity of variances for hack squat strength across the groups (p = 0.44). ANCOVA, with baseline values entered as a covariate, revealed no significant between-group differences in changes in hack squat strength following the 8-week training intervention (F = 0.68, p = 0.51, $\eta p^2 = 0.05$). The effect size was small ($\eta p^2 = 0.05$), indicating that the different set configurations and rest interval strategies used in the three training protocols had only a minimal influence on improvements in hack squat strength (Table 3). Within-group analyses using paired-samples *t*-tests showed significant increases in hack squat strength in all three groups (all *p* = 0.001). Hack squat strength increased by 19.3% in the Myo-reps group, 18.0% in the combined group, and 14.9% in the traditional group (Table 3, Figure 4).

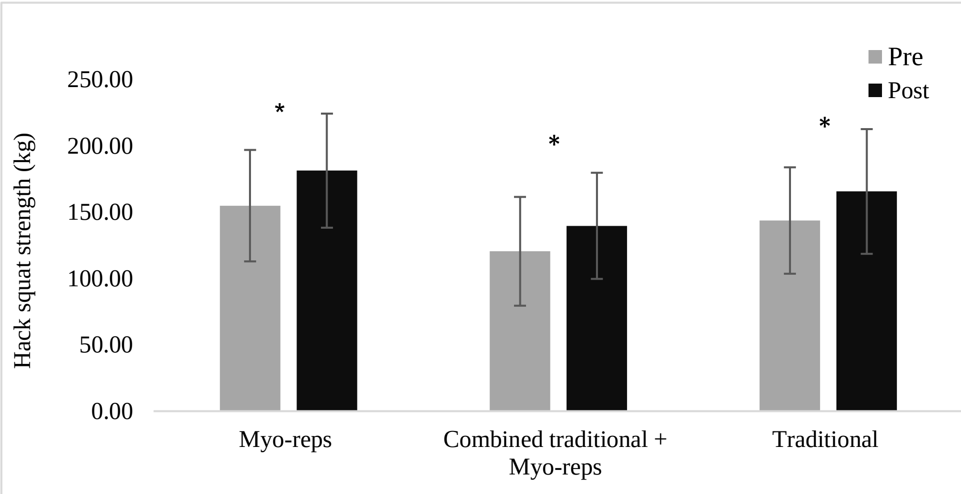

Figure 4. Hack squat strength before and after the training protocol in the study groups. * Significant difference compared with the pre-test within the same group ($p \leq 0.05$).

Table 3. Changes in Acute Serum Decorin and IL-1β Responses, Rectus Femoris Muscle Thickness, and Hack Squat Strength Following 8 Weeks of Traditional, Myo-Reps, and Combined Resistance Training (Mean ± SD)

Variable	Pre (Mean ± SD)	Post (Mean ± SD)	WG (P)	F	P	ηp²	Post hoc
DEC (ng/mL)							
TRT	145.8 ± 15.3	122.2 ± 26.8	0.03*	0.20	0.81	0.01	NS
MRRT	134.2 ± 18.0	111.8 ± 35.0	0.10				
CRT	142.8 ± 23.7	121.7 ± 29.5	0.06				
IL-1β (pg/mL)							
TRT	0.289 ± 0.47	0.298 ± 0.45	0.07	0.40	0.67	0.03	NS
MRRT	0.486 ± 0.99	0.480 ± 0.73	0.10				
CRT	0.321 ± 0.51	0.520 ± 0.78	0.06				
RFMT (mm)							
TRT	27.0 ± 3.3	27.6 ± 3.5	0.07	4.84	0.01	0.27	CRT > TRT†
MRRT	25.8 ± 3.3	27.0 ± 3.7	0.02*				
CRT	24.5 ± 2.5	27.4 ± 2.7	0.001*				
HS (kg)							
TRT	143.7 ± 40.1	165.6 ± 47.0	0.001*				

MRRT	154.9 ± 42.0	181.3 ± 43.0	0.001*	0.68	0.51	0.05	NS
CRT	120.5 ± 41.0	139.7 ± 40.0	0.001*				

DEC, decorin; IL-1β, interleukin-1 beta; RFMT, rectus femoris muscle thickness; HS, hack squat strength; TRT, traditional resistance training; MRRT, Myo-Reps resistance training; CRT, combined resistance training; WG, within-group comparison (paired-samples *t*-test); ANCOVA, analysis of covariance with baseline values entered as covariates; Post hoc, Bonferroni-adjusted pairwise comparisons; ηp^2, partial eta squared; NS, no significant between-group difference. Values are presented as mean ± SD. *Significantly different from pretest ($p < 0.05$). † Significant difference between CRT and TRT according to Bonferroni-adjusted post hoc comparisons ($p < 0.05$)

Discussion

The present investigation sought to compare the acute serum responses of decorin and interleukin-1β (IL-1β) following Myo-reps, traditional, and combined resistance training protocols, as well as to assess the effects of these training modalities on muscle hypertrophy and lower-body muscle strength after an eight-week intervention in resistance-trained male participants. The primary results indicated that all three training protocols elicited comparable acute serum responses of decorin and IL-1β, with no statistically significant differences observed between groups after the third training session in the initial week. Notably, serum decorin levels decreased significantly only within the traditional training group, whereas changes in decorin in the Myo-reps and combined groups, along with IL-1β alterations across all groups, did not achieve statistical significance. Conversely, the combined training regimen yielded greater enhancements in rectus femoris muscle thickness compared to traditional resistance training, while improvements in lower-body muscle strength were similar across all groups. Consequently, the initial hypothesis was only partially corroborated. Although the combined protocol facilitated superior muscle hypertrophy, it did not elicit distinct acute responses in decorin or IL-1β, nor did it provide additional advantages in lower-body muscle strength relative to the other training protocols. Collectively, these findings imply that integrating Myo-reps with traditional resistance training may augment muscle hypertrophy without provoking differential acute myokine or cytokine responses.

Concerning the response of decorin, although reductions were observed across all three groups, statistical significance was achieved solely within the traditional training group, with no significant differences detected between groups. This outcome implies that alterations in serum decorin levels may not account for the variations in hypertrophic magnitude observed among the different training protocols. Aligning with the current findings, Misielska et al. (2019) demonstrated that five weeks of high-intensity circuit training did not significantly modify resting plasma decorin concentrations in women (Micielska et al., 2019). The noted decrease in decorin levels, particularly the significant reduction in the traditional training cohort, may reflect a differential response contingent upon the intensity and nature of the training stimulus. This observation concurs with prior research indicating that decorin modulation is exercise intensity-dependent (Ataeinosrat et al., 2022). Moreover, consistent with the present study, Kanzleiter et al. (2018) reported no significant deviations from baseline in decorin concentrations following endurance and resistance exercise (Kanzleiter et al., 2014). It is noteworthy that Kanzleiter et al. (2018) collected blood samples one hour post-exercise, whereas peak protein release is known to occur immediately post-exercise (Kanzleiter et al., 2014). Additionally, Bugera et al. (2018), employing both traditional resistance training and resistance training combined with blood flow restriction, similarly found no statistically significant differences in decorin levels (Bugera et al., 2018). Contrastingly, Kanzleiter et al. (2014) observed increased plasma decorin concentrations in individuals engaged in high-intensity resistance training (Kanzleiter et al., 2014). However, considering the disparities in decorin secretion magnitude between these studies (Bugera et al., 2018; Kanzleiter et al., 2014), alongside the matched training volume across interventions in Bugera et al. (2018), it is plausible to suggest that total training volume or the extent of muscle mass engaged may serve as more reliable predictors of decorin secretion magnitude than training intensity alone, given that total training volume was substantially greater in Kanzleiter et al. (2014) (Bugera et al., 2018; Domin et al., 2021; Kanzleiter et al., 2014). Overall, inconsistencies between these findings and the present study may be attributed to variations in training protocols, training volume, timing of blood sampling, and participants' physical fitness levels (Bugera et al., 2018; Domin et al., 2021). Furthermore, acute changes in decorin should not be interpreted as direct causal factors but rather as potential mechanisms contributing to observed adaptations (Broniec et al., 2024). Consequently, the effects of resistance training on decorin remain incompletely understood and warrant further investigation; comprehensive elucidation will require future studies with larger sample sizes. Nonetheless, it is well established that decorin binds extracellularly to myostatin, thereby inhibiting myostatin's negative regulatory effects and promoting skeletal muscle fiber hypertrophy (Kanzleiter et al., 2014; Lightfoot & Cooper, 2016).

In the current investigation, no statistically significant differences in serum interleukin-1 beta (IL-1β) levels were detected among the experimental groups following the training interventions. IL-1β was quantified to assess and compare the inflammatory responses elicited by the distinct training protocols. The findings indicate that all three training modalities provoked comparable inflammatory reactions. These results align with those reported by Vatani et al. (2011), who found no definitive evidence supporting alterations in IL-1 levels post-exercise training (Vatani et al., 2011). Given the absence of significant changes in IL-1β concentrations after the training period, it appears that resistance training at varying intensities may not substantially influence this inflammatory marker (Vatani et al., 2011). However, the lack of significant variation in IL-1β may be attributable to an exercise-induced elevation in IL-1 receptor antagonist (IL-1ra) levels, which was not evaluated in the present study. Supporting this notion, Ringleb et al. (2023) demonstrated immediate increases in IL-1ra following a single session of acute resistance exercise (Ringleb et al., 2023). Consequently, the stable IL-1β levels observed herein might reflect a compensatory rise in IL-1ra. Similarly, Uchida et al. (2009) examined IL-1β responses to different training intensities in untrained males and reported no significant changes in circulating IL-1β 24 hours post-exercise relative to baseline (Uchida et al., 2009). Contrarily, Bani et al. (2020) observed significant post-exercise elevations in IL-1β across all groups, with notably greater increases in the high-intensity training and low-intensity blood flow restriction groups compared to the low-intensity training group (Bani et al., 2020). A limitation of the current study pertains to the inherent instability of IL-1β and the potential delayed release following exercise stimuli. Immediate post-exercise blood sampling may have failed to capture peak IL-1β concentrations, potentially explaining the absence of significant intergroup differences. Therefore, future research should consider optimizing blood collection timing in accordance with the kinetic profile of this cytokine. The discrepancy between systemic cytokine alterations and the pronounced hypertrophic adaptations observed in high-density training groups underscores the predominant role of localized muscular mechanisms in driving hypertrophy (Bugera et al., 2018; Schoenfeld, 2020).

In the present study, the greatest increase in muscle thickness was observed in the combined group, followed by the Myo-reps group. This finding is consistent with previous studies showing that high-density training protocols, such as Myo-reps and rest-pause training, can be as effective as or even more effective than traditional training in increasing muscle mass (Schwarz, 2024). In this regard, Karimifard et al. (2023) reported that the rest-pause training group exhibited a greater increase in skeletal muscle mass than the traditional training group (Karimifard et al., 2023). Although Myo-reps and rest-pause training are different methods, both increase training density and reduce rest intervals, thereby producing similar physiological and functional adaptations (Schwarz, 2024). Furthermore, Schwarz et al. (2024) showed that both Myo-reps and traditional training induce hypertrophy, although Myo-reps was associated with a shorter training duration (Schwarz, 2024). Similarly, Prestes et al. (2019) reported that the rest-pause group showed a greater increase in thigh muscle thickness than the traditional training group (Prestes et al., 2019). The present findings indicate that, despite equal training volume and intensity, the physiological stimulus imposed on the muscle is not necessarily the same, and that the quality of training execution plays a determining role in muscular adaptations. In the Myo-reps and combined protocols, the short rest intervals and the performance of repetitions close to muscular failure (lower RIR) may have increased training density, metabolite accumulation, and the recruitment of high-threshold motor units, ultimately resulting in greater metabolic stress (Israetel et al., 2021; Schoenfeld, 2020; Schwarz, 2024). This superiority in hypertrophy, despite equal training volume, highlights the role of metabolic stress alongside other mechanisms of muscle hypertrophy, suggesting that high-density training methods may enhance training effectiveness by augmenting this component (Schoenfeld, 2010). On the other hand, the greater superiority of the combined group may be attributed to the synergistic effect of the two training stimuli, whereby multi-joint exercises, through generating greater mechanical tension and involving a larger muscle mass, and single-joint exercises performed using the Myo-reps method, through increasing local metabolic stress, acted in a complementary manner and together more effectively enhanced the hypertrophic response.

Another finding of the present study was the significant increase in muscle strength in all three groups, with no significant differences among the groups. In fact, the percentage increase in muscle strength was approximately similar across all three groups. Consistent with the findings of the present study, several studies have shown that rest-pause and traditional training produce similar increases in muscle strength.

Fonseca et al. (2023) reported that both methods improved maximal muscle strength to a similar extent in healthy adults (Fonseca et al., 2023). Likewise, Kork et al. (2017) observed nearly identical increases in 1RM following four weeks of training in both groups (Korak et al., 2017). Schwarz et al. (2024) also reported similar adaptations in strength gains between the Myo-reps and traditional training protocols (Schwarz, 2024). In another study, Prestes et al. (2019) found no significant differences in 1RM strength between the rest-pause and traditional training groups (Prestes et al., 2019). In contrast to the present study, Karimifard et al. (2023) reported that following 12 weeks of training, the rest-pause group demonstrated greater strength gains than the traditional training group (Karimifard et al., 2023). The inconsistency between the findings of Karimifard et al. and those of the present study may be attributed to differences in the training protocol, training volume and intensity, and the participants' fitness level (Bugera et al., 2018; Domin et al., 2021). On the other hand, although the high-density training groups showed greater hypertrophy, the absence of significant between-group differences in strength gains is consistent with findings suggesting that increases in muscle strength may be influenced more by neural adaptations, even when the degree of hypertrophy is similar or different (Jenkins et al., 2017).

Overall, the absence of consistent and significant changes in serum decorin and IL-1β levels, despite the observed differences in hypertrophy, suggests that the systemic responses of these factors alone are not sufficient to explain the superiority of high-density training methods. Intramuscular mechanisms, such as mechanical tension, metabolic stress, and activation of the mTOR signaling pathway, are likely to play a more central role in these adaptations (Schoenfeld, 2010; Zunner et al., 2022).

This study has several limitations that should be considered when interpreting the findings. First, although participants received standardized instructions, potential confounding factors such as dietary intake, sleep quality, psychological stress, and other lifestyle behaviors could not be fully controlled. Furthermore, because dietary intake was monitored using self-reported three-day food records, the resulting estimates may have been affected by underreporting, overreporting, or recording errors and may not fully represent participants' habitual dietary intake. Second, the relatively small sample size, the inclusion of only resistance-trained men, and the absence of a non-training control group may limit the generalizability of the findings. More specifically, the exclusive inclusion of young, resistance-trained men limits the generalizability of the findings to women, older adults, untrained individuals, and clinical populations. In addition, serum decorin and IL-1β concentrations were assessed only as acute responses during the first week of training, precluding the evaluation of chronic changes in these biomarkers over the course of the intervention. Moreover, the acute biomarker responses were assessed at only one post-exercise time point, preventing characterization of the temporal response patterns of decorin and IL-1β and potentially missing their peak responses. Furthermore, only circulating concentrations were measured, and no direct assessment of skeletal muscle tissue was performed; therefore, the molecular mechanisms underlying the observed adaptations could not be fully elucidated. Future studies should include larger and more diverse populations, longer intervention periods, and direct analyses of skeletal muscle tissue (e.g., muscle biopsies) to investigate local molecular adaptations. Moreover, longitudinal assessment of decorin and IL-1β, together with other anabolic and inflammatory biomarkers (e.g., myostatin, IGF-1, IL-6, and mTOR-related signaling proteins), may help clarify whether acute molecular responses are predictive of long-term hypertrophic adaptations.

Conclusion

The findings of this study indicate that Myo-reps, traditional, and combined resistance training elicited comparable acute changes in serum decorin and IL-1β concentrations in resistance-trained men. Although serum decorin decreased significantly within the traditional training group, no significant between-group differences were observed in the acute response of either biomarker. Following the 8-week intervention, rectus femoris muscle thickness increased significantly in the Myo-reps and combined groups, and a significant between-group difference was also observed, with a greater increase in the combined group than in the traditional resistance training group. In contrast, lower-body muscle strength improved significantly in all three groups, but no significant differences were observed between the training protocols. Collectively, these findings suggest that combining traditional resistance training with the Myo-reps method may elicit a greater hypertrophic response, as reflected by the increase in rectus femoris muscle thickness, than traditional resistance training alone in young resistance-trained men. However, this finding should not be interpreted as evidence that the combined protocol is superior for muscle strength or other performance outcomes. Importantly, the comparable acute changes in serum decorin and IL-1β concentrations should be interpreted independently of the chronic changes in muscle thickness and do not provide evidence that these biomarkers mediated or contributed to the greater hypertrophic response observed with the combined protocol.

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Conflicts of Interest:
The authors declare no conflict of interest related to this study.

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