# Recovery timeline following resistance training in professional female soccer players

Running head: Post-resistance training recovery in soccer

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**Abstract:** This study determined the time-course of recovery after a low-load high-speed resistance training session (RT) in female soccer players. Ten Brazilian female professional soccer players (age 22.2 ± 5.3 years, body mass 59.8 ± 6.1kg, height 165.9 ± 6.3cm) undertook testing prior to and at immediately, 24 and 48h post-RT. RT consisted of a session commonly prescribed during in-season micro-cycles: 3 sets of 6 repetitions of squat, jump squat, deadlift and lunge exercises at 50% of estimated 1RM. Tests included multiple trials of countermovement jump (CMJ) and 20m sprint, respectively, with both the best and mean efforts recorded. Perceptual measures of delayed onset muscle soreness (DOMS), total quality recovery (TQR) and Brazilian Mood Scale (BRAMS) were collected. Repeated measures ANOVA with effect sizes (ES) assessed the time-course of recovery. Significance was accepted at $\alpha=0.05$. Both mean and best CMJ performance decreased immediately post-RT ($p<0.05$, ES=-0.49; -0.65, respectively), though no significant differences and trivial-small effects existed at 24h ($p>0.05$, ES=-0.15 and -0.08) and 48h ($p>0.05$, ES=0.14 and -0.21). No significant differences and trivial-small effects were evident at any time for mean or best 10m ($p>0.05$, ES=-0.18–0.26) or 20m ($p>0.05$, ES=-0.08–0.19) performance. Perceptual responses including DOMS ($p>0.05$, ES=-0.30–0.45), TQR ($p>0.05$, ES=-0.51–-0.01), fatigue ($p>0.05$, ES=-0.13–0.48) and vigor ($p>0.05$, ES=0.18–0.41) did not change following RT. Light-load, high-speed RT induces only small, immediate changes in lower-body power, without prolonged suppression of recovery parameters. Such training seems feasible for inclusion in competitive micro-cycles at least 24h prior to next match.

**Keywords:** power training, women, soccer, fatigue.

## INTRODUCTION

During the in-season in professional soccer, weekly micro-cycles consist of a mix of training sessions, matches and recovery (20). Given many of these micro-cycles can contain 2 to 3 matches per week, alongside continued training, recovery becomes important for continued tolerance (12,32,35). Further training during these periods has the potential to blunt the recovery process, though it is equally necessary to prepare the team and maintain physical capacity to avoid the loss of adaptations acquired in the absence of training stimulus, as is often the case during congested schedules (26,30). Therefore, the balance between providing appropriate training stimulus to enhance or maintain physical capacity, especially strength, but not impede recovery is often a point of contention for coaches and support staff. For example, in team sports resistance training (RT) prescription is sometimes avoided due to concerns of its effects on subsequent matches' physical performance (9).

RT for strength and power can make important contributions to improvements in the physical performance of soccer players (5,17). Recent evidence supports the use of continued RT for soccer athletes to improve maximal strength, jump performance, sprint time, agility and ball strike speed (5,14,17,34). To improve these actions, training programs targeting maximum strength (7,8,22) or explosive strength (28,29) are suggested as critical for maintenance of the above capacities in soccer players. High velocity and acceleration-based training is associated with lower resistance loads (28,29), which may be more beneficial than heavier loads at slower velocities (7,8,22). This training method is justified by increases in force of muscle contraction, acceleration and speed, which can be translated to important soccer skills such as turning, sprinting and jumping (14,28,29,33). Furthermore, these studies highlighted the low fatigue level induced by this training method compared to heavy-load RT; which might be used as an initial part of a training session without unduly hampering any ensuing technical-tactical field training (14). However, the magnitude of fatigue and ensuing recovery time was not quantified in these studies (14,28,29), and such information would further guide the use of RT during weekly soccer micro-cycles.

Despite the proposed benefits of high velocity – low load RT for soccer players, there is a general reluctance to prescribe RT within weekly micro-cycles (9). In part, these concerns exist based on the potential effect of residual fatigue on speed, power and soccer skill performance (13,24). However, such concerns are only partially justified given Draganidis et al. (13) and Kesoglou et al. (24) reported strength training in isolation produced mild muscle damage and short-lived inflammatory responses in male players, with only small residual effects on soccer skills performance. Of note, these RT sessions involved 40% of 1RM load for the squat movement as quickly as possible and completed 4 sets of 4-6 repetitions (24). In addition, Draganidis et al. (13) compared low-load RT (8-10 repetitions per set at 65-70% of 1RM) with high-load RT (4-6 repetitions per set at 85-90% of 1RM) and found a decrease in leg strength only post-exercise in the high-load group. Furthermore, creatine kinase (CK) peaked at 24 h in the low-load group and at 48 h in the high-load group, while C-reactive protein (CRP) presented a greater elevation post-exercise and at 24 h in the high-load group. Muscle soreness (DOMS) was elevated immediately post and at 24 h in the low-load group, while remained elevated at 48 h post-exercise in the high-load group. Whilst the evidence may not support the avoidance of RT, coaches and practitioners remain hesitant to include RT in the soccer player’s routine without further evidence of the effect of RT on ensuing recovery timelines (9). In addition, conclusions over the residual effect of RT on female athletes and inter-individual variability are limited in scope since all aforementioned studies reported group mean responses on males, which should not be transferred to this population. Thus, further evidence of the effect of high speed – low load RT on ensuing recovery profile in female soccer players is required for new understanding and guiding the training periodization for female players. Therefore, the objective of the present study was to quantify the post-resistance training recovery time-course and individual variability in female soccer players.

## METHODS

### Subjects

Ten Brazilian professional female soccer players (age 22.2 ± 5.3 years, body mass 59.8 ± 6.1 kg, height 165.9 ± 6.3 cm, percent body fat 20.2 ± 4.0%, $VO_{2max}$ 42.0 ± 1.8 $ml.kg^{-}1.min^{-1}$) took part in this study. The study was approved by the ethics committee of the Universidade Federal de Minas Gerais, UFMG-Brazil (approval reference number 74974117.3.0000.5149) and all participants provided verbal and written informed consent form before participation. All players were affiliated to the Brazilian Football Confederation (CBF) and were participants of regional and national championships, trained 5 times per week including technical-tactical, fitness and resistance training sessions. Only field players were included in the current study. To avoid influence of match fatigue, data collection was performed during the transition period, when no matches were scheduled.

**Experimental Approach to the Problem**

As descriptive data, body composition was calculated from the sum of seven skin fold measurements (21), anthropometric measures and Yo-yo intermittent recovery test level 1 (YoyoIR1) (4) were performed in the first training day of the week (Monday) for sample characterization. Following 48 h recovery, a concentric failure test was performed to estimate the 1RM for the squat, deadlift and lunge exercises. Finally, in the following week, during 3 consecutive days (from Monday to Wednesday), testing was performed before, immediately post, 24 and 48 h post a designated RT. More specifically, after 2 days of recovery, all measures of perceptual responses, questionnaires, jump, and running tests were conducted before the RT session. Immediately after RT, athletes provided a Rating of Perceived Exertion (RPE) of the session (15), expressed as global RPE. Further, all testing measures were repeated immediately, 24 h and 48 h post-RT. Of note, after testing on Tuesday (24 h post-RT), a one-hour technical training session was undertaken by the players, which was monitored by a Global Positioning Satellite (GPS) (QStarz BT-Q1300ST**,** Qstarz International Co., Ltd., Taiwan). All testing sessions commenced at ≈8:30 am and all players were already familiarized with all tests and exercises used in the study. Diet was not explicitly controlled but prior to the match and training sessions, athletes were provided with a dietary plan in regards to consumption of fruits and isotonic drink.

## Procedures

*Estimation of 1 Repetition Maximum (RM)*

Athletes performed a test to estimate the resistance corresponding to 1RM of the following exercises: half-squat, deadlift, and lunges. Initially, they performed a warm-up consisting of 1 set of 6 repetitions of each exercise, only with the 20 kg Olympic bar. Given their prior familiarity, athletes then chose a weight to perform repetitions until concentric failure. If the failure did not occur until the sixth repetition, the attempt was interrupted, and a new attempt made at a greater weight based on athlete perception. A maximum of 3 attempts were made for each exercise so that the concentric failure occurred before the sixth repetition. The weight and number of repetitions to failure was used to estimate the 1RM by means of the Lombardi equation (6). This equation produced the best estimates of the 1RM squat when using the 80% 1RM load, with a range of 5-17 maximal repetitions to failure in soccer players (6). Strength testing-predicting a 1RM from repetitions to fatigue have been used (24) to avoid the time-consuming and risky assessment of 1RM testing in professional soccer players. Due to difficulties to perform a maximal test with the jump squat exercise, the 1 RM determined for the half-squat was also used for the jump squat exercise.

*Resistance training protocol*

The training protocol consisted of the half-squat, jump squat, deadlift, and lunge exercises, with emphasis on high-speed and high-power training. Athletes performed the movement as quickly as possible, focusing on a rapid hip extension. Therefore, athletes were instructed to perform the concentric phase at maximal intended velocity and eccentric phase in two seconds. Three sets of six repetitions were performed with the intensity corresponding to 50% of 1RM estimated and a 3-minute recovery interval between sets (11). In justifying the current protocol, previous studies have used similar protocols with light-loads high-velocity (4-8 repetitions per set at 45-60% of 1RM) (14,29,34) in soccer players routine. In addition, this protocol was also similar to previous RT that these athletes had undertaken in-season.

*Pre and post resistance training assessment*

*Performance tests*

Athletes performed a warm-up consisting of three submaximal countermovement jumps. Four maximal CMJ were subsequently performed with an interval of 15-20 seconds between trials. Jumps were performed on a contact mat (Multisprint®, Hidrofit Ltda, Brazil) and the height estimated by the flight time was calculated online through the Multi-Sprint® software with a precision of 0.1 cm. The CMJ started from a standing position with the hands fixed to the hips. Athletes then jumped as high as possible after a quick movement downward. During flight phase, legs remained straight and the landing was in plantar flexion. Data of the best and mean of four jumps were considered for analyses. Values of Intraclass Correlation Coefficient (ICC) and Standard Error of Measurement (SEM) that were determined for this cohort in pre-season corresponded to 0.931 and 0.7 cm, respectively.

Photocells (Multisprint®, Hidrofit Ltda, Brazil) were positioned in the 0, 10 and 20 m points-distance and the time spent to run through the 10 and 20 m was informed online by the Multi-Sprint® software with a precision in 0.001 s. Two trials were performed with an interval of two minutes between them. The photocells were placed at a height of about 1 m. Data were reported as mean of all trials and as the best performance of trials. Values of ICC and SEM corresponded to 0.640 and 0.050 s for the 20 m sprint.

*Perceptual responses*

Perceptual responses were collected with a) DOMS being determined in a 0-10 visual analogue scale (VAS); b) the athlete perception of recovery established using a 6-20 Total quality recovery scale (TQR) (23) and c) an assessment of athletes' mood state was determined with a validated Portuguese version of the BRUMS (25). This instrument consists of 24 items and six subscales evaluating mood: vigor, fatigue, tension, depression, anger, and confusion. Each item is rated on a Likert scale ranging from nothing (0) to extremely (4), and the respondents indicate how they are feeling at that moment. Only results for fatigue and vigor are reported herein, since most of the respondents indicated values different from zero only for them.

## Statistical analysis

Data are presented as mean and standard deviation alongside individual results for all variables. Shapiro-Wilk test was used to verify the data normality. Mauchly's test was consulted and Greenhouse–Geisser correction was applied if sphericity was violated. Then, parametric data were analyzed through a repeated-measures analysis of variance (ANOVA) and Bonferroni post hoc was used when significant differences were found. Respective analyses were undertaken for best and mean efforts of CMJ and sprint tests. Friedman test and Dunns' Post hoc were used for non-parametric data, such as DOMS, TQR, Fatigue and Vigor. Significance was accepted at $\alpha=0.05$. Effect size (ES) and confidence intervals (CI) were also plotted for further analyses. Threshold values for effect size were defined as trivial (<0.2), small (0.2-0.6), moderate (0.6-1.2), large (1.2-2.0) and very large (>2.0) (19). Data analyses were conducted in Statistical Package for the Social Sciences version 18.0 (SPSS, Chicago) and in Graphpad® software (Prism 5.0, San Diego, CA, USA).

## RESULTS

Estimated 1RM values corresponded to 119.92 ± 22.88 kg in half-squat; 77.47 ± 14.25 kg in deadlift and 93.48 ± 23.08 kg in lunges. As context to the training session, post-RT RPE was 4.0 ± 1.3. Of note, the technical-tactical session performed 24 h post-RT consisted of 41.5 ± 7.8 min duration and a total distance of 3.1 ± 0.3 km.

*Performance tests*

Significant post-RT reductions were evident for mean (F=7.284, p=0.001) and best (F=4.635, p=0.010) CMJ. Post hoc and effect size analyses showed significant differences and small effects immediately post RT for mean and best efforts (27.1 ± 2.9 cm, p=0.002, d=-0.49 [-0.65,-0.33] and 27.9 ± 3.0 cm, p=0.010, d=-0.40 [-0.57,-0.24], respectively), compared to pre values (28.5 ± 2.6 cm and 29.2 ± 2.6 cm, respectively). However, no significant difference were present at 24 h (28.0 ± 2.7 cm, p=1.000, d=-0.15, [-0.50, 0.19] and 28.8 ± 2.6 cm, p=1.000, d=-0.08, [-0.45, 0.29]) or 48 h post-RT (28.9 ± 2.8 cm, p=1.000, d=0.14, [-0.14, 0.41] and 29.6 ± 3.0 cm, p=1.000, d=-0.21, [-0.09, 0.51]) for either mean or best CMJ, respectively. Further, significant differences existed between immediately and 48 h post RT for CMJ mean (p=0.005, d=0.56, [0.35, 0.78]) and best efforts (p=0.015, d=1.73, [0.97, 2.49]) (Figure 1a-b)

No significant differences were evident between any time point for 10 or 20 m sprint for mean (F=0.974, p=0.419 and F=0.880, p=0.464) or best performance (F=1.116, p=0.360 and F=0.998, p= 0.374, respectively) following RT (Figure 1c-f). Only trivial effects were found between pre (3.33 ± 0.14 s and 3.29 ± 0.14 s) and post (3.32 ± 0.14 s, d=-0.08, [-0.27, 0.11]; 3.29 ± 0.12 s, d=0.04, [-0.18, 0.09]) pre and 24 h (3.34 ± 0.13 s, d=0.07, [-0.20, 0.35]; 3.30 ± 0.13 s, d=0.07,

[-0.18, 0.32]), pre and 48 h (3.36 ± 0.15 s, d=0.16, [-0.23, 0.55]; 3.32 ± 0.15 s, d=0.19, [0.18, 0.55]) for mean and best 20 sprint time, respectively. Similarly, only trivial-small effects were found between pre (1.93 ± 0.08 s and 1.90 ± 0.08 s) and post (1.92 ± 0.08 s, d=-0.05, [-0.31, 0.21]; 1.90 ± 0.07 s, d=0.09, [-0.13, 0.30]) pre and 24 h (1.91 ± 0.07 s, d=-0.18, [-0.48, 0.12]; 1.89 ± 0.07 s, d=-0.03, [-0.36, 0.30]), pre and 48 h (1.94 ± 0.08 s, d=0.10, [-0.30, 0.51]; 1.92 ± 0.08 s, d=0.26, [-0.15, 0.66]) for mean and best 10 sprint time, respectively

Figure 1 about here

*Perceptual responses*

Friedman statistics for DOMS (Chi-Square ($\chi^2$)=4.750, p=0.191) and TQR ($\chi^2$=1.077, p=0.783) showed no significant differences between time-points (Figure 2a-b), with trivial and small effects for paired comparisons between pre and immediately post (d=0.45, [-0.23, 1.13]; d=-0.01, [-0.34, 0.33]); pre and 24 h (d=-0.30, [-4.92, 4.32]; d=-0.42, [-1.30, 0.47]); pre and 48 h (d=0.33, [-0.70, 1.36]; d=-0.51, [-1.21, 0.20]).

Similarly, BRAMS, including Fatigue ($\chi^2$=1.720, p=0.632) and Vigor ($\chi^2$=3.226, p=0.358) showed no significant differences between any time point (Figure 2c-d). Only trivial and small effects were observed between pre and immediately post (d=-0.13, [-0.54, 0.28]; d=0.18; [-0.13, 0.49]) pre and 24 h (d=0.48, [-0.77, 1.72]; d=0.23, [-0.14, 0.59]); pre and 48 h (d=0.03, [-0.97, 1.02]; d=0.41, [-0.07, 0.89]) for fatigue and vigor, respectively.

Figure 2 about here

## DISCUSSION

This study investigated the time-course of physical performance and perceptual responses after a high speed – low load resistance training session in female soccer players. Our results showed that this type of RT did not unduly affect recovery of speed or power in the 48 h post training. For example, only small and immediate changes in CMJ were evident, without reductions in sprint performance or perceptual responses in the 48 h following RT. Such findings indicate high velocity – low load RT could be considered during the congestion of weekly training micro-cycles without adverse effects on ensuing fatigue status.

Previous studies demonstrate that high velocity – low load RT programs over time improve strength, power, speed and physical performance variables relevant to soccer (14,28,29). These studies reinforce the importance of including RT programs in the training routine to enhance physical capacities related to speed and power (14,16,29). However, in match weeks or during congested schedules, it is important to ensure that RT does not affect recovery for upcoming matches when prescribing training. In the present study no decline in physical performance occurred 48 h post-RT, suggesting that this kind of protocol, does not invoke ongoing fatigue that may hamper speed or power in further sessions. Whilst previous studies report that high velocity – low load RT protocol produce low fatigue (14,16,29), the magnitude of fatigue was not quantified. Further, the current study is the first to report post-RT recovery in female athletes, as previous studies were limited to male players (13,24). Regardless, the current findings corroborate Draganidis et al. (13), who suggested elite players should be able to recover within 24 h following a similar strength training session.

Of interest both mean and best efforts showed similar time-course responses in physical performance. Such a result might be attributed to the low magnitude of fatigue induced by the RT. The only variable showing changes immediately post-training session was CMJ, potentially due to the resistance protocol focusing mainly on vertically movement patterns such as squat, squat jump, deadlift, and lunges (3). Thus, the mild and transient fatigue induced immediately post-training session might have developed only in the vertical-force component due to its specificity with the exercises. For that reason, the performance in 10 and 20 m sprints, consisting of horizontal force drive, was not affected during all time-points of recovery (3). Accordingly, it is feasible that female soccer players can perform a low-load high-velocity RT within 48h of a match with a view that physical recovery may not be excessively affected, though actual use of RT following matches remains to be investigated.

Perceptual responses, including DOMS, TQR, fatigue and vigor were not altered immediately post-RT and no prolonged perceptual fatigue was evident. Subjective indices of fatigue and TQR have been reported in professional male players after a soccer-specific exercise simulation, with no differences between time-points for TQR alongside increased perceived fatigue immediately post-exercise (27). However, due to the different nature of training sessions (low-intensity high-power RT vs 90 min soccer-specific aerobic field test), comparisons between studies are limited. Thus, the current results suggest that low-load high velocity RT can be used as an initial part of a training session without unduly affected perceived recovery.

Previously pain and soreness sensations are reported to peak 48 h post RT in physically active men after maximum (from 0.2 ± 0.3 to 3.4 ± 2.0; $p<0.001$) and forced repetitions (from 0.2 ± 0.3 to 3.7 ± 2.9; $p<0.001$) (1) and after drop jumping and leg curling protocols (31). In the current female players, DOMS peaked at 48 h post-RT (from 1.3 ± 1.4 to 2.8 ± 2.1), though remained comparatively low. In male soccer players, DOMS peaked 48 h after a high-intensity (4-6 repetitions per set at 85-90% of 1RM) and at 24 h after a low-intensity protocol (8-10 repetitions per set at 65-70% of 1RM) (13), suggesting that DOMS is intensity-dependent. Of note, the low DOMS scores were evident even though athletes were returning from two-week holidays and a technical-tactical session was performed after tests at 24 h post-RT.

Despite these novel findings in female players, a few noted limitations exist. A lack of control over some aspects of the intervention, such as the technical-tactical session from the team training routine during data collection, is the main limitation when doing research with professional soccer players (18). Further, the absence of group control limits our findings, though the rested nature and inclusion of baseline data aid an understanding of the effect of RT. Although we did not report specific menstrual cycle phases, some evidence showing performance is not affected by the menstrual cycle in athletes competing in strength-specific and intense anaerobic/aerobic sports (10). Regardless, future studies should investigate the match and training recovery profiles based on different menstrual-cycle phases. Another limitation of the present study consisted of RT was performed in rested condition, which would be rare in an in-season micro-cycle, considering the fatigue induced by the accumulation of matches and training. For example, Andersson et al. (2) showed CMJ performance remains reduced at 69 h post-match in female soccer players. Thus, the results of this study cannot be translated to a post-match context where athletes are already with residual fatigue. Therefore, future studies should investigate female athletes in this context, after fatigue induced by RT and by soccer matches during a competitive micro-cycle.

## PRACTICAL APPLICATIONS

Light-load and high-velocity resistance protocols can be included in the routine of female soccer training with a view that recovery of physical performance and perceptual fatigue will be within 24h. In part, prescription of appropriate volume and load will minimize induced fatigue and assist recovery and training balance.

## ACKNOWLDGMENTS

This work was supported in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors thank CAPES, Fundação de Amparo à Pesquisa do estado de Minas Gerais-(FAPEMIG/Minas Gerais/Brazil), National Counsel of Technological and Scientific Development (CNPq/Brazil) and the Pró-Reitoria de Pesquisa (PRPQ) [Research Pro-Rectory] from the UFMG.

**DISCLOSURE OF INTEREST**

The authors report no conflict of interest.

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## FIGURE LEGENDS

Figure1. Time course of recovery for performance variables. Values are as mean (in black) and individual (in grey). A. Mean countermovement jump; B. Best CMJ countermovement jump; C. Mean 20 m sprint test; D. Best 20 m sprint test; E. Mean 10 m sprint test; F. Best 10 m sprint test. * represents significantly different from pre, # represents significantly different from Post. $p<0.05$, n=10.

Figure 2. Time course of recovery for perceptual variables. Values are as mean (in black) and individual (in grey). A. Delayed onset muscle soreness; B. Total quality recovery; C. Brazilian Mood Scale for fatigue; D. Brazilian Mood Scale for Vigor. $p<0.05$; n=10.