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Effect of different types of conditioning contraction on upper body post-activation potentiation

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Upper body post-activation potentiation

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Title:

Effect of different types of conditioning contraction on upper body post-activation potentiation

ABSTRACT

Muscle contractions preceding an activity can result in increased force generation (postactivation potentiation, PAP). Although the type of muscular contractions could affect subsequent strength and power performance, little information exists on their effects. The purpose of the present study was to examine PAP effects produced by isometric (ISO), concentric (CON), eccentric (ECC), or concentric-eccentric (DYN) conditioning contractions on upper body force and power performance. Ten male, competitive rugby players (mean±SD: age 20.4±0.8 years, height 177.0±8.1 cm, body mass 90.2±13.8 kg) performed a ballistic bench press throw (BBPT) followed by a 10-min rest and one of the conditioning contractions. Following a 12-min rest, the subjects performed another BBPT (post-BBPT). The conditioning contractions, applied on separate days and in counterbalanced randomized order, were a 7-sec isometric barbell bench press for ISO and 1 set of 3 bench press repetitions at 3 repetition maximum for CON, ECC, and DYN (each repetition lasting 2 sec for CON and ECC, overall execution time <7 sec for DYN). Peak power (P_{peak}), peak force (F_{peak}), maximum distance (D_{max}) and rate of force development (RFD) were measured using a linear position transducer. Electromyography (EMG) of the pectoralis major and triceps brachii were also recorded. ISO produced significantly higher P_{peak} (587±116W and 605±126W for pre- and post-BBPT, respectively; $P<0.05$). No significant differences in P_{peak} were revealed for CON, ECC and DYN ($P>0.05$), and no significant differences existed in F_{peak}, D_{max}, and RFD for ISO, CON, ECC, and DYN ($P>0.05$). Finally, EMG was not significantly different between pre- and post-BBPT for any of the conditioning contractions ($P>0.05$). Isometric contractions appear to be the only conditioning contractions increasing upper body power output following long resting periods.

Keywords: complex training, power performance, upper body exercise

INTRODUCTION

Muscular performance is affected by the muscle's contractile history, with increased muscular activity resulting in decreased neuromuscular force generation (24). However, previous muscular activity can also enhance subsequent force generation and improve strength and power performance (3, 19, 25). The phenomenon where previous muscular contractions facilitate subsequent force generation is termed post-activation potentiation (PAP; 28).

The physiological mechanisms involved in PAP are unclear (29). Regulatory light chains phosphorylation and increased recruitment of motor units have been proposed as two potential mechanisms. In the first mechanism, the sensitivity of the actin-myosin interaction to Ca^{2+} released from the sarcoplasmic reticulum is increased, altering the structure of the myosin head, which results in a higher force-generation state of the cross-bridges (24). Previous muscular contractions may also increase the excitation potential resulting in increased motor unit recruitment. This excitation can last for several minutes, increasing post-synaptic potentials that lead in enhanced force generation (15). The small number of studies examining these two mechanisms and their respective methodological limitations prevent a conclusive answer (17).

Numerous studies have examined PAP effects on strength and power performance using different conditioning loads (for review see Tillin and Bishop, 29), showing improved performance in athletes that have used heavy load resistance exercise [e.g. 5 sets at 90% of 1 repetition maximum (RM), 7; 1 set at ~85% of 1RM; 19, 25] prior to explosive movements. Studies that have used dynamic contractions have reported both an increase in performance (19, 30) and no performance change (11, 18). Similarly, studies that have used isometric contractions to examine PAP reported performance enhancement (2, 15) and no change in performance (12, 26). It is interesting to note that the aforementioned studies did not report a decrease in performance, even if they reported no performance enhancement. Therefore, the phenomenon of PAP could potentially be used during training or competition for maintaining performance. Despite the potential application of PAP on performance (10), the type of conditioning contraction that could yield higher performance benefits has received limited attention.

Rixon et al (25) compared different conditioning contractions, reporting increased jumping height and power output performance following isometric contractions, contradicting earlier findings by Baudry and Deschateau (4), who found similar PAP results irrespective of the type of conditioning contraction. However, the different exercises and performance measures used (rate of force development of evoked twitch, 4; height jumped, 25) may account for the contradicting results.

Additionally, PAP has primarily been examined in the lower body, with only a small number of studies examining the effects of upper body exercise on PAP (19, 20). Although it is difficult to compare the results due to different methodologies and performance measures, positive PAP effects have been reported when heavy weight exercise preceded a medicine ball throw (20) and a bench press throw (19). However, despite the importance of upper body performance on various sports (e.g. rugby, javelin), the impact of type of conditioning contraction has largely been ignored. Therefore, the aim of the present study was to examine the effect of isometric, concentric, eccentric, and concentric-eccentric conditioning contractions on upper body PAP and subsequent strength and power performance.

METHODS

Experimental Approach to the Problem

The aim of the present study was to examine the effect of different conditioning contractions as a PAP stimulus on upper body strength and power performance. Ten competitive rugby players completed a ballistic bench press throw followed by a 10-min rest, and the bench press preload conditioning stimulus. Subjects then rested for 12 min and performed another ballistic bench press throw. The bench press preload conditioning contractions were a 7-sec isometric contraction at 110^{o} elbow joint angle, one set of three concentric repetitions at 3RM, one set of three eccentric repetitions at 3RM, or one set of three concentric-eccentric repetitions at 3RM, with each conditioning contraction performed on a separate day. A 3RM bench press preload conditioning stimulus has previously been found to significantly enhance upper body muscle performance in rugby players following a 12-min recovery between the preload stimulus and the explosive activity (19). To avoid any order bias, a counterbalanced, randomised order design was employed.

Performance variables (peak power, peak force, maximum distance, and rate of force development), and electromyography of the pectoralis major and triceps brachii were measured. The performance variables examined were selected as they are commonly used for assessing explosive performance and can provide an indication of any PAP effects, while the electromyography recordings would suggest any potential underpinning physiological mechanisms.

Subjects

Ten male, competitive Rugby League players (mean ± SD: age 20.4±0.8 years, height 177.0±8.1 cm, body mass 90.2±13.8 kg) agreed to participate in the study. The subjects were in the competition phase of their annual training cycle, training 5 times per week. Their sport training programme included a minimum of three sessions of resistance training per week, with training loads ranging from 40% - 90% of 1RM. All subjects had experience of resistance training for at least 2 years prior to the study and were free from any upper body injuries at the time of the study for at least one year. Subjects were asked to refrain from eating 2 h before examination and from drinking coffee and alcohol 24 h prior to each visit to the laboratory. Subjects were allowed to consume water ad libitum prior to and during the exercise task. Approval from the University of Wales Institute Cardiff Ethics Committee was granted and written informed consent was obtained from all subjects.

Procedures

Subjects initially visited the laboratory to be familiarized with the experimental protocol and the subjects' weight and height were measured. Height was measured to the nearest 0.1 cm using a stadiometer (Harpenden, UK) and weight was measured to the nearest 0.1 kg using a calibrated balance beam scale (Seca, UK). Subsequently, each subject's 3RM bench press was determined according to the guidelines set by the National Strength and Conditioning Association (16). Briefly, 3RM was defined as the load which caused failure on the third repetition but without loss of proper exercise technique. To establish the 3RM load, subjects attempted 3 repetitions of a load and, if successful, increased the loading. A 5-min rest interval was allowed between trials, with 3 to 5 trials typically required for determining each subject's 3RM. The 1RM for the bench press exercise was estimated from the 3RM load using a prediction table (16).

Following the first visit, subjects returned to the laboratory on four separate occasions for the experimental sessions. At the start of each experimental session, the subjects were required to complete a standardised warm-up of 5 min of light-intensity cycling and a number of dynamic stretches specific to muscles involved in the relevant exercises. A 5-min rest interval was allowed after the end of the warm-up.

The subjects performed a ballistic bench press throw (BBPT) that served as baseline (pre-BBPT). The load used was 40% of predicted 1RM, as this load has been reported to be optimal for peak power output in rugby players (19). After the BBPT, a 10-min rest was allowed, followed by one of the conditioning contractions. The conditioning contractions were a 7-sec isometric contraction at 110^{o} elbow joint angle (ISO), one set of three concentric repetitions at 3RM (CON), one set of three eccentric repetitions at 3RM (ECC), or one set of three concentric-eccentric repetitions at 3RM (DYN). Each repetition lasted 2 sec for CON and ECC, while overall execution time was <7 sec for DYN. Each conditioning contraction was applied in a counterbalanced, randomised order on separate days. All exercises were executed on a Smith machine. Experienced spotters were present at all times to ensure safety of subjects and appropriate exercise technique execution. In addition, the spotters lowered the bar for CON and lifted it for ECC, enabling the subjects to perform only the concentric or eccentric phase, respectively, of the relevant conditioning contraction. Finally, following a 12-min rest, the subjects performed another BBPT (post-BBPT). A schematic diagram of the experimental procedure can be seen in Figure 1.

FIGURE 1 ABOUT HERE

Peak power output (P_{peak}), peak force (F_{peak}), maximum distance (D_{max}) and rate of force development (RFD), were measured using a linear position transducer (Ballistic Measurement System [BMS]; Fitness Technology, Skye, South Australia, Australia), which was fixed on the lifting bar. An analog-to-digital conversion of the variable-voltage output (sampling at 500 Hz), relating to the displacement of the BMS cable, converted that output to displacement via its customised software. BMS has been reported to yield an intraclass correlation coefficient of 0.93 for the bench press throw (1).

Electromyography (EMG) was used to record muscle activation during the pre- and post-BBPT. EMG monitoring electrodes with full-surface solid adhesive hydrogel (Kendall, H59P Soft-E) were placed on the pectoralis major and triceps brachii of the right side after the skin was shaved, abraded and cleaned. The electrodes were positioned longitudinally on the belly of each muscle, with an inter-electrode distance of 1 cm. All wires were carefully taped to reduce noise while allowing unrestricted movement. Data were collected telemetrically (Mega, ME6000) at 1000 Hz and subjected to full-wave rectification, using the equipment's own software (Mega, MegaWin). Baseline maximum EMG activity (mEMG) was calculated as a 25 point moving average. Average EMG data (aEMG) were calculated as the average activation 0.5 s before and after mEMG. Pre- and post-BBPT aEMG was then normalised to baseline mEMG and presented as a percentage (pre- and post-BBPT EMG).

Testing took place on the same time of day for each subject, and with a minimum of 24 hours intervening between testing sessions. Subjects refrained from any strenuous activities or resistance/ plyometric training at least 48 hours before each testing session.

Statistical analyses

Non-parametric statistics were followed due to the small sample size. For all performance variables, pre-BBPT values for the four conditioning contractions were examined with Friedman's test to examine that there were no differences at baseline between the four conditioning contractions. Wilcoxon's signed-rank test was used for paired comparisons to identify any changes between pre- and post-BBPT. EMG for each muscle group was compared using Friedman's test, followed by Wilcoxon's signed-rank test if a difference was revealed. In accordance to previous suggestions (23, 27) and approaches (11), no adjustments were made for multiple comparisons, as the data were directly or indirectly intercorrelated. All data are presented as mean ± SD, unless otherwise stated. Significance was set at $P<0.05$ and all statistical analyses were conducted using SPSS v15.0.

RESULTS

The subjects' 3RM bench press scores were 89.3 ± 12.5 kg. Friedman's test revealed no difference at baseline conditioning contraction values for all performance variables ($P>0.05$). Pre-post BBPT pairwise comparisons revealed a significant difference in P_{peak} for the ISO conditioning contraction ($P=0.038$, effect size = 0.77). No significant differences were revealed in F_{peak}, D_{max}, RFD, and EMG following the ISO, CON, ECC, and DYN conditioning contractions (P>0.05). The performance variables and percentage difference scores (%Δ values) for all conditioning contractions can be seen in Table 1, while aEMG activity data are presented in Table 2.

TABLE 1 ABOUT HERE

TABLE 2 ABOUT HERE

DISCUSSION

This is the first study to examine the effect of type of muscle contraction on upper body PAP. Considering the importance of the upper body on a range of sports (e.g. throwing events in athletics, weightlifting, rugby), the effect of PAP on upper body power performance has received very little attention. Although numerous studies have examined PAP in the lower limbs, these findings may not be transferable to the upper body. Muscle structure and function results in different activation levels between muscles (5), which could impact on their PAP capacity. Our results suggest that a 7-second maximal isometric contraction induces PAP that enhances power output performance following 12 min rest, while the concentric, eccentric and dynamic contractions did not yield a similar result.

The current study used a similar load and rest interval as Kilduff et al (19), but failed to reveal any performance improvement following the CON and DYN conditioning contractions. It is unclear why this discrepancy between the studies was present. One possible explanation may lie on the interaction between the resting interval and load, which can affect PAP (19, 20, 28). The load used may have been appropriate for the subjects' training phase in Kilduff et al (19) while not appropriate for the training phase of our subjects, which could have impacted on performance (19, 20). Furthermore, in a more recent study, Bevan et al (6) also used a protocol and sample similar to Kilduff et al (19) and reported that an 8-min and not a 12-min interval between the conditioning stimulus and performance appears to be optimal. It is therefore proposed that the optimal load for power production is assessed before any testing in future studies or training with individuals that are in a periodized training plan. This, in combination with careful consideration of the rest interval, could produce optimal results.

Although the type of conditioning contraction is a parameter that could affect PAP, little attention has been given to this aspect. Dynamic and isometric contractions have been primarily used in previous studies to examine PAP, with mixed results when performance improvement was considered. For example, using twenty three competitive athletes, Kilduff et al (19) demonstrated improvement in CMJ performance following 1 set of 3RM dynamic back-squats. In contrast, Jones and Lees (18) found no improvement in CMJ performance following 5-squats at 85% 1RM in eight strength trained athletes. To the authors' knowledge, only one study attempted to directly compare conditioning contractions (25), reporting that isometric contractions induced higher PAP than dynamic contractions. In the present study, isometric conditioning contractions induced PAP following a 12-min rest interval but dynamic conditioning contractions did not, offering partial support to Rixon et al's (25) findings.

Normalised aEMG results did not indicate any differences in muscle activity between pre- and post-BBPT for either pectoralis major or triceps brachii. In addition, no differences were revealed in muscle activity between the four conditioning contractions. Motor unit excitation has been suggested as one of two possible mechanisms responsible for the PAP phenomenon. Previous contractions increase post-synaptic potential leading to enhanced force generation (15). As no increased muscle activity was revealed for any of the two muscles examined following the conditioning contractions, it seems unlikely that the increase in power following the isometric conditioning contractions is due to neural factors. Indeed, Murphy and Wilson (21) suggested that neural factors did not affect performances after examining various muscle function tests with various loads. Although a comparison between the two muscles was not within the scope of the current study, Gentil et al (13) compared triceps brachii to pectoralis major activity during the bench press exercise and reported higher activation of the pectoralis major. However it would be erroneous to draw comparisons to our study, as the bench press presents markedly different biomechanical characteristics and muscle activation demands to the ballistic bench press throw (8, 22).

Although it never reached statistical significance, there was a trend for ISO to consistently produce positive results for all four performance variables compared to the other conditioning contractions (Table 1), suggesting that the isometric contractions may have induced a longer PAP period. If this was the case, it could explain why post-BBPT ISO values were consistently better than pre-BBPT. This could have a practical application to sports with prolonged resting periods where a maximum post-activation period would be beneficial. However, this is only a postulation and merits further research.

PRACTICAL APPLICATIONS

The phenomenon of PAP can be used to positively impact on power performance, both in the field and in the weights room, while the type of conditioning contraction appears to play an important role. Our study demonstrated that if a long period of inactivity is present (i.e. 12 min) – during competition or during training – then isometric contractions are the only conditioning contractions that can potentially offer some benefit. Future studies should consider examining type of conditioning contraction effects on PAP and the interaction between load and resting interval.

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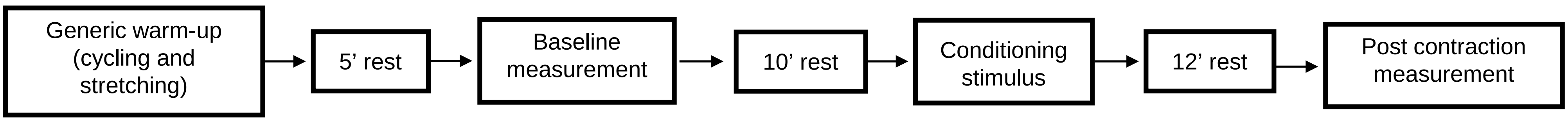
FIGURE LEGENDS

Figure 1. Schematic diagram of the experimental procedures. Measures of performance and muscle activity during a ballistic bench press throw were taken before (baseline) and following (post contraction) the conditioning stimuli, which were an isometric, concentric, eccentric, or dynamic barbell bench press performed on separate days.

Figure 1


Generic warm-up (cycling and stretching)
5’ rest
Baseline measurement
10’ rest
Conditioning stimulus
12’ rest
Post contraction measurement

TABLES

Table 1. Performance variables scores (mean±SD) and %Δ values (percentage difference post-BBPT – pre-BBPT) for ballistic bench press throw (BBPT) before (pre-BBPT) and after (post-BBPT) the different conditioning contraction stimuli.

Contraction	**ISO**			**CON**			**ECC**			**DYN**		
Variables	**Pre-BBPT**	**Post-BBPT**	**%Δ**	**Pre-BBPT**	**Post-BBPT**	**%Δ**	**Pre-BBPT**	**Post-BBPT**	**%Δ**	**Pre-BBPT**	**Post-BBPT**	**%Δ**
P_{peak} (W)	587 ± 116	605 ± 126*	2.8	548 ± 102	564 ± 108	3.3	593 ± 124	601 ± 152	0.8	585 ± 126	579 ± 113	-0.5
F_{peak} (N)	611 ± 80	627 ± 94	2.8	558 ± 74	567 ± 85	1.7	605 ± 98	605 ± 99	0.6	592 ± 111	571 ± 104	0.9
D_{max} (m)	0.66 ± 0.05	0.66 ± 0.05	0.3	0.70 ± 0.26	0.66 ± 0.07	-4.6	0.64 ± 0.05	0.66 ± 0.05	1.4	0.65 ± 0.07	0.65 ± 0.09	1.2
RFD ($N \cdot s^{-1}$)	13229 ± 445	13465 ± 512	0.2	13159 ± 1013	12657 ± 1573	-0.6	12726 ± 1219	13287 ± 350	0.0	13317 ± 418	13164 ± 550	0.5

ISO, isometric contractions; CON, concentric contractions; ECC, eccentric contractions; DYN, dynamic contractions; P_{peak}, peak power; F_{peak}, peak force; D_{max}, maximum displacement; RFD, rate of force development.* indicates significant difference between pre- and post-BBPT.

Table 2. EMG activity (mean±SD) for ballistic bench press throw (BBPT) before (pre-BBPT) and after (post-BBPT) the different conditioning contraction stimuli.

EMG (%)	**ISO**		**CON**		**ECC**		**DYN**	
Muscle	**Pre-BBPT**	**Post-BBPT**	**Pre-BBPT**	**Post-BBPT**	**Pre-BBPT**	**Post-BBPT**	**Pre-BBPT**	**Post-BBPT**
PM	32.7 ± 5.2	33.8 ± 7.0	29.8 ± 3.7	26.1 ± 5.7	30.7 ± 5.7	28.3 ± 6.4	28.0 ± 8.5	29.1 ± 7.1
TB	27.9 ± 7.1	30.7 ± 9.3	36.1 ± 7.5	29.7 ± 7.7	29.3 ± 5.2	30.9 ± 7.2	30.2 ± 6.6	31.8 ± 9.8

ISO, isometric contractions; CON, concentric contractions; ECC, eccentric contractions; DYN, dynamic contractions; PM, Pectoralis major; TB, Triceps brachii.