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Effect of Pause Versus Rebound Techniques on Neuromuscular and Functional Performance After a Prolonged Velocity-Based Training

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Purpose: A variation of the traditional squat (SQ) rebound technique (REBOUND) including a momentary pause ~2 seconds (PAUSE) between eccentric and concentric phases has been proposed. Although there is a consensus about the lower acute effects on performance of this PAUSE variant compared with traditional REBOUND technique, no information exists about the differences in longitudinal adaptations of these SQ executions. ***Methods:*** A total of 26 men were randomly assigned into the PAUSE (n = 13) or REBOUND (n = 13) groups and completed a 10-week velocity-based training using the SQ exercise, only differing in the technique. Neuromuscular adaptations were assessed by the changes in the 1-repetition maximum strength and mean propulsive velocity achieved against the absolute loads (in kilograms) common to pretest and posttest. Functional performance was evaluated by the following tests: countermovement jump, Wingate, and sprint time at 0 to 10, 10 to 20, and 0 to 20 m. ***Results:*** Whereas both groups showed significant increases in most of the neuromuscular tests ($P < .05$), the PAUSE (effect size [ES] = 0.76–1.12) presented greater enhancements than REBOUND (ES = 0.45–0.92). Although not significant, improvements in Wingate and sprint time at 0 to 10 and 0 to 20 m were higher for PAUSE (ES = 0.31–0.46) compared with REBOUND (ES = 0.10–0.29). Conversely, changes on countermovement jump and sprint time at 10 to 20 m were superior for REBOUND (ES = 0.17–0.88) than for PAUSE (ES = 0.09–0.75). ***Conclusion:*** Imposing a pause between eccentric and concentric phases in the SQ exercise could be an interesting strategy to increase neuromuscular and functional adaptations in sport actions that mainly depend on concentric contractions. Moreover, sport abilities highly dependent on the stretch-shortening cycle could benefit from the REBOUND or a combination of the 2 techniques.

Keywords: resistance training, stretch-shortening cycle, plyometric, contraction, pure-concentric, eccentric-concentric

The back squat (SQ) is one of the most commonly used and effective resistance training exercises for strengthening the lower limbs, protecting against injuries and enhancing athletic performance.[1,2] Numerous studies have demonstrated that increases in lower-limb strength after SQ training transfer positively to functional athletic performance in both short-duration actions, such as sprints and vertical jumps[2,3] and long-duration movements (eg, rowing, cross-country, or cycling).[4,5] During traditional SQ, the subject starts from an upright position and descends (eccentric phase) to a specific depth (half, parallel, or full SQ), and then immediately reverses the motion and ascends back to the starting position (concentric phase).[6]

Recently, some studies have proposed a slight variation of the traditional SQ technique, by including a momentary pause (~2 s) between eccentric and concentric phases.[2,7,8] Despite the fact that this pause would increase the measure's reliability (lower within-subject variation),[9] different investigations have found that a large stop between the lengthening (eccentric) and shortening (concentric) phases decreases substantially the subsequent concentric performance.[9–11] This fact could be explained by the dissipation of the elastic energy stored in the muscle series' elastic components and the reduction of the reflexively induced neural input and potentiation of the contractile machinery.[11–14] Nevertheless, although there is a clear consensus about the superior acute effects (ie, short-term) of rebound SQ executions (REBOUND) compared with pause SQ contractions (PAUSE), no study has yet investigated the differences in longitudinal adaptations of both SQ executions through a resistance training intervention.

A practical and reliable method for training prescription and load control in longitudinal resistance training interventions is the use of velocity as a monitoring variable, named velocity-based training (VBT).[2,15,16] Based on this methodology, a very close association between the movement velocity and relative intensity (percentage 1-repetition maximum [%1RM]) could be found in several exercises, including the SQ (ie, load–velocity relationship).[2,3,15] In addition the VBT would allow researchers/coaches to: (1) assess the athlete's maximum strength (1-repetition maximum [1RM]) in the SQ exercise,[2,3] without the need to perform a maximal test or a repetitions to failure test and (2) determine the % 1RM the athlete is using in this exercise by measuring the first repetition of the set.[6,7] Thus, the VBT would ensure that each of the SQ repetitions performed throughout the intervention is executed at the programmed %1RM, therefore avoiding the mismatches that might occur when programming is solely based on the fixed intensity value (in kilograms) measured at the preintervention test.[16,17]

Therefore, the present study aimed to analyze the effects of imposing a pause between eccentric and concentric phases in the SQ exercise on neuromuscular and functional adaptations after a longitudinal resistance training intervention.

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Method

Experimental Approach to the Problem

A longitudinal and experimental design was used to analyze the effects of the SQ technique, with (PAUSE) and without (REBOUND) a pause between the eccentric and concentric phases, on the neuromuscular and functional adaptations. To address this aspect, 26 well-trained men were randomly allocated into 2 groups, only differing in the SQ technique used: PAUSE (n = 13) and REBOUND (n = 13). Both experimental groups trained twice a week (48–72 h apart) for 10 weeks (20 sessions), following a progressive VBT program (see Resistance Training Program section). Subjects conducted a set of neuromuscular and functional assessments pretraining (the week before; T0) and posttraining (the week after; T1) in 3 testing sessions (Monday, Wednesday, and Friday) (Figure 1). In addition to the functional evaluations (Monday –20-m sprint, countermovement jump [CMJ], and Wingate [WGT] tests), the other days (Wednesday and Friday), participants performed 1 of the 2 SQ progressive loading tests (PAUSE and REBOUND). Therefore, all participants completed all neuromuscular and functional evaluations. Prior to evaluations, participants completed 5 familiarization sessions separated by 48 to 72 hours. The first familiarization session was used for anthropometric measurements, medical examination, and individual identification of the SQ depth (ie, full SQ) maintained in the following testing and training sessions. Then, in random order, each participant performed 2 familiarization sessions for each SQ variant. Despite the fact that all subjects had wide experience in resistance training at maximal voluntary velocity, they were familiarized with the verbal encouragement "as fast as possible" used by the researchers before each repetition, as well as on the correct technique to perform each SQ variant. Participants were required to avoid any other type of strenuous physical activity, exercise training, or sports competition for the duration of the present study.

Subjects

The required sample size will be determined on the basis of the changes in the 1RM after the training intervention. According to previous research on subjects with similar characteristics,[2] an effect size (ES) of 1.22 can be found after 10 weeks of resistance training. These differences with a power of 80% and alpha of .05 could be identified with 12 participants using the G*Power statistical software (version 3.1.9.7; Franz Faul, Universitat Kiel, Kiel, Germany). A total of 26 men (age 22.8 [4.1] y, body mass 75.3 [8.5] kg, height 1.76 [0.06] m) with recreational to high level in their respective sport (soccer, basketball, cycling, and athletics) volunteered to participate in this study. Participants were randomly assigned in a counterbalanced way according to the initial 1RM in the REBOUND SQ into 2 groups, only differing in the SQ technique used during the VBT intervention: PAUSE (n = 13) and REBOUND (n = 13). No physical limitations, health problems, or musculoskeletal injuries that could affect testing or training were found, following a medical examination. None of the subjects were taking drugs, medications, or dietary supplements known to influence physical performance. In the 6 months previous to this investigation, subjects conducted 2 to 4 resistance training sessions per week including the 2 SQ variations under study as part of their conditioning. The study complied with the Declaration of Helsinki and was approved by the bioethics commission of the University of Murcia. Participants were informed of the experimental procedures, potential risks, and benefits before providing written informed consent.

Testing Procedures

Load–Velocity Relationship and 1RM Strength Determination. After at least 3 full rest days subsequent to the familiarization sessions (T0) and the end of the VBT program (T1), the individual load–velocity relationships in each SQ variation were determined by means of a progressive loading test up to the 1RM, only differing in the SQ execution (ie, with or without pause). Following a standardized warm-up,[6] the initial load was set at 20 kg and was gradually increased in 10-kg increments until the attained mean propulsive velocity (MPV) was ≤0.60 $m \cdot s^{-1}$.[2] Thereafter, load was individually adjusted with smaller increments (5 down to 2.5 kg) so that the 1RM could be precisely determined. Three repetitions were executed for light (<50% 1RM), 2 for medium (50%–80% 1RM), and only 1 for the heaviest loads (>80% 1RM). Interset recoveries ranged from 3 (light loads) to 5 minutes (heavy loads).[2] The heaviest load that each participant could properly lift using a full range of motion, and without external help was considered

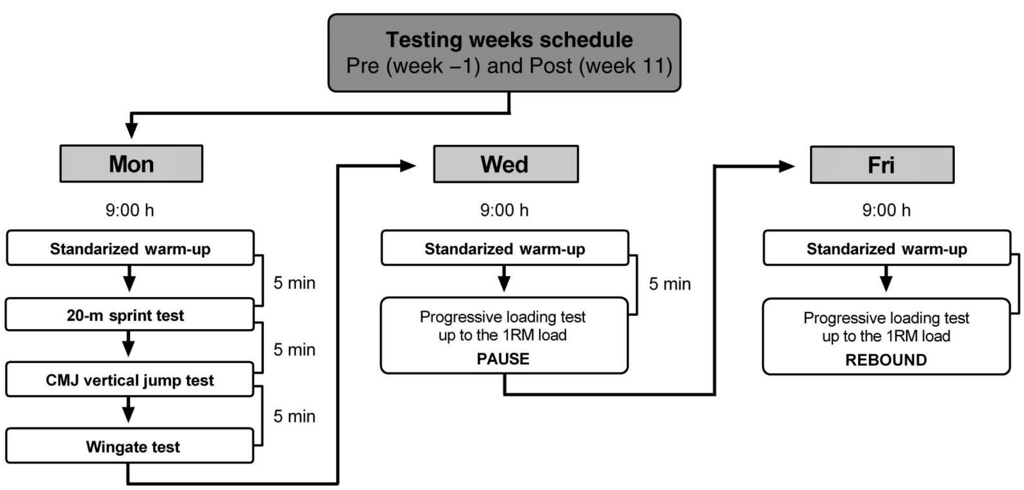

Figure 1 — Testing schedule undertaken for all groups during the preassessments (T0; week –1) and postassessments (T1; week 11) of the velocity-based intervention. 1RM indicates 1-repetition maximum; CMJ, countermovement jump.

his 1RM.[7] In addition, T1 and T2 were conducted at the same time of day (09:00–11:00 h) to control the circadian rhythms effects on neuromuscular performance[18] and under similar environmental conditions (21°C–22°C and 53%–62% humidity). A very high test–retest reliability of this testing protocol (intraclass correlation coefficients [ICCs] = .99; 95% confidence interval, .99–1.00; coefficient of variation [CV] = 2.5%) has been recently described.[19]

SQ Techniques. For both SQ variations, subjects started from an upright position, with the knees and hips fully extended, stance approximately shoulder-width apart with both feet positioned flat on the floor in parallel or externally rotated to a maximum of 15°. The barbell rested across the back at the level of the acromion. From this position, they were required to descend in a continuous motion (eccentric phase) until the first of these 2 criteria was met: (1) posterior thighs and calves made contact with each other or (2) the lumbar spine angle was equal to 0°.[7] When this depth position was achieved:

1. PAUSE SQ: participants momentary release the weight of the bar for 2 seconds on 2 bar spotters placed at both sides of the Smith machine (Multipower Fitness Line, Peroga Fitness, Murcia, Spain) with a precision scale (±1 cm), thus pausing the movement between the eccentric and concentric phases (minimize the contribution of the stretch-shortening cycle) and ceasing to apply force for the pause duration. Finally, they were instructed to reverse the movement and ascend back to the upright position (concentric phase). In order to prevent the participants from conducting a small countermovement before the concentric phase, as well as to ensure a correct pause in terms of duration and weight release, 2 skilled researchers (>10 y of experience in resistance training) supervised each repetition during the training and testing sessions.
2. REBOUND SQ: subjects explosively reversed the movement and ascended back to the upright position as soon as they reached the end of the eccentric phase, thus taking advantage of the stretch-shortening cycle.

Participants of both groups were required to perform the concentric phase at maximal intended velocity and the eccentric phase at a controlled mean velocity of 0.45 to 0.65 $m \cdot s^{-1}$.[15] Lifting the feet off the ground at the end of the movement was not allowed. The software of the velocity transducer was employed to control each repetition displacement during both the load–velocity evaluations and VBT sessions. As this software offers the displacement of each repetition in real time, researchers provided feedback to participants when they reduced the full range of motion (determined in the first familiarization session) by > 5%.[2] All lifts during testing and training were conducted using a Smith machine with no counterweight mechanism. Repetitions evaluated during testing and training sessions were recorded by using a linear velocity transducer with a sampling frequency of 1000 Hz (T-Force System; Ergotech, Murcia, Spain). This technology has been tested for barbell velocity measurement with excellent results of reproducibility (ICC = 1.000, CV ≤ 1.4%) and repeatability (ICC = .999, CV ≤ 2.0%), as detailed elsewhere.[19,20]

Measures from the following neuromuscular parameters were considered for the analysis: 1RM strength and average mean propulsive velocity attained against all absolute loads (MPV-ALL) common to T0 and T1.

Sprint and Vertical Jump Tests. Two maximal 20-m sprints, separated by a 3-minute rest, were conducted on a running track. Photocell timing gates (Chronojump Boscosystem, Barcelona, Spain), placed every 10 m, were used to measure sprint times. Therefore, the times to cover 0 to 10, 10 to 20, and 0 to 20 m could be determined. The shortest T20 time was saved for further analysis.[3] Following 5 minutes of rest, subjects performed 5 maximal countermovement vertical jumps (CMJ), separated by 1 minute of recovery. Jump height was measured using an infrared timing system (Optojump; Microgate, Bolzano, Italy). The highest and lowest CMJ values were removed, and the resulting average was kept for analysis. An excellent test–retest reliability has previously been reported for the T20 (CV = 1.0%, ICC = .98) and the CMJ (CV = 2.3%, ICC = .99) tests.[3]

WGT Test. All WGT tests were performed in a mechanically braked cycle ergometer (Monark 874E; Monark, Varberg, Sweden) adapted with a crank-based power meter (1 Hz, ±1% accuracy, scientific model; SRM GmbH, Julich, Germany). The saddle and handlebar positions of the cycle ergometer, individually adjusted to anthropometric characteristics, were identically reproduced on T1 and T2. Following a 3-minute standardized warm-up,[21] from a full stop with the pedal of the dominant leg placed at 45° from vertical, participants conducted a 30-second all-out effort at a resistance of 0.075 kg^{-1} body mass. The highest and average power of the 30 seconds was defined as the peak power (WGT peak power output) and mean power (WGT mean power output), respectively. A high test–retest reliability for the WGT has been previously reported (CV = 3.5%, ICC = .87).[21]

Resistance Training Program. Participants conducted a 10-week VBT (2 d a week) using only the SQ exercise. Both groups (PAUSE and REBOUND) trained using the same %1RM (progressively increasing from 60% to 80% 1RM along the intervention), interset recovery (4 min) and volume (4 to 5 sets and 8 to 4 repetitions) (Table 1). Thus, PAUSE and REBOUND only differed in the SQ technique used during the training program. Similar linear periodization models monitored by the VBT method have been proved highly effective in improving neuromuscular and functional performance in both the upper and lower limbs.[2,22] Relative loads for each group were determined from the close

Table 1 Descriptive Characteristics of the VBT Performed by the PAUSE and REBOUND Groups

Scheduled	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
%1RM	~60%	~60%	~65%	~65%	~70%	~70%	~75%	~75%	~80%	~80%
Sets × reps	4 × 8	5 × 8	4 × 8	5 × 8	4 × 6	5 × 6	4 × 5	5 × 5	4 × 4	5 × 4
Target MPV, $m \cdot s^{-1}$										
PAUSE	0.74	0.74	0.68	0.68	0.63	0.63	0.58	0.58	0.52	0.52
REBOUND	1.00	1.00	0.92	0.92	0.84	0.84	0.76	0.76	0.68	0.68

Abbreviations: %1RM, percentage of 1-repetition maximum; MPV, mean propulsive velocity; reps, repetitions; VBT, velocity-based training. Note: %1RM: relative intensity; Target MPV: maximal intended velocity repetition performed at the end of each session's warm-up to ensure that the load (in kilograms) to be used matched the velocity associated with the intended %1RM.

load–velocity relationship previously found both for the PAUSE[7] and REBOUND[6] techniques. Thus, a target MPV to be attained in the first (usually the fastest) repetition of each training session was used as an accurate estimation of %1RM. After a standardized warm-up (5 min of running at a self-selected intensity, 5 min of joint mobilization exercises, and 3 sets of progressively faster 30-m running accelerations), adjustments in the proposed load (in kilograms) were made when needed so that the MPV of the first repetition matched that programmed velocity (±0.03 $m \cdot s^{-1}$). Once the load (in kilograms) was adjusted, it was maintained for the rest training sets during the session. Furthermore, participants were instructed to conduct each repetition as fast as possible.

Statistical Analyses

Means and SDs were calculated by using standard statistical methods. The normality of the variables at Pre (T0) was analyzed with the Shapiro–Wilk test, whereas the homogeneity of variance across groups (PAUSE and REBOUND) was verified using the Levene test. Equivalence between groups was verified by the 2 one-sided test, based on previous interventions.[2,23,24] A 2 (group: PAUSE vs REBOUND) × 2 (time: Pre [T0] vs Post [T1]) factorial analysis of variance with Bonferroni adjustment was used to analyze the differences between groups. The intragroups ESs were calculated using unbiased Hedge g^*.[25] Percentage of change (Δ) was calculated as: (mean Post – mean Pre)/mean Pre. Statistical significance was accepted at $P < .05$. The null hypothesis tests were performed using SPSS software (version 17.0; SPSS, Chicago, IL).

Results

There was not any dropout during the study. Compliance with the resistance training program was 100% of all sessions scheduled for both training groups. Groups were found to be equivalent at Pre (T0) for all the variables analyzed ($P \le .05$). Participants of PAUSE and REBOUND performed exactly the same number of sessions (20), total series (90), and total repetitions (558). Moreover, the 2 groups trained under the same relative intensity, both daily and throughout the training program (average ~70% 1RM). However, as participants obtained higher 1RM values in the REBOUND variant (1RM PAUSE = 94.1 [10.7] kg; 1RM REBOUND = 103.8 [17.2] kg), differences were observed in the total weight (ie, kilograms) lifted by each group during the training program (REBOUND: 19.264 [4.623] kg; PAUSE: 17.220 [4.339] kg).

Excluding the 1RM value of the pause technique ($1RM_{PAUSE}$) in the REBOUND group, the 2 SQ groups significantly increased all neuromuscular parameters ($P < .05$, Table 2). Specifically, each group achieved the highest improvements at the specific technique at which it trained (ie, PAUSE for PAUSE and REBOUND for REBOUND). Nevertheless, the PAUSE (Δ = 11.8%–15.5%; ES = 0.76–1.12) presented greater enhancements than REBOUND (Δ = 8.1%–11.6%; ES = 0.45–0.92) in all parameters. Significant "time × group" interaction were observed in favor of the PAUSE group for $1RM_{PAUSE}$ ($P < .001$, F value = 26.784) and $MPV\text{-}ALL_{PAUSE}$ ($P = .006$, F value = 11.112) (Table 2, Figure 2).

Similar to neuromuscular parameters, although not significant, improvements in WGT peak power output, WGT mean power output, times to cover 0 to 10, and 0 to 20 m were higher for PAUSE (Δ = 1.7%–7.3%; ES = 0.31–0.46) compared with REBOUND (Δ = 0.6%–2.6%; ES = 0.10–0.29). On the contrary, whereas both groups increased significantly CMJ performance, this enhancement was higher for REBOUND (Δ = 13.5%; ES = 0.88) than for PAUSE (Δ = 12.1%; ES = 0.75). The enhancement in the time to cover 10- to 20-m distance was also greater in REBOUND technique (Δ = 1.2%; ES = 0.17) than in PAUSE (Δ = 0.9%; ES = 0.09).

Discussion

The main findings of the current study indicate that imposing a pause between eccentric and concentric phases in the SQ exercise could be an interesting strategy to increase neuromuscular and functional adaptations, especially for sport actions whose performance depends mainly on concentric contractions. On the other hand, sport abilities which highly depend on the stretch-shortening cycle could benefit from the REBOUND or a combination of both techniques.

Based on the changes experienced by the 2 groups, both PAUSE and REBOUND SQ executions were found as effective

Table 2 Changes in Selected Neuromuscular and Functional Performance Variables From Pretraining (T1) to Posttraining (T2) for Each Resistance Training Group (REBOUND or PAUSE)

	Training intervention							
	REBOUND				PAUSE			
Variable	Pre	Post	Δ (%)	ES	Pre	Post	Δ (%)	ES
$1RM_{REBOUND}$, kg	93.0 (17.8)	103.8 (17.2)*	11.6%	0.60	94.1 (16.5)	105.2 (11.5)*	11.8%	0.76
$1RM_{PAUSE}$, kg	81.5 (15.5)	88.8 (15.5)	9.0%	0.45	81.5 (11.4)	94.1 (10.7)*,**	15.5%	1.10
$MPV\text{-}ALL_{REBOUND}$, $m \cdot s^{-1}$	0.85 (0.09)	0.94 (0.10)*	10.6%	0.92	0.83 (0.09)	0.93 (0.10)*	12.0%	1.02
$MPV\text{-}ALL_{PAUSE}$, $m \cdot s^{-1}$	0.74 (0.09)	0.80 (0.10)*	8.1%	0.61	0.72 (0.09)	0.83 (0.10)*,**	15.3%	1.12
T0–10, s	1.65 (0.10)	1.64 (0.11)	0.6%	0.10	1.66 (0.10)	1.62 (0.11)	2.4%	0.37
T10–20, s	1.31 (0.11)	1.29 (0.11)	1.2%	0.17	1.29 (0.11)	1.28 (0.11)	0.9%	0.09
T0–20, s	2.96 (0.09)	2.93 (0.11)	0.9%	0.29	2.95 (0.10)	2.90 (0.11)	1.7%	0.46
CMJ, cm	34.9 (4.3)	39.6 (5.9)*	13.5%	0.88	35.4 (5.3)	39.7 (5.9)*	12.1%	0.75
WGT_{PEAK}, W	998 (185)	1023 (195)	2.5%	0.13	1080 (191)	1159 (198)	7.3%	0.40
WGT_{MEAN}, W	680 (95)	698 (101)	2.6%	0.17	699 (92)	729 (95)	4.2%	0.31

Abbreviations: 1RM, 1-repetition maximum; CMJ, countermovement jump; ES, effect size; MPV, mean propulsive velocity; T0–10, 0- to 10-m sprint time; T10–20, 10- to 20-m sprint time; T0–20, 0- to 20-m sprint time; WGT_{MEAN}, Wingate mean power output; WGT_{PEAK}, Wingate peak power output. Note: Data are represented as mean (SD). *Significant differences when comparing Pre–Post. **Statistically significant "time × group" interaction.

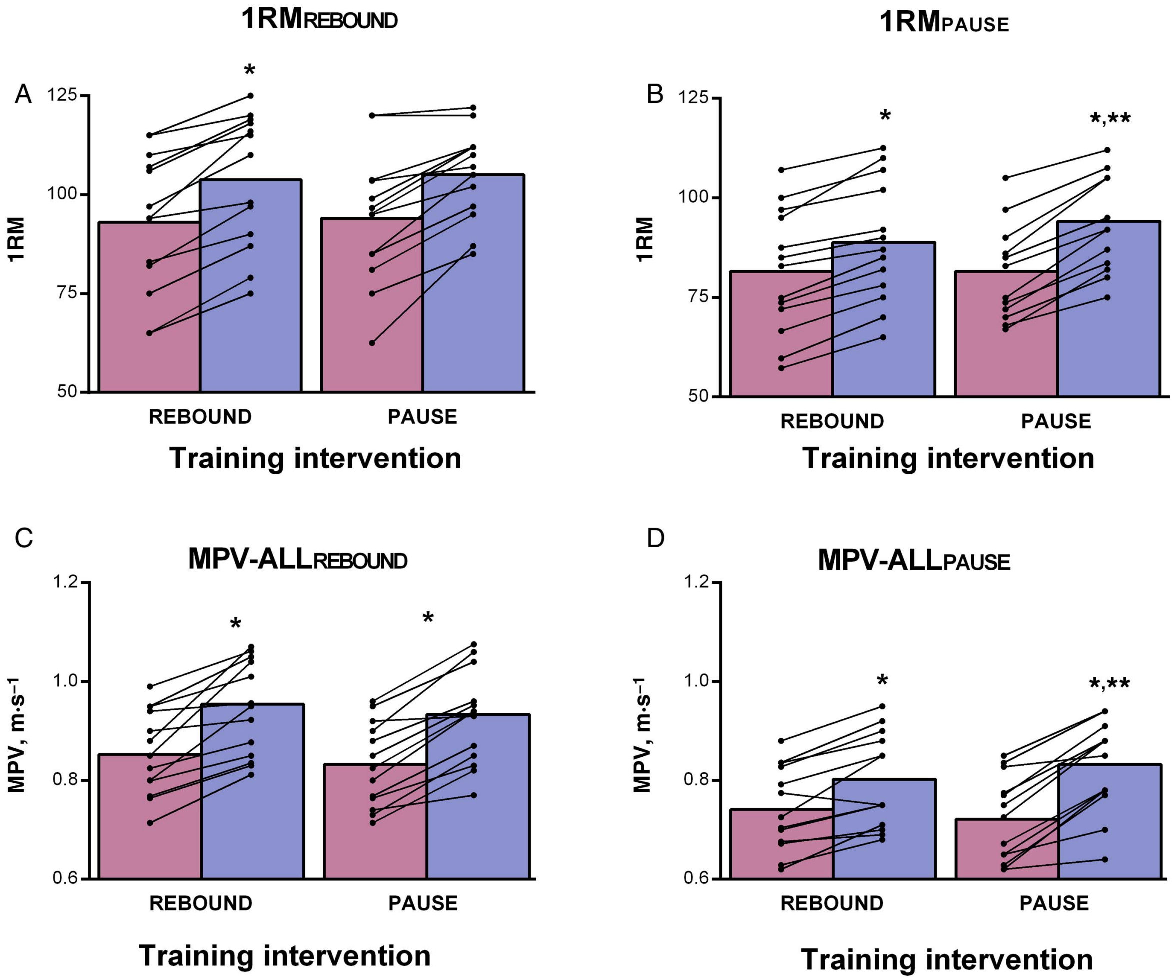

Figure 2 — Mean and individual changes in 1RM (panels A and B) and MPV-ALL (panels C and D) from pretraining (left column) to posttraining (right column) for each resistance group. 1RM indicates 1-repetition maximum; MPV, mean propulsive velocity. *Significant differences when comparing Pre–Post. **Statistically significant "time × group" interaction.

approaches to increase performance following a VBT intervention. It is worth noting that VBT programs have been found as more efficient (less total training volume) and effective (higher strength and functional adaptations) than traditional percentage-based training methodologies.[26,27] The VBT ensures that each SQ repetition is executed at the programmed %1RM, thus avoiding the mismatches that typically occur when programming is solely based on the fixed intensity values (in kilograms) measured at the preintervention test (ie, traditional percentage-based training).[26,27] Likewise, both SQ techniques specifically increased the neuromuscular performance (ES = 0.45–1.12), whereas lower changes were found in functional tasks (ES = 0.09–0.88). These superior enhancements in strength variables (1RM or MPV-ALL) are in agreement with previous investigations analyzing other aspects related to the SQ technique such as the range of motion[2] or movement velocity.[15] It could be hypothesized that not specifically training these functional abilities throughout the intervention, as well as the possible need of a refamiliarization with some less-common tests (eg, WGT), could explain these inferior functional adaptations in both groups. An example of this aspect can be seen in Galiano et al[3] where the weekly inclusion of CMJ and sprints tasks reduced the differences between neuromuscular and functional adaptations following a VBT program.

On the other hand, comparison of both contractions showed greater neuromuscular adaptations for the PAUSE variant (ES = 0.76–1.12) than for the REBOUND (ES = 0.45–0.92) (Table 2, Figure 2). Although previous investigations have compared the acute effects of PAUSE and REBOUND techniques,[9,10] to the best of authors' knowledge, this is the first investigation comparing the longitudinal effects of both techniques in the SQ exercise. Results found by the current research could suggest differences between short- and long-term effects of these SQ variants. Specifically to the PAUSE contraction, whereas the reduced participation of the stretch-shortening cycle would generate a decrease in the acute performance (eg, lower jump height or barbell velocity),[11–14,28] adaptations after prolonged resistance training programs could be maximized by imposing a pause between SQ phases. Different kinematics and physiological mechanics could underlie the findings. For example, it is hypothesized that the lower initial acceleration at the beginning of the concentric phase in PAUSE executions due to the reduced participation of the stretch-shortening cycle,[29] could allow a greater production of muscular tension (as more cross bridges have time to attach as the velocity decreases)[30,31] in order to solve the subsequent sticking region. This continuous exposure to higher time under tension in the critical zone (ie, sticking region) along the training program, could explain part of these superior neuromuscular adaptations in the PAUSE variant. Nevertheless, as the current study did not measure the previously mentioned aspects, future studies are encouraged to extend the knowledge about the kinematics and physiological mechanisms that could underlie these results. Furthermore, it is worth noting that, although the 2 groups were training as fast as possible, the PAUSE group achieved more improvements by training at lower absolute velocities (in meters per second; Table 1). This finding would support the importance of executions at maximal voluntary velocity for maximizing strength adaptations,[15,32] although this velocity is moderate/low in absolute terms. On the other hand, the PAUSE technique showed these superior neuromuscular enhancements by using ~12% (2.044 kg) less total weight along the VBT program. Thus, in agreement with results found by previous investigations,[2] the PAUSE variant could represent a proper strategy to reduce the stress generated on muscle-tendon units and therefore relieve the possible pain and discomfort. Regarding the changes in functional abilities, PAUSE achieved higher improvements than REBOUND, especially in those tasks whose performance depends specifically on concentric contractions: initial phase of the sprint test (time to cover 0–10 m) and the WGT peak power output (PAUSE: ES = 0.37–0.40, REBOUND: ES = 0.10–0.13). On the contrary, greater improvements for tests with higher stretch-shortening cycle participation, especially for the CMJ test (PAUSE: ES = 0.75, REBOUND: ES = 0.88), were found in the REBOUND group. Overall, these results would agree with the "specificity" training principle, which holds that training adaptations are highly dependent on, among other aspects, the technique and contraction trained.[33,34] Another example of this specificity principle was also found in the neuromuscular variables, since each SQ variant achieved the highest improvements at the specific technique at which it trained (ie, PAUSE for PAUSE and REBOUND for REBOUND).

Despite the fact that the current study expands the knowledge about the longitudinal effects of PAUSE and REBOUND executions in the SQ exercise, it presents some limitations which should be addressed. First, the time under tension was not matched between groups, but this parameter was considered as an intrinsic property of the REBOUND and PAUSE techniques. Nevertheless, it is worth noting that matching by time under tension would have meant unbalancing the groups in terms of training volume (number of sets or repetitions). Thus, notwithstanding this limitation, future investigations are encouraged to contrast the results obtained by the present study by equalizing the time under tension between the 2 SQ techniques. Moreover, evaluating morphological changes on the knee extensor structures, as the muscle architecture (eg, vastus lateralis) or patellar tendon, would extend the knowledge about the physiological mechanics that could underlie the results found by the current study. Finally, it would be of great value that future studies include other functional evaluations, such as changes of direction, vertical SQ jumps, and longer sprints (eg, 0–40 m).

Practical Applications

Practitioners could benefit from using the PAUSE in sports whose performance depends mainly on concentric contractions of knee extensors, such as short sprints and cycling trials. On the other hand, team sports, characterized by actions such as accelerations from standing and vertical jumps, could maximize their performance by combining PAUSE (for short accelerations) and REBOUND (for vertical jumps and longer sprints) techniques. Moreover, the PAUSE variant would represent an interesting approach to decrease the stress produced on the muscle-tendon units, as it allows working at the same %1RM as REBOUND SQ but using less absolute weight.

Conclusion

Imposing a pause between eccentric and concentric phases in the SQ exercise could be an interesting strategy to increase neuromuscular and functional adaptations, especially for sport actions whose performance depends mainly on concentric contractions. Moreover, sport abilities which highly depend on the stretch-shortening cycle could benefit from the REBOUND or a combination of the 2 techniques.

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