PREVIOUS BALLISTIC AND HEAVY CONDITIONING STIMULI CAN ACUTELY ENHANCE THROWING PERFORMANCE

Theodoros M. Bampouras[1], Alex Gill[2], and Joseph I. Esformes[2]

Lancaster Medical School, Lancaster University, Lancaster, UK[1]
Cardiff School of Sport and Health Sciences, Cardiff Metropolitan University, Cardiff, UK[2]

The purpose of this study was to compare the effects of a ballistic and a heavy load conditioning stimulus on subsequent bench throw performance. Eleven male, competitive rugby players (mean ± SD: body mass 91.5 ± 9.6kg, height 1.79 ± 0.03 m) with at least two years of resistance training exercise performed two ballistic bench throws after warm up. Following a 10-min rest, they performed either a ballistic bench throw (BAL) or a heavy load bench press (HEAVY) conditioning stimulus. Subsequent to a 4-minute rest, they performed another two ballistic bench press throws. No significant differences were revealed for peak power, peak force, rate of force development and force at peak power for either conditioning stimulus. However, significant differences were revealed for bar displacement for the BAL group, and for peak velocity and velocity at peak power for both groups. The results suggest that a ballistic conditioning stimulus can induce post activation performance enhancement and it appears more sport specific in its results than a heavy load conditioning stimulus.

KEYWORDS: explosive performance, postactivation potentiation, peak velocity

INTRODUCTION: Following muscular contractions and subsequent brief rest, voluntary muscular performance is enhanced (Esformes & Bampouras, 2013). This phenomenon (previously termed postactivation potentiation, PAP) has recently been termed postactivation performance enhancement (PAPE; Blazevich & Babault, 2019) and it refers to the muscular performance enhancement seen beyond the duration of time one would expect PAP to occur (i.e. <3 minutes) following high-intensity voluntary muscular contractions. PAPE, therefore, has intuitive appeal for sports where brief, maximal explosive efforts are required, such as sprinting, jumping, or throwing.
The majority of literature has used isometric or heavy load dynamic exercises as a conditioning stimulus to induce PAPE, with successful results (see review by Seitz & Haff, 2016). Only a few studies have used ballistic or plyometric exercises as a conditioning stimulus, and only two of those examining upper body performance (Esformes et al. 2011; Boden et al. 2019). The effect of ballistic exercise as a conditioning stimulus, however, may prove more beneficial to enhancing performance of subsequent exercise than heavy load exercises. The lower fatigue this type of exercise is likely to induce will consequently reduce the rest required between the end of the conditioning stimulus and subsequent performance. Secondly, ballistic exercises as a conditioning stimulus are similar to the actual performance, therefore increasing the specificity of the conditioning stimulus activity (Maloney et al. 2014). And finally, plyometric activities prior to the actual performance have less apprehension in being used by the athletes (Esformes et al. 2011). Therefore, the aim of the study was to compare the effects of a ballistic and a heavy load conditioning stimulus on subsequent bench throw performance.

METHODS: Eleven male, competitive rugby players (mean ± SD: body mass 91.5 ± 9.6kg, height 1.79 ± 0.03 m) volunteered to participate. All subjects had actively participated in resistance training exercise for at least 2 years prior to the experiment. The subjects were free of any injury or medical conditions for at least six months prior to testing. The study was approved by the Institutional Ethics Committee and the subjects provided written, informed consent to participate in the study.
All subjects visited the laboratory to familiarise themselves with the bench press and bench throw exercises. Subjects' anthropometrics were obtained in this session; height was measured to the nearest 0.1cm using a Holtain Fixed Stadiometer, Harpenden, UK) and body

mass was measured to the nearest 0.1kg (Model 770, Seca, UK). In addition, the subject's bench press one repetition maximum (1RM) was determined on a Smith machine, according to the guidelines set by Baechle and Earle (2000). 1RM was the load that caused failure or significant exercise technique alteration. To establish the 1RM load, subjects attempted one repetition of a load and, if successful, increased the loading. Subjects were permitted up to a 5-minute rest interval between efforts. Around 3 to 5 trials were required to establish each subject's 1RM.

The subjects were then required to attend the laboratory on two separate sessions. A standard dynamic warm up protocol was used for all sessions to avoid injury. This consisted of 400m jogging and upper body warm up drills of medicine ball throws and medicine ball slam downs for 3 sets of 8 repetitions. On completion of the warm up, the subjects performed two bench throws at 40% 1RM (Pre-BT), with this particular load used as it has been reported to be optimal for peak power output in rugby players (Kilduff et al. 2007). Following a 10 minute rest (to avoid possible potentiation effects by the Pre-BT), the subjects performed either a ballistic exercise (BAL) or a heavy load (HEAVY) conditioning stimulus in a randomised, counterbalanced order. BAL consisted of one set of bench throw exercise at 40% 1 RM, and approximately 5s were required by each subject to complete the bench throw exercise. HEAVY consisted of one set of 3RM (~87% 1RM) bench press, and approximately 10s were required by each subject to complete the bench press exercise. The bench press and the bench press throw exercises were completed as quickly and explosively as possible and performed on a Smith machine. For either movement to be deemed successful, the bar had to touch the chest of the subject and return to full extension of the arms. Finally, following the conditioning stimulus, subjects remained inactive for a period of 4 minutes (a duration sufficient to avoid confusions with PAP and still induce maximum benefits; Blazevich & Babault 2019) before performing two more bench throws (Post-BT).

Peak power (Ppeak), peak force (Fpeak), distance (D), peak velocity (Vpeak), rate of force development (RFD), force at peak power (F@Ppeak), and velocity at peak power (V@Ppeak) were measured using a linear position transducer (Ballistic Measurement System [BMS]; Fitness Technology, Skye, South Australia, Australia), fixed on the Smith machine's 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 (Alemany et al. 2005). Subjects were instructed to avoid strenuous activities or resistance training at least 24 hours prior to testing. All tests took place with a minimum of 24 hours intervening and at the same time of the day. A schematic of the experimental procedures can be seen in Figure 1 below.

The average of the two bench throws for Pre-BT and Post-BT was used for further analysis. As some variables were not normally distributed, Friedman's test was used to examine for differences between all variable levels, followed by Wilcoxon's test where differences were revealed. Because the measurements were directly or indirectly intercorrelated, no adjustments were made for multiple comparisons, but caution was exercised in the interpretation of the results and effects sizes were calculated for significant comparisons. Significance level was set at 0.05. For all statistical analysis IBM SPSSv23 was used.

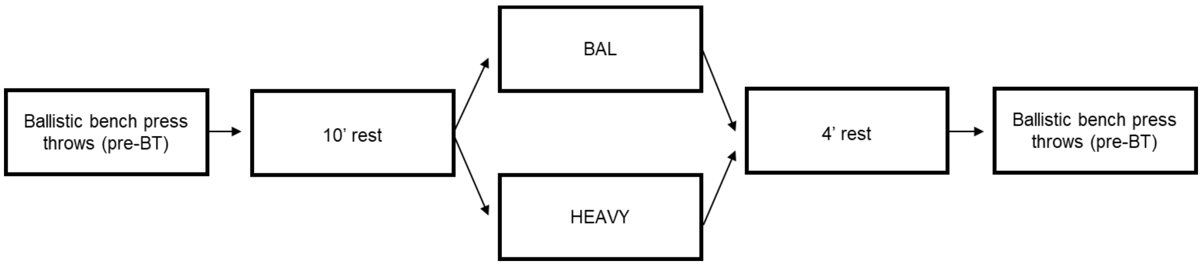

Figure 1. Schematic of the experimental procedure used. BAL, 1 x 3 repetitions of 40% 1RM ballistic bench throws, HEAVY 1 x 3 3RM bench presses.

RESULTS: No significant differences were revealed for Ppeak, Fpeak, RFD and F@Ppeak ($P > 0.05$) for any of the two conditioning stimuli. However, significant differences were revealed for D for the BAL group only ($P < 0.05$), and for Vpeak ($P < 0.05$) and V@Ppeak ($P < 0.05$) for both groups. All results can be seen in Table 1 below.

Table 1. Pre- and Post-BT performance variables scores for the ballistic (BAL) and heavy load (HEAVY) conditioning stimulus conditions. Data is presented as mean ± SD. *denotes significant difference from respective Pre-BT. Effect sizes of significant comparisons are included in brackets.

	BAL		HEAVY	
	Pre-BT	Post-BT	Pre-BT	Post-BT
Ppeak (W)	378.7 ± 68.5	436.8 ± 71.5	350.1 ± 118.7	451.9 ± 103.2
Fpeak (N)	380.2 ± 75.6	413.3 ± 110.2	416.1 ± 71.7	390.8 ± 94.9
D (m)	0.20 ± 0.05	0.25 ± 0.05* (1.0)	0.25 ± 0.14	0.26 ± 0.06
Vpeak ($m·s^{-1}$)	1.1 ± 0.4	1.2 ± 0.3* (0.3)	1.0 ± 0.5	1.3 ± 0.2* (0.8)
RFD ($N·s^{-1}$)	9291 ± 1904	9563 ± 1980	10550 ± 1562	9441 ± 1866
F@Ppeak (N)	319.0 ± 58.6	328.1 ± 63.0	349.5 ± 47.0	326.3 ± 70.1
V@Ppeak ($m·s^{-1}$)	1.0 ± 0.4	1.2 ± 0.2* (0.6)	0.9 ± 0.5	1.2 ± 0.2* (0.8)

BAL, ballistic conditioning stimulus; HEAVY, heavy load conditioning stimulus; Pre-BT, bench throw before the conditioning stimulus; Post-BT, bench throw before the conditioning stimulus; Ppeak, Peak power; Fpeak, peak force; D, distance; Vpeak, peak velocity; RFD, rate of force development; F@Ppeak, force at peak power; V@Ppeak, velocity at peak power;

DISCUSSION: The aim of the present study was to examine whether a ballistic conditioning stimulus is able to induce PAPE on subsequent bench throw performance and compare it with a heavy load conditioning stimulus. Our findings show that a ballistic pre-activity could improve aspects of subsequent performance and, therefore, could be considered a viable means of inducing PAPE.

This is the first study that has shown that a ballistic conditioning stimulus could positively impact a subsequent ballistic performance on the upper body. Our findings add to the literature on PAPE and potentially offer a practical alternative to heavier loads for improvement of subsequent performance. The small number of studies examining ballistic or plyometric activities as a conditioning stimulus aside, there is no consensus on the outcomes of conditioning stimulus (Seitz & Haff, 2016). A study by Bodden et al. 2019, conceptually similar to the present one, examined the effect of a ballistic and non-ballistic conditioning stimulus on subsequent push-up performance. They found that both ballistic and non-ballistic conditioning stimuli decreased push up performance, as measured by impulse. Our results do not follow this pattern, showing that a ballistic conditioning stimulus can acutely improve certain performance parameters. The discrepancy between our study and Bodden et al.'s can most likely be placed on the load and rest used. Bodden et al. (2019) used 13 repetitions of a range of 1RM percentages (30%-90%) as the conditioning stimulus, with less rest interval. It is very likely that the increased fatigue induced by this protocol prevented gains in performance, a notion explored by Tsoukos et al. (2019) who showed that PAPE effects were modulated by prior fatigue. Further, the load lifted during the push ups (69.2% - 75% of body mass, Suprak et al. 2011) is heavier than the load used in the present study (40% 1RM), impeding more the ability for increased velocity movements. The present results support the use of a lower number of ballistic repetitions with a larger rest interval to obtain performance increases.

Both conditioning stimuli had a positive impact on performance. Both affected the velocity-related variables (Vpeak and V@Ppeak), but with BAL impacting on V@Ppeak more than Vpeak (20% v 9.1% respectively), while HEAVY having a similar impact on both (30% v 33%); the higher impact of HEAVY is also supported by the larger effect sizes. It is feasible that despite the lower BAL load fatiguing the muscle less, the load was actually less than optimal to yield higher PAPE effects. Alternatively, it could also be that because the BAL load was

lower, a smaller resting period would have shown greater effects, as suggested by Seitz & Haff (2016).
Interestingly, despite the larger change in velocity with the HEAVY conditioning stimulus, bar displacement was only significantly higher with the BAL conditioning stimulus. The explanation might exist in the different kinematic characteristics between the two conditioning stimuli. The ballistic bench throw has no deceleration phase in the movement (as the bar is allowed to leave the hands at the end of the movement) while the bench press contains a deceleration phase towards the end of the movement (Newton et al. 1996). As the aim of the bench throw is increased velocity at release, it is likely that the Post-BT Vpeak increase was achieved at release, increasing the subsequent bar displacement (as it was released at a higher velocity). On the contrary, with the bench press having a deceleration phase (the bar does not leave the hands at the end of the movement), the Vpeak increase happened 'within' the movement. Thus, it is likely that that as BAL was more specific to the post-BT movement, it resulted in a significant bar displacement change for BAL and a non-significant one for HEAVY.
The present study used a relatively homogenous group of rugby players, in terms of previous resistance training history. The review by Seitz & Haff (2016), suggested that training history and strength levels affect the upper body PAPE responses. Therefore, the present results apply to athlete groups of similar characteristics and are likely not generalizable.

CONCLUSION: Our findings suggest that a ballistic conditioning stimulus can also (in comparison to a heavy conditioning stimulus) improve subsequent bench throwing performance. With velocity-based training receiving more and more attention as a viable means of quantifying and prescribing strength training programmes (e.g. Balsalobre-Fernández et al. 2018, Orange et al. 2019), exploring the potential of PAPE for more accurate and effective prescribing is an attractive notion. For example, using the relevant equation from Garcia-Ramos et al. (2018) and replacing for the achieved velocities (Vpeak from Table 1), the percentage load ranges from 37kg-54kg. Future studies should examine PAPE potential in a more pragmatic training scenario, with a) repeated trials, to explore its effectiveness (performance gains v additional time required), and b) in a 'hybrid' format, where utilisation of the rest interval for other exercises (without detrimental effect to PAPE) is explored.

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