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Upper body resistance exercise reduces time to recover following a high-volume bench press protocol in resistance trained men

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Running head: Resistance exercise enhances recovery from strength training

Abstract

The aim of this study was to compare the effects of active and passive strategies on the recovery response following a high-volume bench press protocol.

Twenty-five resistance trained men (Mean ± SD: age = 25.8 ± 3.6 y; body mass = 87.1 ± 12.1 kg; height = 177.4 ± 4.9 cm) performed a high-volume bench press session (8 sets of 10 reps at 70% of 1RM). Subsequently, they were randomly assigned to an active recovery (AR) group (n = 11) or to a passive recovery (PR) group (n = 14). AR consisted of light bench press sessions performed 6 hr and 30 hr after the high-volume exercise protocol. Muscle performance [bench throw power (BTP) and isometric bench press (IBP)] and morphology [muscle thickness of pectoralis major (PECMT) and of triceps brachii (TRMT)] were measured prior to exercise (BL), and at 15-min (15P), 24-hr (24P) and 48-hr (48P) post-exercise.

Post-exercise recovery of both maximal strength and power were accelerated in AR compared to PR. Both BTP and IBP were significantly (p<0.001) reduced at 15P and 24P in PR while changes were significant (p<0.001) at 15P only in AR. PECMT was still significantly (p=0.015) altered from BL at 48P in PR while changes were significant (p<0.001) at 15P only in AR. No significant interactions (p>0.05) between PR and AR were detected for TRMT and muscle soreness.

The present results indicate that AR enhances the recovery rate following high-volume exercise sessions and may be included in resistance training programs to optimize muscle adaptations.

Key Words: Strength Training, Muscle Thickness, Pectoral muscle, muscle architecture

INTRODUCTION

Recovery from exercise represents a key factor to optimize adaptations to sport training and exercise (5). Various physiological systems respond to different exercise stimuli and require different time to return to physiological conditions (27). Impaired muscle performance, changes in muscle morphology and muscle soreness are common symptoms of muscle damage and inflammation induced by resistance exercise (25,26).

During the last decades, many strategies were developed by athletes and coaches to accelerate muscle recovery from subsequent training sessions or competitive events (13). Active recovery, cold water immersion, massage and nutrition have been widely used to reduce muscle soreness after exercise, restore performance and/or accelerate lactate removal (5,17,23). It is a common belief that active recovery (AR) accelerates the recovery process and the return to homeostasis after intense exercise sessions (3). AR usually consists of submaximal work performed during the recovery between different bouts of supramaximal exercise (32,34), during the recovery phase following a training session (22), or following a team sport match (13).

Several experimental studies to date compared AR with other strategies such as passive recovery or stretching. Some authors reported increased total work during repeated bouts of high intensity exercise when AR strategies were adopted compared to passive recovery (32). Consistently, Gill et al. (13) reported enhanced rates and magnitude of recovery after a competitive rugby match compared to passive recovery. On the contrary, Andersson et al. (3) reported no significant effects of AR on recovery patterns of neuromuscular and biochemical parameters between two soccer matches in elite female players. In this study the decline in jump, sprint and maximal isokinetic torque following soccer matches were not attenuated by AR. In addition, creatine

kinase, urea and uric acid blood concentrations were not influenced by the recovery strategies adopted.

The possible positive effects of AR are associated with reduced muscle edema, enhanced muscle fiber regeneration and decrease in the inflammatory response resulting from high demanding exercise sessions (9,10,28). Only a few studies to date have investigated the effects of AR on the recovery phase following resistance training. Recently, Peake et al. 2017 (28) reported similar effects of AR and cold water immersion on the inflammatory response following a high- volume resistance training session for lower body. To the best of our knowledge, only one experimental study investigated the effects of resistance exercise sessions performed as strategy to accelerate recovery (2). The authors reported enhanced recovery rates of strength performance when an upper-body exercise session was performed the day after a lower-body workout compared to passive recovery. Changes in microvascular blood flow after exercise and increased concentrations of anabolic hormones were adduced as possible mechanisms activated by AR (2,29).

Although some studies have investigated changes in muscle architecture and strength loss during the recovery phase following a high-volume resistance exercise session (8,14), there is a lack of studies concerning the effects of AR on these parameters.

Thus, the aim of the present study was to compare the effects of AR and passive recovery (PR) on changes in muscle performance and muscle architecture following a typical hypertrophy bench press protocol.

Based on the aforementioned principles and physiological effects that may be induced by light resistance exercise, it was hypothesized that AR may reduce the time to recover following a damaging bench press protocol.

METHODS

Experimental approach to the problem

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, participants were assessed for anthropometric measures and one-repetition maximum strength (1-RM) on the bench press exercise. Participants reported back to the laboratory between 72 hr and 96 hr following their initial visit and performed the exercise training session. Participants of both groups were asked to perform eight sets of ten repetitions at 70% of the previously measured 1-RM. Recovery time between sets was 75 s. During the exercise session, if the required number of repetitions per set were not completed, then the load was reduced by 5% of 1RM in the subsequent set to enable the participant to complete the required number of repetitions. No forced repetitions were performed in either protocol. Immediately prior to the exercise session (Baseline; BL) strength and power assessments were performed. Following the workout, participants were tested 15 min, 24-hr and 48-hr post-exercise to assess the acute fatiguing effect of the workout. Muscle ultrasonography were obtained at each time point. The resistance protocol was constituted by the bench press exercise only. Participants in the active recovery (AR) group were asked to complete five sets of ten repetitions at the bench press using a load corresponding to 10% of the previously measured 1-RM, 6-hr and 30-hr following the high-volume exercise session. This load was selected to increase muscle blood flow without inducing additional mechanical and metabolic stress to the muscles involved in the bench press exercise. Participants in passive recovery (PR) group were asked to avoid any physical activity, except for

the assessment sessions, for 48 hr following the exercise session. All resistance and assessment sessions were supervised by the same qualified investigators.

[Place Figure 1 here]

Subjects

Twenty-five experienced, resistance trained men who were strength trained at least 3 times a week for more than 3 years (Mean ± SD: 6.5±3.1 y), participated to the present study. All the participants had at least 2 years of experience in periodized resistance training programs including high volume resistance workouts and supervised by strength and conditioning coaches. They were randomly assigned into the AR group (n = 11; age = 25.7 ± 4.0 y; body mass = 86.0 ± 10.5 kg; height = 177.7 ± 5.4 cm) or into the PR (n = 14; age = 25.7 ± 3.4 y; body mass = 88.0 ± 13.5 kg; height = 177.1 ± 4.7 cm). All the participants volunteered to take part in this investigation. Inclusion criteria required participants to be between the ages of 18 and 35 years, and the ability to press at least their body mass (1-RM bench press = 115.2 ± 14.1 kg; 1.3 ± 0.2 times body mass and 113.0 ± 18.0 kg; 1.3 ± 0.2 times body mass for AR and PR, respectively) 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 5-min cycling 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 (6). The 1-RM test for the barbell bench press was performed using methods previously described by Hoffman (16). Briefly, each participant performed two warm-up sets using a resistance of approximately 40-60% (6-8 reps) and 60-80% (3-5 reps) 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 above standardized warm-up was repeated. During each visit, participants were required to perform a bench press throw test (BT) and an isometric bench press test (IBP). BT test was performed using a smith machine as previously described by Bartolomei et al. (7). Participants laid down on a bench in supine position with the bar on their chest. They were instructed to push with maximum explosive intent 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 1-RM. 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 (BTP) expressed by the participants. Intraclass correlation coefficient for BTP was 0.96 (SEM: 17.5 W; minimal important difference; MID = 25.8 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 position their feet on the ground. Elbow angle, and grip width were measured using a goniometer and a measuring tape, respectively, 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 (IBPF) and the rate of force development were calculated. Each participant performed two IBP trials and a recovery time of 3 min was observed between the attempts. For IBP, peak force was measured and the peak rate of force development using a 20-ms window (pRFD20) was calculated as previously described by Haff et al. (15). Intraclass correlation coefficients were 0.67 (SEM = 2531.1 N · sec^{-1}; MID = 2759.2 N · sec^{-1} and 0.91 (SEM = 67.2 N; MID = 75.8 N) for pRFD20 and IBPF, respectively.

In order to activate both the sternoclavicular portion of the pectoralis major and the triceps brachii (20), a narrow grip width, corresponding to 100% of the biacromial distance, was adopted. The same grip width was used for BT, IBP, 1-RM bench press and during the exercise session.

During all isometric and ballistic measurements, participants were verbally encouraged by the study investigators.

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) and for the triceps brachii muscle (TR). PEC muscle thickness (PECMT) was measured at the site between the third and fourth costa under the clavicle midpoint (1). TR size (TRMT) was measured at the posterior upper arm

at 60% distal between the lateral epicondyle of the humerus and the acromial process of the scapula (1,36). Measurements were carried out while the participant stood in supine decubitus and in lateral decubitus for PEC and TR measurements, respectively. The participants were required 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 (gain = 50dB; image depth = 5 cm). During the measurements, participants were asked to relax their arm and pectoral muscles and maintain the supine or the right lateral 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 coefficients (ICCs) were 0.95 (SEM = 1.05 mm; MID = 0.72 mm) and 0.93 (SEM = 1.23 mm; MID = 1.05 mm) for PECMT and TRMT, respectively.

Muscle pain and soreness score

Participants were asked to assess their subjective feelings of soreness intensity of both PEC (sorPEC) and TR (sorTR) using a 100-mm visual analog scale (VAS) (19,24). No soreness was recorded as 0 and the worst possible soreness as 100. Participants were asked to mark the

VAS immediately after flexion and extension of shoulders and elbows, to assess sorPEC and sorTR, respectively. 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 preceding 24 hr. Participants were instructed not to eat or drink (except water) within 10 hr 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. Performance and morphological data were analyzed using a two-way (group x time) analysis of covariance (ANCOVA) with repeated measures, where baseline score served as covariate. If the assumption of sphericity was violated, a Greenhouse-Geisser correction was applied. In case of a significant time x group interaction, each group was analyzed separately by a one-factor ANOVA with repeated measures on time. The partial eta squared statistic was reported as an effect size (ES), and according to Stevens (33), 0.01, 0.06, and 0.14 were used to represent small, medium, and large effect sizes, respectively.

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 Assessments

Results for power and maximal strength performance measures are shown in Figure 2 and Figure 3, respectively. A significant group x time interaction was noted for BTP ($F = 7.033$; $p = 0.003$; $\eta^2 = 0.156$). Power was significantly reduced from baseline at 15P and 24P in PR (-125.6 ± 51.4 W; $p < 0.001$; 95% confidence interval [CI]: -95.3 to -150 W and -36.3 ± 31.9 W; $p = 0.008$; CI -19.8 to -52.8 W, respectively), while the reduction in AR was significant at 15P only ($p = 0.001$).

Significant interactions between PR and AR were also detected for IBPF ($F = 3.499$; $p = 0.027$; $\eta^2 = 0.156$). A significant decrement in IBPF from BL was observed at 15P and 24P in PR (-205.8 ± 117.5 N; $p < 0.001$; CI: -144 to -267 N and -86.9 ± 129.4 N; $p = 0.042$; CI: -19 to -155 N, respectively), while in AR the decrease was significant at 15P only (-172.2 ± 73.7 N; $p < 0.001$; CI: -134 to -211 N). No significant trial differences were noted at any time point for IBPF ($p > 0.05$).

[Place Figure 2 and Figure 3 here]

Ultrasound Measurements

Significant group x time interactions were found for PECMT ($F = 8.371$; $p < 0.001$; $\eta^2 = 0.285$). PECMT was significantly elevated from BL at 15P (+5.2 mm; $p < 0.001$), at 24P (+2.8 mm; $p < 0.001$) and at 48P (+1.6 mm; $p = 0.015$) in PR. Significant changes from BL were detected at 15P only in AR (+4.2 mm; $p < 0.001$). No significant interactions between group and time were noted for TRMT ($F = 1.036$; $p = 0.366$; $\eta^2 = 0.047$).

Significant main effects were detected for TRMT ($F = 5.634$; $p = 0.006$; $\eta^2 = 0.212$,). Changes in PECMT and TRMT can be observed in Figure 4 and Figure 5.

[Place Figure 4 and Figure 5 here]

Muscle Soreness

The results of the VAS for both PEC and TR in PR and AR can be observed in Table 1. No significant interactions between the trials were detected for both sorPEC and sorTR ($F = 0.997$; $p = 0.350$; $\eta^2 = 0.045$ and $F = 0.813$; $p = 0.471$; $\eta^2 = 0.036$, respectively). Significant time effects were observed for both sorPEC and sorTR ($F = 39.881$; $p < 0.001$; $\eta^2 = 0.655$ and $F = 59.153$; $p \leq 0.001$; $\eta^2 = 0.729$, respectively). Both sorPEC and sor TR were significantly ($p < 0.05$) elevated from BL at 15P, 24P and 48P.

[Place Table 1 here]

DISCUSSION

The purpose of this study was to investigate the effects of light resistance exercise protocols performed after a high volume resistance exercise session on performance and muscle morphology recovery. According to theoretical data, we hypothesized that AR would reduce the time to fully recover. The present findings confirmed this hypothesis.

The results of the present investigation showed that significant reductions in muscle strength and power performance occurred following a high-volume bench press exercise session and were still significant 48-hr post the exercise session. In addition, significant changes in muscle architecture were detected 48-hr following the exercise session. This is consistent with other studies that detected muscle swelling still present 72 hrs following a high-volume exercise protocol for lower body (8,14,17). In addition, the results showed that AR significantly enhanced the recovery rate following a high-volume resistance exercise session for upper-body. In particular, power performance expressed at bench press (BTP) and maximal isometric force at bench press (IBPF), were restored within 24 hr post exercise in AR while these parameters were still reduced at 24P in PR.

Significant changes in muscle architecture from BL have been detected 15 min post the bench press damaging protocol. In AR however, the initial condition was restored within 24 hr while in PR this parameter was still significantly altered at 48P. Changes in muscle architecture following damaging resistance exercise protocols are related to vasodilation (35), reactive hyperemia and delayed onset of muscle swelling (10). Muscle swelling is also related to the inflammatory response following high-volume resistance exercise protocols (8,12). The enhanced recovery of the initial muscle morphology after resistance protocols may indicate a reduced inflammatory response using AR. AR indeed, may influence post-recovery inflammatory responses by inducing transitory increases in local skeletal muscle blood flow and temperature (35). These transitory adaptations may represent a stimulus to muscle recovery following a damaging resistance exercise protocol. Influencing exercise-induced muscle inflammation however, may also affect the adaptative processes (21) and influence the amount of adaptations to resistance exercises. Detrimental effects of regular cold water immersion on long term adaptation to resistance training and muscle hypertrophy have been reported by Roberts et al. (29). Even high dosages of nonsteroidal anti-inflammatory drugs, however, have not been associated with reduced hypertrophic responses to resistance training in men (30). On the contrary, nonsteroidal anti-inflammatory drugs showed significant detrimental effects on muscle adaptation to resistance exercise in rats (31).

A positive effect of AR on time course of recovery of neuromuscular and biochemical parameters following resistance training has been previously reported by Abaidia et al. (2). In this study however, an upper body resistance training session accelerated the recovery of slow concentric force of leg muscles. Not consistently, another study (3), did not report any significant effect of AR on the recovery between soccer matches. AR may be more effective to enhance

recovery from a single resistance training session compared to a complex sport including many different neuromuscular and metabolic stimuli (4). In addition, to the best of our knowledge, the present investigation is the first to include the same resistance exercise (bench press) in both damaging exercise session and recovery protocol.

Enhanced recovery rates may increase the training frequency of the different muscle groups within the mesocycle and consequently increase the total training volume. Training volume has been proved to be a key factor for muscle adaptation to resistance training (11). No significant positive effects of AR were detected on morphological changes of TR. In both AR and PR groups indeed, TRMT returned to BL within 24 hr from the exercise session. Muscle architecture of TR showed a faster recovery rate compared to PEC. Muscle dimension and muscle architecture may influence the recovery rate following heavy resistance exercise. Convergent big muscles like pectoralis major may be more susceptible to exercise-induced muscle damage compared to pennate muscles like triceps brachii, characterized by shorter fascicle lenghts.(25, 26). Thus, the recovery of initial muscle architecture may be delayed in PEC compared to TR.

Significant correlations have been previously reported between drops in strength and power performances and changes in muscle architecture following a high volume resistance exercise session. A different recovery pattern however, has been detected in PR for muscle morphology and performance. Consistently with our previous observations on lower body (8), strength and power performances showed a faster rate of recovery compared to muscle morphology. Interestingly, the neuromuscular system was able to express high levels of strength and power even when muscle morphology was still altered.

Muscle soreness do not appear to be influenced by the recovery strategy adopted. In addition, as previously reported by other authors (24), muscle soreness was not related to the decrease in muscle architecture and performance following a high-volume resistance session.

In conclusion, results of the present investigation showed that AR reduced the time to recover from a high-volume bench press session compared to PR. Differences on the recovery process between active and passive recovery strategies involve maximal isometric strength and muscle power as well as muscle morphology of pectoral muscles. The present study however, investigated the effect of AR on the recovery phase following a single bout of resistance exercise. The main limitation of the study is that the effects of AR included in long-term resistance training programs, were not investigated. Another limitation is the use of a single exercise in the resistance training session. Resistance training programs indeed, are usually composed by several different exercises.

Practical Applications

Strength and conditioning coaches may include light resistance training sessions in periodized strength training programs to enhance recovery between heavy workouts and to optimize neuromuscular adaptations. Very low intensity bench press protocols can be included in subsequent exercise sessions focused on different muscle groups as AR strategy to accelerate the recovery of PEC muscles following high-volume workouts. This strategy may be particularly indicated when several resistance training sessions are performed in a short training period as in the accumulation phase of Block periodized strength training programs (18).

References

1. Abe, T, Kondo, M, Kawakami, Y, Fukunaga, T. Prediction equations for body composition of Japanese adults by B- mode ultrasound. *Am J Hum Biol* 6(2),161-170,1994.

2. Abïdia, A, Delacroix, B, Leduc, C, Lamblin, J, McCall, A, Baquet, G, Dupont, G. Effects of a strength training session after an exercise inducing muscle damage on recovery kinetics. *J Strength Cond Res* 31(1),115-125,2016.

3. Andersson, HM, Raastad, T, Nilsson, J, Paulsen, G, Garthe, I, Kadi, F. Neuromuscular fatigue and recovery in elite female soccer: effects of active recovery. *Med Sci Sports Exerc*, 40(2), 372-380,2008.

4. Bangsbo, J. The physiology of soccer--with special reference to intense intermittent exercise. *Acta Physiol Scand*. Supplementum 619,1-55,1994.

5. Barnett, A. Using recovery modalities between training sessions in elite athletes. Does it help? *Sports Med*, 36: 781-796,2006.

6. Bartolomei S, Nigro F, Gubellini L, Semprini G, Ciacci S, Hoffman JR, Merni F. Acute Effects of Ammonia Inhalants on Strength and Power Performance in Trained Men. *J Strength Cond Res* 32(1),244-247,2018.

7. Bartolomei S, Nigro F, Ruggeri S, Lanzoni IM, Ciacci S, Merni F, Sadres E, Hoffman JR, Semprini G. A Comparison between Bench Press Throw and Ballistic Push-Up tests to assess upper-body power in trained individuals. *J Strength Cond Res*. 32(6),1503-1510,2018.

8. Bartolomei, S, Sadres, E, Church, DD, Arroyo, E, Gordon III, JA, Varanoske, AN, Wang, R, Beyer, KS, Oliveira, LP, Stout, JR, Hoffman, JR. Comparison of the recovery response from high-intensity and high-volume resistance exercise in trained men. *Eur J Appl Physiol* 117(7),1287-1298,2017.

9. Clarkson, PM, Nosaka, K, Braun, B. Muscle function after exercise-induced muscle

damage and rapid adaptation. *Med Sci Sport Exerc* 24(5),512-520,1992.

10. Clarkson, PM, Sayers, SP. Etiology of exercise –induced muscle damage. *Can J Appl Physiol* 24,234-248,1999.

11. Colquhoun, RJ, Gai, CM, Aguilar, D, Bove, D, Dolan, J, Vargas, A, Couvillion, K, Jenkins, ND, Campbell, BI. Training Volume, Not Frequency, Indicative of Maximal Strength Adaptations to Resistance Training. *J Strength Cond Res* 32(5), 1207-1213,2018.

12. Csapo, R, Alegre, LM, Baron, R. Time kinetics of acute changes in muscle architecture in response to resistance exercise. *J Sci Med Sport* 14(3):270-274,2011.

13. Gill, ND, Beaven, CM, Cook, C. Effectiveness of post-match recovery strategies in rugby players. *Br J Sports Med* 40(3),260-263,2006.

14. Gordon III, JA, Hoffman, JR, Arroyo, E, Varanoske, AN, Coker, NA, Gepner, Y, Wells, AJ, Stout, JR, Fukuda, DH. Comparison in the recovery response from resistance exercise between young and middle-aged men. *J Strength Cond Res* 31(12),3454-3462,2017.

15. Haff, GG, Ruben, RP, Lider, J, Twine, C, Cormie, P. (2015) A comparison of methods for determining the rate of force development during isometric midthigh clean pulls. *J Strength Cond Res* 29(2):386-395,2015.

16. Hoffman, JR. Physiological Aspects of Sport Training and Performance (Second Edition). Champaign, IL: Human Kinetics 2014.

17. Howatson, G, Goodall, S, Van Someren, KA. The influence of cold water immersions on adaptation following a single bout of damaging exercise. *Eur J Appl Physiol 105(4), p.615,2009*

18. Issurin VM. New horizons for the methodology and physiology of training periodization. *Sports Med* 40, 189-206, 2010

19. Lee, KA, Hicks, G, Nino-Murcia, G. Validity and reliability of a scale to assess fatigue. *Psychiatry Res* 36,291-298,1991

20. Lehman, GJ. The influence of grip width and forearm pronation/supination on upper body myoelectric activity during the flat bench press. *J Strength Cond Res* 19(3), p.587,2005

21. Markworth, JF, Maddipati, KR, Cameron-Smith, D. Emerging roles of pro resolving lipid mediators in immunological and adaptive responses to exercise-induced muscle injury. *Exerc Immunology Rev* 22,2016

22. Mika, A, Mika, P, Fernhall, B, Unnithan, VB. Comparison of recovery strategies on muscle performance after fatiguing exercise. *Am J Physl Med Rehabil* 86(6),474-481,2007

23. Nédélec, MA, McCall, C, Carling, F, Legall, S. Berthoin, Dupont, G. Recovery in 492 soccer: part II-recovery strategies. *Sports Med* 43(1),9-22,2013

24. Nosaka, K, Newton, M, Sacco, P. (2002) Delayed-onset muscle soreness does not reflect the magnitude of eccentric exercise-induced muscle damage. *Scand J Med Sci Sports* 12: 337 346,2002

25. Nosaka, K, Newton, M. 2002. Difference in the magnitude of muscle damage between maximal and submaximal eccentric loading. *J Strength Cond Res* 16(2),202-208,2002

26. Paschalis, V, Koutedakis, Y, Jamurtas, AZ, Mougios, V, Baltzopoulos, V. Equal volumes of high and low intensity of eccentric exercise in relation to muscle damage and performance. *J Strength Cond Res* 19(1),184,2005

27. Peake, JM, Neubauer, O, Della Gatta, P, Nosaka, K. Muscle damage and inflammation during recovery from exercise. *J Appl Physiol* 122(3): 559-570,2017

28. Peake, JM, Roberts, LA, Figueiredo, VC, Egner, I, Krog, S, Aas, SN, Suzuki, K, Markworth, JF, Coombes, JS, Cameron- Smith, D, Raastad, T. The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. *J Physiol* 595(3),695-711,2017

29. Roberts, LA, Raastad, T, Markworth, JF, Figueiredo, VC, Egner, IM, Shield, A, Cameron- Smith, D, Coombes, JS, Peake, JM. Post- exercise cold water immersion attenuates acute anabolic signalling and long- term adaptations in muscle to strength training. *J Physiol* 593(18),4285-4301,2015

30. Schoenfeld, BJ. The Use of Nonsteroidal anti-inflammatory drugs for exercise-induced muscle damage. *Sports Med* 42(12),1017-1028,2012

31. Soltow, QA, Betters, JL, Sellman, JE, Lira, VA, Long, JH, Criswell, DS. Ibuprofen inhibits skeletal muscle hypertrophy in rats. *Med Sci Sport Exerc* 38(5),840,2006

32. Spierer, DK, Goldsmith, R, Baran, DA, Hryniewicz, K, Katz, SD. Effects of active vs. passive recovery on work performed during serial supramaximal exercise tests. *Int J Sports Med* 25(02),109-114,2004

33. Stevens, JP. Applied multivariate statistics for social science (Fifth Edition) Taylor and Francis, New York,2009

34. Toubekis, AG, Tsolaki, A, Smilios, I, Douda, HT, Kourtesis, T, Tokmakidis, SP. Swimming performance after passive and active recovery of various durations. *Int J Sports Physiol Perform* 3(3),375-386,2008

35. Wunsch, SA, Muller-Delp, J, Delp, MD. Time course of vasodilatatory responses in skeletal muscle arterioles: role in hyperemia at onset of exercise. *Am J Physiol Heart Circ Physiol* 279,1715-1723,2000

36. Yasuda, T, Fujita, S, Ogasawara, R, Sato, Y, Abe, T. Effects of low- intensity bench press training with restricted arm muscle blood flow on chest muscle hypertrophy: a pilot study. *Clin Physiol Funct Imaging* 30(5),338-343,2010

Table 1: Changes in Muscle Soreness

Assessment	Trial	BL	15P	24P	48P
sorPEC (mm)	AR	0.0 ± 0.0	49.2 ± 16.6**	27.9 ± 26.6**	16.7 ± 23.2**
	PR	0.0 ± 0.0	56.5 ± 23.1**	21.7 ± 15.3**	15.7 ± 20.2**
sorTR (mm)	AR	0.0 ± 0.0	54.4 ± 26.2**	27.8 ± 24.1**	15.5 ± 21.2**
	PR	0.0 ± 0.0	65.8 ± 21.2**	39.6 ± 26.5**	27.6 ± 29.4**

sorPEC = soreness pectoral; sorTR = soreness triceps. ** indicates a significant ($p \leq 0.01$) difference from BL. All data are reported as mean ± SD.

Figure Legends

Figure 1. Experimental design of AR and PR protocols. BL= baseline; 15P = 15 min post; 24P = 24 hours post; 48P = 48 hours post.

Figure 2. Changes in bench throw power (BTP) 15-min (15P), 24-hour (24P) and 48-hour (48P) post-exercise. AR = active recovery. PR = passive recovery. * indicates a significant ($p \leq 0.05$) difference from BL. ** indicates a significant ($p < 0.01$) difference from BL. All data are reported as mean ± SD.

Figure 3. Changes in isometric bench press force (IBPF) 15-min (15P), 24-hour (24P) and 48-hour (48P) post the training session. AR = active recovery. PR = passive recovery. * indicates a significant ($p \leq 0.05$) difference from BL. ** indicates a significant ($p < 0.01$) difference from BL. All data are reported as mean ± SD.

Figure 4. Changes in PECMT occurred 15-min (15P), 24-hour (24P) and 48-hour (48P) post the training session. * indicates a significant ($p \leq 0.05$) difference from BL. ** indicates a significant ($p < 0.01$) difference from BL. AR = active recovery. PR = passive recovery. All data are reported as mean ± SD.

Figure 5. Changes in TRMT occurred 15-min (15P), 24-hour (24P) and 48-hour (48P) post the training session. * indicates a significant ($p \leq 0.05$) difference from BL. ** indicates a significant ($p < 0.01$) difference from BL. AR = active recovery. PR = passive recovery. All data are reported as mean ± SD.

Figure 1

Click here to access/download;Figure;Fig. 1 Active Rek.tif

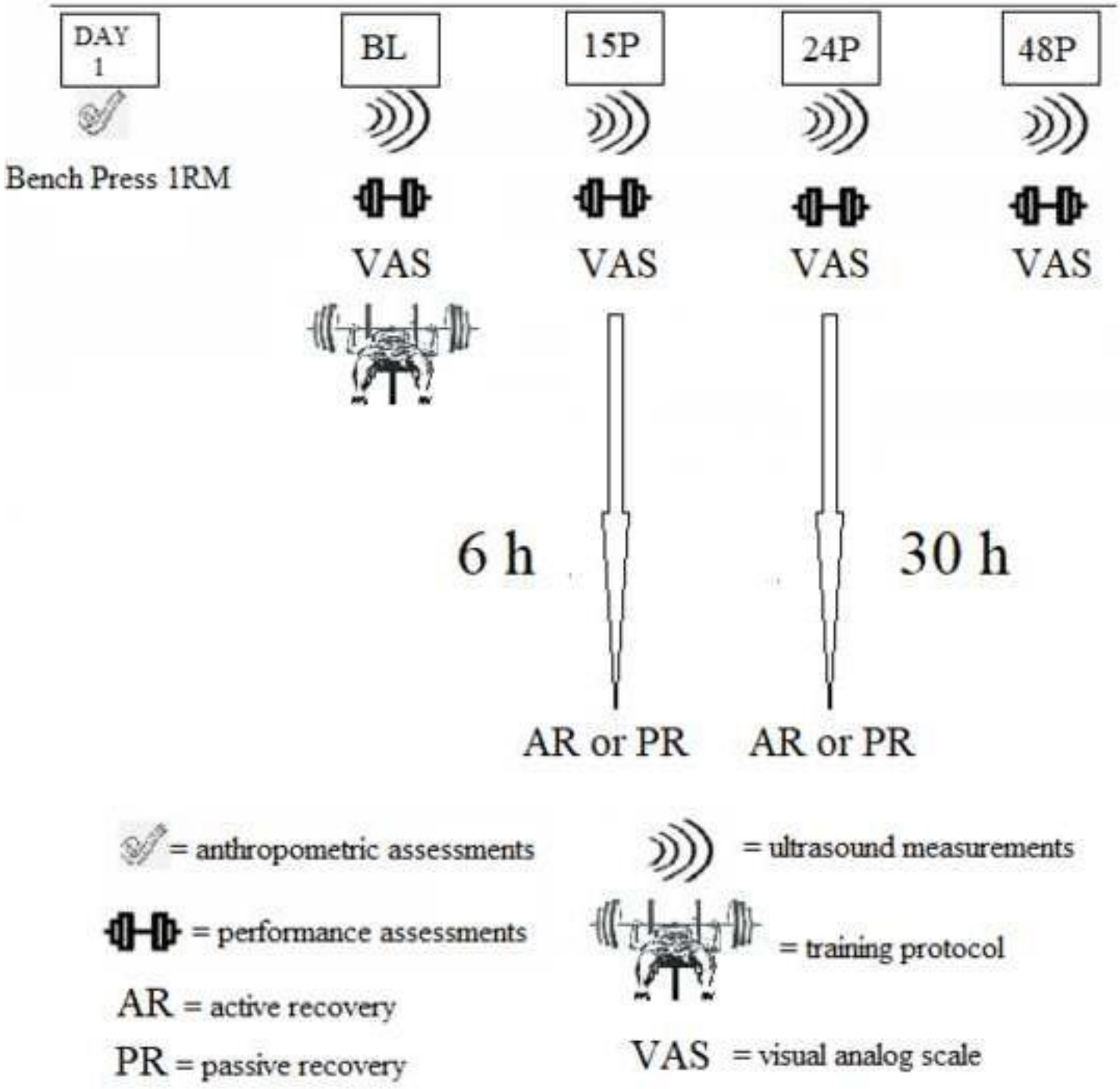

Figure2

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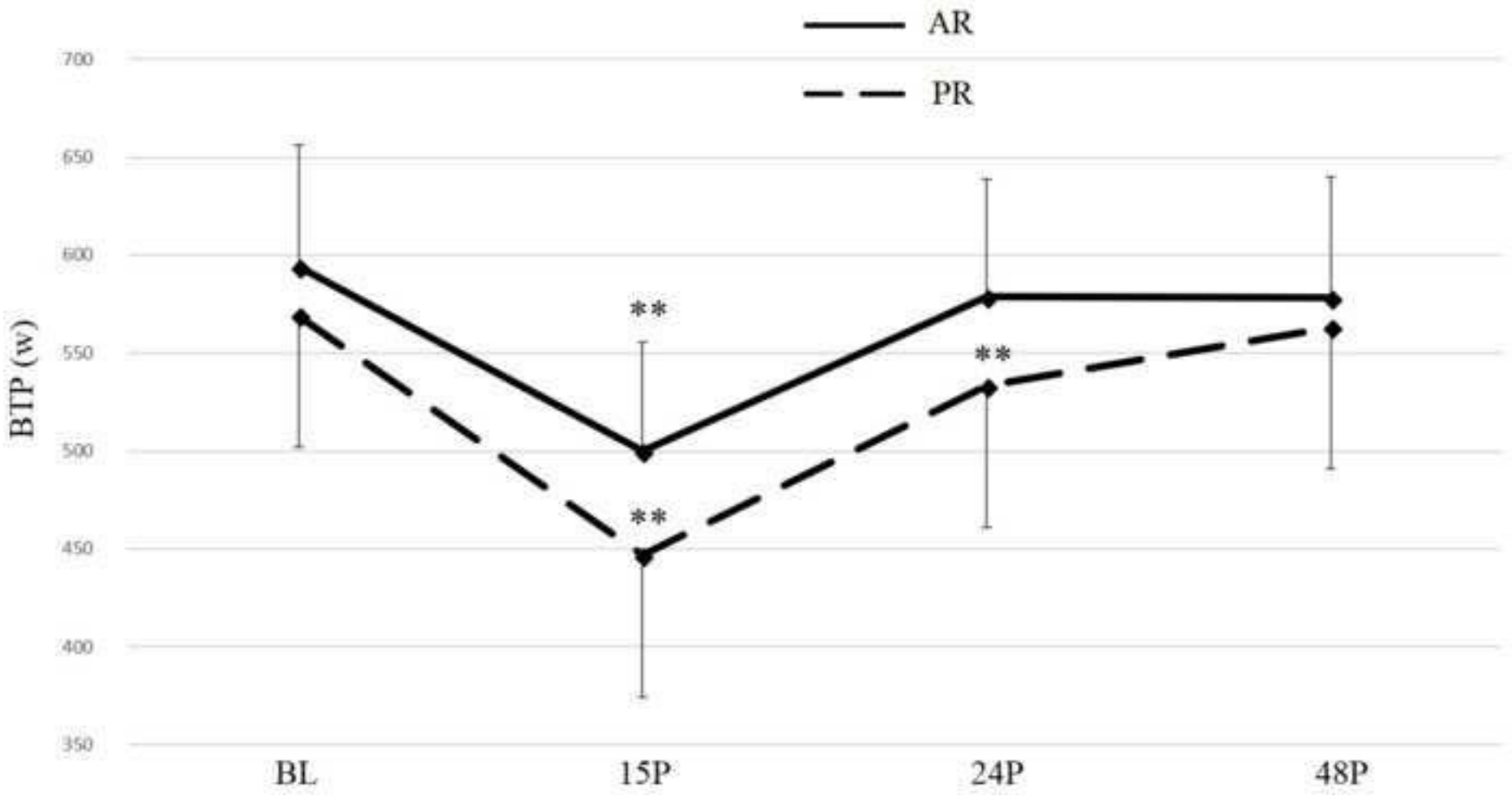

Figure3

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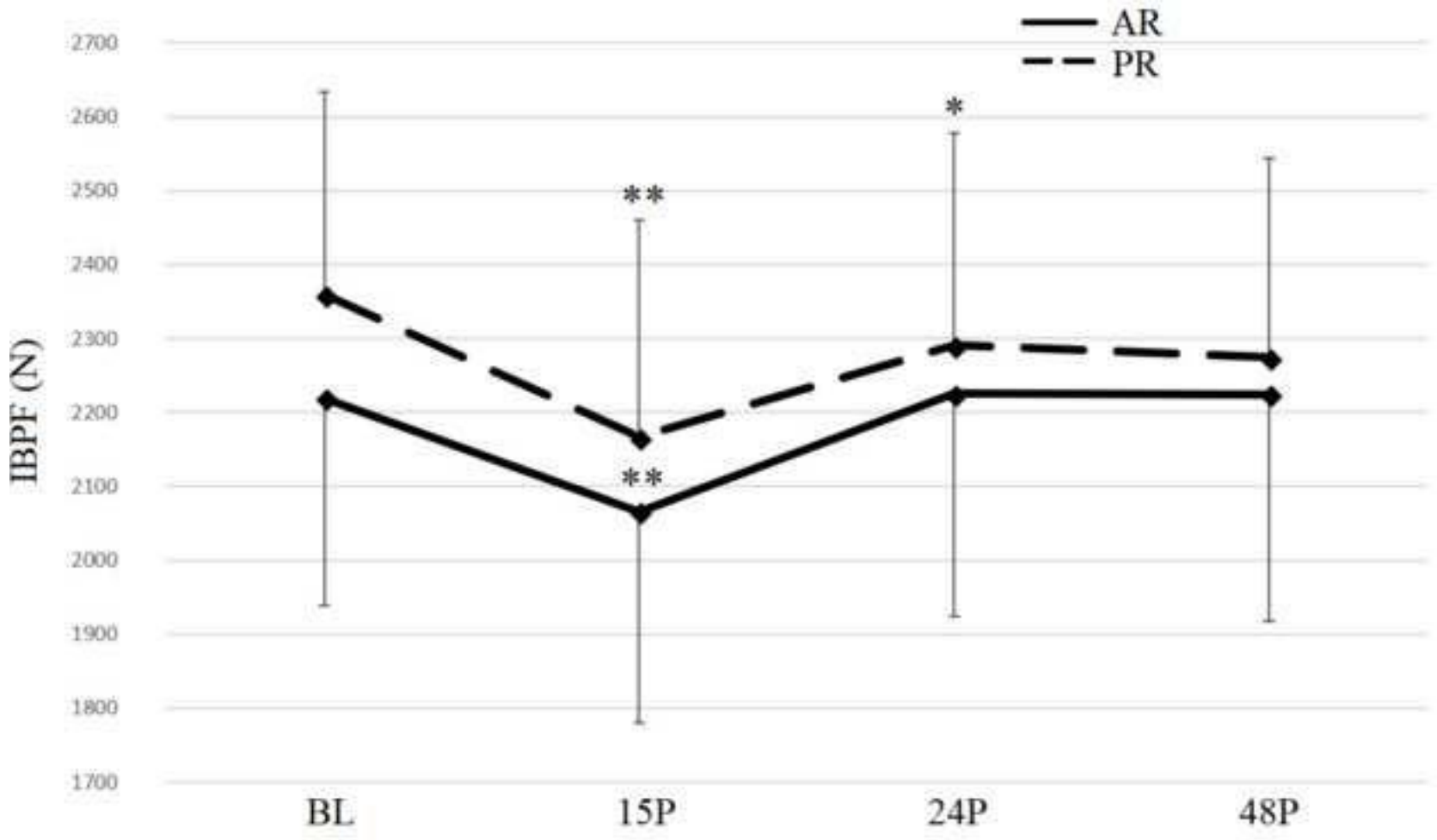

Figure4

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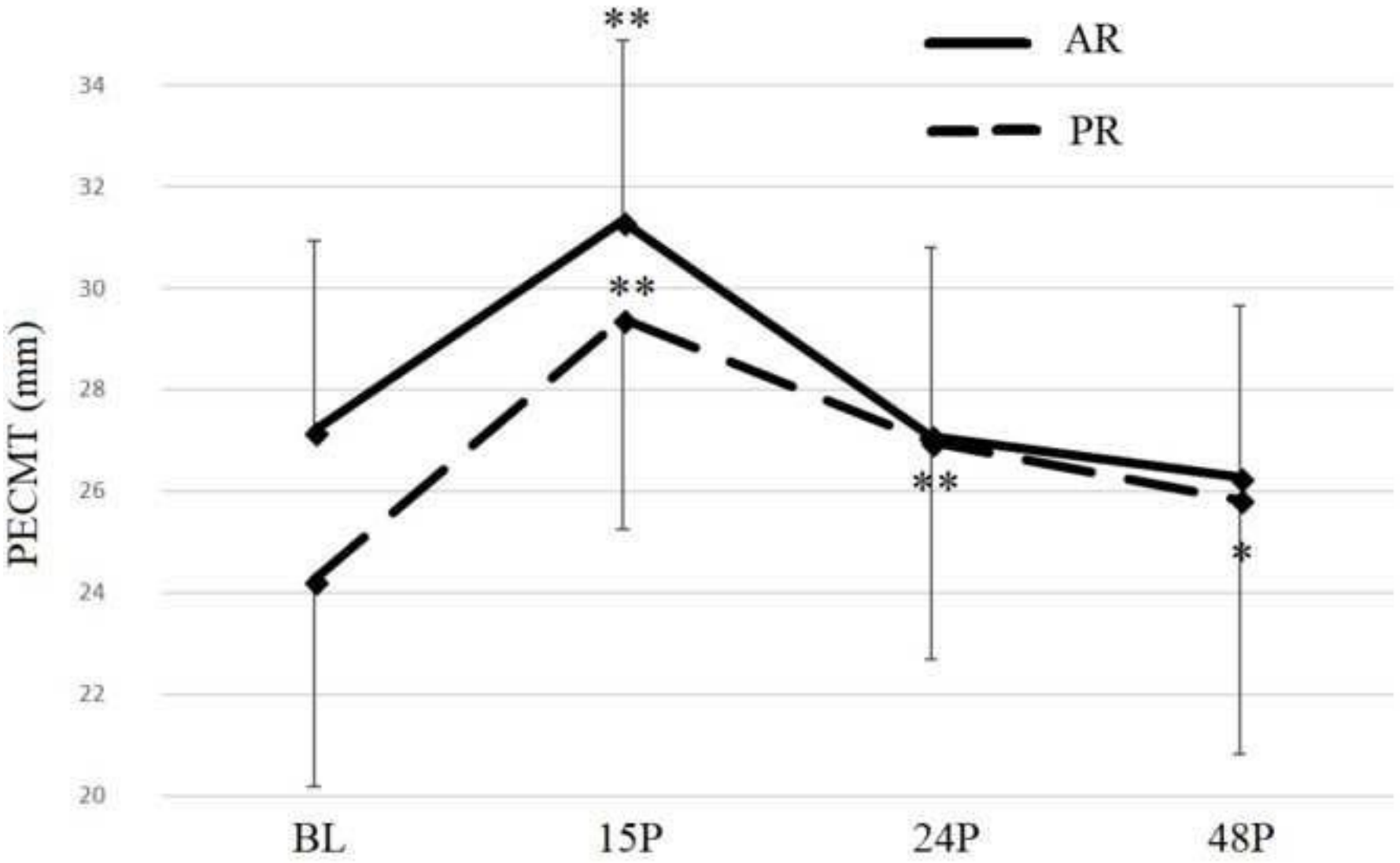

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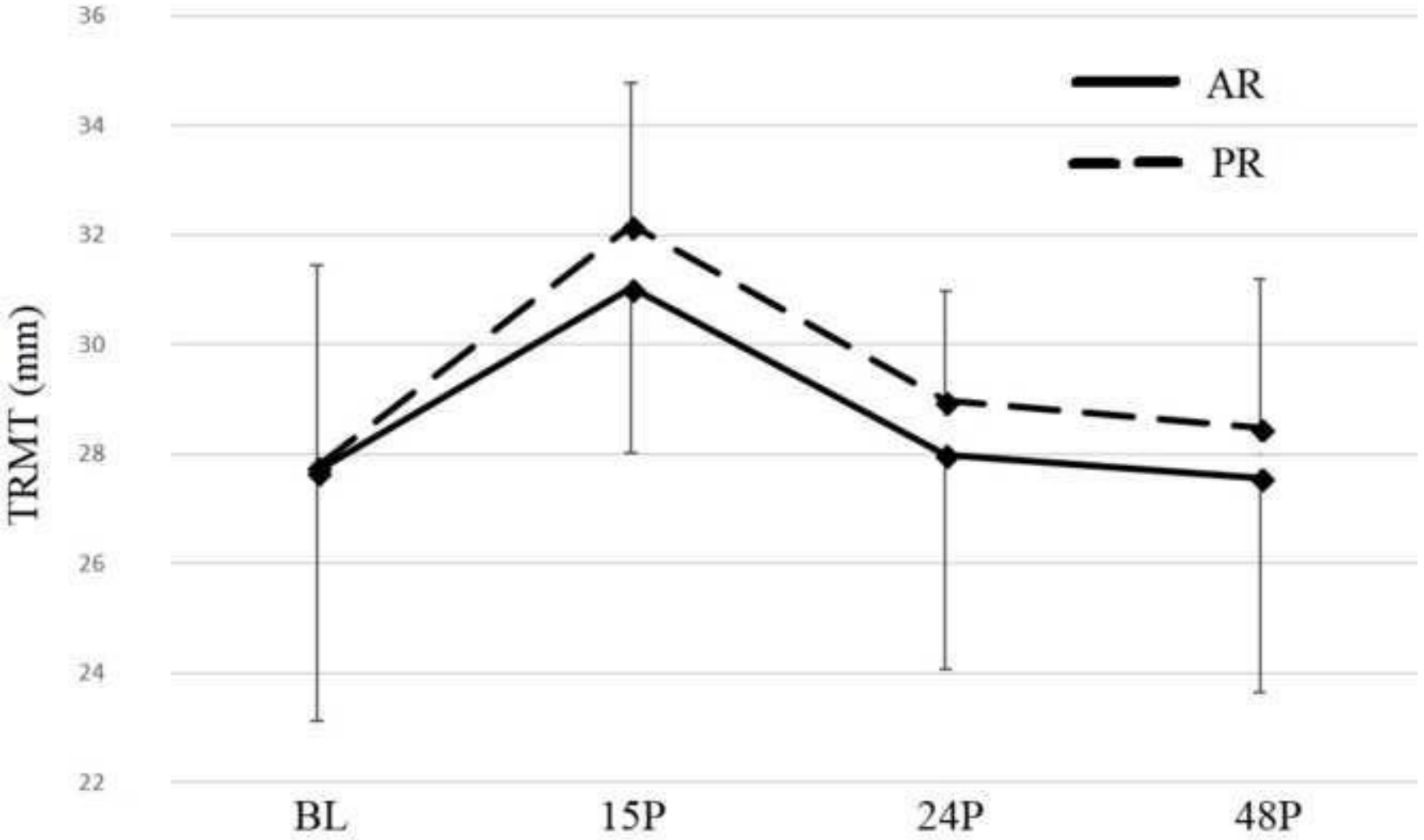
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