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A Comparison of the Effect of Conditioning Activity Type on Post-activation Potentiation

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A Comparison of the Effect of Conditioning Activity Type on Post-activation Potentiation

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Abstract

This study compared the effects of two conditioning exercise types on subsequent countermovement jump performance. Fifteen male collegiate rugby players (age 21.1 ± 2.3) completed two experimental protocols in a randomized order. The first protocol consisted of 3 sets of a 5 second maximal isometric half squat (ISO), with 1 minute rest intervals between sets. The second protocol consisted of 2 sets of 5 depth jumps (DJ) at a platform height which was determined by the athletes' reactive strength index (RSI). These methods were each adapted from prior literature where post-activation potentiation (PAP) was achieved, in order to determine the relative timing and amplitude of the effect using a repeated measures design. Results of a two-way ANOVA for CMJ height reveal a significant main effect of time (($F[5,60] = 8.291$, $p < 0.001$, $\eta^2 = 0.409$), and pairwise comparisons reveal a significant increase in CMJ height at 4-minutes compared to baseline (3.4 ± 0.9%, $p = 0.044$), as well as a significant decline in CMJ performance from 4-minutes to both 8-minutes (-7.7 ± 3.3%, $p = 0.001$), and 10-minutes (-4.7 ± 0.7%, $p = 0.005$). No significant interactions or main effects were found for CMJ height or other performance indices. Potentiating via the DJ or ISO protocols lent no significant difference in CMJ variables, therefore practitioners may use either protocol to enhance jumping performance in their athletes.

Key Words

Countermovement vertical jump, maximal voluntary isometric contraction, ballistic exercise, complex training

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Introduction

Post-activation potentiation (PAP) is an acute phenomenon in which increases in muscular strength and power are precipitated by a preceding high-intensity conditioning exercise (28). This conditioning exercise stimulates pathways both within the cells of skeletal muscle tissue and at the central nervous system level, manifesting in performance enhancements for several minutes thereafter (1,2,4-7,9-15,17,20-22,27,29,30,33). The procedures used to elicit PAP in athletes have varied greatly in the literature, as have the magnitudes of potentiation. Because of the discrepancy of methods in PAP studies, further research will be required to develop effective stimuli for eliciting PAP in subjects.

Many factors can be manipulated in order to influence the PAP response in subjects. The exercise used to elicit the PAP response, called the conditioning exercise, can be manipulated. This can vary from a heavy resistance movement, a plyometric jump, or an isometric maximal voluntary contraction (1,2,4,5,7,9,11-15,17,20,22,27,29,30,32). For this conditioning exercise, acute programming variables such as volume, intensity, and rest intervals between sets may be modified in order to manipulate the response in the subjects. Total volume is denoted as the total repetitions in a set multiplied by the total number of sets, intensity is manipulated either as a percentage of the one-repetition maximum of a weighted movement, the intensity of a plyometric movement, or the volitional intensity of an isometric contraction, and the rest intervals are the time between sets in seconds or minutes. To test the amplitude of potentiation in subjects, a test-exercise is performed both pre- and post- conditioning. For studies on lower body PAP, the countermovement jump (CMJ) has been commonly used as a test exercise.

The most commonly used conditioning exercises to elicit PAP in the literature include heavy resistance exercise (HRE) such as high-intensity back squats or bench press movements, or maximal voluntary isometric contractions (MVIC) (1,2,4,7,9,13,14,17,22,30,32). A recent body of research has examined the effects of lighter load, high velocity movements, termed ballistic exercise (BE), on its ability to potentiate subsequent exercises such as the CMJ or sprint test. These BE movements have included bench press throws, squat jumps, depth jumps, body-weight lunges, and overhead shot put throws, and they have been shown to enhance performance significantly (5,11,12,15,27,29,30). In this body of research, however, there has been no examination of these potentiation effects when compared to methods of HRE or isometric contractions. An investigation which compared the relative effectiveness between BE and either a HRE or MVIC could provide evidence for this modality, and provide insights for its use going forward. The BE movements are much more accessible than HRE or MVICs because they may not necessitate the use of as much equipment, making them a favorable option in dynamic warm-up protocols where the goal is to increase rate of force development (RFD) before an event.

The purpose of this research study was to determine the differences in the timing and amplitude of the PAP effect between unloaded depth jumps and isometric squats. We hypothesized that both stimuli will be sufficient in eliciting PAP in a CMJ in rugby athletes. Additionally, we hypothesized that the peak increases in performance will occur sooner in the DJ protocol than in the MVIC squat press, with no significant differences in peak amplitude.

Methods

Experimental Approach to the Problem

The purpose of the present study was to compare two conditioning exercises and their effect on the power performance of a subsequent activity. A repeated measures design tested the effects of conditioning activity type on athletic performance across several time intervals. The conditioning activities consisted of a maximal voluntary isometric contraction MVIC leg press and a depth jump (DJ), followed by countermovement jumps (CMJ) performed on a force platform at 2-minute time intervals. These activities were selected based on their success in potentiating CMJ performance in elite and recreational athletes (2,5,29,30). Outcome measures taken from the CMJ's included vertical jump height, mean rate of force development (MRFD), peak rate of force development (PRFD), and peak power output (PPO), and compared to a pre-test CMJ in order to determine the degree of PAP at each time interval. Subjects took part in a familiarization session in order to determine the optimal DJ platform height, isometric squat bar height, and to acclimate them to the procedures of the following sessions. Two experimental sessions followed, which were randomized via a coin flip. These sessions included the standardized warm-up, pre-test CMJ, conditioning activity, and post-test CMJ's at 2, 4, 6, 8, and 10 minutes.

Subjects

Fifteen male collegiate rugby players volunteered to participate in this study. All subjects reported at least 1 year of plyometric training experience, and were in the competition phase of their training cycle. No subjects reported any previous musculoskeletal injuries within the last 6 month, and all demonstrated proficiency in the depth jump exercise. Written informed consent was ascertained before the onset of the introductory session, as well as hold harmless agreements. The study was reviewed by the Institutional Review Board of Western Washington University, and approved for the use of human subjects.

Procedures

The first session included familiarization to the movements and protocol of the study, as well as determination of the optimal heights of the DJ platform and fitting within a custom-made isometric squat device. For this study, a custom made isometric squat platform was constructed, which consisted of a barbell attached to a wooden platform by adjustable length chains. Because subjects of various heights were tested, a calibration of the isometric squat device was performed in this initial session in order to expedite the process during data collections. The subjects were instructed to enter a half squat position, with a hip angle of 95° and knee angle of 120°, which were measured using a goniometer. These joint angles were used in prior research by Gullich & Schmidtbleicher (9) to successfully potentiate elite athletic participants. The bar was then placed and the chain clipped, and the links on the chain counted and recorded for ease of setup during the data collection phase. After calibration, the subjects were instructed on the methods of the standardized warm-up protocol, and performed a trial run. This protocol was adapted from the procedures of Tobin et al. (29), and consisted of 5 minutes of cycling at a self-selected pace, 10 deep squats, 10 forward lunges, and 5 submaximal CMJs. After warming up, subjects were familiarized with both the CMJ and a DJ from a 12 inch plyometric platform, and were allowed multiple practice efforts in order to demonstrate their proficiency. Subjects were allowed to assist their CMJ and DJ with an arm swing, but were required to consistently do so throughout all trials. After familiarization, subjects were tested for their optimal DJ platform height, between a 12 inch, 18 inch, and 24 inch plyometric platform. To determine the optimal height for the DJ platform, subjects were instructed to perform three DJ's onto the force platform at each of the plyometric platform heights. Each of the jumps was separated by 30 seconds, with a 2-minute rest between the platform heights. Measurements taken during this movement were the height of the jump (H_{DJ}) and the ground contact time (T_{DJ}), with the optimal height being determined as the highest ratio of H_{DJ} : T_{DJ}, denoted the reactive strength index (RSI)(5).

Sessions two and three consisted of warm up procedures, a pre-conditioning CMJ, one of the two conditioning exercises (which were ordered randomly) and post-conditioning CMJ's performed every 2 minutes for a 10 minute period. For the MVIC protocol, the subjects performed 3 sets of 5 second contractions, each separated by a minute. The DJ protocol was adapted from research by Chen and colleagues, and consisted of 2 sets of 5 DJ's at the determined height, with the sets separated by a single minute (5). Subjects were given vocal encouragement in both trials, as well as instructions by a certified strength and conditioning specialist for movement efficiency and maximal effort. An Advanced Mechanical Technology Inc. (AMTI; Watertown, MA) force platform was used to measure ground reaction force during each CMJ movement, set at a sampling rate of 1000 Hz.

For each subject, all research sessions were separated by at least 4 days in order to ensure that subjects were completely rested for the following session. Furthermore, subjects were asked to refrain from high intensity exercise for at least 48 hours prior to the session.

In the experimental sessions, a custom made Labview program (National Instruments, Austin, TX) calculated jump height, MRFD, PRFD, and peak power from the VGRF sampled from the force platform. Vertical jump height was calculated using the impulse-momentum relationship, which determined the center of mass velocity at takeoff. This velocity is then entered into the equation $VJ = V^2/2g$, where VJ is the vertical jump height, V is the velocity at takeoff, and g is the acceleration due to gravity. MRFD was determined by calculating the difference between the minimum and maximum vGRF and dividing it by the time between the data points (16). PRFD was determined using the highest slope in the force-time curve over a 10-millisecond time interval during the CMJ (3). PPO was determined by calculating the highest product of force and velocity during a 10-millisecond time interval during the CMJ.

In the introductory session, vertical jump height and RSI were calculated using a flight-time calculation. This uses the time from toe off to landing in order to calculate the subject's take-off velocity via the equation $V = (g*t_{flight})/2$, where t_{flight} denotes the time in seconds that the subject spends from toe off to landing. This is then entered into the aforementioned equation $VJ = V^2/2g$ to determine jump height. For RSI, this jump height was divided by the ground contact time in the depth jump, as used by Chen et al. (5).

Statistical analysis

All statistical analysis for this study was performed on SPSS version 25 (IBM; North Castle, NY). This study utilized a two-way repeated measures analyses of variance (ANOVA)(conditioning activity × recovery time) in order to examine the effects of time (pre-conditioning, 2, 4, 6, 8 and 10 minutes), as well as condition (MVIC vs. DJ) on vertical jump height, MRFD, PRFD, and PPO. In the case of a significant interactions, simple effects analyses were undertaken. In the case of significant main effects, pairwise comparisons were performed in order to determine if potentiation was statistically significant at specific time intervals. Effect size calculations for the significant interactions and main effects were determined using partial eta squared (η^2). Statistical significance was set at a value of $p < 0.05$. Test-retest reliability for each dependent variable was determined through intra-class correlations (ICC), using a 2-way mixed model.

Results

Reliability analysis for each of the dependent variables can be found in table 1. CMJ height displayed high degree of test-retest reliability, with an average ICC of 0.978, and a 95% confidence interval between 0.941-0.994. Results of the two-way ANOVA for CMJ height revealed no significant time by condition interaction ($F[5,60] = 1.516$, $p = 0.224$, $\eta^2 = 0.112$) or main effect of condition ($F[1,12] = 0.009$, $p = 0.926$, $\eta^2 = 0.001$). A significant main effect of time however, was found ($F[5,60] = 8.291$, $p < 0.001$, $\eta^2 = 0.409$). Based on the significant main effect of time in the CMJ analysis, pairwise comparisons were performed in order to determine at which time intervals a significant change in CMJ performance was found. CMJ height was significantly higher at 4 minutes compared to baseline ($p = 0.044$), as well as significantly lower at 8 minutes when compared to 4 minutes ($p = 0.001$), and significantly lower at 10 minutes compared to 4 minutes ($p = 0.005$).

A two-way ANOVA for MRD revealed no significant time by condition interaction effect ($F[5,65] = 0.748$, $p = 0.467$, $\eta^2 = 0.054$), nor a significant main effect of time ($F[5,65] = 1.024$, $p = 0.387$, $\eta^2 = 0.073$) or condition ($F[1,12] = 3.007$, $p = 0.107$, $\eta^2 = 0.118$). A two-way ANOVA for PRFD revealed no significant time by condition interaction effect ($F[5,55] = 1.451$, $p = 0.254$, $\eta^2 = 0.117$), nor a significant main effect of time ($F[5,55] = 2.767$, $p = 0.060$, $\eta^2 = 0.201$) or condition ($F[1,11] = 4.521$, $p = 0.057$, $\eta^2 = 0.291$). A two-way ANOVA for PPO revealed no significant time by condition interaction effect ($F[5,65] = 0.995$, $p = 0.406$, $\eta^2 = 0.068$), nor a significant main effect of time ($F[5,65] = 1.540$, $p = 0.231$, $\eta^2 = 0.106$) or condition ($F[1,13] = 0.019$, $p = 0.893$, $\eta^2 = 0.001$).

Discussion

The purpose of the current study was to compare the timing and amplitude of the PAP effect of two conditioning activity types, an isometric exercise (ISO) and ballistic exercise (BE), in collegiate male rugby players. We hypothesized that both conditions would lead to significant potentiation in the athletes, and that the BE protocol would potentiate sooner, with no differences in peak amplitude between the protocols.

Results of the two-way ANOVA for CMJ height depicted a significant main effect of time, but with no significant interaction effect or effect of conditioning activity. Based on the effect of time, we conducted pairwise comparisons in order to determine the timing of the PAP effect, showing significant differences between baseline and 4 minutes, as well as 4 minutes and 8 minutes, and 4 minutes and 10 minutes. These results support the hypothesis that both conditions lead to significant potentiation in male rugby players, with significant potentiation in CMJ height evident at 4 minutes post-intervention, and a significant decrement in performance at 8 and 10 minutes. Our secondary hypothesis however is not supported by these findings. Due to the lack of a significant interaction effect, we found that there is no significant difference in the timing of the PAP effect between the two conditioning protocols.

Similar to previous literature, our findings suggest that the depth jump is an effective tool to enhance performance in collegiate male athletes, with no significant difference in peak amplitude of PAP when compared to maximal isometric contractions. Tobin et al. (29) studied a DJ protocol in elite rugby players, using a warm-up of ballistic exercises, including a single set of 5 DJ's to elicit PAP. They reported significant increases at 1, 3, and 5 minutes post-conditioning, with average increases of 4.8%, 3.9%, and 3.5%, respectively. Our protocol led to significant potentiation at 4 minutes post-conditioning, and analysis of the PAP amplitude reveals that the average potentiation in both protocols at 4 minutes was 3.4%. The methods for the DJ protocol in our study used RSI to determine an optimal platform height for our subject, as opposed to a static platform height for all subjects. This method was adapted from Chen et al. (5), which used RSI to find the ideal platform height to potentiate collegiate volleyball players. Our findings support the results of their study, finding significant potentiation at a similar time interval.

Our results are also supported by literature using ISO protocols to elicit PAP. Bogdanis et al. (2) determined that ISO squats significantly enhanced CMJ performance between 4 and 6 minutes post-conditioning in elite track and field athletes, with an average amplitude of 3%. In a similar athletic population, Gullich & Schmidtbleicher (9) found that ISO squats significantly enhanced CMJ performance from 3-5:20 minutes post-conditioning, with an average amplitude of 3.3%. These findings are similar to those of our study, which finds significant PAP in both treatments at 4 minutes post-conditioning, and an amplitude of the PAP effect of 3.4%.

The current data suggest no significant effects when analyzing PRFD, MRFD, or PPO. Fewer sources in the literature have studied these jump characteristics, and those have shown discrepancies in their results. Of studies measuring pre-post changes in peak or mean power, some have found significant increases in average power at 3 minutes (22), as well as peak power for 8-12 minutes (14,17), all using HRE as a conditioning stimulus. Conversely, a study by Esformes et al. (6) found no significant change in either RFD or PPO at 5 or 10 minutes post-conditioning, using both HRE and BE as conditioning protocols. Furthermore, although

McLellan et al. (16) found that PRFD is a primary contributor towards CMJ performance, it also displayed low retest reliability, and they urged caution when interpreting this data.

Post-activation potentiation was found to have a similar peak amplitude in both the DJ and MVIC squat conditions. The accepted primary mechanism for PAP occurs through the phosphorylation of the myosin regulatory light chains (RLC) located within the skeletal muscles (8,23-26,31). These effects are expressed primarily in type II fibers, which display greater RLC concentrations, and longer durations of myosin RLC phosphorylation (10,18,19,23). Based on our findings, we conclude that there was an equivalent stimulation of the intramuscular PAP pathway in both the DJ and MVIC squat condition, as both led to a similar increment in CMJ performance. Both exercises were selected based upon their previously demonstrated ability to potentiate high performing athletes, but had key qualitative differences that we believed would influence the PAP timing. The DJ was selected due to its efficiency in activating type II motor units, and therefore accruing a maximal stimulation of RLCs with a minimal effect of fatigue (9,27,29). Conversely, an MVIC task was selected in order to elicit a maximal stimulation of all voluntary motor units, despite a considerably greater time under tension (2,9,30). Despite these differences in conditioning activity, there was no delineation between the DJ or MVIC for PAP amplitude or onset. Because of the interplay between PAP and muscular fatigue, there still may have been differences in the peak stimulation of the PAP pathway, however added fatigue may have masked these differences. It is unlikely however that a large difference in muscular fatigue was present between the two protocols, as this would have more-so pronounced a difference in the PAP timing.

In the current study, a large individual response to the treatments led some subjects to display large degrees of potentiation, while others were non-responders. This finding may also suggest a limitation in the subject sample. Collegiate rugby players were selected on the basis of their ability to potentiate in previous PAP literature (1,14,29). It has been argued that due to training experience in both strength and plyometric modalities, as well as a high relative strength, these subjects would yield a high response to PAP. Unfortunately, the current study does not take into consideration measures of relative strength, RSI, or training age as cut-offs for participation, which means both high and low PAP responders were present. For future studies, measures of relative strength, as well as RSI should be considered as criteria for participation. It was noted during data analysis a possible relationship between RSI and percent potentiation in CMJ height, but this was not reported as it was not relevant to the research question. A study with the purpose of examining the relationship between RSI and potentiation may be of importance, as RSI has not yet been studied as a characteristic of high responding athletes.

Practical Applications

Based on the findings of this study, we have found that both the MVIC squat and the DJ provide an adequate stimulus to potentiate CMJ performance in rugby athletes. Both exercise protocols led to similar potentiation in athletes, and are therefore interchangeable depending on equipment availability, athlete preference, and phase of training. When using the DJ for conditioning, it is suggested to use RSI as a determinant of platform height, in order to elicit a maximal response. For athletes with lesser plyometric experience, the isometric squat can be considered an equally effective alternative. Our findings suggest that the average effect of this potentiation is 3.4%, and that the timing occurs at 4 minutes post-conditioning. It is important to note that large individual differences in timing and amplitude are present, and therefore practitioners must monitor and adjust their athletes' PAP protocol, in order to provide the greatest effect.

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Appendix A

Tables

Table 1. Intra-class correlations (ICC) with 95% confidence intervals (CI) and statistical significance

	CMJ Height	MRFD	PRFD	PP
ICC	0.978	0.757	0.827	0.935
95% CI	0.941 - 0.994	0.420 - 0.912	0.599 - 0.936	0.847 - 0.976
p	< 0.001	0.001	< 0.001	< 0.001

Table 2. Mean & standard deviation of jump height across condition & time intervals

	Pre-conditioning	Post-conditioning (min)				
		2	4	6	8	10
ISO	0.444 ± 0.073	0.451 ± 0.083	0.456 ± 0.073	0.452 ± 0.075	0.442 ± 0.066	0.429 ± 0.074
DJ	0.436 ± 0.059	0.458 ± 0.070	0.455 ± 0.081	0.448 ± 0.079	0.434 ± 0.071	0.439 ± 0.074

ISO = isometric squat condition ; DJ = depth jump condition

Figures

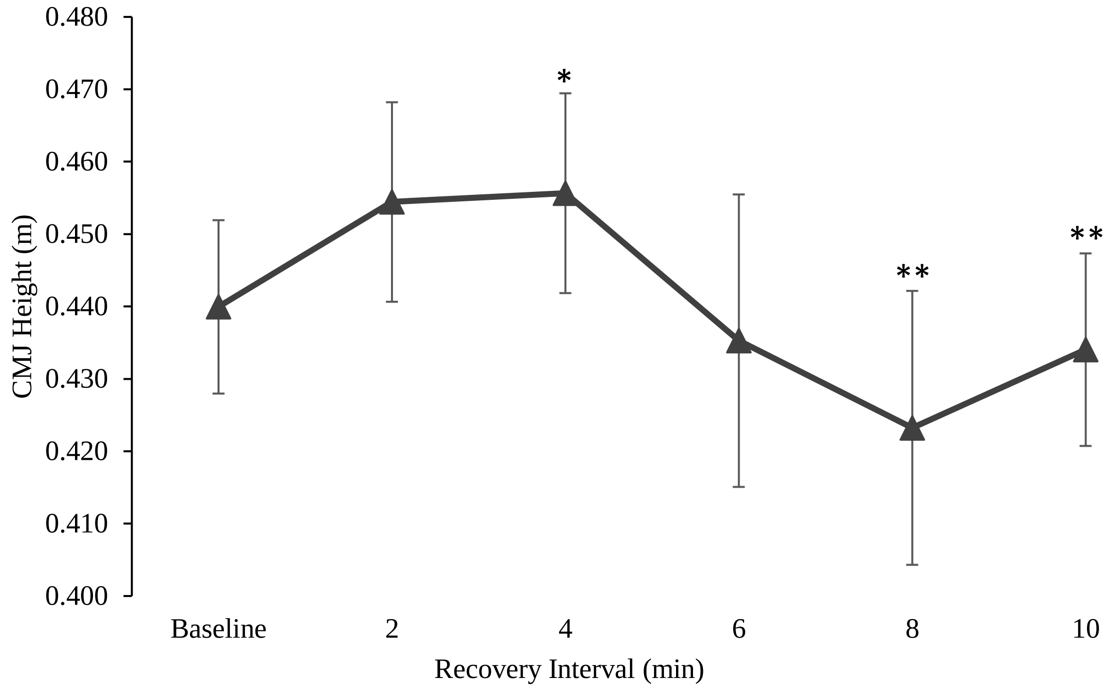

Figure 1. Pooled, average CMJ height (m) over time (min), with standard error. * = significant difference from baseline ($p < 0.05$) , ** = significant decrease from 4-minute condition ($p < 0.01$).

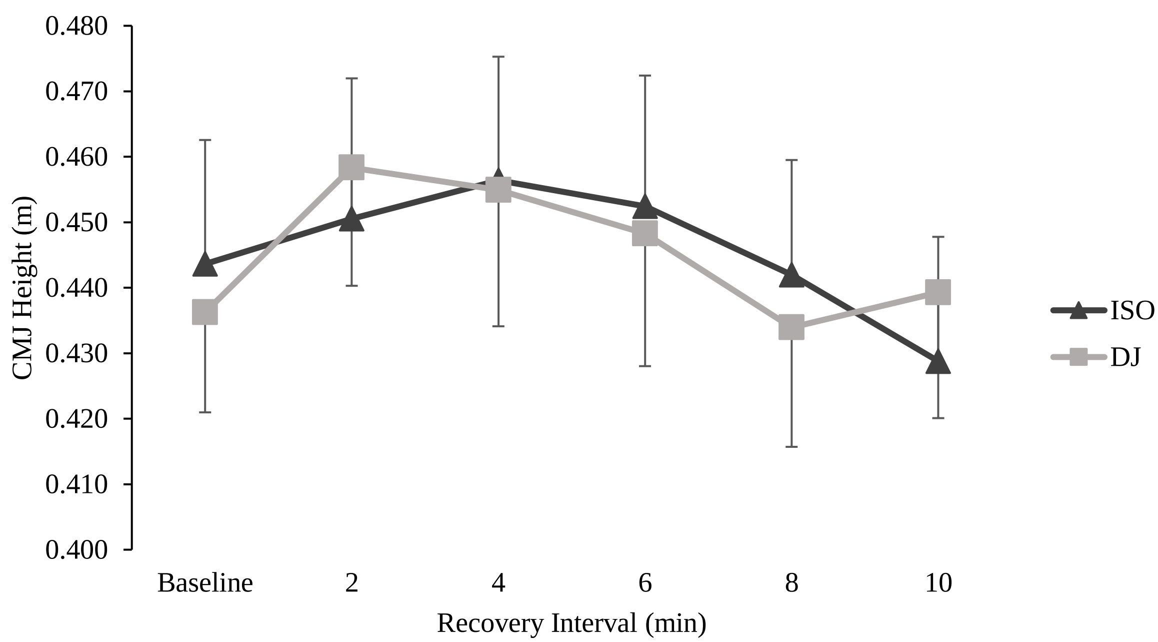

Figure 2. Average CMJ height in each condition over time (min), with standard error. ISO = isometric squat condition, DJ = depth jump condition.

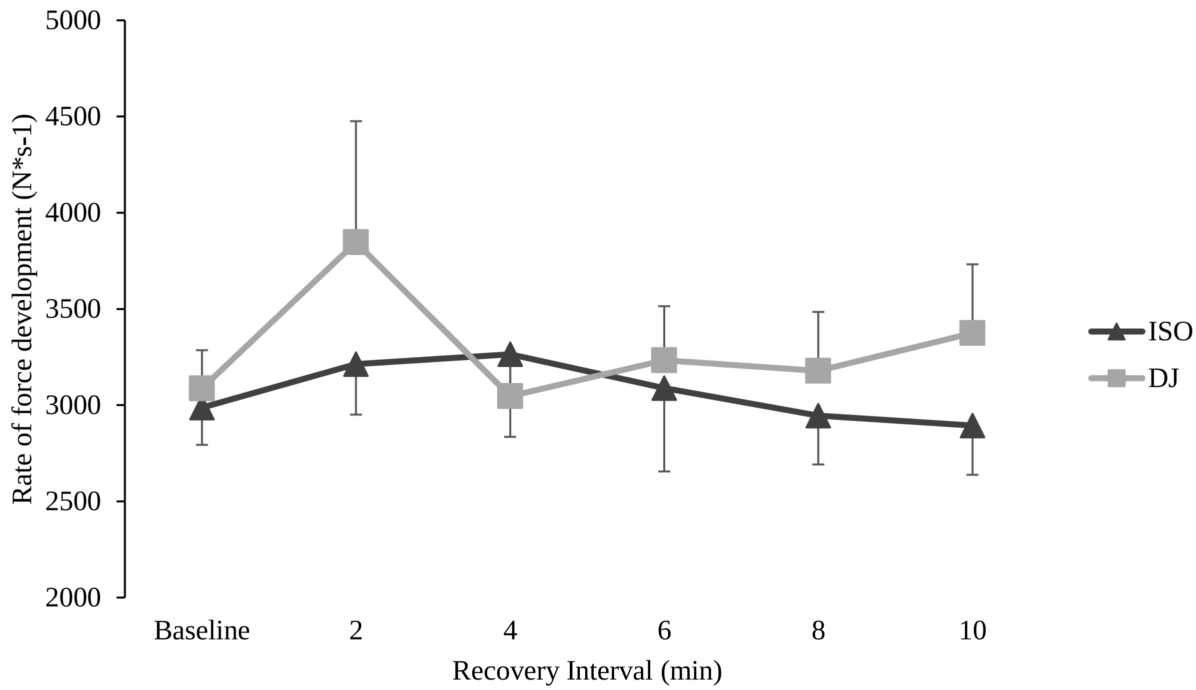

Figure 3. Average mean rate of force development (MRFD) in each condition over time (min), with standard error. ISO = isometric squat condition, DJ = depth jump condition.

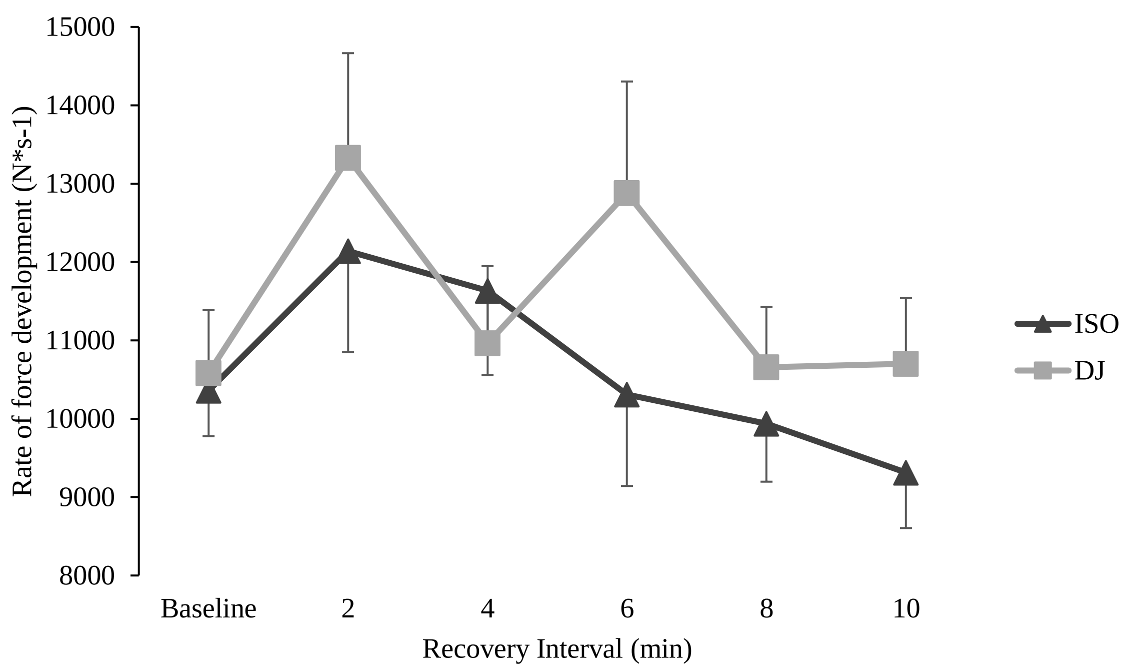

Figure 4. Average peak rate of force development (PRFD) in each condition over time (min), with standard error. ISO = isometric squat condition, DJ = depth jump condition.

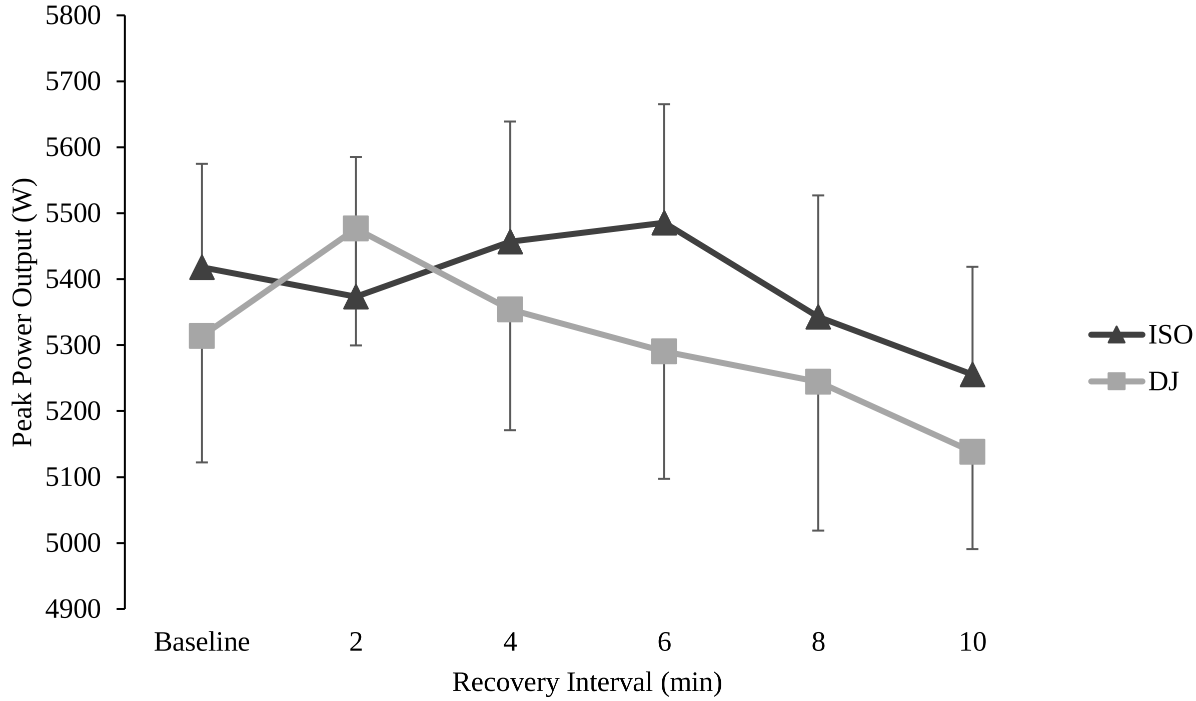

Figure 5. Average peak power (PPO) in each condition over time (min), with standard error. ISO = isometric squat condition, DJ = depth jump condition.