

# ACUTE AND DELAYED EFFECTS OF A RESISTANCE TRAINING SESSION LEADING TO MUSCULAR FAILURE ON MECHANICAL, METABOLIC, AND PERCEPTUAL RESPONSES

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## ABSTRACT

Párraga-Montilla, JA, García-Ramos, A, Castaño-Zambudio, A, Capelo-Ramírez, F, González-Hernández, JM, Cordero-Rodríguez, Y, and Jiménez-Reyes, P. Acute and delayed effects of a resistance training session leading to muscular failure on mechanical, metabolic, and perceptual responses. *J Strength Cond Res* 34(8): 2220–2226, 2020—This study explored the acute and delayed (24 and 48 hours after exercise) effects of a resistance training session leading to muscular failure. Eleven resistance-trained men completed a training session consisting on 3 sets of repetitions to failure during the back-squat exercise performed at the maximum possible speed with a load equivalent to a mean propulsive velocity (MPV) of  $1 \text{ m} \cdot \text{s}^{-1}$  ( $\approx 60\%$  of 1 repetition maximum). A number of mechanical (number of repetitions and starting MPV of the set, MPV achieved against the 1MPV load, countermovement jump [CMJ] height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (OMNI-RES perceived exertion) variables were measured. The results revealed (a) a decrease of 38.7% in set 2 and 54.7% in set 3 of the number of repetitions performed compared with the first set ( $p < 0.05$ ), (b) a reduction in the MPV of the repetitions and an increase in lactate concentration and OMNI-RES values with the succession of sets ( $p < 0.05$ ), (c) comparable decrements in CMJ height after the 3 sets (25–32%), (d) a decrease in CMJ height ( $p < 0.05$ ; 6.7–7.9%) and in the MPV attained against the 1MPV load ( $p < 0.05$ ; 13–14%) after 24 and 48 hours of completing the training session, but

no significant changes were observed in handgrip strength ( $p > 0.05$ ;  $< 2\%$ ), and (e) uric acid and ammonia concentrations above the basal levels ( $p < 0.05$ ). The large decrements in mechanical performance together with the high metabolic stress discourage the frequent use of resistance training sessions leading to muscular failure.

**KEY WORDS** back squat, jump height, movement velocity, velocity-based training

## INTRODUCTION

Resistance training is recognized as one of the most effective methods to enhance physical fitness and, consequently, the health status (7,17). Multiple resistance training variables can be manipulated when designing resistance training programs (e.g., exercise type and order, number of sets and repetitions, loading magnitude, rest between sets and repetitions, and movement velocity) (24). A variable that strongly determines the mechanical and metabolic responses is the number of repetitions performed in the set with respect to the maximum number of repetitions that could be performed before reaching muscular failure (19,22,27). The training to failure strategy (i.e., maximizing the level of effort or leaving no repetitions in reserve) has traditionally been used when aiming to increase maximum strength and muscle mass (6,20). However, there are also studies suggesting that training to failure is not the optimal stimulus for maximizing athletic performance (8,14,23,26). In this regard, it is important to explore the acute effect of training to failure on the different mechanical and metabolic variables that are known to play an important role in the neuromuscular adaptations triggered by resistance training (29,32).

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Several studies have been conducted to explore the acute and delayed effects of training to failure on mechanical and metabolic responses (9,11,12,19,22,27). Morán-Navarro et al. (19) reported that training to failure increases the time required to recover the neuromuscular function as well as the metabolic and hormonal homeostasis. Similarly, Pareja-Blanco et al. (22) and González-Badillo et al. (11) showed that training to failure induces higher mechanical fatigue, greater autonomic cardiovascular stress, and an increased hormonal response and muscle damage compared with performing only a half of the maximum numbers of repetitions per set. It is important to note that the abovementioned studies used longer interset rest periods (5 minutes) than the typically recommended rest periods for maximizing hypertrophic adaptations (1–3 minutes) (31). Therefore, because training to failure could be recommended primarily for inducing hypertrophic adaptations (29,30), it would be of interest to explore the effect of training to failure on mechanical and metabolic responses when shorter rest periods (e.g., 3 minutes) are allowed between successive sets.

To expand the knowledge in the literature regarding the training to failure strategy, in this study, we evaluated the acute and delayed (24 and 48 hours after exercise) effects of a resistance training session leading to muscular failure on mechanical, metabolic, and perceptual responses. The back-squat exercise was chosen because it is one of the most effective exercises to develop lower-body muscular strength (28). The main difference with respect to previous studies that also examined the effect of training to failure with the squat exercise (11,19,22) is that we used a lower relative load ( $\approx 60\%$  1 repetition maximum [1RM] vs.  $\approx 70\text{--}80\%$  1RM) and shorter interset rest periods (3 vs. 5 minutes). Reaching muscular failure with a light load should induce a larger decrement of the maximal capacity of the muscles to generate force than reaching muscular failure with a higher load (10). Therefore, the objectives of this study were to explore the effect of training to failure with a low relative load during the squat exercise on mechanical (number of repetitions per set, movement velocity, countermovement jump [CMJ] height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (OMNI-RES perceived exertion) variables. The hypothesis was that significant impairments would be observed for all variables at the different points of measure, while the magnitude of the impairment would be comparable, if not higher, than the previously reported for protocols of repetitions to failure conducted with higher relative loads.

## METHODS

### Experimental Approach to the Problem

Subjects attended to a university laboratory to be tested during 3 consecutive days (Figure 1). The training session was conducted on the first day and it comprised 3 sets of repetitions to failure during the squat exercise performed at the maximum possible speed with a load equivalent to

a mean propulsive velocity (MPV) of  $1 \text{ m}\cdot\text{s}^{-1}$  (1MPV load;  $\approx 60\%$  1RM (21)). The MPV achieved against the 1MPV load, CMJ height, and handgrip strength were measured at the beginning of the training session (i.e., before the 3 sets of repetitions to failure). The same variables were also measured in sessions 2 and 3 (i.e., 24 and 48 hours after the training session). In addition, CMJ height, blood lactate concentration, and the OMNI-RES perceived exertion were collected in session 1 after each set of repetitions to failure. Uric acid and ammonia concentration were also measured at the end of the training session, whereas uric acid was also measured in sessions 2 and 3. The 3 sessions were performed in the morning, at the same time of day for each subject, and under constant environmental conditions ( $20^\circ \text{ C}$  and  $60\%$  humidity).

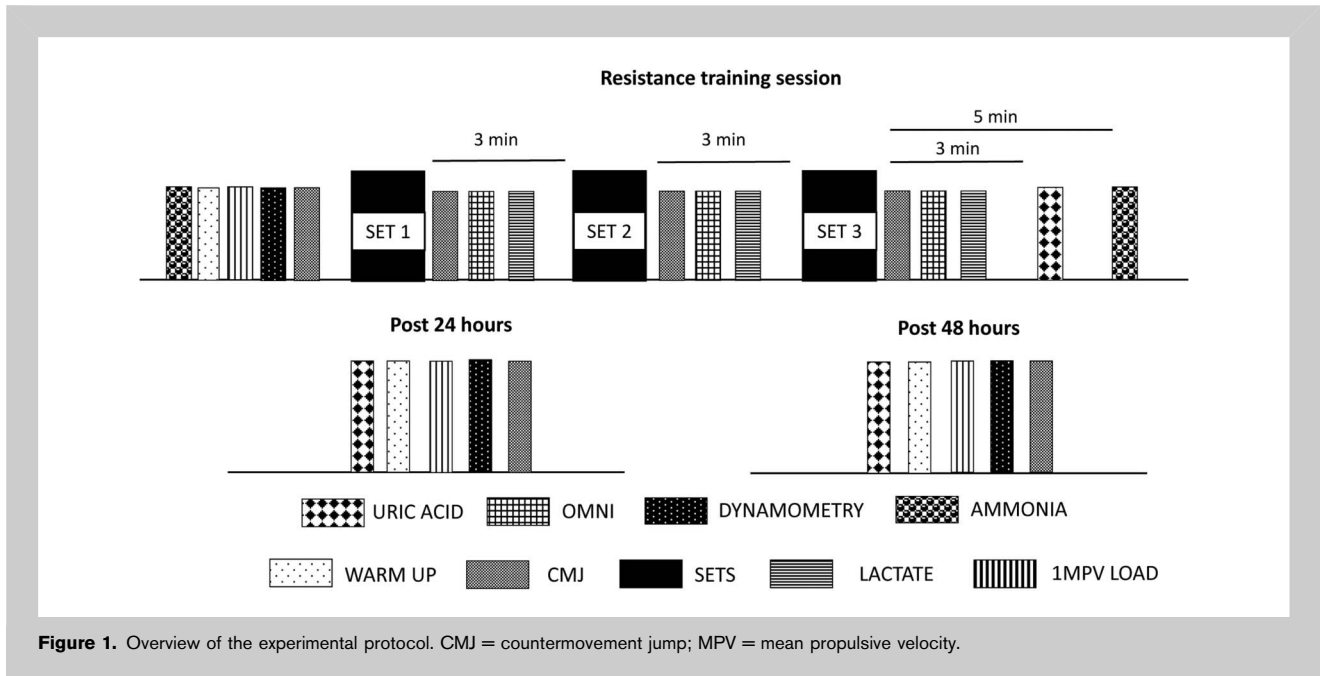
### Subjects

Eleven male physically active sports science students (mean  $\pm$  SD; age:  $22.5 \pm 3.1$  years [range: 18–27], height:  $1.79 \pm 0.10$  m, and body mass:  $73.4 \pm 7.2$  kg) volunteered to participate in this study. All subjects were familiarized with all measurements as well as with the sets of repetitions to failure in the back-squat exercise before the initiation of the study. No physical limitations, health problems, or musculoskeletal injuries that could affect testing or training were found after a medical examination. Subjects reported no use of drugs, medications, or dietary supplements known to influence physical performance. Subjects were informed of the procedures to be used and signed a written informed consent form before initiating the study. The study protocol adhered to The Code of Ethics of the World Medical Association (Declaration of Helsinki) and was approved by the institutional review board of the University of Jaén.

### Procedures

**Resistance Training Session.** Before the 3 sets of repetitions to failure, subjects completed a standardized warm-up that included jogging, joint mobility exercises, and 5 submaximal CMJs. Thereafter, an incremental loading test was performed to determine the load associated with an MPV of  $1 \text{ m}\cdot\text{s}^{-1}$  (1MPV load). The first initial external load was set to 20 kg (mass of the unloaded barbell of the Smith machine) for all subjects and was progressively incremented from 10 to 2.5 kg until the 1MPV load was reached. Once the 1MPV load was identified, subjects performed 5 repetitions as fast as possible against this load with 15 seconds of rest between successive repetitions. It should be noted that the same procedure was followed during the sessions 2 and 3 but, in these sessions, subjects used the same absolute loads than in session 1. In sessions 2 and 3, subjects did not perform any set of repetitions to failure.

The main part of the training session consisted of 3 sets of maximum number of repetitions to failure during the squat exercise performed on a Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain). Rest periods of 3 minutes were implemented between successive sets. The external load



used was individually selected as the load associated with a MPV of  $1 \text{ m}\cdot\text{s}^{-1}$  ( $52.7 \pm 10.0 \text{ kg}$ ). The depth of the squat was performed until the thighs were parallel to the floor. An elastic cord was used to ensure the correct depth during all repetitions. Namely, subjects descended until their glutei contacted with the elastic cord and, immediately after, they performed the concentric phase at the maximum possible speed.

*Mechanical Measures of Fatigue: Set of Repetitions to Failure.* Subjects were encouraged to perform all repetitions at the maximum possible velocity and the MPV of all repetitions were recorded using a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain) that was attached to the barbell of the

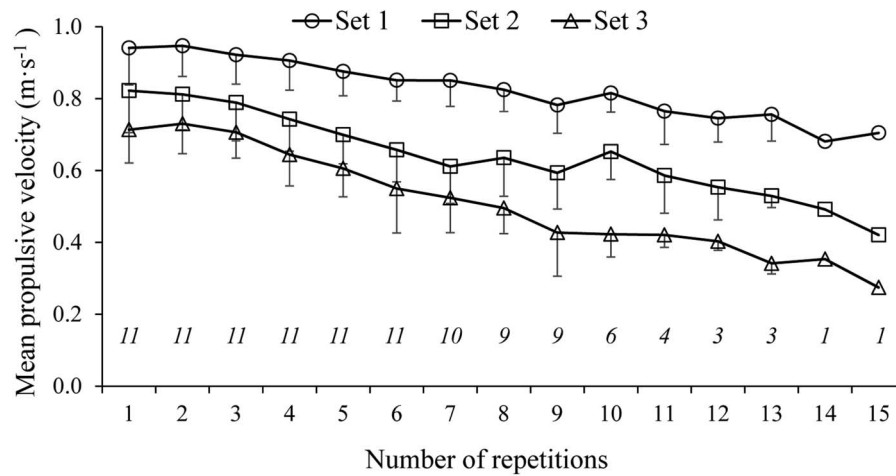
Smith machine. The number of repetitions completed in each set and the MPV of the repetitions were analyzed.

*Mechanical Measures of Fatigue: Velocity Achieved Against the One Mean Propulsive Velocity Load.* After the standardized warm-up described above, subjects performed 5 repetitions separated by 15 seconds against the 1MPV load. The magnitude of this load was determined in session 1, but the same absolute load was used in the 3 sessions to assess differences in MPV when the same load is lifted. The fastest and the slowest repetitions were discarded, and the average values of the 3 remaining repetitions were used for statistical analysis. The MPV was measured using a linear velocity transducer.

**TABLE 1.** Descriptive values of the different variables collected at each time point (mean  $\pm$  SD).

	Session 1					
	Pre	Set 1	Set 2	Set 3	Session 2	Session 3
Starting velocity ( $\text{m}\cdot\text{s}^{-1}$ )	No	$0.94 \pm 0.10$	$0.82 \pm 0.12$	$0.71 \pm 0.09$	No	No
No. of repetitions (a.u.)	No	$22.5 \pm 5.3$	$13.8 \pm 3.0$	$10.2 \pm 2.7$	No	No
1MPV load ( $\text{m}\cdot\text{s}^{-1}$ )	$1.00 \pm 0.07$	No	No	No	$0.87 \pm 0.07$	$0.86 \pm 0.08$
CMJ height (cm)	$34.1 \pm 5.8$	$25.7 \pm 6.1$	$24.2 \pm 5.6$	$23.2 \pm 7.0$	$31.4 \pm 6.1$	$31.8 \pm 6.2$
Handgrip strength (kg)	$45.7 \pm 6.8$	No	No	No	$45.6 \pm 8.1$	$44.9 \pm 6.6$
Lactate ( $\text{mmol}\cdot\text{L}^{-1}$ )	No	$9.6 \pm 1.4$	$13.4 \pm 4.3$	$14.2 \pm 3.1$	No	No
Uric acid ( $\text{mg}\cdot\text{dl}^{-1}$ )	No	No	No	$12.61 \pm 2.15$	$7.80 \pm 1.13$	$7.32 \pm 2.10$
Ammonia ( $\mu\text{mol}\cdot\text{L}^{-1}$ )	$49.5 \pm 7.1$	No	No	$157.7 \pm 52.1$	No	No
OMNI-RES (a.u.)	No	$9.09 \pm 0.70$	$9.64 \pm 0.50$	$9.91 \pm 0.30$	No	No

MPV = mean propulsive velocity; CMJ = countermovement jump.



**Figure 2.** Averaged across the subjects (experimental points) and SDs (error bars) of the mean propulsive velocity achieved during the 3 sets of repetitions to failure. The numbers depicted within the figure indicate the number of subjects who were included in the analysis of each repetition. Subjects were excluded from the analysis when they reached failure in 1 of the 3 sets performed.

*Mechanical Measures of Fatigue: Countermovement Jump Height.* Jump height was measured using an infrared platform (Optojump Microgate, Borzano, Italy). Countermovement jump height was measured at 4 points during the training session (1 after the handgrip strength assessment, and 10 seconds after the completion of each set of repetitions to failure), and only in one occasion during sessions 2 and 3 (after the handgrip strength assessment). The first measurement of CMJ height in session 1 was compared against the measurements made in sessions 2 and 3 to assess the delayed fatigue effect of the training session. Countermovement jump height was also assessed immediately after each set to evaluate the magnitude of the decrement in jumping capabilities after a set of repetitions to failure. Subjects performed the CMJ with their hands fixed on their hips. Three trials were performed at each time point separated by 10 seconds. The average value of the 2 trials with higher jump height was used for statistical analyses.

*Mechanical Measures of Fatigue: Handgrip Strength.* The handgrip strength was measured using an electronic dynamometer (Baseline Smedley, New York, NY, USA) during the 3 sessions. The measurements were always taken 2 minutes after the completion of the 5 repetitions with the 1MPV load. For measurement, subjects assumed a standing position with their elbow extended perpendicular to the floor. The dynamometer axis was visually aligned with the arm by the tester. The grip width was self-selected and it was kept constant for all measurements. The testing protocol consisted of 2 maximal isometric contractions of 5 seconds with their dominant hand (i.e., the hand they used for writing). A rest period of 60 seconds was implemented

between both trials, and the highest value was used for statistical analyses.

*Metabolic Measures of Fatigue: Blood Lactate Concentration.* Blood lactate measurements were obtained from the fingertip 1 minute after the completion of each set. A portable lactate analyzer (Lactate Scout; SensLab GmbH, Leipzig, Germany) was used for lactate measurements. The lactate analyzer was calibrated before each exercise session according to the manufacturer's specifications.

*Metabolic Measures of Fatigue: Uric Acid.* An automatic reflection photometer (Boehringer Mannheim, Germany) was used to measure the concentration of uric acid. Uric acid was measured 3 minutes after the completion of the last set of repetitions to failure. Uric acid was also measured during the sessions 2 and 3 before the initiation of the warm-up.

*Metabolic Measures of Fatigue: Ammonia.* Ammonia was measured at the beginning of the training session before the warm-up and again 5 minutes after the completion of the last set of the training session. A portable dry chemistry analyzer (PocketChem BA PA-4130; Menarini Diagnostics, Florence, Italy) was used for ammonia measurements.

*Perceptual Measures of Fatigue.* Immediately after finishing each set, the subjects provided their rating of perceived exertion using the OMNI-RES (0–10) where 0 is extremely easy and 10 represents extremely hard (25). An image of the OMNI-RES was shown to the subjects immediately after completing each set. Subjects were instructed to report the OMNI-RES value referent to their general state of fatigue and not only relative to the muscles used in the squat exercise.

### Statistical Analyses

Data are presented as mean  $\pm$  *SD*. The normal distribution of the data was confirmed using the Shapiro-Wilk test ( $p > 0.05$ ). The homogeneity of variances was assessed using Mauchly's sphericity test and the Greenhouse-Geisser correction was applied when the assumption of homogeneity of variances was violated. One-way repeated-measures analyses of variance (ANOVAs) were conducted on the different mechanical (MPV of the first repetition, MPV of the last repetition, number of repetitions, MPV achieved against the 1MPV load, CMJ height, and handgrip strength), metabolic (lactate, uric acid, and ammonia concentrations), and perceptual (OMNI-RES perceived exertion) variables. Note that these variables were compared between the different training sets (acute effect) or between the different testing sessions (delayed effect). When significant *F* values were obtained, pairwise differences between mean values were tested using Bonferroni post hoc procedures. Eta squared ( $\eta_p^2$ ) was calculated for the ANOVAs where the values of the effect sizes (ES) 0.01, 0.06, and above 0.14 were considered small, medium, and large, respectively (4). The magnitude of the differences was also examined through the Cohen's *d* ES. The criteria for interpreting the magnitude of the ES were: trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), and extremely large (>2.0) (13). Alpha level of significance was set at  $p \leq 0.05$ . Data were analyzed using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA).

### RESULTS

The descriptive values of the different variables collected at each time point are presented in Table 1. Meaningful differences in the MPV values were observed between the 3 sets of repetition to failure (Figure 2). However, the MPV of the last repetition ( $0.333 \pm 0.042 \text{ m} \cdot \text{s}^{-1}$ ) did not differ between the 3 sets ( $F = 0.22$ ,  $p = 0.808$ ,  $\eta_p^2 = 0.021$ ).

#### Mechanical Measures of Fatigue

The number of repetitions performed was reduced with the increment in the number of sets ( $F = 94.7$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.905$ ; set 1 > set 2 [ES = 2.09] and set 3 [ES = 3.09], set 2 > set 3 [ES = 1.28]). Similarly, the starting MPV of the set was reduced with the increment in the number of sets ( $F = 51.5$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.837$ ; set 1 > set 2 [ES = 1.08] and set 3 [ES = 2.32], set 2 > set 3 [ES = 1.04]). Significant differences in CMJ height were also observed between the 4 measurements collected in the training session ( $F = 63.7$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.864$ ). Countermovement jump height was significantly reduced after all sets of repetitions to failure compared with the pre-session value (ES = 1.41 for set 1, 1.75 for set 2, and 1.70 for set 3). No significant differences in CMJ height were observed between the 3 sets of repetitions to failure.

The CMJ height significantly differed between the measurements collected at the beginning of the 3 sessions ( $F = 10.2$ ,  $p = 0.001$ ,  $\eta_p^2 = 0.506$ ) due to higher values obtained in

the session 1 compared with the sessions 2 (ES = 0.46) and 3 (ES = 0.38), whereas no significant differences were observed between the sessions 2 and 3 (ES = 0.08). Similarly, significant differences were observed for the MPV reached against the 1MPV load ( $F = 16.5$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.623$ ) due to higher MPV values obtained in the session 1 compared with the sessions 2 (ES: 1.81) and set 3 (ES: 1.98), whereas again no significant differences were observed between the sessions 2 and 3 (ES: 0.23). Finally, no significant differences ( $F = 0.38$ ,  $p = 0.688$ ,  $\eta_p^2 = 0.037$ ) and trivial ES (range: 0.01–0.12) were observed for handgrip strength between the 3 sessions.

#### Metabolic Measures of Fatigue

Significant differences in blood lactate concentration were identified ( $F = 12.9$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.563$ ). Blood lactate was lower in the set 1 compared with the set 2 (ES: 1.31) and set 3 (ES: 2.01), whereas no significant differences were observed between the sets 2 and 3 (ES: 0.22). The concentration of uric acid significantly differed between the training sessions ( $F = 28.2$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.738$ ). Uric acid was higher in the session 1 compared with the sessions 2 (ES: 2.93) and set 3 (ES: 2.49), whereas no significant differences were observed between the sessions 2 and 3 (ES: 0.30). Finally, ammonia concentration was significantly higher after the training session ( $p < 0.001$ ; ES: 3.65).

#### Perceptual Measures of Fatigue

Significant differences in OMNI-RES values were observed between the 3 training sets ( $F = 10.8$ ,  $p = 0.001$ ,  $\eta_p^2 = 0.521$ ). The reported OMNI-RES values were higher after the set 3 compared with the set 1 (ES: 1.63), whereas no significant differences were obtained between the sets 1 and 2 (ES: 0.91) or between the sets 2 and 3 (ES: 0.68).

### DISCUSSION

This study was designed to document the acute and delayed effects (24 and 48 hours after exercise) of a resistance training session leading to muscular failure with a low relative load ( $\approx 60\%$  1RM) during the squat exercise on mechanical, metabolic, and perceptual responses. The results revealed large impairments for all the variables measured. Namely, we observed (1) a decrease of 38.7% in the set 2 and 54.7% in the set 3 of the number of repetitions performed compared with the first set of the training session; (2) a reduction in the MPV achieved against a given repetition together with the increment in the number of sets (Figure 2), whereas lactate concentration and OMNI-RES values were incremented with the number of sets; (3) comparable decrements in CMJ height compared with the pre-session value after the 3 sets of repetitions to failure; (4) a decrease in CMJ height and in the MPV attained against the 1MPV load after 24 and 48 hours of completing the training session, while no significant changes in handgrip strength were observed; (5) a uric acid concentration above the basal levels of  $\approx 2.5\text{--}3 \text{ mg/dl}$  (5) during the 3 sessions; and (6) an

increase of 218% in ammonia concentration after the training session. The large decrements in mechanical performance together with the high metabolic stress discourage the frequent use of resistance training sessions leading to muscular failure.

The magnitude of the starting MPV and the MPV of the successive repetitions showed a marked decrease with the increment in the number of sets (Figure 2). Similarly, a progressive reduction in the number of repetitions completed was also observed with the succession of sets. These results suggest that once a set of repetitions to failure has been completed with a light load, the same absolute load will represent a considerably higher relative load (% 1RM). In this regard, it should be noted that the starting MPV of the set was  $0.94 \text{ m}\cdot\text{s}^{-1}$  in set 1,  $0.82 \text{ m}\cdot\text{s}^{-1}$  in set 2, and  $0.71 \text{ m}\cdot\text{s}^{-1}$  in set 3, which according to Pallarés et al. (21), represent approximately a 65% 1RM, 70% 1RM, and 78% 1RM, respectively. In line with the observed decrements in mechanical variables with the succession of sets, we also observed an increment in the metabolic (i.e., lactate concentration) and perceptual (i.e., OMNI-RES values) markers of fatigue with the increment in the number of sets. The similar trend of the different variables further supports the use of movement velocity as an objective and affordable measure that can be used to evaluate in real time the degree of fatigue induced by the resistance training session (16,18,27).

The CMJ height has also been proposed as a practical means of monitoring the neuromuscular status of the lower limbs (3,15,27). In line with previous studies (11,19,22), we observed a significant decrease in CMJ height after the 3 sets of repetitions to failure. The decrement in CMJ height observed in our study was of similar magnitude than the reported decrement in previous studies ( $\approx 30\%$ ) (11,22). Of even greater importance could be the fact that CMJ height and the MPV attained against the 1RM load remained reduced 24 and 48 hours after completing the training session. These results suggest that mechanical performance could be compromised for several days after completing a resistance training session leading to muscular failure. It should be noted that although handgrip strength has also been proposed as a practical measurement of monitoring the neuromuscular status (2), it was the only measurement collected in this study that was not able to detect the delayed impairment effect of the training session. Therefore, although the findings of this study support the use of CMJ height and of the velocity achieved against a given absolute load for monitoring and quantifying physical readiness, they also discourage the measurement of handgrip strength for assessing the neuromuscular fatigue induced by a lower-body resistance training session.

In line with the results obtained for mechanical variables (i.e., number of repetitions, movement velocity, and CMJ height), the markers of metabolic fatigue (i.e., lactate, uric acid, and ammonia concentrations) were also considerably higher after the resistance training session. Namely, uric acid

concentration remained above the basal levels of 2.5–3 mg/dl (5) immediately after the training session ( $12.61 \pm 2.15 \text{ mg}\cdot\text{dl}^{-1}$ ) as well as 24 ( $7.80 \pm 1.13 \text{ mg}\cdot\text{dl}^{-1}$ ) and 48 ( $7.32 \pm 2.10 \text{ mg}\cdot\text{dl}^{-1}$ ) hours after exercise. Similarly, ammonia concentration was incremented by 218% immediately after the training session. The high ammonia concentration is an indicator of the degradation of purines due to the depletion of the deposit of muscle ATP (1). Collectively, these results confirm the very high metabolic stress induced by resistance training sessions leading to muscular failure (9,11,12,19,22,27), suggesting that the training to failure strategy may be counterproductive when it is assiduously implemented because it could contribute to reach a state of overtraining.

A potential limitation of this study is that we did not compare the effects of the training session leading to failure against other training strategies such as the nonfailure training (i.e., leaving a certain number of repetitions in reserve). However, previous studies have already documented the differences in mechanical and metabolic variables between training strategies differing in the level of effort (11,19,22). This study complements the information provided by previous studies since we examined a lower relative load ( $\approx 60\%$  1RM vs.  $\approx 70\text{--}80\%$  1RM) and we allowed shorter interset rest periods (3 vs. 5 minutes). However, although this study could provide valuable information for practitioners, the manipulation of both the relative load and the interset rest periods does not allow to discriminate which factor presents a higher influence in the differences identified with respect to previous studies. It would be important that future studies compare the effects of training with failure against different loading magnitudes under the assumption that reaching failure with a lighter load could induce larger impairments in both mechanical and metabolic variables.

## PRACTICAL APPLICATIONS

A training session consisting of 3 sets of repetitions to failure with a light load ( $\approx 60\%$  1RM) during the squat exercise induces large acute and delayed (24 and 48 hours after exercise) decrements on mechanical performance as well as a high metabolic stress. The deterioration in mechanical performance together with the high metabolic stress observed in this study discourage the frequent use of resistance training sessions leading to muscular failure. The results of this study also support the use of mechanical variables such as movement velocity or CMJ height (but not handgrip strength) to examine the physical readiness at the beginning and during the development of a resistance training session. These mechanical measurements may help coaches to decide when to suspend or stop a workout based on the decrement detected in mechanical performance.

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