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Original Research

Effects of Different Between Test Rest Intervals in Reproducibility of the 10-Repetition Maximum Load Test: A Pilot Study with Recreationally Resistance Trained Men

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ABSTRACT

International Journal of Exercise Science 12(4): 932-940, 2019. The purpose of this study was to compare the effect of 24-, 36-, 48-, 72- and 96-hours between-test rest intervals on the reproducibility of the 10-RM smith machine back squat (BS), bench press (BP) and leg press at 45 degrees (LP45) exercises. Twelve resistance trained men (26.6 ± 4.5 yrs; 179.0 ± 5.5 cm; 92.2 ± 24.6 kg) performed five sets of identical 10-repetition maximum (10-RM) tests for the BS, BP, LP45 exercises, each set with a different interval between tests: 1) twenty-four hours (Post-24), 2) thirty-six hours (Post-36), 3) forty-eight hours (Post-48), 4) seventy-two (Post-72), and 5) ninety-six hours (Post-96). Significant differences in 10-RM from pretest to posttest were observed for BS in Post-24 ($p < 0.001$; Δ% = -12.62), Post-36 ($p < 0.001$; Δ% = -6.57), and Post-96 ($p = 0.015$; Δ% = 6.84). Similarly, significant differences in 10-RM from pretest to posttest were observed for BP in Post-24 ($p < 0.001$; Δ% = -9.22), Post-36 ($p = 0.032$; Δ% = -3.04), and Post-96 ($p < 0.001$; Δ% = 5.37). Finally, significant differences in 10-RM from pretest to posttest were observed for LP45 in Post-24 ($p < 0.001$; Δ% = -16.55), Post-36 ($p = 0.032$; Δ% = -5.09), and Post-96 ($p < 0.001$; Δ% = 5.54). The reproducibility of 10-RM was examined using intraclass correlation coefficients; BS: 0.944, 0.977, 0.988, 0.986, and 0.954 for Post-24, Post-36, Post-48, Post-72, and Post-96, respectively; BP: 0.894, 0.966, 0.966, 0.960, and 0.976; and LP45: 0.832, 0.957, 0.984, 0.974, and 0.977 5. Based on the findings, the optimal between test rest interval duration for 10-RM testing, to provide the best reproducibility, in resistance trained men appears to be 48 to 72 hours for the BS, BP, and LP45 exercises.

KEY WORDS: Performance, strength training, women

INTRODUCTION

This improvement in muscle strength (i.e., increased force production capability) is one of the commonly desired outcomes from resistance training (RT) (6); thus, establishing valid and efficient methods to measure strength is important. Traditionally, muscle strength is assessed via completion of the full movement of a given exercise (5). The repetition maximum (RM) test, the maximum load for which a given number of full repetitions can be competed, is the most widely used test to measure strength. Maximal strength can be assessed using 1-repetition (1-RM) but often multiple repetition RM (e.g., 10-RM) are determined as it involves submaximal loads (19), might be more reflective of the training performed prior, and often is more useful for determining subsequent training or experimental loads to be used (3). As such, each RM test fits a particular need; however, the specific circumstances under which these tests are valid have not been fully established.

To help ensure that the measure of strength (i.e., RM load) determined is valid, test-retest designs are employed. From these repeated tests, the intra-class correlation coefficient (ICC), with the acceptable difference between test and retest defined as less than 5%, are examined to establish reliability (13, 24). Tests and retests should be performed on separate days to allow for establishment of the between-day reliability. Since RM testing produces can induce neuromuscular fatigue, it is suggested that the between-day rest interval range between 48 and 72 hours to allow for adequate recovery and thus valid measurements (13, 24); however, although several studies have investigated rest duration (10, 14, 15), the effect of rest duration between tests on the reliability of RM tests have not been established across rest periods up to 96 hours in 24 hour increments and thus the optimal rest time between tests remain unclear. Therefore, the purpose of this study was to compare the effect of 24-, 36-, 48-, 72- and 96-hours between-test rest intervals on the reproducibility of the 10-RM smith machine back squat (BS), bench press (BP) and leg press at 45 degrees (LP45) exercises.

METHODS

Participants

Twelve recreationally resistance trained men (age: 26.6 ± 4.5 yrs; height: 179.0 ± 5.5 cm; weight: 92.2 ± 24.6 kg; BMI: 28.9 ± 7.3) were recruited for this study. An *a priori* sample size calculation (using effect Size = 0.85; 1-β = 0.90; α = 0.05; Nonsphericity Correction = 1.0) was conducted using G*Power (2, 4); this calculation indicated that ten subjects would be adequate to achieve the aforementioned statistical power. To be included, subjects had to have been involved in a structured resistance training program that adhered to the guidelines of American College of Sports Medicine (1) for at least one year prior to the study (actual training duration prior to study was 27 ± 5 months). Furthermore, subjects were required to have experience performing the BS, BP and LP45 exercises. Subjects were excluded from participation if they had any potential injury, orthopedic limitation or pre-existing medical condition that could compromise their health from study procedures or confound the results of the study. During the six-week period of data collection subjects were instructed to not engage in any RT or other strenuous physical activity outside of the study, and to not consume alcohol or caffeine. Prior to the study all participants were provided with a verbal explanation of the study and read and signed an informed consent form and a Physical Activity Readiness Questionnaire. All procedures were in accordance with the Declaration of Helsinki and were approved by the Institutional Human Experimental Committee at the University.

Protocol

A counter-balanced, randomized, cross-over, and within-subject for each rest interval experimental design was used to examine the effect of between test rest time on the reliability of 10-RM (Figure 1). Participants visited the laboratory on twelve occasions during a six-week period. During the first two visits, the participants performed a familiarization of all procedures. Following familiarization, ten experimental sessions, two sessions for each protocol. On the first visit for each protocol, a 10-RM test was conducted for the BS, BP, and LP45. During the second protocol visit, subjects performed the same test but with a different rest interval for each of the conditions: a) twenty-four hours (Post-24), b) thirty-six hours (Post-36), c) forty-eight hours (Post-48), d) seventy-two hours (Post-72), and e) ninety-six hours (Post-96). The five between test rest intervals were performed in a randomized order. For all procedures the same apparatus was used for a given exercise (Pure Strength Line Olympic Flat Bench, Leg Press, and Multipower, Technogym, Cesena, Italy).

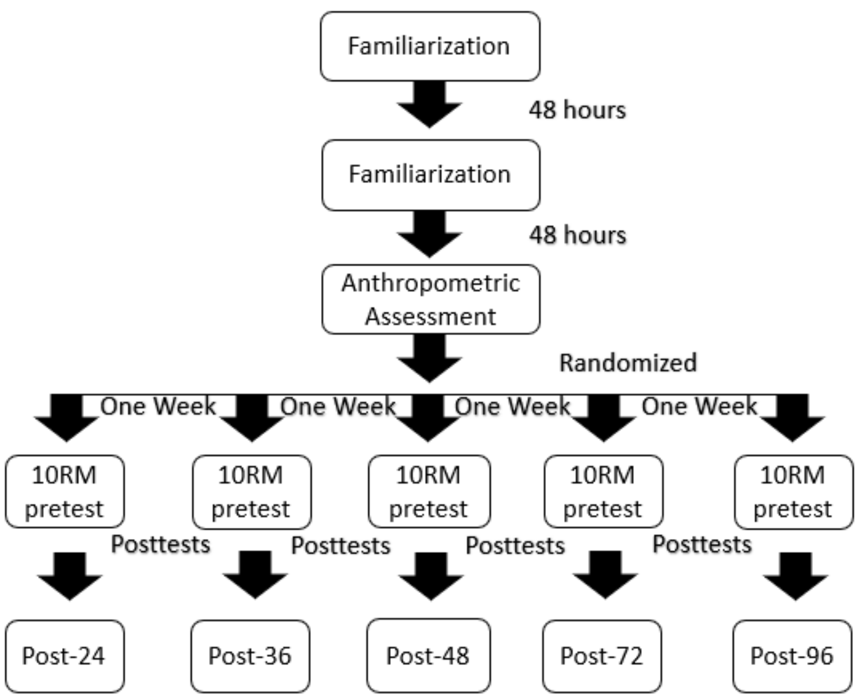

Figure 1. Study design. Post-24 = twenty-four-hour rest interval; Post-36 = thirty-six-hour rest interval; Post-48 = forty-eight-hour rest interval; Post-72 = seventy-two-hour rest interval; Post-96 = ninety-six-hour rest interval.

Participants' 10-RM was determined using the method described by Simão et al. (24). Initially, subjects performed a standardized warm up consisting of fifteen repetitions with a self-suggested load, approximately 50% of normal training load. Following the warm up, a 10-RM test was performed for each of the exercises (BS, BP, and LP45), using a balanced and randomized order of exercises and a fifteen-minute rest interval between exercises. For the 10-RM test the greatest load for which 10 consecutive repetitions could be completed was determined. Execution of the exercises was standardized insofar as no pauses were allowed between the concentric and eccentric portions of the lift. A maximum of three trials per exercise were allowed per testing session; each trial separated by three minutes of passive rest. Testing was then repeated on another day with a different rest interval between each for the 5 conditions examined (Post-24, Post-36, Post-48, Post-72, and Post-96). In an effort to minimize the error, the following strategies were adopted (24): a) all subjects received standardized instructions about exercise technique and data collection, b) subjects received feedback as to their technique and were corrected if appropriate, c) all subjects were always verbally encouraged.

Statistical Analysis
Data are presented as means ± standard deviations (SD). Initially, a Shapiro-Wilk and Mauchly's test was used to analyze normality and homoscedasticity of the data, respectively. Since reproducibility of test results were examined, intraclass correlation coefficients (ICCs) were calculated for each set of pre and posttests (11); furthermore, paired Student's t-tests were used to compare values for absolute loads between pre and posttest for a given rest interval (e.g., Post-24). To determine the magnitude or meaningfulness of potential effects of rest-interval duration, effect size (ES) estimates were calculated using the standardized mean difference. The ES represent the standardized within-group change for each measurement time point compared with resting values (ES = [Mean post – Mean pre] / *SD* of the resting or pre-value). The magnitude of the ES was interpreted using the scale proposed by Rhea (20) for recreationally trained subjects, where < 0.5, 0.50 – 1.25, 1.25 -1.9, and > 2.0 represented trivial, small, moderate, and large effects, respectively. All analyses were performed using SPSS version 21 (SPSS Inc., Chicago, IL, USA) and significance was set at an alpha level of 0.05.

RESULTS

The reproducibility of 10-RM testing is provided in Table 1.

Table 1. Intraclass correlation coefficients for 10-RM testing.

	Post-24	Post-36	Post-48	Post-72	Post-96
SmithBack Squat	0.944	0.977	0.988	0.986	0.954
Bench Press	0.984	0.966	0.966	0.960	0.967
Leg Press 45º	0.832	0.957	0.984	0.974	0.977

Note. Post-24 = twenty-four-hour rest interval; Post-36 = thirty-six-hour rest interval; Post-48 = forty-eight-hour rest interval; Post-72 = seventy-two-hour rest interval; Post-96 = ninety-six-hour rest interval.

Significant differences in 10-RM from pretest to posttest were observed for BS in Post-24 ($p < 0.001$; Δ% = -12.62), Post-36 ($p < 0.001$; Δ% = -6.57), and Post-96 ($p = 0.015$; Δ% = 6.84) (Figure 2). Similarly, significant differences in 10-RM from pretest to posttest were observed for BP in Post-24 ($p < 0.001$; Δ% = -9.22), Post-36 ($p = 0.032$; Δ% = -3.04), and Post-96 ($p < 0.001$; Δ% = 5.37) (Figure 2). Finally, significant differences in 10-RM from pretest to posttest were observed for LP45 in Post-24 ($p < 0.001$; Δ% = -16.55), Post-36 ($p = 0.032$; Δ% = -5.09), and Post-96 ($p < 0.001$; Δ% = 5.54) (Figure 2).

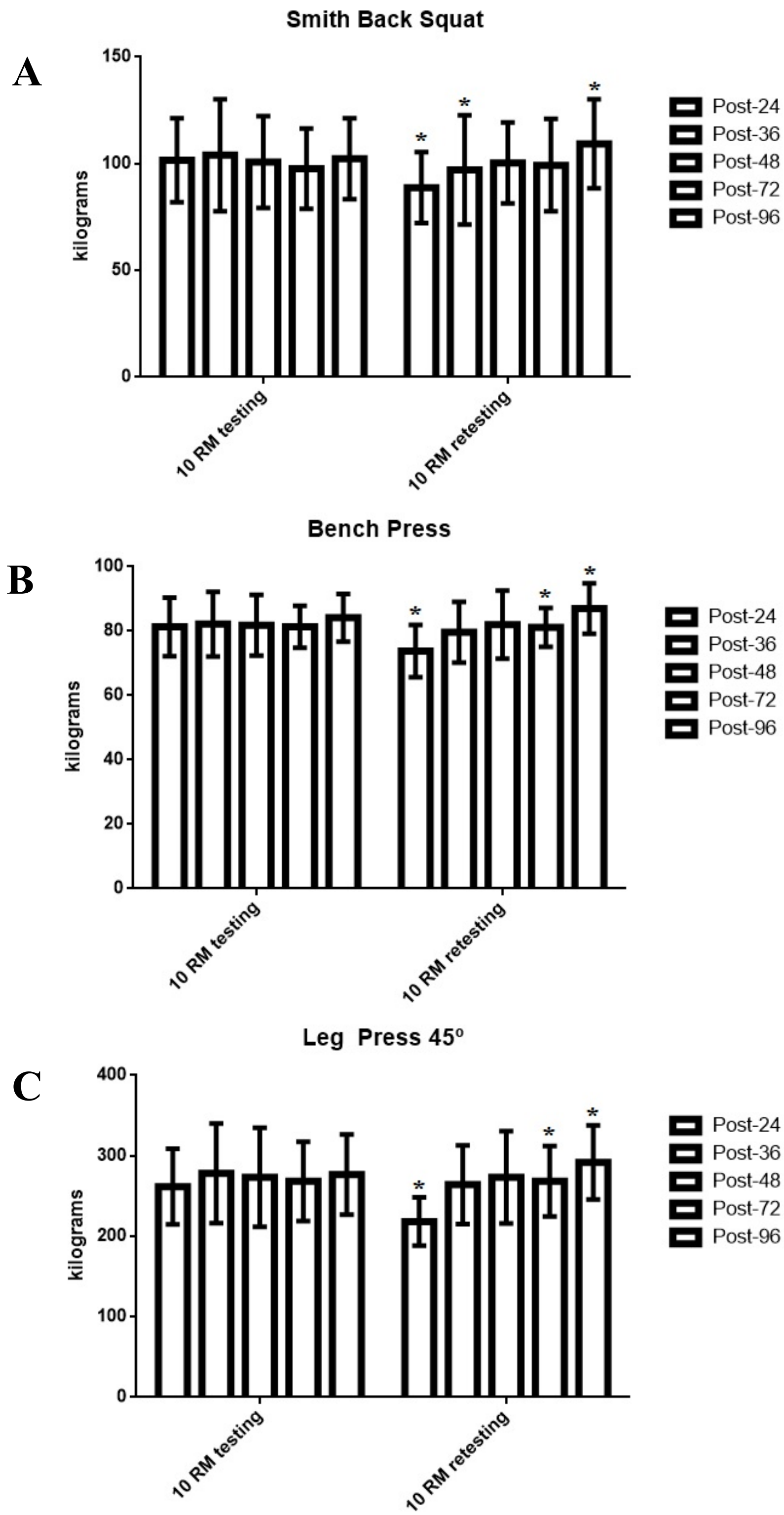

Figure 2. Ten-repetitions maximum (10-RM) load (mean ± SD). (A) Smith back squat; (B) bench press; (C) leg press 45º. RM = repetition maximum. Post-24 = twenty-four-hour rest interval between testing days; Post-36 = thirty-six-hour rest interval between testing days; Post-48 = forty-eight-hour rest interval between testing days; Post-72 = seventy-two-hour rest interval between testing days; Post-96 = ninety-six-hour rest interval between testing days. *Significantly ($p < 0.05$) different from corresponding pretest value.

DISCUSSION

The purpose of this study was to compare the effect of 24-, 36-, 48-, 72- and 96-hours of rest between tests on the reproducibility of the 10-RM for BS, BP, and LP45. Our results confirm the initial hypothesis which suggested that a between-day rest interval ranging between 48 and 72 hours provide better reproducibility. The results of the present study indicate that rest intervals greater than 72 hours should not be used for the 10-RM test, despite increasing the load on the posttests, because the difference between posttests and pretest exceed 5%. The results of this support previous findings, which observed the same optimal range of 48-72 hours of rest (10, 14, 15).

Previous research has shown that adequate recovery periods are needed between exercises during a RT program to achieve consistency in repetitions (10, 15, 23, 26) and thus by extrapolation this must also relate to RM testing. In the current study, 24 and 36 hours of rest resulted in a significant decrease in the 10-RM load between test days for all 3 exercises examined; whereas, no reductions were found with 48 and 72 hours of rest. These results are consistent with previous literature (15) and indicate that rest intervals less than 48-hours between 10-RM testing days are inefficient for the major upper and lower body muscle group exercises used in this study.

Simão et al. (24) examined other aspects of 10-RM testing procedures and, although not empirically determined, suggested that between-test rest interval of 48 to 72 hours be used. Other studies (10, 14, 15) have examined the effects of between-day rest interval duration on resistance exercise performance. Mclester et al. (14) tested four different recovery periods on repetition performance. The resistance exercise session consisted of single and multi-joint exercises, which combined involved both the upper and lower body musculature, using 10-RM loads. In agreement with the present study, they found that 24 hours between sessions was insufficient for maintaining resistance exercise performance independent of the number of sets (3 vs. 7 sets) and suggested that 48 hours between sessions allowed sufficient recovery to optimize performance. Similarly, Jones et al. (10) investigated the repetition performance in resistance exercise session for upper and lower body muscles in three sets with 10-RM loads and four different rest intervals (48-, 72-, 96-, and 120-hours). The authors reported similar results to those of the present study and found no significant difference between 72-, 96- and 120-hours and similarly suggesting that 48-hours of rest was optimal for muscular force production. To the best of our knowledge, the present study is the first research to examine different between-day rest intervals up to 96 hours in 24 hours increments for test-retest reliability of the 10-RM test.

Recently, Miranda et al. (15) examined the repetition performance in resistance exercise sessions for chest muscles (bench press, 30º incline bench press, and 45º incline bench press exercises) in four sets with 8-RM loads and three different rest intervals (24-, 48-, and 72-hours). Blood lactate concentrations was measured at pre-session, immediately post-session, and three- and five-minutes post-session. Authors reported similar results to the current study and found significant decreases in repetition performance and significantly higher blood lactate concentrations with

24-hours of rest compared to longer rest intervals (48- and 72-hours). Physiological mechanisms can help to explain the findings of previous and the current study that a minimum of 48 hours of rest is needed between sets. For example, fatigue is inversely correlated with the rest interval as the buffering of glycolytic metabolism of H+ and lactate removal occurs during this recovery (19). In this sense, motor units are either not recruited, or may not be able to fire with sufficient frequency, for muscle fibers to generate maximal force[18] as a result of the accumulated fatigue.

There are limitations and delimitations to be considered when interpreting the results of the present study. First, the 10-RM test was purposely chosen for its practical applicability and cardiovascular safety (18); thus, the finding of a minimum of 48 hours of rest to be needed between sets might not apply to other RM schemes (e.g., 1-RM or 3-RM). Second, inter-individual differences in repetition duration exists and the duration and velocity of each repetition was not tightly controlled. Although this reduces the internal validity of the results, as the movement velocity could potentially influence the outcome, such difference of repetition duration is normally occurring based among other factors on extremity length. Reduction in velocity during a set of resistance exercise has been shown to be an indicator of neuromuscular fatigue, and indeed changes in repetition duration for a given individual occur over the course of a set performed to momentary concentric failure (9, 21); the procedure used in the present study. Conversely, the freedom to choose the pace duration enhances the ecological (external) validity of the findings, as it better represents real-life exercise scenarios. Third, the results of this study may only apply to the exercises examined which were all compound multi-joint exercises involving a large muscle mass. Whether the same between-day rest interval optimizes reliability of 10-RM testing for single joint exercises is less clear. Finally, only men were examined, so these results cannot be extrapolated to women, who have been shown to be less fatigable than men for dynamic contractions (8, 16) and to have higher relative muscle force (17).

In conclusion, the optimal between test rest interval duration for 10-RM testing, to provide the best reproducibility, in resistance trained men appears to be 48 to 72 hours for the BS, BP, and LP45 exercises. Further research is needed to better understand the effects of different between-day rest intervals for different exercises and in female trainees.

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