Two vs. One Resistance Exercise Sessions in One Day: Acute Effects on Recovery and Performance

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Abstract

The purpose of this study was to compare the recovery response of one resistance training session (1TRS) vs. two resistance training sessions (2TRS) performed in one day, on upper body performance, muscle morphology and muscle soreness in trained men.

Twenty-four resistance trained men were randomly assigned into a 1TRS group (N=12; age=25.0±2.4y; body mass=87.6±14.0kg; height=177.1±4.9cm) or into a 2TRS group (N=10; age=24.4±1.6; body mass=81.1±5.6kg; height=176.6±6.7cm). 1TRS performed one training session including 8 sets of 10 reps at 70% of 1RM at the bench press, while 2TRS group divided the same training volume in 2 workouts, with a recovery time of 4 h. Performance [bench press throw power (BPT) and isometric bench press (IBP)] and muscle thickness of pectoralis major (PECMT) were assessed at baseline (BL), 15-min (15P), 24-h (24P) and 48-h (48P) post-exercise.

Training intensity was significantly higher in 2TRS compared to 1TRS ($p<0.001$). Faster recovery rates were detected for BPT ($p=0.039$) and PECMT ($p=0.05$) in 2TRS compared to 1TRS. Both BTP and PECMT were significantly lower ($p<0.05$) in 1TRS than in 2TRS at 24P.

Results indicate that the recovery process may be accelerated by splitting a high resistance training volume into two different training sessions performed in one day.

Key Words: power, muscle morphology, training frequency, strength

Main Text

INTRODUCTION

Multiple daily training sessions have been frequently used by athletes competing in strength and power events to optimize adaptations and to increase their total training volume during high-intensity training phases (Storey et al. 2012). Some athletes, however, prefer to split the workout in two or more daily training sessions without increasing the total daily training volume, in attempt to maintain training intensity and reduce fatigue (Fleck and Kraemer 2012, Hartman et al. 2007). Performing multiple training sessions per day may elevate training intensity (Hakkinen 1992, Hakkinen et al. 1988b), a parameter that is considered a primary factor to further stimulate strength adaptations in resistance trained individuals (Sale et al. 1988). In particular, performing 2 short training sessions in one day instead of a single long workout, may be more favorable for neural adaptations (Hakkinen and Kallinen 1994).

Training studies involving high performance athletes did not report additional benefits and adaptations of performing two training sessions (2TRS) per day compared to one training session (1TRS) per day (Hakkinen et al. 1988a-1988b, Hakkinen 1992). Those authors, however, demonstrated a higher increase in EMG activation when 2TRS were performed in one day. This observation has been confirmed by Hakkinen and Kallinen (1994) and shows the beneficial effect of performing multiple training sessions per day on resistance training intensity. More recently, Hartman et al. (2007) also found greater increases in isometric force and EMG activation when a similar total training volume was divided into two smaller workouts within the same day. Despite a higher increase in testosterone was detected in 2TRS per day compared to 1TRS per day, the authors suggested that performing 2TRS may be more beneficial for neural adaptations rather than for muscle hypertrophy (Hartman et al. 2007). Weightlifters and other strength and power athletes are characterized by the ability to produce high peaks of force and high neural activations in multiple daily training sessions (Storey et al. 2012).

Twice-daily training may also affect muscle fatigue and recovery (Chiu et al. 2004), factors that are considered critical for the optimization of resistance training programs (Markus et al. 2021). Recently, the recovery process following both lower and upper body resistance exercise has been monitored using several parameters of performance, muscle morphology and muscle soreness (Bartolomei et al. 2017, Bartolomei et al. 2019a, Gordon III et al. 2017). Changes in these parameters have been shown to be relevant to understand the recovery process following different protocols of resistance exercise (Bartolomei et al. 2019b). However, the acute effects on physiological responses and recovery of splitting the same daily training volume in 2TRS are still unknown. Thus, the first aim of the present investigation was to compare the post-training effects of 1TRS per day vs- 2TRS per day on upper body performance, muscle morphology and muscle soreness in trained men. Moreover, the second aim of the present study was to compare training intensities in each exercise session when 1 or 2 equated-volume exercise sessions were performed in one day. It was hypothesized that performing 2TRS would reduce the time course for muscle recovery and improve training intensity during the workouts compared to a single equated-volume bench press session.

MATERIALS AND METHODS

Experimental design

The experimental design followed by each participant is depicted in Figure 1. Participants were requested to report to the laboratory on four separate occasions. During the first visit, they were assessed for one-repetition maximum strength (1-RM) at the bench press exercise and for anthropometric measures. Participants reported back to the laboratory at least 72 h following their initial visit and performed the exercise training session. Participants were randomly assigned to either a one-training session per day group (1TRS) or a two-training sessions per day (2TRS), respectively. Then they were asked to perform one exercise session consisting in 8 sets of 10 repetitions or two exercise sessions consisting in 4 sets of 10 reps each, with 4 h of rest between the first and the second workout. Reps were performed using the 70 % of the previously measured 1RM, and recovery time between sets was 75 s. 2TRS group performed the first workout in the morning, between 10 am and 11 am, and the second workout 4 hours later, between 2.30 pm and 3.30 pm. The 1TRS group performed the workout in the afternoon, between 2.30 pm and 3.30 pm. During the exercise session, if the required number of repetitions per set were not completed, the load was reduced in the subsequent set to enable the participant to complete the required number of repetitions. No forced repetitions were performed in either protocol. The intensity (in percentage of the 1RM) used by the participants in each set was registered. Immediately prior to the first exercise session (Baseline; BL), strength and power assessments were performed. Following the workout, participants were tested 15 min, 24-h and 48-h post-exercise to assess the acute fatiguing effect of the workout. Muscle ultrasonography were obtained at each time point. The resistance protocol was comprised of the bench press exercise only. All resistance and assessment sessions were supervised by the same certified strength and conditioning coaches.

[Place Figure 1 here]

Participants

Twenty-four resistance trained men who were strength trained at least 3 times a week for more than 3 years, participated in the present study. They were randomly assigned into the 1TRS group performing one training session (N = 12; age = 25.0 ± 2.4 y; body mass = 87.6 ± 14.0 kg; body height = 177.1 ± 4.9 cm; body fat = 14.3 ± 6.5 %) or into the 2TRS group performing two training sessions in one day (N = 10; age = 24.4 ± 1.6; body mass = 81.1 ± 5.6 kg; body height = 176.6 ± 6.7 cm; body fat = 10.8 ± 3.1 %). All the participants volunteered to take part in this study. Inclusion criteria required participants to be between the ages of 18 and 35 years, and the ability to press at least their body mass (Average bench press 1RM= 111.5 ± 17.5 kg) at the bench press. Participants were not permitted to use any additional dietary supplementation, and did not consume any androgens or other performance enhancing drugs. Screening for performance enhancing drug use and additional supplementation was accomplished via a health questionnaire completed at recruitment stage. The study was approved by the University's Ethical Committee. Testing procedures were fully explained to each participant before obtaining individual written informed consent.

Strength and Power Testing

Prior to 1-RM bench press testing, participants performed a standardized warm-up consisting of five min on a cycle ergometer against a light resistance, 10 body weight squats, 10 body weight walking lunges, 10 dynamic walking hamstring stretches, and 10 dynamic walking quadriceps stretches (Bartolomei et al. 2018a). The 1-RM test for the barbell bench press was performed using methods previously described by Bartolomei and colleagues (Bartolomei et al. 2018b). Briefly, each participant performed two warm-up sets using a resistance of approximately 40-60% and 60-80% of his perceived maximum, respectively. For each exercise, 3-4 subsequent trials were performed to determine the 1-RM. A 3-5 min rest period was provided between each trial. Trials not meeting the range of motion criteria for each exercise or where technique was not appropriate, were discarded. During all other visits the same standardized warm-up, as described above, was repeated. During each visit, participants were required to perform a bench press throw test (BPT) and an isometric bench press test (IBP). The BPT test was performed using a smith machine as previously described by Bartolomei et al. (2018b). Participants laid down on a bench in supine position with the bar on their chest. They were instructed to push as explosively as possible until complete extension of the arms and to throw the bar as high as possible. Two spotters were placed at each side of the smith machine to decelerate the bar during the descending phase. Participants pressed loads corresponding to 50% of their 1RM. Two trials were performed with a recovery time of 3 min. During all repetitions, an optical encoder (Tendo Unit model V104, Tendo Sports Machines, Trencin, Slovak Republic) measured the mean power (BPT) expressed by the participants. Intraclass coefficient for BPT was 0.96 (SEM: 17.5 w).

An isometric bench press (IBP) assessment was also performed using a power rack that permitted fixation of the bar. The bench was positioned over a force plate (Kistler 9260, 500 Hz, Winterthur, Switzerland). Participants were required to position themselves on the bench with a 90° elbows flexion and were not permitted to touch the floor with their feet. Elbow angle, and grip width were measured in order to reproduce the same position for all testing sessions. Participants were asked to press against the bar as hard as possible for 6 s. The force expressed against the bar was transmitted by the bench to the force plate and the peak force was registered. Each participant performed two IBP and a recovery time of 3 min was observed between the attempts. For IBP, peak force was measured. During all isometric and ballistic measurements, participants were verbally encouraged by the study investigators. Intraclass coefficient for IBP was 0.98 (SEM: 86.5 N).

Ultrasonography measurements

Non-invasive skeletal muscle ultrasound images were collected from the participant's left side. Prior to image collection, all anatomical locations of interest were identified using standardized landmarks for the pectoralis major muscle (PEC). PEC muscle thickness (PECMT) was measured at the site between third and fourth costa under the clavicle midpoint. Measurements were carried out while the participant stood in supine decubitus for PEC measurements. Measurement required the participants to lay on the examination table for a minimum of 15 min before images were collected. The same investigator performed all landmark measurements for each participant.

A 12 MHz linear probe scanning head (Echo Wave 2, Telemed Ultrasound Medical System, Milan, Italy) was coated with water soluble transmission gel to optimize spatial resolution and used to collect all ultrasound images. The probe was positioned on the surface of the skin without depressing the dermal layer and the view mode (gain = 50dB; image depth = 5 cm) was used to take panoramic pictures of the VL. During the measurements, participants were asked to relax their arm and pectoral muscles and maintain the supine decubitus position. All ultrasound images were taken and analyzed by the same technician. Muscle thickness (MT) measures were obtained using a longitudinal B-mode image. Three consecutive MT images were captured and analyzed for each muscle. For each image, MT was measured with a single perpendicular line from the superficial aponeurosis to the deep aponeurosis. The average of the three MT measures was used for statistical analyses. Intra-class correlation coefficient for PEC was 0.95 (SEM = 1.05 mm).

Muscle soreness score

Participants were asked to assess their subjective feelings of soreness (SOR) intensity of PEC using a 100-mm visual analog scale (VAS) (Lee et al. 1991; Bijur et al. 2001). No soreness was recorded as 0 and the worst possible soreness as 100. Soreness intensity were evaluated at BL, 15P, 24P, 48P.

Dietary logs

Participants were instructed to record as accurately as possible everything they consumed during each 3-day trial. For the following experimental trial, participants were required to duplicate the content, quantity, and timing of their daily diet during the previous 24 h. Participants were instructed not to eat or drink (except water) within 10 h of reporting to the laboratory for each experimental trial. The USDA Nutritional Database (US Department of Agriculture, Beltsville, MD) was used to analyze total calories, carbohydrates, protein, and fat.

Statistical analysis

A Shapiro-Wilk test was used to assess the normal distribution of the data. If the assumption of sphericity was violated, a Greenhouse-Geisser correction was applied. Performance and morphological data were analyzed using a repeated measures two-way (group x time) mixed factorial analysis of variance (ANOVA). In case of a significant group × time interactions, each group was analyzed separately by a one-factor ANOVA with repeated measures on time. The partial eta squared statistic was reported as the effect size (ES), and according to Stevens (2009), 0.01, 0.06, and 0.14 represents small, medium, and large effect sizes, respectively. Training intensities were compared in 1TRS and 2TRS using independent sample *t* tests.

Where appropriate, percent changes were calculated as follows: [(post-exercise mean – pre-exercise mean) / pre-exercise mean] × 100. Significance was accepted at an alpha level of $p \leq 0.05$, and all data are reported as mean ± SD.

RESULTS

Performance and muscle morphology assessments

The mean training intensity was significantly higher ($p < 0.001$) in 2TRS (59.9 ± 6.5 % of 1RM) compared to 1TRS (48.7 ± 5.3 % of 1RM). Results for strength and power performance measures and muscle morphology are reported in Table 1. A significant group x time interaction was observed for BPT ($F = 3.425$; $p = 0.039$; $\eta^2 = 0.363$, Figure 2). Decrements in BPT were significantly different from BL at 15P (- 22.0%; $p < 0.001$) and 24P (-6.6%; $p = 0.016$) in the 1TRS group and at 15P (-13.0%; $p < 0.001$) in the 2TRP group. No significant group x time interactions were found for IBP ($F = 1.939$; $p = 0.154$; $\eta^2 = 0.102$). Significant time effects were found for BPT ($F = 33.486$; $p < 0.001$; $\eta^2 = 0.848$) and IBP ($F = 32.673$; $p < 0.001$; $\eta^2 = 0.658$).

Significant group x time interactions were observed for PECMT ($F = 2.993$; $p = 0.050$; $\eta^2 = 0.136$, Figure 3). Increases in this parameter from BL were significant at 15P (+21.7%; $p < 0.001$)

and 24P (+10.9%; $p = 0.001$) in the 1TRS group and at 15P (+15.5%; $p = 0.001$) in the 2TRP group. A significant main effect of time was also observed for PECMT ($F = 59.553$; $p < 0.001$; $\eta^2 = 0.758$).

[Place Figure 2, Figure 3 and Table 1 here]

Muscle Soreness

The results of the VAS for PEC soreness is shown in Figure 4. A significant group x time interaction was noted ($F = 3.828$; $p = 0.020$; $\eta^2 = 0.168$). Increases in muscle soreness from BL were significant at 15P ($p < 0.001$) and 24P ($p < 0.05$) in both 1TRS and 2TRS groups. Moreover, significant time effects were also observed for muscle soreness ($F = 24.269$; $p < 0.001$; $\eta^2 = 0.634$).

[Place Figure 4 here]

DISCUSSION

The results of the present study show that resistance trained individuals maintain a significantly higher training intensity when the same training volume is split in 2TRS performed in one day compared to 1TRS. This is consistent with previous studies showing that weightlifters were able to maintain high levels of training intensities when training twice a day (Hakkinen 1992, Storey et al. 2012). In these studies, however, both exercise sessions included high intensity-low volume exercises only. Conversely, in the present investigation, participants performed two high volume workouts in one day. Even if high volume resistance training protocols are commonly used by athletes and sport enthusiasts to stimulate muscle growth, training intensity may enhance neural activation and induce further strength adaptations (Hakkinen and Kallinenen 1994, Hartmam et al. 2007).

Another finding of the present study is that the same resistance training volume resulted in faster recovery responses when it was divided into two different exercise sessions performed with 4 h of rest between them, compared to a unique daily session. Upper body power, indeed, was restored 24 h earlier in the 2TRS group compared to the 1TRS group. Both 2TRS and 1TRS may have produced a similar mechanical stress; metabolic stress, however, may have been reduced by splitting the same workout in two different sessions. Consistently, lower accumulations of metabolites such as lactate, inorganic phosphate and hydrogen ions were reported when long rest periods between sets were utilized (Mayhew et al. 2005; Schoenfeld 2013; de Salles et al 2009). In the present study, changes in the muscle morphology of pectoral muscles may suggest that a lower metabolic stress occurred in 2TRS compared to 1TRS. In addition, muscle morphology was restored 24 h earlier in 2TRS group compared to 1TRS group. Changes in muscle morphology following a single high-volume resistance exercise session are related to muscular function (Tillin and Bishop 2009) and have been recently correlated with serum concentrations of IL6 and CK in trained individuals following a high volume resistance exercise protocol (Bartolomei et al. 2017). A faster return to initial muscle morphology may indicate that a lower reactive hyperemia occurred following a 2TRS protocol compared to a 1TRS protocol. In addition, the lack of delayed onset of muscle swelling in 2TRS may suggest that a lower level of muscle inflammation took place when a similar daily training volume was divided in two different workouts. Despite some authors recently questioned the importance of post-exercise muscle damage and inflammation for muscle hypertrophy (Abe et al. 2005, Brentano and Martins Kruel 2011), several studies support the idea that immune response and inflammation may represent key factors for muscle repair and regeneration (Tindball 2005; Schoenfeld 2012-2013). In particular, it has been demonstrated that cytokines produced within skeletal muscle, stimulate satellite cells proliferation (Bondersen et al 2004), and contribute to the muscle hypertrophic response (Nielsen and Pedersen 2007). As suggested by Hartman et al. (2007) and by Hakkinen and Kallinen (1994), splitting the same training volume in 2TRS may be more appropriate to stimulate neural adaptations than to enhance hypertrophic responses in resistance trained individuals. A possible limitation of the present study may be represented by the lack of information about endocrine and immunological responses following both training protocols.

Despite a lower level of muscle soreness was registered 30 min after the second workout of 2TRS compared to 1TRS (42.4 mm and 57.8 mm in 2TRS and 1TRS, respectively), a similar pattern of recovery for this parameter was observed in both groups. This is consistent with Evangelista et al. (2011) that did not report any significant difference in resistance exercise-induced muscle soreness when different rest times between sets were applied. In addition, previous studies showed that lower body muscle soreness was not significantly correlated with muscle inflammation, swelling and drops in performance following resistance exercise (Bartolomei et al. 2017). Some authors suggested that muscle soreness may not be considered a good indicator of muscle damage and inflammation since the perception of this parameter may be influenced by several subjective components (Nosaka et al 2002; Onhaus and Adler 1975).

In conclusion, the results of this investigation indicated that splitting a similar training volume in two resistance exercise sessions promotes training intensity and facilitates the recovery of both performance and muscle morphology in trained men. This strategy may be particularly appropriate to increase maximal strength by optimizing neural adaptations. Strength and conditioning coaches may consider this twice-a-day training strategy to facilitate recovery and to minimize the risk of overtraining.

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Table 1: Changes in performance and muscle architecture measures.

Assessment	Group	BL	15P	24P	48P
BPT (w) †	1TRS	555.4 ± 46.9	433.1 ± 55.6*	518.7 ± 52.9*	551.2 ± 60.45
	2TRS	520.4 ± 48.6	452.5 ± 40.3*	510.1 ± 52.4	514.8 ± 50.4
IBP (N)	1TRS	2240.2 ± 271.1	2011.1 ± 271.2	2155.8 ± 284.7	2177.2 ± 269.0
	2TRS	2080.2 ± 270.3	1913.7 ± 233.3	2058.7 ± 277.3	2078.5 ± 253.8
PECMT (mm) †	1TRS	23.9 ± 4.1	29.1 ± 4.2*	25.5 ± 4.2*	25.5 ± 5.1
	2TRS	21.5 ± 2.8	25.0 ± 3.6*	22.3 ± 3.2	21.4 ± 2.9

BTP = bench throw power; IBP = isometric bench press. PECMT = muscle thickness of pectoralis major; 1TRS = 1 training session per day; 2TRS = 2 training sessions per day. † indicates a significant ($p < 0.05$) difference between the two protocols; * indicates a significant ($p \leq 0.01$) difference from BL. All data are reported as mean ± SD.

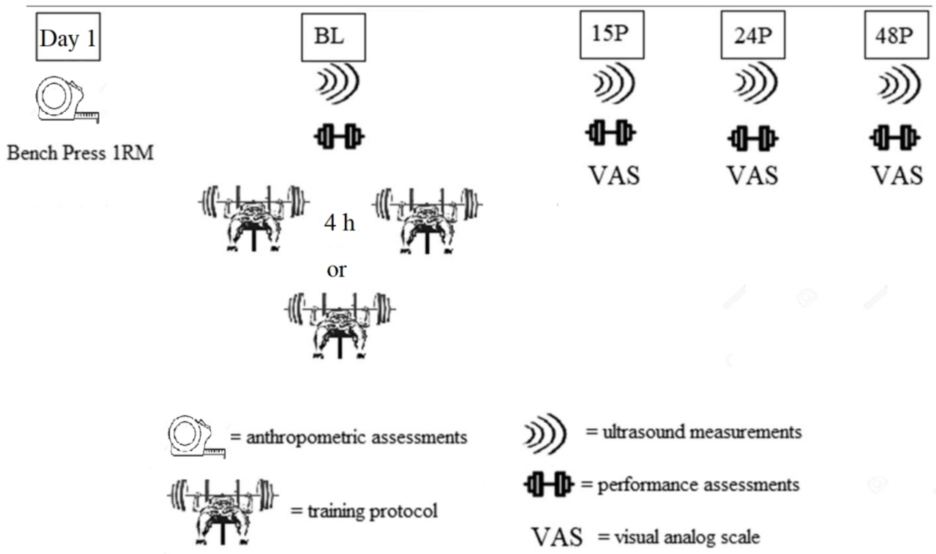
Figure Legends

Figure 1. Experimental protocol of the research design. BL= baseline; 15P = 15 min post; 24P = 24 hours post; 48P = 48 hours post. 1RM = 1 repetition maximum; VAS = visual analogue scale.

Figure 2. Changes in bench press throw power (BTP) 15-min (15P), 24-hour (24P) and 48-hour (48P) post-exercise. * indicates a significant ($p \leq 0.05$) difference from BL. All data are reported as mean ± SD.

Figure 3. Changes in muscle thickness of pectoral muscle (PECMT) 15-min (15P), 24-hour (24P) and 48-hour (48P) post the training session. * indicates a significant ($p \leq 0.05$) difference from BL. All data are reported as mean ± SD.

Figure 4. Changes in muscle soreness (VAS) of pectoral muscle 15-min (15P), 24-hour (24P) and 48-hour (48P) post the training session. * indicates a significant ($p \leq 0.05$) difference from BL. All data are reported as mean ± SD.



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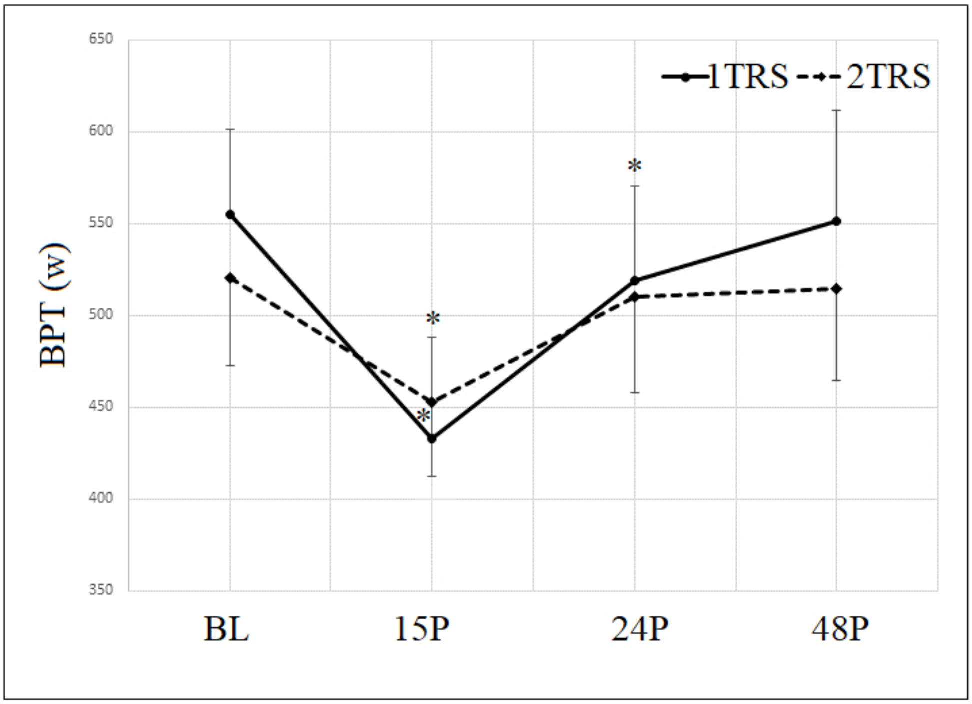

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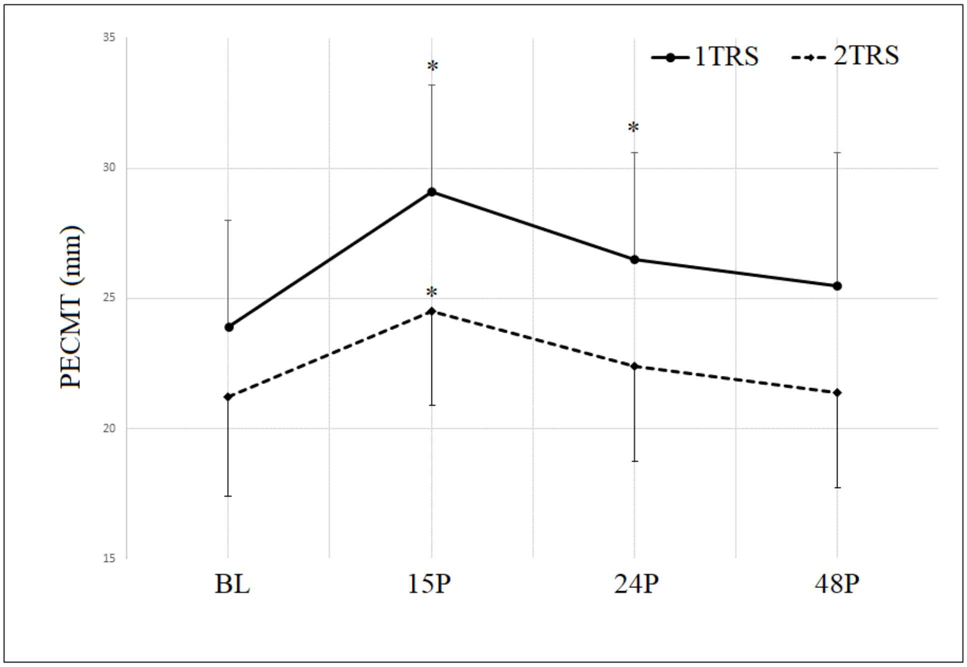

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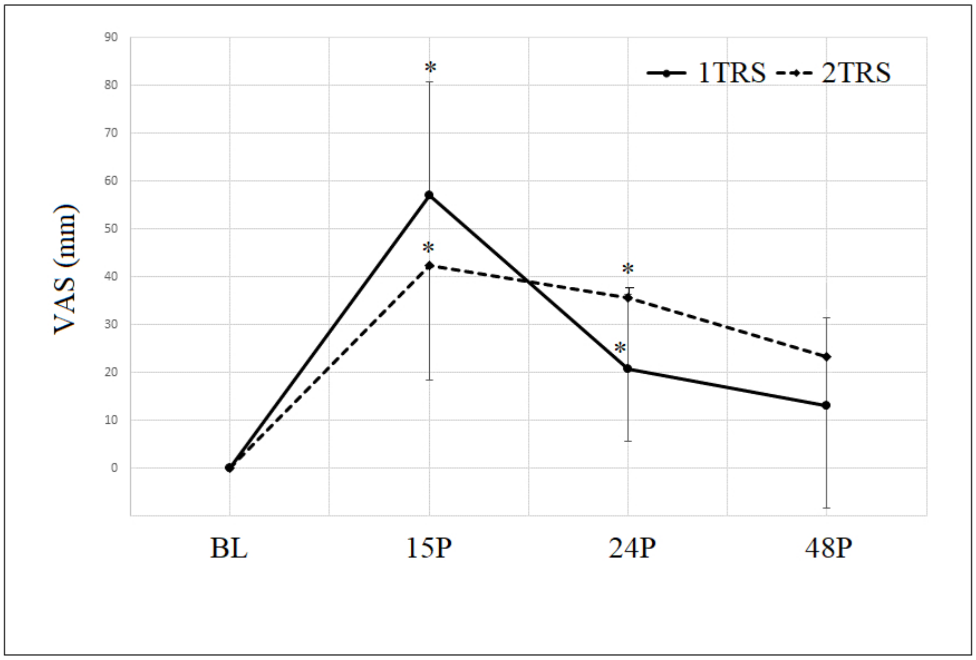

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