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ACUTE EFFECTS OF REST REDISTRIBUTION SET STRUCTURES ON MUSCLE ACTIVATION, PERCEIVED FATIGUE, AND JUMP PERFORMANCE*

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Abstract: The rest redistribution (RR) method is a contemporary approach in resistance training that redistributes the same total duration as the traditional set (TS) method but with shorter and more frequent rest intervals. This study aimed to compare the acute effects of the TS and RR methods on muscle activation, perceived fatigue, and jump performance. Twenty-two sports science students (age: 23.50 ± 3.05 years) with resistance training experience participated in this randomized crossover design study. Participants performed barbell squat exercises at 70% of their one-repetition maximum using three different resistance training protocols: TS (5 sets of 8 repetitions; 3 minutes of rest between sets), RR1 (40 sets of 1 repetition; 18.5 seconds of rest between sets), and RR2 (10 sets of 4 repetitions; 1 minute and 20 seconds of rest between sets). Findings indicated that, in terms of set main effects, significant differences were observed in average and peak muscle activation, countermovement jump (CMJ) height, and perceived exertion, while no significant differences were found in group interactions ($p > 0.05$). However, for the protocol x set interaction, a significant difference was observed only in perceived exertion ($p < 0.05$). These results suggest that traditional and rest redistribution set structures produce similar performance outcomes under equal training volumes, while lower perceived fatigue is experienced with the traditional set protocol during ongoing sets. In contrast, general training evaluations revealed lower perceived fatigue with the RR2 protocol.

Keywords: Countermovement jump, muscle activity, neuromuscular performance, rate of perceived exertion, resistance training.

REST REDISTRIBUTION SET YAPILARININ KAS AKTİVASYONUNA, ALGISAL YORGUNLUĞA VE SIÇRAMA PERFORMANSINA AKUT ETKİSİ

Öz: Dinlenmenin Yeniden Dağıtımı (DYD) yöntemi, geleneksel set (GS) yöntemiyle aynı toplam süreyi yeniden dağıtan, ancak daha kısa ve daha sık dinlenme aralıkları içeren, direnç antrenmanında çağdaş bir yaklaşımdır. Bu çalışma, GS ve DYD yöntemlerinin kas aktivasyonu, algılanan yorgunluk ve sıçrama performansı üzerindeki akut etkilerini karşılaştırmayı amaçlamıştır. Direnç antrenmanı deneyimi olan 22 spor bilimi öğrencisi (yaş: 23,50 ± 3,05) bu randomize çapraz tasarımlı çalışmaya katılmıştır. Katılımcılar, üç farklı direnç antrenmanı protokolü kullanarak, tek tekrar maksimumlarının %70'inde barbell squat egzersizleri yaptılar: GS (5 set 8 tekrar; setler arasında 3 dakika dinlenme), DYD1 (40 set 1 tekrar; setler arasında 18,5 saniye dinlenme) ve DYD2 (10 set 4 tekrar; setler arasında 1 dakika 20 saniye dinlenme). Bulgular, set ana etkileri açısından, ortalama ve en yüksek kas aktivasyonu, karşı hareket sıçraması (CMJ) yüksekliği ve algılanan eforda önemli farklılıklar gözlemlendiğini, ancak grup etkileşimlerinde önemli bir fark bulunmadığını gösterdi ($p > 0,05$). Ancak, protokol x set etkileşimi için, yalnızca algılanan eforda önemli bir fark gözlemlenmiştir ($p < 0,05$). Bu sonuçlar, geleneksel ve dinlenmenin yeniden dağıtımı set yapılarının eşit antrenman hacimleri altında benzer performans sonuçları ürettiğini, ancak devam eden setler sırasında geleneksel set protokolü ile daha düşük algılanan yorgunluk yaşandığını göstermektedir. Buna karşın, genel antrenman değerlendirmeleri DYD2 protokolü ile daha düşük algılanan yorgunluk ortaya koymuştur.

Anahtar Kelimeler: Karşı hareketli sıçrama, kas aktivitesi, nöromüsküler performans, algılanan zorluk derecesi, direnç antrenmanı.

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INTRODUCTION

Resistance training is highly important for both improving athletic performance and reducing injury risks (Suchomel et al., 2016), as well as for promoting a healthy lifestyle (Westcott, 2012). In resistance training methods, numerous variables (e.g., type and order of exercises, number of sets and repetitions, load lifted, rest intervals between sets, and movement speed) are manipulated to alter acute training stimuli and to elicit specific physiological adaptations (Spiering et al., 2008). In general, strength and conditioning coaches implement two types of set structures in resistance training programs: the traditional set structure (TS) and the alternative set structures of cluster (CL) and rest redistribution (RR) (Haff et al., 2008).

The traditional set structure consists of performing repetitions continuously without rest within sets and incorporating rest intervals between sets (Jukic et al., 2021). One of the alternative set structures, cluster set (CL), includes short rest intervals (15–45 seconds) within sets in addition to the rest intervals between sets (Haff et al., 2008; Hardee et al., 2012). Another alternative set structure, RR, maintains the total rest duration equivalent to the traditional set structure but redistributes this duration into shorter and more frequent rest intervals (Jukic & Tufano, 2019a; Tufano et al., 2017).

Alternative set structures (CL, RR) in resistance training have been found to minimize perceived exertion and lactate accumulation while increasing average and peak movement velocity, average and peak power output, compared to traditional sets (Cuevas-Aburto et al., 2022a; Jukic et al., 2020a; Jukic & Tufano, 2022a). However, in contrast to the existing literature, a study reported that when traditional sets were not performed to failure, traditional and RR structures resulted in similar velocity and power outputs, with RR exhibiting a lower rate of perceived exertion (RPE) (Jukic & Tufano, 2019a). Subgroup analyses that independently examined each alternative set structure indicated that CL was generally more effective than RR in reducing mechanical, metabolic, and perceptual markers of fatigue (Jukic et al., 2020a). This is primarily attributed to CL having a longer total rest duration compared to RR. Although cluster sets seem superior to traditional and RR sets for optimal performance, the extra rest intervals in cluster sets prolong the overall training duration, making them less feasible in practice (Tufano et al., 2016). Therefore, RR, characterized by redistributing rest intervals into shorter but more frequent durations, has become a key method employed by strength and conditioning coaches to minimize fatigue during resistance training without extending the total workout time (Jukic & Tufano, 2022a).

In the literature, studies on traditional and RR set methods often focus on lower or upper body exercises with 3–4 sets (Jukic et al., 2020a). Research investigating higher set and repetition counts remains limited (Jukic et al., 2020a). Furthermore, studies have evaluated traditional and alternative set structures based on various parameters such as RPE, lactate levels, movement speed (measured by devices like push-band or LPT), and jump metrics (assessed via force platforms) (Jukic et al., 2020a).

Muscle activation measurement, an essential method for examining the effects of resistance training, provides critical insights into muscle recruitment patterns, force production, muscle tone, and fatigue levels (Cerrah et al., 2010). Electromyography (EMG) is a valuable tool that allows a detailed analysis of muscle activity during movement. However, limited research focuses on muscle activation responses concerning alternative rest methods. For instance, studies comparing the rest-pause method with the traditional set method reported higher motor unit recruitment with the rest-pause method (Korak et al., 2017; Marshall et al., 2012).

Similarly, studies comparing CL with traditional sets have indicated that CL offers advantages in terms of athletic performance and fatigue management (Morales-Artacho et al., 2019; Ortega-Becerra et al., 2021; Páez-Maldonado et al., 2024). For example, Páez-Maldonado et al. (2024) noted that the CL method yielded higher median frequency (MDF) values, suggesting better muscle function preservation, and lower root mean square (RMS) values, indicating reduced neuromuscular fatigue. However, it remains unclear in the literature whether the benefits of the CL method stem from the extra rest time or the structured intra-set rest intervals. Comparing an RR structure with a traditional set structure, while maintaining an equal total rest duration, could provide significant contributions to the literature. To date, no studies have compared the muscle activation responses of RR and traditional set structures.

This study aims to fill existing gaps in the literature by examining a group of sports science students with resistance training experience. Participants performed three different set structures (TS, RR1, RR2) during resistance training sessions involving the Smith machine squat exercise, with muscle activation measured using surface electromyography (EMG). The primary aim of the study is to compare the effects of traditional, and RR set structures on muscle activation, perceived exertion (RPE), and counter-movement jump (CMJ) performance. Secondarily, the study aims to evaluate the changes in active jump performance before and after training based on set structures. The hypotheses of the study are as follows: RR set structures (RR1, RR2) are hypothesized to result in higher muscle activation, lower perceived exertion, and less decline in post-training active jump performance compared to traditional set structures. In this study, we aim to contribute to the literature by demonstrating how protocols in which rest is redistributed within sets, as opposed to traditional set structures, can delay neuromuscular fatigue and maintain mechanical performance. It is anticipated that the findings will assist coaches and sports scientists in planning strength and power training more effectively, thereby enhancing training quality whilst reducing the risk of excessive fatigue.

MATERIALS AND METHODS

Experimental Design

This study employed a randomized crossover experimental design to examine the acute effects of traditional set (TS) and rest redistribution (RR) set structures on muscle activation, perceived exertion, and counter-movement jump (CMJ) performance during resistance training. Each participant attended four experimental sessions separated by 48–72 hours to ensure full recovery and to minimize potential carryover effects. In the initial session, participants were introduced to the experimental procedures and underwent anthropometric measurements, familiarization with the exercise protocols, and assessment of their one-repetition maximum (1 RM) and maximal voluntary isometric contraction (MVIC). To reduce the risk of delayed onset muscle soreness (DOMS) and injury, participants completed three sets of eight repetitions at 70% of their 1 RM during the first session as an adaptation exercise. This specific exercise volume and intensity have been determined with the aim of triggering a protective neuromuscular adaptation generally known as the 'repeated bout effect'. According to this approach, whilst sufficient mechanical stimulation is provided during exercise, excessive fatigue and severe muscle damage are prevented in subsequent experimental phases (Hyldahl, Chen and Nosaka, 2017; McHugh, 2003).

In subsequent sessions, participants were randomly assigned to one of three experimental protocols: TS, RR1, or RR2. The order of testing for each participant was determined manually by drawing lots. This randomization procedure was carried out to distribute the testing order within the group and to minimize any potential order or learning effects. The TS protocol consisted of 5 sets of 8 continuous repetitions with 3 minutes of rest between sets. The RR1 protocol involved 40 sets of 1 repetition with 18.5 seconds of rest between sets, while the RR2 protocol included 10 sets of 4 repetitions with 80 seconds of rest between sets. All protocols were matched for total repetitions (40), rest duration (12 minutes), and load intensity (70% of 1 RM). Surface electromyography (s-EMG) data were collected throughout the exercise protocols to assess muscle activation, and perceived exertion (RPE) was recorded at specific intervals during each protocol (after the 8th, 16th, 24th, 32nd, and 40th repetitions). CMJ performance was measured before and 10 minutes after the exercise protocols, and session RPE (s-RPE) was recorded 30 minutes post-session.

Participants
Twenty-two mix students from the Faculty of Sports Sciences at Pamukkale University (mean age: 23.50 ± 3.05 years; height: 173.68 ± 7.19 cm; body mass: 71.22 ± 10.82 kg) participated voluntarily in the study. G*Power 3.1.9.7 software was used to determine the sample size based on repeated-measures ANOVA ($\alpha = 0.05$, $\beta = 0.80$, effect size $f = 0.25$) (Beck, 2013), which indicated a requirement for a minimum of 21 participants. Eligibility criteria included at least one year of resistance training experience, no chronic illnesses or injuries within the past year, and no use of dietary supplements for six months prior to the study. Participants were instructed to maintain consistent dietary habits and refrain from any additional resistance training during the study period. They were asked before each session whether they had complied with the instructions. Written informed consent was obtained from all participants, and the study was approved by the Institutional Review Board of Pamukkale University (Approval Date: 05.09.2023, Approvel No: 14), in accordance with the Declaration of Helsinki.

Procedures
<u>Familiarization Session</u>
During the first session, participants were familiarized with all testing protocols and devices. The warm-up protocol included 5 minutes of light jogging at 8–10 km/h followed by dynamic mobility exercises targeting the lower extremities and hip joints, such as ankle flexion with resistance bands, hip rotations, and bodyweight squats. Participants were then trained on the proper execution of the back squat exercise using the Smith machine, the use of the Push-Band device for CMJ assessment, and the Borg scale (0–10) for RPE evaluation. MVIC and 1 RM assessments were conducted following the familiarization process.

<u>Squat Movement</u>
The squat was performed with the barbell on the trapezius muscle, feet shoulder-width apart, 90 degrees knee flexion angle. The speed of the movement was performed with a controlled descent in the eccentric phase and maximum speed in the concentric phase. The technique and speed of the squat movement were observed by the same researcher. The squat was performed on the Smith machine, a stationary machine.

<u>1 RM Testing</u>
1 RM was assessed ($R^2 = 0.94$) using the PUSH Band 2.0 device (Toronto, Canada), a validated and reliable tool for speed-based strength assessments (Balsalobre-Fernández et al., 2016). Through velocities derived from sub-maximal loads and a known minimum velocity threshold (MVT), the regression equation can be used to determine the available 1RM strength levels (Jovanović & Flanagan, 2014). After a standardised warm-up, participants entered their most recent 1 RM into the Push application (Version 7.18.0) and performed 3 repetitions of squats on the Smith machine at 40, 50, 60, 70 and 80 percent of the 1 RM defined by the software. Passive rest was given for 3 minutes between loads. They were instructed to perform the

concentric phase of the movement at maximum speed (Balsalobre-Fernández et al., 2016). The push-band device was placed on the inside of the left collar of the barbell, parallel to the floor on top of the barbell (Balsalobre-Fernández et al., 2016).

MVIC Measurement
The isometric squat method is a way to normalize EMG signals in the back squat movement (Balshaw & Hunter, 2012). MVIC was measured in a standardized isometric squat position, with participants' knees and hips flexed to 90°. A Smith machine bar loaded with 130% of the participants' 1 RM was used to stabilize the position. The MVIC test was taken from the dominant leg. MVIC was measured once for each participant. Participants performed a 5-second maximal isometric contraction while receiving verbal encouragement. EMG signals were recorded during the contraction and normalized for comparison across sessions. Markings were made with an acetate pen to ensure that the placement of the EMG sensor was at the same point between trials.

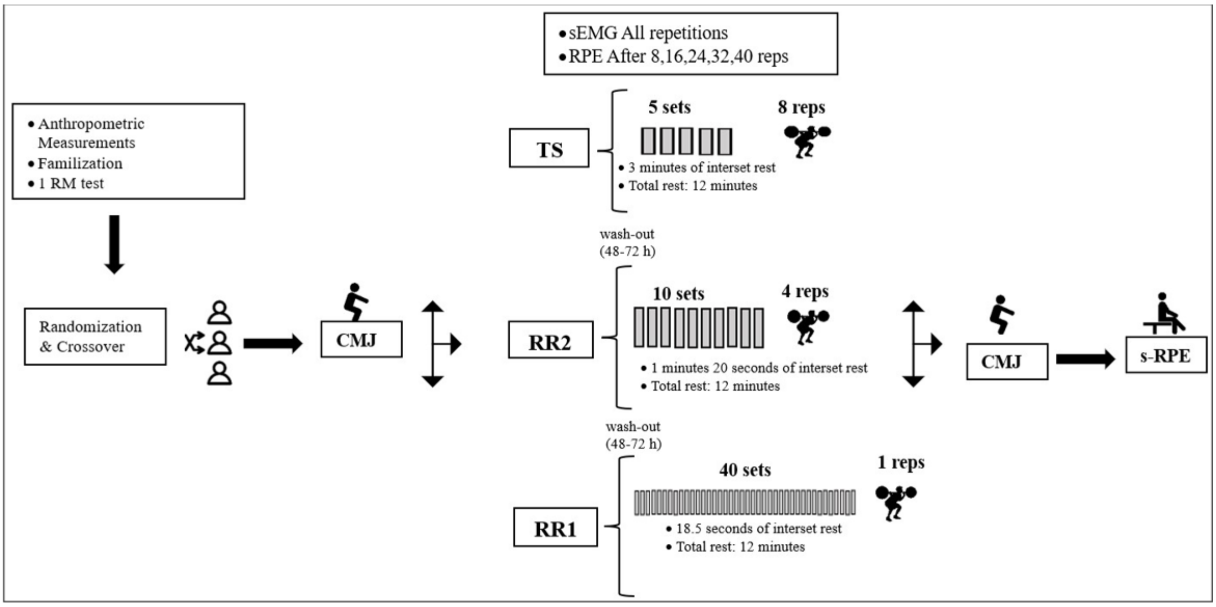

Figure 1. Experimental design of the study

Experimental Sessions
Each experimental session followed a standardized sequence: (1) 5-minute warm-up on a treadmill, (2) dynamic mobility exercises, (3) pre-session CMJ performance assessment, (4) execution of one of the experimental resistance training protocols (TS, RR1, or RR2), (5) continuous EMG data collection during the protocols, (6) RPE assessments between each set, (7) post-session CMJ performance assessment, (8) foam rolling for muscle recovery, and (9) s-RPE evaluation 30 minutes post-session. Foam rolling was applied to the gastrocnemius, hamstrings, quadriceps, gluteus maximus, and adductors for 10 minutes using a standardized protocol to alleviate potential muscle soreness.

Data Collection Tools
s-EMG was used to assess muscle activation in the vastus lateralis. Electrodes were placed following SENIAM guidelines (Stegeman & Hermens, 2007). Raw EMG signals were recorded using a Trigno wireless system (Delsys, USA) with a sampling rate of 2000 Hz and processed to calculate root mean square (RMS) and median frequency (MDF) values. CMJ height was measured using the Push-Band device. In the validity and reliability study of the force platform and the Push-band 2.0 device, there is a correlation of 0.94 for CMJ jump height (Montalvo et

al., 2021). Participants performed two CMJs with hands on their hips, and the highest jump height was recorded. RPE values were assessed using the Borg scale (0-10) (Williams, 2017) between sets during the resistance training protocols. s-RPE was recorded post-session to evaluate overall session intensity.

Statistical Analysis

Descriptive statistics were expressed as means ± standard deviations. Data normality was assessed using skewness and kurtosis values (acceptable range: ±2.0) and the Shapiro-Wilk test. A two-way repeated-measures ANOVA was used to evaluate the main effects of protocols, sets, and their interaction on muscle activation, perceived exertion, and CMJ performance. Bonferroni adjustments were applied for post hoc comparisons. Effect sizes were calculated using partial eta-squared (η^2p), with thresholds for small (<0.01), moderate (0.01–0.059), and large (>0.138) effects (Cohen, 1988). All statistical analyses were conducted using SPSS software (Version 23.0), and the significance level was set at $p < 0.05$.

RESULTS

Descriptive Statistics and Data Normality

Descriptive statistics, including means and standard deviations for mean muscle activation, peak muscle activation, CMJ performance, and perceived exertion (RPE and s-RPE), are provided in Table 1. Additionally, Table 1 includes pairwise comparison results, showing significant differences across sets for each protocol.

Table 1. Descriptive statistics (means ± sd) and pairwise comparisons across protocols and sets

Measurement	Categories	TS	RR1	RR2
		X ± SS	X ± SS	X ± SS
Mean Muscle Activation (%)	1st Set	35.32 ±11.60	37.13 ±9.21	35.55 ±11.22
	2nd Set	33.48±11.04	36.36±10.09	33.97±11.51
	3rd Set	32.24±12.62[a]	36.51±9.76	34.16±12.20
	4th Set	32.14±12.26	36.21±10.01	33.91±12.55
	5th Set	32.26±12.42[a]	36.35±9.51	33.36±12.62
Peak Muscle Activation (%)	1st Set	81.81 ±24.26	80.37±28.49	81.18 ±25.78
	2nd Set	72.28±21.01[a]	77.39±29.36	77.71±24.46
	3rd Set	71.08±24.66[a]	72.99±26.89[a]	75.47±24.67
	4th Set	72.36±23.16[a]	71.65±27.28 [a,b]	73.07±24.13[a]
	5th Set	71.11±23.60[a]	70.27±22.96 [a,b]	71.97±24.95[a]
CMJ (cm)	Pre-Test	39.99±8.06 [f]	39.73±7.40 [f]	40.24±7.80[f]
	Post-Test	38.11±7.55 [e]	36.88±7.23 [e]	36.97±7.27[e]
Perceived Exertion (RPE, 0–10)	1st Set	4.50±1.26	4.05±1.62	3.82±1.18
	2nd Set	4.59±1.05	4.77±1.57[a]	4.27±1.20
	3rd Set	4.77±1.23	5.45±1.63 [a,b]	4.95±1.09[a,b]
	4th Set	5.23±1.54	6.18±1.76 [a,b,c]	5.45±1.50[a,b,c]
	5th Set	5.68±1.62 [a,b,c,d]	6.50±1.90 [a,b,c]	5.86±1.55 [a,b,c,d]
Session RPE (0–10)	s-RPE	5.27±1.24	5.55±1.65[a]	5.00±1.02[a]

a: Significant difference from Set 1; b: Significant difference from Set 2; c: Significant difference from Set 3; d: Significant difference from Set 4; e: Significant difference from Pre-Test; f: Significant difference from Post-Test.

Muscle Activation

The analysis of mean muscle activation revealed no significant main effect of protocol ($F(2,42) = 0.548$, $p = 0.581$, $\eta^2p = 0.017$), suggesting that TS, RR1, and RR2 protocols resulted in comparable overall activation levels. However, a significant main effect of sets was observed ($F(4,84) = 6.579$, $p < 0.001$, $\eta^2p = 0.095$), indicating a progressive decline in mean activation across successive sets (Figure 2). Pairwise comparisons showed that this decline was steepest in the TS protocol compared to RR1 and RR2, as also highlighted in the descriptive statistics in Table 1. No significant interaction effect between protocol and sets was observed (F(8,168) = 1.043, p = 0.404, η²p = 0.032) (Table 2).

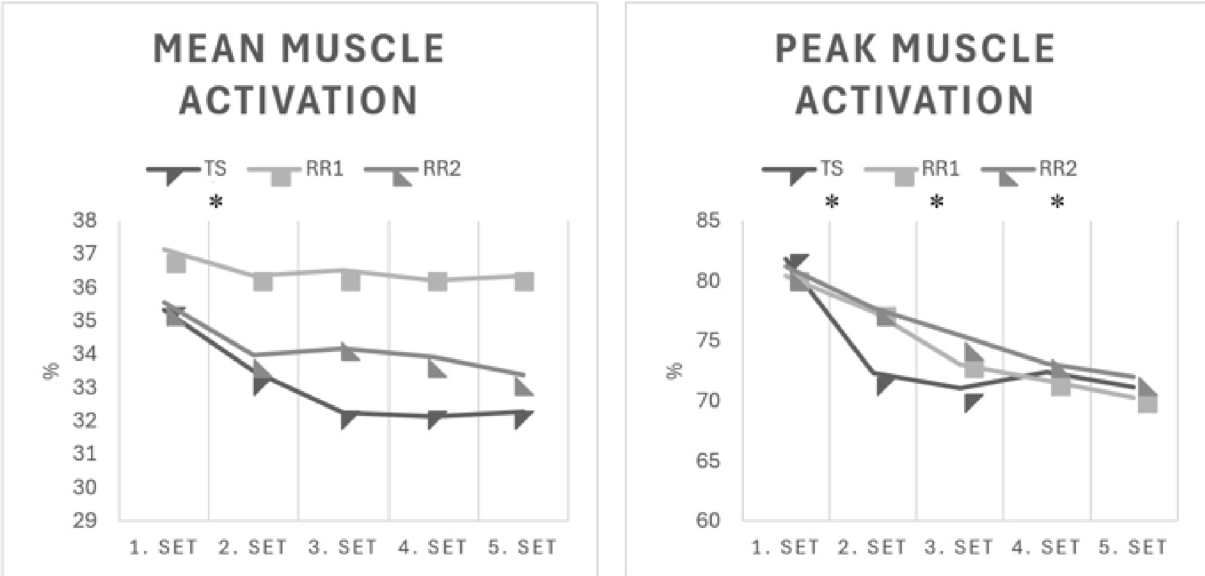

Figure 2. Comparison of mean and peak muscle activation percentages in different set structures. * A significant difference exists between the sets.

For peak muscle activation, no significant main effect of protocol was found (F(2,42) = 0.044, p = 0.957, η²p = 0.001). However, a significant main effect of sets was observed (F(4,84) = 20.493, p < 0.001, η²p = 0.245), reflecting a decline in peak activation across successive sets (Figure 2). The descriptive statistics in Table 1 indicate that the decline was similar across all three protocols. No significant interaction effect between protocol and sets was found (F(8,168) = 1.079, p = 0.378, η²p = 0.033) (Table 2).

Table 2. Two-Way Mixed ANOVA Results for Muscle Activation, RPE, and CMJ Performance.

Measurement	**Protocol Effect**			**Set Effect**			**Protocol × Set Interaction**		
	F	**p**	**ηp²**	**F**	**p**	**ηp²**	**F**	**p**	**ηp²**
Mean Muscle Activation (%)	0.548	0.581	0.017	6.579	**0.000**	0.095	1.043	0.404	0.032
Peak Muscle Activation (%)	0.044	0.957	0.001	20.493	**0.000**	0.245	1.079	0.378	0.033
CMJ (cm)	0.055	0.946	0.002	92.721	**0.000**	0.595	2.233	0.116	0.066
RPE-sRPE (0-10)	1.080	0.346	0.033	47.889	**0.000**	0.432	2.410	**0.009**	0.071

Perceived Exertion (RPE and s-RPE)

RPE values increased significantly across sets, as indicated by a significant main effect of sets (F(4,84) = 47.889, p < 0.001, η²p = 0.432). The main effect of protocol was not significant (F(2,42) = 1.080, p = 0.346, η²p = 0.033). However, a significant interaction effect between protocol and sets was detected (F(8,168) = 2.410, p = 0.009, η²p = 0.071), suggesting that the rate of increase in RPE differed across protocols. Post hoc comparisons revealed that RR1 exhibited a more rapid increase in RPE values compared to TS and RR2, particularly in the later sets (Table 2). Figure 3 illustrates the trends in RPE values, showing that the RR1 protocol consistently produced higher perceived exertion values during later sets compared to TS and RR2.

Session RPE (s-RPE), measured 30 minutes post-session, did not show significant differences between protocols ($p > 0.05$). Descriptive data indicated mean s-RPE values of 5.27 ± 1.24 for TS, 5.55 ± 1.65 for RR1, and 5.00 ± 1.02 for RR2, with the lowest perceived overall exertion observed in the RR2 protocol (Table 1).

Counter-Movement Jump Performance

A significant main effect of sets was observed for CMJ performance ($F(1,21) = 92.721$, $p < 0.001$, $\eta^2p = 0.595$), with post-session CMJ heights significantly lower than pre-session values across all protocols (Table 1). The main effect of protocol was not significant ($F(2,42) = 0.055$, $p = 0.946$, $\eta^2p = 0.002$), and no significant interaction effect was found ($F(2,42) = 2.233$, $p = 0.116$, $\eta^2p = 0.066$). Pairwise comparisons indicated that TR exhibited the smallest decline in CMJ performance, while RR2 showed the greatest reduction. Pre-session CMJ heights were comparable across protocols, confirming consistent baseline performance levels (Table 1, Figure 3). Figure 3 highlights the changes in CMJ performance, showing a significant post-session decline across all protocols, with TS demonstrating better maintenance of performance compared to RR1 and RR2.

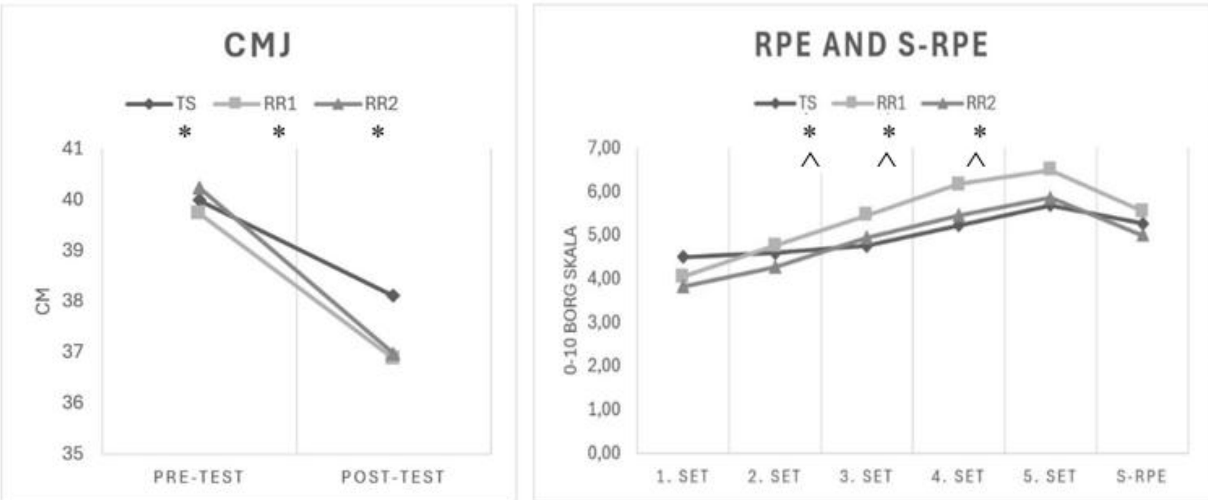

Figure 3. Comparison of jump heights and perceived difficulty levels in different set structures. * A significant difference exists between the sets. ^ A significant interaction is observed between Protocol*Set.

DISCUSSION AND CONCLUSION

This study investigated the acute effects of three different protocols (TS, RR1, and RR2) on muscle activation, perceived fatigue, and countermovement jump (CMJ) performance during squat exercises performed on a Smith machine. To our knowledge, this is the first study comparing traditional and rest redistribution set structures in terms of muscle activation. The primary findings of the study were: (a) no significant differences in muscle activation, RPE, and CMJ performance between traditional and rest redistribution protocols; and (b) significant differences in pre- and post-training active jump performance (CMJ) within each protocol.

The results suggest that when traditional sets are not performed to failure and under equal training volume and rest durations, neuromuscular and perceptual fatigue during and after training are not significantly affected by different set structures. While no significant differences were observed between resistance training protocols, significant differences were evident within protocols across sets for mean muscle activation, peak muscle activation, jump performance, and perceived fatigue. Moreover, significant protocol × set interactions were found only for perceived fatigue. Research by Jukic and Tufano (2022b) supports this observation, demonstrating that rest redistribution protocols result in reduced perceptual exertion during clean pull exercises while preserving mechanical performance metrics such as velocity and power output (Jukic & Tufano, 2022a). This suggests that RR protocols may be advantageous in settings where perceived fatigue needs to be minimized, without significantly altering neuromuscular outcomes.

For mean muscle activation, there was a significant decrease across sets in the TS protocol, while no significant decrease was observed across sets in the RR1 and RR2 protocols. This indicates that force production may be better maintained in rest redistribution protocols. However, for peak muscle activation, significant decreases were observed across sets in all three protocols, suggesting similar levels of force production and fatigue among protocols. In the literature, there are no studies examining the effects of different set structures on mean and peak muscle activation during squat. Mean muscle activation reflects the average activation of the muscle throughout the set, considering contraction and relaxation cycles. Peak muscle activation, on the other hand, indicates the highest level of activation during the concentric phase of the set. This finding is consistent with a systematic review by Jukic et al. (2020), which highlighted that both cluster and rest redistribution set structures can mitigate performance decrements in muscle activation and mechanical output during resistance training, compared to traditional sets (Jukic et al., 2020a). The reduction in neuromuscular fatigue in RR protocols is likely attributed to shorter, more frequent rest intervals that facilitate better ATP-PCr replenishment during training sessions (Wiewelhove et al., 2019).

Similarly, CMJ performance did not differ significantly between TS, RR1, and RR2 protocols. Post-training CMJ performance was significantly reduced compared to pre-training values in all protocols. There are limited studies in the literature examining the effects of different set structures on CMJ performance. Cuevas-Aburto et al. (2022b), investigated the acute effects of TS, CL, and RR protocols during squat and bench press exercises on movement velocity, RPE, s-RPE, throwing velocity in handball, and CMJ performance in 31 resistance-trained men at a 10 RM load. Total rest durations were matched across TS and RR protocols, while CL included intra-repetition rest intervals. The study concluded that CL and RR protocols resulted in higher movement velocities and lower RPE values, but no significant differences were observed among the three protocols for s-RPE, throwing velocity, and CMJ performance.

In terms of RPE and s-RPE, no significant differences were found among the TS, RR1, and RR2 protocols. However, perceived difficulty increased significantly with successive sets. Significant protocol × set interactions suggest that the TS protocol allowed for completing sets with lower perceived fatigue compared to the RR1 and RR2 protocols. Studies in the literature have similarly investigated the effects of different set structures on RPE and s-RPE. Jukic and Tufano (Jukic & Tufano, 2022b), examined the acute effects of TS and RR protocols on movement velocity and RPE during clean pull exercises at loads of 80%, 100%, and 120% of 1 RM in 15 resistance-trained men. The study reported that RR resulted in lower RPE values, reduced peak velocity decay, increased concentric repetition time, and higher peak vertical displacement compared to TS. While TS protocols may appear to induce lower RPE at submaximal intensities, RR protocols have been shown to provide significant benefits in velocity maintenance and perceptual fatigue management under heavier loads or more intense conditions (Jukic & Tufano, 2019b). This highlights the importance of protocol selection based on the specific goals of a training program.

Jukic et al. (2020b), included 32 studies in a systematic review and meta-analysis examining the acute effects of TS, CL, and RR protocols on mechanical, metabolic, and perceptual fatigue. The study concluded that alternative set structures (CL, RR) achieved higher absolute average velocity, peak velocity, average power, and peak power values. Furthermore, compared to the TS protocol, alternative set structures yielded lower lactate accumulation and RPE values during and after resistance training. Except for one study, our findings contradict the literature. Cuevas-Aburto et al. (2022b), found no significant differences in s-RPE values among TS, CL, and RR protocols. However, in the majority of the literature, during exercises such as clean pull, bench press, and squat comparing traditional and rest redistribution set structures at <70% 1 RM intensity, RPE values were found to be lower in rest redistribution set structures (Ho et al., 2021; Jukic et al., 2020a; Jukic & Tufano, 2019a, 2022a).

Muscle activation, CMJ performance, RPE, and s-RPE were similarly affected in TS, RR1, and RR2 protocols. It was hypothesized that muscle activation, perceptual fatigue, and jump performance would yield better results in rest redistribution set structures. However, contrary to our hypothesis, no significant differences were observed between protocols for any variable. The similar fatigue levels in muscle activation, RPE, s-RPE, and CMJ values across TS, RR1, and RR2 protocols might stem from physiological and mechanical factors: sufficient inter-set rest durations in TS, RR1, and RR2 protocols for significant ATP-PCr replenishment, participants' daily psychological status, nutrition levels (Maughan & Shirreffs, 2012), variability in sleep duration and quality (Watson, 2017), differences in participants' training levels, relatively low intensity, and the high number of sets used. As the number of sets increases, movement velocity does not decrease in CL, whereas it decreases in TS and RR protocols (Cuevas-Aburto et al., 2022a). This could explain the similar neuromuscular and perceptual responses in TS and RR protocols.

This study has some limitations. Metabolic and hormonal responses were not measured. Additionally, although no differences were found in muscle activation, perceptual fatigue, and jump performance between traditional and rest redistribution set structures, it should be noted that these findings may not be valid for different loads (e.g., ≤50% of 1 RM, ≥80% of 1 RM), different volumes (e.g., 3 sets of 6 repetitions), different exercises (e.g., upper body-focused exercises), or different populations (e.g., elite athletes, women). The current performance levels and training histories of the individuals participating in the study may have influenced their perceptual and neuromuscular responses to the Rest Redistribution (RR) protocols applied. It is likely that participants with greater training experience were able to recover the ATP-PCr system more rapidly during intra-set rest intervals and tolerate fatigue better. This suggests that they may manage neuromuscular and perceptual fatigue more effectively compared to participants with relatively less training experience. The absence of a direct comparison across different athletic levels limits the general applicability of the findings regarding which specific set structure is optimal for different performance levels. Furthermore, it remains to be determined whether performing the squat movement with free weights would yield significant differences in the findings of this study.

The results of this study indicate that traditional and rest redistribution set structures do not produce significant differences in muscle activation levels, perceptual fatigue levels, or jump performance during 40-repetition squat exercises performed on the Smith machine at 70% of 1 RM by university students with strength training experience. When traditional sets are not performed to failure, rest redistribution set structures appear to maintain fatigue at similar levels.

PRACTICAL AND THEORETICAL RECOMMENDATIONS

Based on the findings of this study, the following practical and theoretical recommendations are offered to strength and conditioning coaches and researchers:

Performance-Related Interchangeability and Rest Prescriptions (Practical): As traditional (TS) and rest-redistribution (RR) set structures produce similar acute responses in muscle activation and counter-movement jump (CMJ) performance under equal volume at 70% 1RM, strength and conditioning coaches can use these protocols interchangeably. Coaches can feel assured in selecting either technique depending on logistical factors such as time constraints or equipment availability, or the athlete's personal choice, without risking any loss in immediate mechanical and neuromuscular engagement. Particularly for athletes with experience in strength training or students of sports science, it is recommended that a rest period of at least 3 minutes be allowed between sets in traditional set structures (5 sets of 8 repetitions). If the rest periods are redistributed, athletes should use the RR2 method (10 sets of 4 repetitions), resting for at least 80 seconds between sets, whilst maximising recovery without excessively increasing the frequency of rest intervals.

Proximity to Failure and Fatigue Management (Practical): Temporal changes in perceived exertion (RPE) levels provide a valuable tool for coaches. The RR2 protocol (10 sets of 4 repetitions) is strongly recommended for use during the in-season period, the taper phase, or on days when managing overall systemic fatigue is crucial, as it reduces fatigue during general training sessions. On the other hand, if the psychological goal is to minimize fatigue during active work sets, TS can still be used as longer rest intervals may make the immediate execution of sets less tiring. Moreover, it should be emphasized that, as highlighted in other studies (Jukic & Tufano, 2022b; Oliver et al., 2016), when traditional set structures are applied to the point of close to muscle failure, the use of set structures that redistribute rest periods is highly beneficial for maintaining mechanical efficiency.

Examination of Various Loading Factors and Populations (Theoretical): Given that performance outcomes are similar at moderate-to-high intensity (70% of 1RM), future research should examine these specific RR structures under different volumes, intensities, and diverse populations. By focusing on loads close to maximum (85% of 1RM and above) or lighter, power-oriented loads (50% of 1RM and below), there is a need to clarify whether performance becomes more dependent on intra-set rest at the extremes of the load spectrum in terms of maintaining movement speed and mechanical output.

Long-Term Adaptations and Kinematic Profiling (Theoretical): Sports scientists should design long-term studies to investigate whether the reduction in overall perceived fatigue observed in the RR2 protocol of this study leads to chronic adaptations (e.g. hypertrophy, strength, maximum force). In addition, utilizing ongoing kinematic observation (like tracking the speed of the barbell) for every repetition could provide insights into the slight mechanical variations among different methods.

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