Impact of accommodating resistance in potentiating horizontal jump performance in professional rugby league players.

Original investigation

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Abstract

This study investigated the efficacy of deadlifts and box squats, with a combination of traditional and accommodating resistance, as a potentiating (PAP) stimulus of standing broad jumps (SBJ) in a multiple set contrast protocol. Twelve professional rugby league players (21.4 ± 2.5yrs; 181.3 ± 8.3cm, 91.9 ± 8.8kg; 1RM back squat/BM 1.59 ± 0.21; 1RM deadlift/BM 2.11 ± 0.25; ≥3 years resistance training experience) performed baseline SBJ before a contrast PAP protocol involving 2 repetitions of 85% 1RM box squat or deadlifts, loaded with a combination of traditional barbell weight (70% 1RM) and elastic band resistance (~15% 1RM), followed by two SBJs. Exercises were separated by 90s, and four contrast pairs were performed in total. Using a repeated measures design, all subjects performed the squat followed by the deadlift and finally the control (SBJ only) condition in the same order across consecutive weeks. Changes from baseline in SBJ distance were moderate for the box squat (Effect Size=0.64-1.03) and deadlift (ES=0.80-0.96) and trivial in the control condition (ES=0.02-0.11). The magnitude of differences in PAP effect were considered moderate (d = 0.61) for set 1, trivial for set 2 (d = 0.10) and set 3 (d = 0.05) in favor of box squats, and moderate for set 4 (d = 0.58) in favor of deadlifts. Accommodating resistance, either box squats or deadlifts are an effective means of potentiating SBJ performance across multiple sets of a contrast protocol with only 90s rest.

Introduction

There exists a large and still growing body of evidence to support the phenomenon of post-activation potentiation (PAP) (1,2,3,4). In practical terms, PAP can be described as a lighter or explosive exercise which has been enhanced by a previous muscular contraction, or potentiating stimulus (1, 2). When properly executed, a PAP protocol has the potential to increase the velocity and therefore the power output of the explosive exercise (1,2) resulting in a greater acute (3) and chronic (4) training stimulus.

It has been reported that recovery periods of 5 to 8 minutes may be necessary after the performance of a heavy resistance potentiating stimulus before a PAP effect can be seen in horizontal jump exercise (5, 6). In an applied setting, such as professional team sports, contrast protocols of alternating heavy and light sets, or a heavy exercise paired with an explosive or ballistic exercise are often used (7,8). The requirement of such lengthy recovery periods to induce a PAP effect could extend the duration of a training session so that it then becomes impractical to implement. One possible solution to this problem is the use of variable resistance training (VRT) utilizing accommodating resistance in the form of elastic bands or weighted chains attached to a barbell. VRT involving 60-70% of one repetition maximum (1RM) from traditional barbell weight (TRAD), plus an additional 15-20% from either bands or chains, has previously been shown to elicit a PAP effect after only 90s of rest (9,10,11).

Most of the available literature has examined a single potentiating stimulus followed by either a single explosive exercise, or multiple light exercises performed at different points of time (12,13,14). Recent research involving VRT has shown that the PAP effect can be elicited across multiple sets which may be more practical from an applied point of view (9,10,11). One such applied setting is in the preparation of professional rugby league players. Sprint running, and more specifically sprint accelerations have been reported as being key components for success during offensive and defensive actions in rugby league (15,16). For example, Baker & Newton (16) reported a significant 7% difference in sprint momentum (body mass multiplied by 10m sprint velocity) between professional and semi-professional rugby league players.

The principle of specificity would dictate that to increase sprint acceleration, performing sprints of up to 10m in a contrast protocol of this kind would be an appropriate method for rugby league players. This can be a challenging strategy to implement with large squads of players as it is common that facility and logistical constraints may not allow weight lifting and sprinting to be performed simultaneously. 10m-sprint velocity has been reported to be significantly correlated ($r = 0.77$; $P < 0.05$) to a standing broad jump (SBJ) (17) making the exercise a potential alternative during training where a 10m sprint is not possible. It has been suggested that coaches seeking to enhance the transfer of training effect from gym-based strength and power sessions should look to implement horizontally oriented jumps and plyometrics (18,19).

In a recent study, Seitz *et al.* (11) used box squats as the potentiating stimulus for subsequent SBJ, however this may not be the only suitable choice. Acceleration performance is reliant upon an athletes' ability to produce high levels of horizontal ground reaction forces (GRF) (20) while research has revealed a significant relationship ($P = 0.024$) between horizontal GRF and hamstring activity (21). Box squats have previously been shown to be a predominantly knee joint, or quadriceps dominant exercise (22) and it could be argued that, due to its hip dominance and greater activation of the posterior chain, the deadlift may be a suitable alternative (23). The purpose of this study therefore, is to investigate the efficacy of deadlifts and box squats, with a combination of traditional and accommodating resistance, as a potentiating stimulus of standing broad jumps in a multiple set contrast protocol.

Methods

Twelve reserve team professional rugby league players from a club in the Betfred Superleague ([mean ± SD] age: 21.4 ± 2.5y; height 181.3 ± 8.3cm; body mass 91.9 ± 8.8kg; 1RM back squat/BM 1.59 ± 0.21, 1RM deadlift/BM 2.11 ± 0.25; ≥ 3 years resistance training experience) volunteered to complete two familiarization sessions and three experimental sessions. All subjects were informed of the aims, benefits, risks, and procedures of the study before participating in the investigation and were required to read and sign an informed consent form. All procedures in this investigation were conducted in accordance with the declaration of Helsinki.

Study design & Experimental procedures

The data collection process took place mid-way through the competitive season during which time two reserve-team matches were played. Furthermore, three field-based team sessions and one additional resistance training session for the upper-body were performed each week. Other than game time during the two matches, the training loads and periodization of the upper-body gym sessions were the same for all participants. The reserve team squad were made available for the study, however due to the nature of rugby league as a collision sport, only 12 players remained injury free and available for all sessions. During the first testing and familiarization session, all subjects were assessed for back squat 1RM, anthropometric data were recorded and participants were familiarized with the box squat PAP protocol. Seven days later, the first experimental session took place. All subjects performed the procedure, during which players were required to perform a contrast PAP protocol comprising 2 paused box squats with TRAD + bands alternated in a set-by-set basis with SBJ for a total of four sets. After a further seven days, the second testing and familiarization session, this time for the deadlift 1RM and deadlift PAP protocol, took place. One week after the deadlift 1RM testing, the deadlift experimental condition was performed where all subjects were required to perform a contrast PAP protocol comprising 2 deadlifts with TRAD + bands alternated in a set-by-set basis with SBJ for a total of four sets. There was a final 7-day break before the control protocol of 4 sets of SBJ only were performed. A repeated measures design was used and the non-randomized order was implemented due to both logistical and time constraints imposed by the coaching staff.

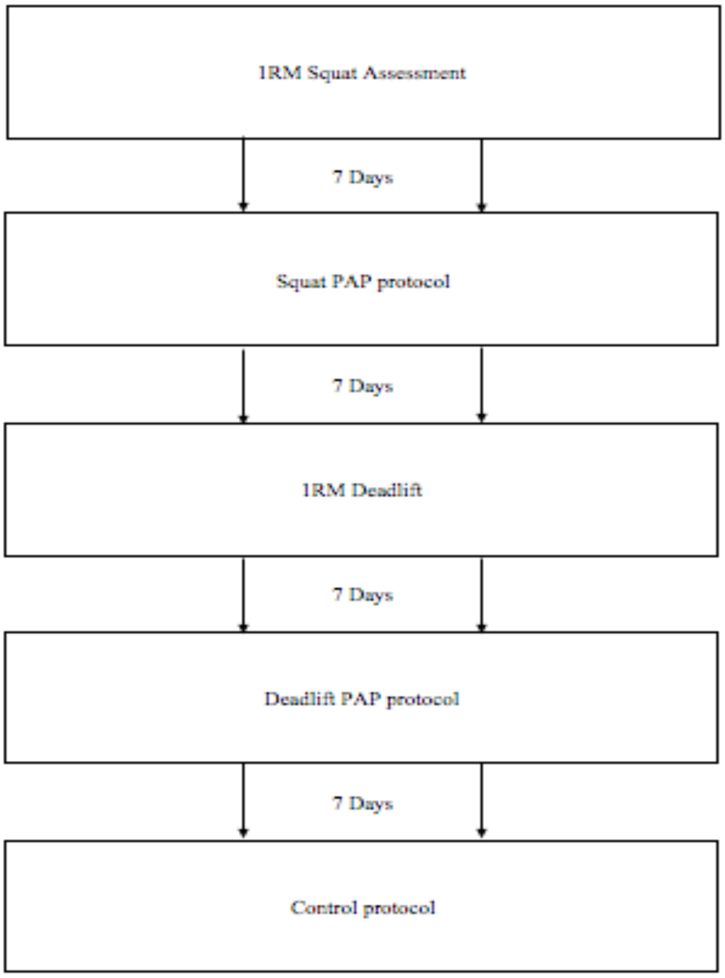

Figure 1. A flowchart depicting the experimental design whereby all subjects performed the squat, deadlift, and control conditions in order across consecutive weeks.

Anthropometric measurement

Height and body mass were measured using a calibrated stadiometer (Seca, 213 portable stadiometer, Hamburg, Germany) and a Seca 803 scale (Seca, Hamburg, Germany) respectively.

Band tension measurement

Two elastic bands (EliteFTS, Pro resistance bands, London Ohio, U.S.A) were anchored to the bottom of the squat rack (Hammer Strength Power Rack, Life Fitness, Rosemont IL, USA) and looped over the sleeves on an unloaded barbell (Eleiko, Halmstadt, Sweden). Subjects were **stationary** in both the lockout and bottom position of the box squat or deadlift while standing on a force plate sampling at 600Hz (400 Series Performance Force Plate, Fitness Technology, Australia), the mass of the player, barbell and box were accounted for and the resistance produced by the bands at either position was measured. The band tension was the average over the entire range of motion and represented 18.61 ± 1.02 to 10.37 ± 1.22 % at the top and bottom of the box squat, and 29.24 ± 1.97 to 0.00 ± 0.00 at the top and bottom of the deadlift.

Table 1. The resistance used for the box squats and deadlifts with bands during the warm-up and the contrast protocol.

Box Squat			
	Warm-up Set 1	Warm-up Set 2	Box Squat Contrast Protocol
Free-weight resistance (%1RM)	30	50	70
Band Resistance* (% 1RM)	14.5 ± 1	14.5 ± 1	14.5 ± 1
Total Resistance (% 1RM)	44.5 ± 1	64.5 ±1	84.5 ±1
Deadlift			
	Warm-up Set 1	Warm-up Set 2	Deadlift Contrast Protocol
Free-weight Resistance (% 1RM)	30	50	70
Band Resistance* (% 1RM)	14.6 ± 1	14.6 ± 1	14.6 ± 1
Total Resistance (% 1RM)	44.6 ± 1	64.6 ±1	84.6 ±1

1RM squat and deadlift assessment

A specific preparation took place consisting of 10 repetitions with an empty barbell, one-minute of rest, six repetitions at 40%, one-minute of rest, four repetitions at 60%, two-minutes of rest, two repetitions at 80%, three-minutes of rest before one final repetition at 90% of an estimated 1RM. Three-minutes of recovery time were allowed before the first 1RM attempt, with a further four-minutes between subsequent trials (11). The load on the bar was adjusted with the perception of difficulty of the participants who continued until a maximum load was reached. Squat depth was required to be at a level whereby the top of the players' thighs reached at least parallel to the floor, which was visually assessed by a qualified strength and conditioning professional. Following the 1RM test, the subjects were familiarized with the experimental procedures took place.

Baseline SBJ assessment

Participants completed a standardized warm-up before performing two sub-maximal repetitions of the SBJ, followed by one max-effort jump with 30s between each. After a further two minutes of rest, two max effort SBJ were completed with one minute of recovery time. The trial resulting in the greatest distance represented the baseline measurement. Subjects started with their toes on a line marked at 0 cm and were instructed, with strong verbal encouragement, to jump as far as possible with an arm swing. The distance from the back of the heel to the 0 cm start line was measured in accordance with previous research (11). The intraclass correlation coefficient for SBJ was 0.96 with 95% confidence interval = 0.87-0.99.

Contrast PAP protocol

After baseline SBJ measurement, a specific preparation routine was performed. Two sets of four repetitions at 30 and 50% 1RM accommodated with band tension were completed (Table 1.), while the paused box squat was used with a percentage of the back squat 1RM in accordance with previous research (9,11). This style of warm-up was used before the heavy potentiating stimulus to mimic a typical weights session involving PAP contrast sets (9,11). The PAP contrast sets protocol was adapted from Seitz *et al.* (11) and consisted of two reps with 70% 1RM from TRAD plus an approximately 15% from bands followed by 90s of rest. Players then completed two max-effort broad jumps with 10s between each followed by a further 90s before starting the next contrast set. A total of four contrast sets were performed and the greatest SBJ distance from each set was recorded

The control condition consisted of the same protocol except the box squats and deadlifts were replaced with two SBJ. The following equation was used to determine the postactivation potentiation effect: $\%PAP = [(SBJ_{\text{contrast PAP protocol}} - SBJ_{\text{baseline}}) \div SBJ_{\text{contrast PAP protocol}}] \times 100$ where, $SBJ_{\text{contrast PAP protocol}}$ = the greatest SBJ distance recorded in each set of the contrast PAP protocol and SBJ_{baseline} = the baseline SBJ distance (11).

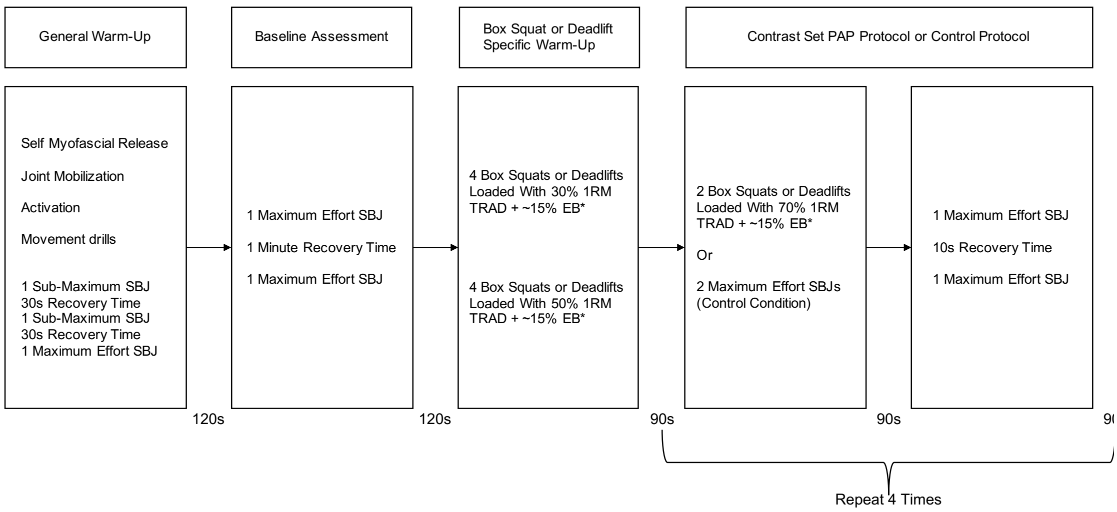

Figure 2. A schematic representation of the experimental sessions. * The mean resistance coming from the elastic bands across the entire range of motion was 14.5 ± 1% of 1RM for the box squat, and 14.6 ± 1% of 1RM for the deadlift. PAP =

Post-activation potentiation; SBJ = Standing broad jump; EB = Elastic band resistance; TRAD = Traditional barbell weight

Statistical analyses

Effect size statistics were used to calculate the changes in jump distance before and after each set of the protocols and were calculated by dividing the difference in means by the pooled standard deviation. Cohen's d was calculated to determine the magnitude of difference in PAP and maximum PAP effect between squat and deadlift protocols. Changes were considered trivial <0.2; small 0.2-0.6; moderate 0.6-1.2; and large 1.2-2 (24). All statistical analyses were carried out using SPSS Statistics for Macintosh (International Business Machines Corp, Armonk, New York, USA).

Results

For the box squat protocol, changes were moderate for sets one, (ES=1.03, 95%CI=0.54-1.52; two, (0.9, 0.49-1.31); three (0.96, 0.36-1.56); and four (0.64, 0.05-1.23) (Fig. 4.). Changes for the deadlift protocol were also moderate for sets one (0.80, 0.22-1.38); two (0.96, 0.36-1.56); three (0.84, 0.42-1.26); four (0.92, 0.32-1.52) set (Fig.4.). In contrast, changes were unclear for all sets of the control condition (set 1, 0.11, -0.47-0.69; set 2, 0.02, -0.39-0.43; set 3, 0.04, -0.54-0.62; set 4 0.11, -0.47-0.69) since confidence intervals cross both negative and positive values.

*Table 2**.*** Percent changes and effect size statistics for standing broad jump performance across the four sets of the contrast box squat, contrast deadlift, and control protocols. Percent change data presented as mean ± standard deviation. ES = effect size, 95% CI = 95% confidence interval.

	Set 1	Set 2	Set 3	Set 4
Contrast Box Squat Protocol				
% Change from baseline	6.01 ± 2.25	5.13 ± 2.04	5.14 ± 2.12	3.82 ± 2.08
ES, 95% CI	1.03, 0.54-1.52	0.90, 0.49-1.31	0.96, 0.36-1.56	0.64, 0.05-1.23
Contrast Deadlift Protocol				
% Change from baseline	4.64 ± 2.24	5.35 ± 2.20	5.00 ± 3.1	5.31 ± 2.97
ES, 95% CI	0.80, 0.22-1.38	0.96, 0.36-1.56	0.84, 0.42-1.26	0.92, 0.32-1.52
Control Protocol				
% Change from baseline	0.80 ± 1.28	0.24 ± 2.73	0.30 ± 1.42	0.67 ± 2.24
ES, 95% CI	0.11, -0.47-0.69	0.02, -0.39-0.43	0.04, -0.54-0.62	0.11, -0.47-0.69

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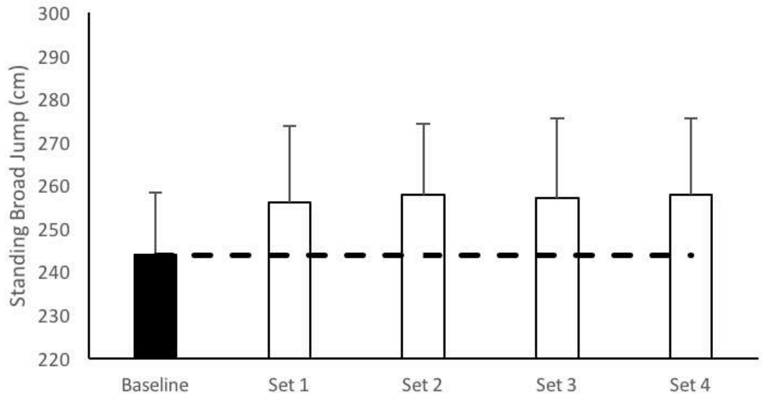

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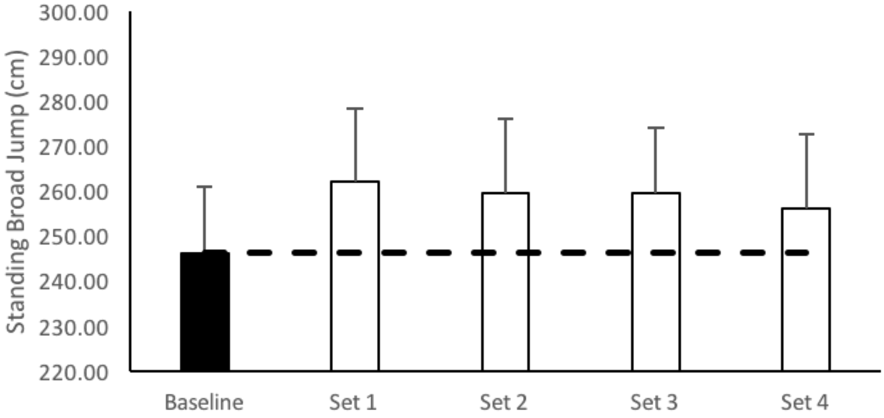

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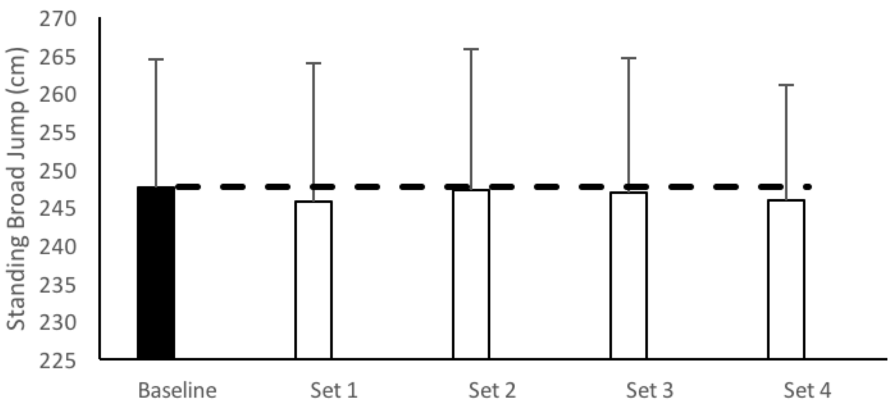

Figure 3. Changes in standing broad jump performance across four sets of the squat (A), deadlift (B) and control (C) protocols.

The magnitude of differences in PAP effect between conditions were considered moderate (*d* = 0.61) for set 1, trivial for set 2 (*d* = 0.1) and set 3 (*d* = 0.05) and small for set 4 (*d* = 0.58). The difference in maximum PAP effect between protocols was considered small (*d* = 0.3).

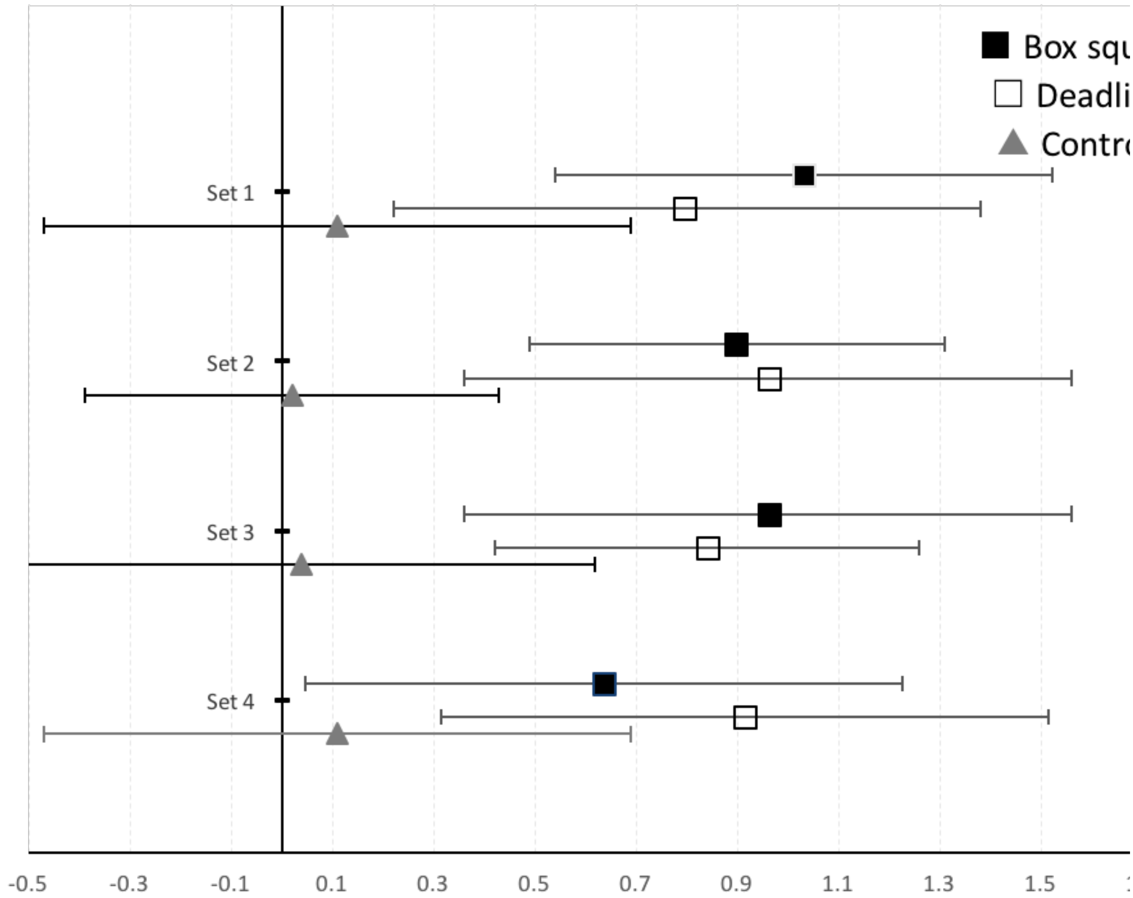

Figure 4. Standardized effect sizes of the box squat and deadlift conditions. Plots represent the magnitude of changes between baseline standing broad jump and the standing broad jump recorded in each of the four sets of the contrast protocol. Error bars indicate 95% confidence intervals of the mean difference between time points.

Discussion

The purpose of this study was to establish whether the deadlift could be as effective as a previously validated protocol involving box squats at potentiating SBJ performance across four PAP contrast sets. The results of the present investigation indicate that a PAP effect of 6.01 ± 2.25% or 5.35 ± 2.20% can be elicited after 90s rest following the completion of either box squats or deadlifts accommodated with bands. Change in the control group was "unclear" and it may be that any change could be too small to be practically important. This is evidenced by mean difference, however the wide CI would indicate that interpretation of this in the control group needs to be done with caution. The findings of the study suggest that participants had varied responses to the control condition and may need further investigation to elucidate if there was no clear PAP effect in the control group.

These results are consistent with Baker (9), who reported a 6.7% increase in peak power output (PPO) 90s after a set of two heavy box squats accommodated with bands. In another study, Baker (10), observed that a set of three heavy bench presses loaded with TRAD plus chains could increase PPO by 4.8%, again after only 90s of rest, while Seitz *et al.* (11) reported a 5.0 ± 4.1% increase in SBJ distance after two heavy paused box squats combining TRAD and bands. This outcome is important because, to the authors knowledge, this is the first study to establish that deadlifts accommodated with bands can potentiate horizontal jump performance after only 90s of rest. Further, it provides evidence to indicate that this may be a more time efficient manner to potentiate horizontal jump performance than the previously reported five to eight minutes (5,6).

The main differences in these studies are that Evetovich *et al.* (5) used a set of three parallel back squats at 85% 1RM using only TRAD to potentiate a subsequent SBJ after eight minutes of rest. Ruben *et al,* (6) by comparison used protocol of ascending intensity back squats up to 90% 1RM, again with TRAD only, to increase horizontal force and power outputs measured over multiple hurdle jumps after five minutes of rest. From an applied perspective, a protocol needing only 90s rest between sets would be advantageous to a strength and conditioning coach, who may have large groups of athletes to manage alongside the competing demands of tactical and technical sessions throughout the training day. Although the exact neuromuscular mechanisms behind the potentiating effect of VRT are unknown, two potential explanations are proposed. Firstly, any exercise with an ascending strength curve involves a deceleration phase towards the end of the concentric portion of the lift which may be overcome through VRT (25) This can allow the athlete to operate at near-maximum levels throughout a greater range of motion, thus allowing the muscles to operate closer to their maximum capacity which may allow for a greater potentiating effect. Secondly, Tillin & Bishop (26) stated that there is a relationship between fatigue and potentiation whereby PAP can occur earlier if less fatigue is present. Therefore, VRT may be less fatiguing than TRAD when the same intensity is used (27) and may allow PAP to occur earlier.

The second finding of this study is that the above established potentiating effect is present across multiple sets of a contrast PAP protocol. This result is consistent with several studies investigating PAP across a multiple set contrast protocol (9,10,11). Baker (9), reported that loaded jump squat peak power output was increased by 6.4 - 7.5% after two heavy box squats loaded with TRAD plus VRT across three sets. Likewise, Baker (10) investigated the effects of three heavy bench presses accommodated with chains on 60kg weighted bench throw performance. The reported peak power output was increased by 4.8 - 7.7% across three sets. Seitz *et al*. (11) published the only study to date investigating the potentiation of horizontal jump performance across multiple contrast sets, the authors reported increases in SBJ distance of 4 - 5.7% across four sets. Each of these studies, including the present one, used sub-maximal loads to induce the PAP effect, which may be of importance when looking to implement a multiple set protocol.

Talpey, Young, & Saunders (28) reported that when using a 5RM load, countermovement jump peak power output was increased only in the first set and decreased in the second and third of a contrast protocol. One possible explanation is that, in a single set a repetition maximum load will favor potentiation over fatigue (13). Across multiple sets however, by the time subsequent sets are performed, fatigue may have accumulated and the PAP effect muted (26). The present study is only the second to show that horizontal jump performance can be potentiated across multiple sets, and the first to use the deadlift as the conditioning activity. The potential benefit being that a greater training stimulus should occur over time, which could, in turn, lead to an increased ability to apply force horizontally (3). Studies have highlighted the ratio of horizontal to vertical ground reaction forces and their importance to acceleration and sprint performance (20,21,29,30). This is of importance for team sports, such as rugby league which require high levels of sprint acceleration (15,16). The hypothesis that training to enhance horizontal force can benefit acceleration performance is supported by Della Iacono *et al.,* (18) who reported a greater improvement in 10m sprint velocity after a three-week training intervention involving horizontal jumps compared to a similar protocol using vertical jumps (ES = 0.66 and 0.16 $P < 0.05$ for horizontal and vertical jumps respectively). Likewise, Loturco *et al.* (19) found greater improvements in sprint-time (-8.5% vs -4%, $P < 0.05$) after 10 weeks of either horizontal- or vertical-drop jumps.

When the magnitude of the PAP effect was analyzed across the four sets, a difference between conditions was observed. The box squat condition displayed an increased level of PAP in the first set which tended to decrease as the sets continued while the deadlift condition produced a more consistent response (Fig.4.). This may have been due to the eccentric portion and possible stretch shortening cycle contribution of the box squat, which was not present in the predominantly concentric deadlift. Although subjects were instructed to pause briefly at the bottom position of the box squat, this has been shown to have little impact on the kinetic variables or muscle activation when compared to a non-paused back squat (22). This differs from the findings of Seitz and colleagues (11) who reported a more consistent effect from the squat condition (ES = 0.69, 0.58, 0.81, 0.67). While Seitz *et al.* (11) used a similar protocol, the authors were able to control physical activity for 48 hours before the experimental condition which may play a part in the observed differences. Furthermore, there were differences between the levels of relative strength in the back squat seen in Seitz *et al.* (11) (1RM/BM = 1.85) and the present study (1RM/BM = 1.59). This may have led to a discrepancy in findings since greater levels of relative strength are associated with a larger PAP effect (11, 26). This phenomenon could also be a mechanism to explain the aforementioned differences in PAP effect between conditions. Since differences in relative strength levels of the exercises performed (1RM/BM = 1.59 vs 2.11 for squat and deadlift respectively) were recorded it stands to reason that a different PAP response could be observed. This shows that there may be a dose-response relationship between relative strength and PAP, whereby relatively weaker individuals may require less volume in order to maintain higher power outputs. It is an area which warrants further research to broaden our understanding of the potentiating effects of accommodating resistance.

Practical application

Based on the present results, strength and conditioning practitioners seeking to implement a contrast set PAP protocol should consider using a combination of ~70% 1RM TRAD plus ~15% band tension as a potentiating stimulus. This will allow a shorter rest period of 90s to be used as opposed to the previously reported five to eight minutes (5,6). In accordance with previous research, the PAP effect can be elicited across four contrast sets which will allow a full protocol to be completed in approximately 12 minutes, which may be of use when dealing with large numbers of athletes and other competing demands. Furthermore, previously only box squats have been shown to potentiate horizontal jumping performance after 90s, and over multiple sets (11). The present findings are the first to report that similar levels of potentiation can be achieved with the deadlift as a conditioning stimulus and that they can be reproduced across four PAP contrast sets with 90s between each. Limitations of the present study include the inability to truly randomize the subjects into separate groups and also the varying match demands prior to and during the data collection process. Issues such as these are a feature of performing research on professional in-season athletes and are, as such, unavoidable. Future research is warranted to examine the contribution of eccentric, concentric and stretch shortening cycle actions to the acute and temporal PAP response to accommodating resistance exercise. Further research could also be undertaken to assess a longer-term training intervention of this type and how it might transfer to variables such as acceleration and sprinting performance.

Conclusion

Accommodating resistance, either box squats or deadlifts are an equally effective means of potentiating SBJ performance across multiple sets of a contrast protocol with only 90s of rest.

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