International Journal of EXERCISE SCIENCE

Original Research

Bench Press Range-of-Motion and Velocity-based Repetition Control: Effects on Ballistic Push-up Performance in Males

KYLE S. COLLINS†[1], ADAM P. BRADLEY†[1], BRYAN K. CHRISTENSEN‡[1], ROMAN W. WALDERA‡[2], LUKUS A. KLAWITTER‡[3], LIAM OGREN*[1], and R.W. SALATTO‡[4]

[1]Department of Health, Nutrition, and Exercise Sciences, North Dakota State University, Fargo, ND, USA; [2]School of Health and Consumer Sciences, South Dakota State University, Brookings, SD, USA; [3]School of Health and Human Performance, Northern Michigan University, Marquette, MI, USA; [4]Department of Kinesiology, Vanguard University, Costa Mesa, CA, USA

*Denotes undergraduate student author, †denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(1): 38-53, 2024. The purpose of this study was to investigate whether the ballistic push-up (BPU) is responsive to post-activation performance enhancement (PAPE) after a bench press conditioning exercise using velocity-based repetition control. Additionally, we aimed to evaluate the effects of range of motion (ROM) conditions on subsequent BPU performance. In a randomized crossover design, 18 males performed two conditions (full ROM and self-selected partial ROM) of bench press at 80% of their 1RM until mean concentric velocity dropped 10%. Each participant performed two pre- and six post-test BPUs to assess the PAPE effect. Paired sample t-tests assessed bench press performance measures. Multiple two-way repeated measures ANOVAs assessed differences in flight time, impulse, and peak power for the pre- and post-test BPUs. No significant differences existed between ROM conditions for total repetitions, volume load, or peak velocity. Compared to partial ROM, full ROM showed greater displacement (0.42 ± 0.05 vs. 0.34 ± 0.05 m), work (331.99 ± 67.72 vs. 270.92 ± 61.42 J), and mean velocity (0.46 ± 0.09 vs. 0.44 ± 0.08 m/s). Neither bench press ROM condition enhanced the BPU and were detrimental in some cases. Several time points showed partial ROM (flight time: 2 min post, impulse: 12 min post, peak power: 12 min post) significantly greater than full ROM, possibly indicating less fatigue accumulation. The BPU may require a different stimulus or may not be practical for PAPE effects in college-aged males. Partial ROM can be an alternative that achieves similar peak velocities while requiring less overall work.

KEY WORDS: Spoto Press, conditioning activity, PAPE, velocity loss, linear encoder

INTRODUCTION

The bench press is a popular multi-joint exercise used to strengthen the upper-body musculature and test upper-body strength (14, 22, 25). Full range-of-motion (ROM) is commonly used and is characterized by lowering the bar to the chest and then pressing the bar back to full elbow extension (14, 22, 25). However, the full ROM bench press includes a “sticking region,” or phase in the concentric portion of the lift where the bar decelerates, especially at higher loads. This region is thought to be the result of reduced mechanical force output, and the most likely place where the lift can fail (8, 14, 25, 27). While solely performing full ROM may not yield optimal results, including partial ROM exercises can provide stimulus absent of the sticking region and enhance performance outcomes (8, 27).

Partial ROM exercises have a long history in resistance training and have been the subject of numerous research studies (8, 25, 26, 30). Partial ROM bench press has been shown to decrease the concentric velocity of the movement (8, 25); however, research also shows an inverse relationship with maximal loads and ROM, where less ROM can produce more force and tolerate heavier maximal loads (7, 8, 25). Indeed, similar (27) and greater strength gains have been reported with partial ROM compared to full ROM (30). Several methods exist in defining the exact partial ROM which can involve the use of specialized equipment. For example, a recent study concluded that using a cambered barbell (greater ROM) increased anterior deltoid muscle activity, while the standard bar showed greater pectoralis major and triceps brachii-long head activity (18). Mendonca et al (2021) examined the effects of partial ROM bench press with a supramaximal load of 130% of the recorded 1 repetition maximum (1RM) and four-boards (10 cm) to control the bottom end of the ROM (28). Other studies have investigated bench press and at one-third, two-thirds, and full ROM using a smith machine to stop and unload the bar at the bottom (25). However, the practical application of these may be cost-prohibitive, and anecdotally, partial ROM can be performed using a standard free-weight barbell to a self-selected depth.

Increasing upper-body strength is important for athletes and can positively impact performance, especially for maximal effort, short-duration movements (13, 25, 39). Additionally, performing a heavy resistance exercise can influence the subsequent force and power output of the targeted muscles (37, 42, 49). This increase in performance following a high-intensity, voluntary muscle contraction is known as post-activation performance enhancement (PAPE) (37, 49), which is used in context of applied practice such as improving jump or sprint performance. This can be differentiated from the more common term post-activation potentiation, which is suggested for the mechanistic properties of elevated muscle twitch seen in laboratories (37, 49). Recent literature has demonstrated a lighter, ballistic movement can be enhanced in the minutes following a high intensity load conditioning exercise (5,42). However, careful consideration must be given to the volume and intensity of the conditioning exercise, as the stimulus must be great enough to elicit a PAPE response without causing detrimental acute fatigue (12).

Velocity-based training has emerged as a valid resistance training prescription method that can account for day-to-day fluctuations in performance and readiness (24, 42, 48). Improvements in available technology such as linear position encoders and accelerometers have made it possible to monitor the velocity of each exercise repetition, allowing the implementation of velocity loss thresholds (VLT) (24, 38, 42). This allows the set to be terminated if the concentric velocity drops below a set percent (e.g., 10%) from the highest repetition velocity, which can manage neuromuscular fatigue (38, 42, 48). For example, Tsoukos et al (2021) investigated the potentiation effect of a conditioning bench press at 80% 1 repetition maximum (1RM) with set VLTs of 10% and 30%, on bench press throw performance. The 10% VLT saw significantly higher bench press throw potentiation, whereas the 30% allowed more repetition fatigue which possibly delayed performance benefits (42).

Studies have used the bench press throw as a post-conditioning exercise test for PAPE (42), but recently the ballistic push-up (BPU) has been suggested as a valid measure of upper-body power (2,45). Peak and mean power of the bench press throw has shown very large correlations with the BPU (r = 0.74 – 0.75), and a very large correlation found (r = 0.87) between the 1RM bench press and the 1RM predicted by the BPU (2). This indicates that the BPU may be a valid method to estimate upper-body power (2), and used in lieu of the bench press throw. One previous study investigated the PAPE effects of a high intensity bench press conditioning exercise on the plyometric push-up, though the authors concluded the bench press conditions could have caused undue fatigue (4). Additionally, the PAPE effects of self-selected partial ROM bench press on a subsequent upper-body power test is unclear. Therefore, we aimed to test whether the BPU is sensitive to PAPE after a conditioning exercise using 80% 1RM with a 10% VLT, which has demonstrated PAPE in past literature (42). Secondly, we examined the differences between the full and partial ROM conditions on enhancing the BPU in college-aged males. We hypothesized the BPU will respond to PAPE, and that the full ROM will elicit a higher number of repetitions, higher repetition velocity, and greater enhancement of the BPU.

METHODS

This study was a cross-sectional, crossover design with participants block randomized to bench press condition. Each participant completed three testing sessions at the lab separated by at least 5 days, and testing was conducted at the same time of day. The first day started with completing informed consent, screening paperwork, anthropometric measures, familiarization, and 1RM testing. On days two and three, participants completed one set of bench press with maximal concentric effort with a load of 80% 1RM in either the full or partial ROM condition. Repetitions of the set ceased when a VLT of 10% (mean concentric velocity drops to 90% of highest attained velocity) was reached. Two BPUs were performed as a pre-test to establish baseline performance, and six as a post-test with two minutes between each to assess any PAPE effects over time, similar to previous literature (42). Independent variables were ROM condition and BPU time points, and dependent variables were BPU flight time, net impulse, and peak power.

Participants

An a priori power analysis using G*Power software with a medium effect size ($f = 0.25$; $\alpha = 0.05$; $1-\beta = 0.80$), similar to previous literature (17, 23). This indicated a minimum sample size of 16, and a total of 18 college-aged males (Table 1) volunteered for this study. Recruitment was done by list-serve email, flyers, and word-of-mouth. Inclusion criteria were as follows: males between the ages of 18 to 35, a bench press 1 repetition maximum (1RM) of at least 80% of their own body mass, and strength training experience defined as performing at least 2 resistance training sessions per week for the last year including the bench press exercise. Exclusion criteria included any upper-body musculoskeletal injuries within the last 12 months, any neuromuscular disorders, answering "yes" to any questions on the PAR-Q+ form, or self-reported use of any performance enhancing drugs such as anabolic steroids. Participants were asked to avoid alcohol and caffeine for 12 hours, and exercise for 24 hours prior to each testing session. Additionally, participants filled out a dietary recall on the first day and were asked to maintain similar dietary habits before testing. All participants read and signed an informed consent form, and procedures were approved by the university Institutional Review Board. This research was carried out in accordance with the ethical standards of the International Journal of Exercise Science (31).

Table 1. Descriptive Statistics (mean ± SD) of the male participants (n = 18).

Age (y)	23.50 ± 4.32
Height (m)	1.80 ± 0.08
Body Mass (kg)	85.70 ± 13.47
1RM (kg)	102.40 ± 24.03
1RM/BM	1.19 ± 0.21
80% Load (kg)	81.94 ± 19.36
Bench Grip Width (m)	0.60 ± 0.06
Biacromial Width (m)	0.38 ± 0.02

Protocol

Anthropometric measures were taken prior to familiarization during the initial visit. Height was measured using a portable stadiometer (SECA Corporation, Hamburg, Germany), body mass was measured with a digital scale (Sunbeam Products Inc., Boca Raton, FL), and biacromial distance using a large bone caliper (Lafayette Instrument, Lafayette, IN). Next, the participants were familiarized with the BPU with hand widths calculated as 120% of biacromial distance rounded to the nearest centimeter. This was done to standardize testing across participants, and in accordance with previous literature where the narrower hand placement (120%) showed higher force production (32). For each testing session, tape marks were placed on a single AMTI force plate (AccuPower; Watertown, MA), which was large enough (76 cm × 101 cm) to accommodate 120% of biacromial distance for all participants. Participants placed their hands on the force plate and were instructed to lower their chest until a stable prone position was achieved, while keeping their body generally straight. After achieving this position, participants were instructed to push with maximal explosive effort until arms full extended and hands left the force plate (46). Participants were given the same verbal instructions of "Up, lower, hold, and go!" while performing the BPU.

Next, participants were familiarized with the bench press ROM conditions using free weights and a self-selected grip position. Each participant was instructed to grip the bar in a position where they felt the 'strongest' (22, 35). Grip distance was measured on the bar between index fingers and kept the same for all sessions. The ROM conditions utilized the same tempo: a quick eccentric phase, a brief pause at the bottom, and explosive concentric phase (X:1:X:0). Instructions were given that during the full ROM the bar would touch the chest, and during the partial ROM the bar would stop an estimated 3 inches from the chest. Recent literature suggests that the initial point of the sticking region, characterized by the first peak velocity, occurs about 3 to 5 cm (about 1 to 2 inches) off the chest (20, 25). Additionally, a 3-inch high-density foam portable bench block was used during familiarization and on the partial ROM testing day warm-up as a guide to indicate the desired ROM. No block was utilized during actual partial ROM testing, and participants were instructed to stop the downward bar movement at the same position as when the block was in place. This position was observed by the research team and feedback given as necessary. While performing the bench press, participants laid supine on a flat bench that supported the head, shoulders, and hips, with feet on the floor, and used a closed pronated grip on the bar.

Finally, 1RM testing was performed with procedures adapted from previous literature and involved incremental loading starting at 50% of an estimated 1RM (22,41). Briefly, 8 to 10 repetitions were performed at 50% of the estimated 1RM, 3 to 5 repetitions were performed at 75% of the estimated 1RM, followed by a single repetition at 90% of the estimated 1RM. Participants then made 1RM attempts, and if successful, loads increased by 2.5 kg to 5 kg until failure. No more than five 1RM attempts were made, and a minimum of three minutes of rest was provided between the warm-up sets and 1RM efforts (22). All investigators are certified strength and conditioning coaches and provided spotting and verbal encouragement.

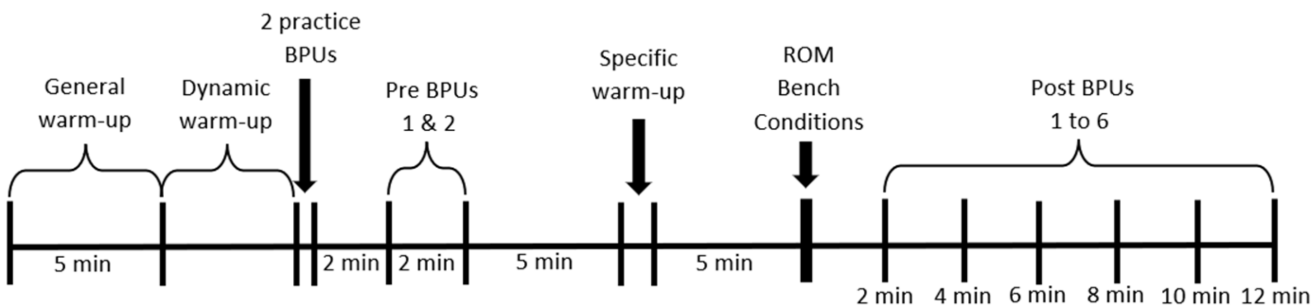

Figure 1. Representation of the protocol for the 2nd and 3rd testing days. BPU = ballistic push-up.

On visits two and three (Figure 1), participants began with a general warm-up of five minutes on a stationary bike and then completed upper-body dynamic movements consisting of 10 repetitions each way for ear-to-shoulder, overhead reach with side bend, crossover arm swings, overhead arm swings, and push-ups. Two practice BPUs were then performed to further warm-up, followed by two minutes of rest, and then two recorded BPU trials two minutes apart with the best performance used for baseline. After five minutes of rest, participants performed a bench press ROM-specific warm-up consisting of 1 set of 8 repetitions at 40% 1RM, three minutes of rest, and 1 set of 5 repetitions at 60% 1RM. After a final 5-minute rest, one maximal effort set of the bench press was performed, with load set to 80% 1RM and VLT set at 10%. A GymAware linear position encoder (Kinetic Performance Technology, Canberra, Australia) was placed under the collar of the barbell in-line with the lifters shoulder to measure the vertical repetition velocity. GymAware reliability is reported as good (intraclass correlation coefficient = 0.78, standard error of measurement percentage = 7.9%) with free weight bench press loads of

80% 1RM (33), and ranks among the top of velocity tracking devices for reliability and validity, possibly due to its ability to account for some horizontal displacement (47). For each session the VLT was tracked with an iPad (Apple Inc., Cupertino, CA) and GymAware application where an audible alarm occurred once it was reached. Investigators then instructed and assisted participants to stop and re-rack the weight. If the participants had initiated a repetition while the VLT occurred, they were allowed to finish the repetition. Following this, the post-conditioning BPUs occurred every two minutes for 12 minutes on the force plate (total of 6).

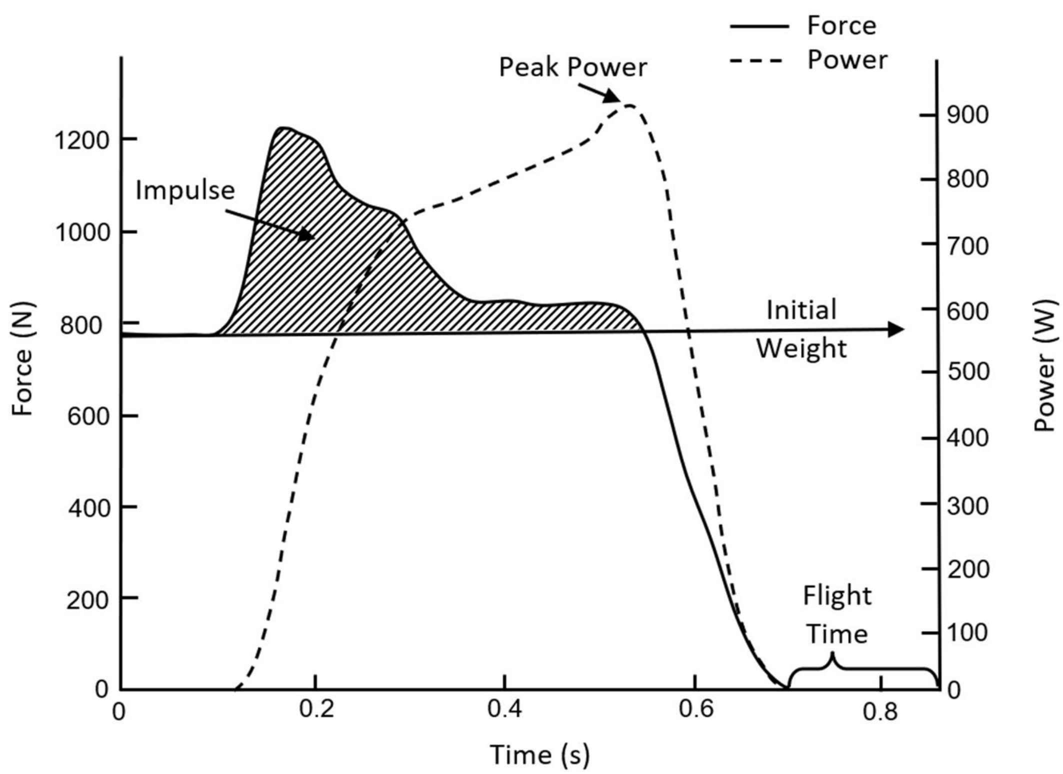

Figure 2. Ballistic push-up (BPU) force-time and power-time curves illustrated from one of the participants. Flight time, impulse, and peak power are highlighted.

For each BPU trial, force-time data was recorded at 1000 Hz and then exported to MATLAB (The MathWorks, Inc., Natick, MA) for processing with a custom script. Data were filtered using a zero-lag, low-pass, fourth order Butterworth filter with a cutoff of 50 Hz. Flight time was calculated by finding flight start and flight end points that were force-time data less than 10 N and greater than 10 N, respectively (34,40). Initial system weight was established from the stable starting position, which was then used to determine onset and offset of the concentric propulsive phase of the BPU. Impulse was determined using trapezoidal integration to find the area under the curve greater than the initial system weight. Peak power was the greatest value of the product of vertical force and velocity (Figure 2). Velocity was obtained by the cumulative trapezoidal integration of acceleration, which was calculated from the vertical force-time data.

Statistical Analysis

Statistical analyses were performed using SPSS version 27 (IBM Corp., Armonk, NY), with significance set at $p < 0.05$ and all data presented as mean ± SD, unless otherwise stated. The Shapiro-Wilk test and Q-Q plots were used to assess the data normality. Paired sample t-tests assessed performance measures during the bench press ROM conditions, which included total repetitions performed, volume load (sets × reps × load), displacement, work, mean velocity, and peak velocity. Cohen's *d* was used to estimate t-test effect size, with 0–0.19 a trivial effect, 0.20–0.59 a small effect, 0.60–1.19 a moderate effect, 1.20–1.99 a large effect, 2.0–3.99 a very large effect, and > 4.0 an extremely large effect (16). Multiple 2 × 7 repeated measures analysis of variance (condition × time points) assessed the effects of the independent bench press ROM conditions on the dependent BPU variables (flight time, impulse, and peak power). If the assumption of sphericity was violated the Greenhouse-Geisser corrected values were used. Partial eta squared estimated explained variance and effect size, with a value of 0.01 considered a small effect, 0.06 a medium effect, and 0.14 a large effect. Significance of pairwise comparisons and 95% confidence intervals of the difference in means were based on the Bonferroni adjustment for multiple comparisons.

RESULTS

The dependent variables of the BPU were normally distributed. Differences between the bench press conditions (total repetitions performed, volume load, displacement, work, mean velocity, and peak velocity) are listed in Table 2. There were no significant differences between ROM conditions for total repetitions performed, volume load, or peak velocity. Full ROM showed significantly greater displacement, work, and mean velocity when compared to partial ROM. The repeated measures ANOVA resulted in a non-significant interaction (ROM × time) for flight time ($F = 1.655$, $p = 0.14$, $\eta^2 = 0.089$), impulse ($F = 1.173$, $p = 0.33$, $\eta^2 = 0.065$), and peak power ($F = 1.034$, $p = 0.391$, $\eta^2 = 0.057$). Regarding ROM main effects, there was a non-significant main effect for flight time ($F = 0.648$, $p = 0.432$, $\eta^2 = 0.037$), impulse ($F = 0.943$, $p = 0.345$, $\eta^2 = 0.053$), and peak power ($F = 1.299$, $p = 0.27$, $\eta^2 = 0.071$). Regarding time main effects, there was a significant effect for flight time ($F = 3.506$, $p = 0.003$, $\eta^2 = 0.171$), impulse ($F = 4.334$, $p = 0.004$, $\eta^2 = 0.203$), and peak power ($F = 5.767$, $p < 0.001$, $\eta^2 = 0.253$).

Table 2. Differences (mean ± SD) between range-of-motion (ROM) conditions during the bench press conditioning exercise.

	Full ROM	Partial ROM	*p*-value	Cohen's *d*
Total Reps	4.67 ± 1.03	4.78 ± 1.00	0.742	–0.079
Volume Load (kg)	377.65 ± 104.68	384.72 ± 91.99	0.785	–0.065
Displacement (m)	0.42 ± 0.05	0.34 ± 0.05	<0.001*	2.480
Work (J)	331.99 ± 67.72	270.92 ± 61.42	<0.001*	2.351
Mean Velocity (m/s)	0.46 ± 0.09	0.44 ± 0.08	0.016*	0.633
Peak Velocity (m/s)	0.67 ± 0.14	0.66 ± 0.14	0.615	0.121

* = significant ($p < 0.05$) difference between ROM conditions.

Comparisons of BPU flight time, impulse, and peak power between ROM conditions and across time points are shown in Figures 3, 4, and 5, respectively. Post-hoc testing revealed that flight time for the partial ROM was significantly greater than full ROM at 2 minutes post (p = 0.014, mean difference [md] = 0.028, 95% confidence interval of the difference [95% CI] = 0.006 – 0.05). Additionally, the full ROM flight time at 2 minutes post was significantly less than the pre-test (p = 0.016, md = 0.037, 95% CI = 0.005 – 0.07), and 12 minutes post was significantly greater than 2 minutes post (p = 0.039, md = 0.036, 95% CI = 0.001 – 0.07). For impulse, the partial ROM was significantly greater than full ROM at 12 minutes post (p = 0.02, md = 3.93, 95% CI = 0.701 – 7.17). Additionally, the partial ROM impulse recorded at 4 minutes post (p = 0.02, md = 5.28,

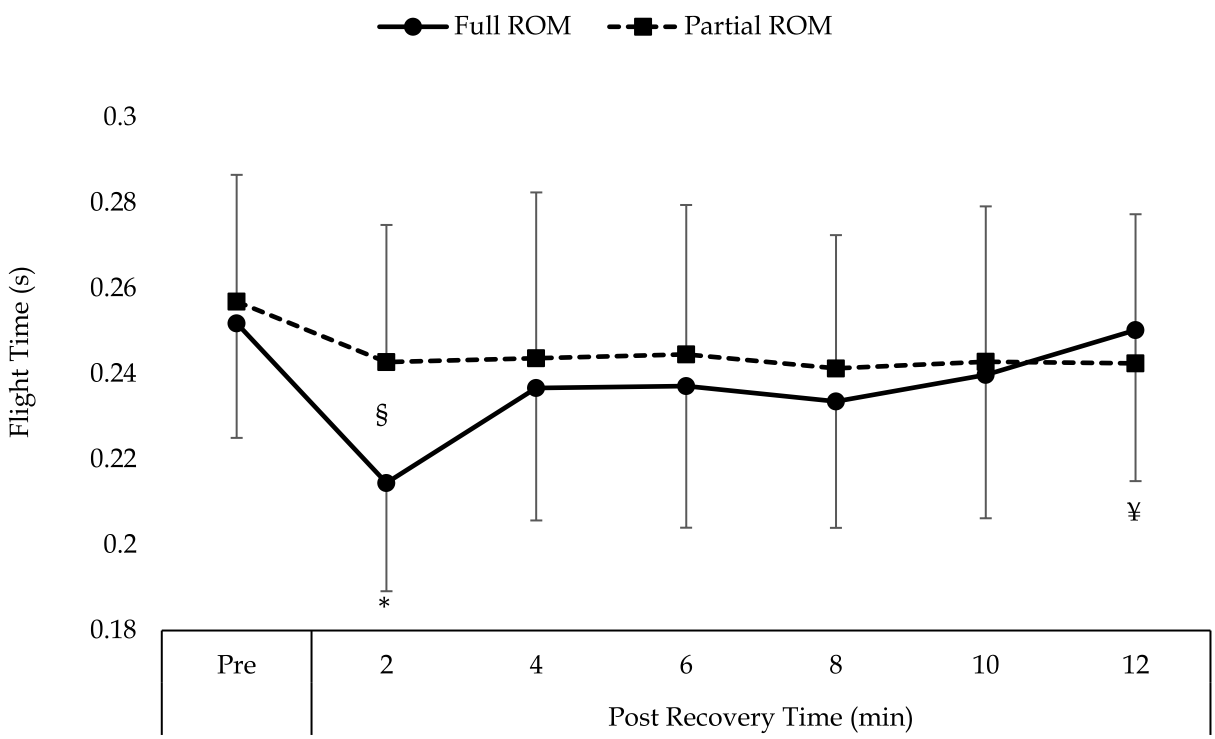

Figure 3. Comparisons of ballistic push-up (BPU) flight time between range-of-motion (ROM) conditions and across time points. 95% confidence intervals are reflected downward for full ROM and upward for partial ROM. * = significant ($p < 0.05$) difference from the pre-test BPU, ¥ = significant ($p < 0.05$) difference from the 2 min BPU, § = significant ($p < 0.05$) difference between ROM conditions.

95% CI = 0.55 – 10) and 8 minutes post (p = 0.002, md = 5.63, 95% CI = 1.74 – 9.51) were significantly less than the pre-test. For peak power, the partial ROM was significantly greater than full ROM at 12 min post (p = 0.009, md = 65.26, 95% CI = 18.63 – 111.89). Additionally, the partial ROM peak power recorded at 4 minutes post (p = 0.038, md = 71.34, 95% CI = 2.35 – 140.32), 6 minutes post (p = 0.018, md = 79.01, 95% CI = 9.05 – 148.98), and 8 minutes post (p = 0.003, md = 90.57, 95% CI = 24.57 – 156.57) were significantly less than the pre-test. While some differences existed for time and even between ROM, none of the measures were greater than the pre-test values.

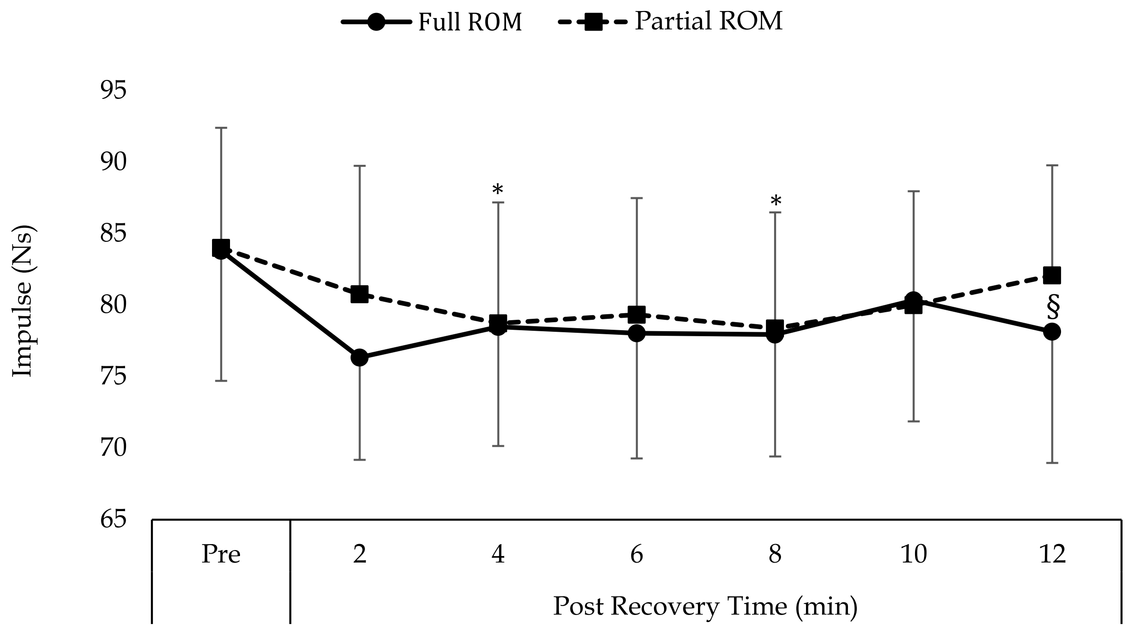

Figure 4. Comparisons of ballistic push-up (BPU) impulse between range-of-motion (ROM) conditions and across time points. 95% confidence intervals are reflected downward for full ROM and upward for partial ROM. * = significant ($p < 0.05$) difference from the pre-test BPU, § = significant ($p < 0.05$) difference between ROM conditions.

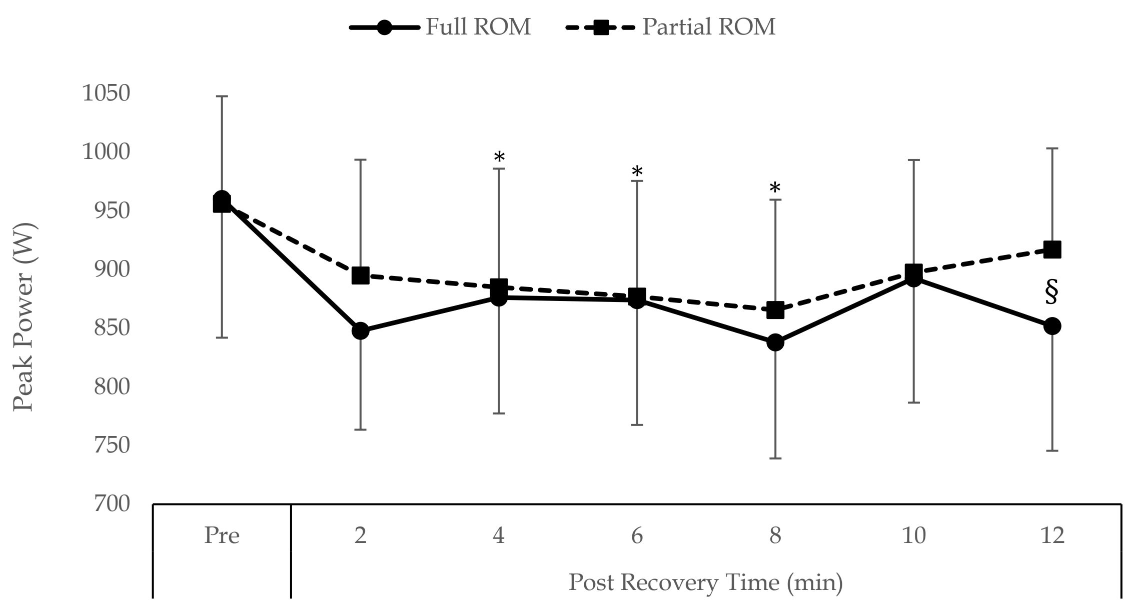

Figure 5. Comparisons of ballistic push-up (BPU) peak power between range-of-motion (ROM) conditions and across time points. 95% confidence intervals are reflected downward for full ROM and upward for partial ROM. * = significant ($p < 0.05$) difference from the pre-test BPU, § = significant ($p < 0.05$) difference between ROM conditions.

DISCUSSION

The purposes of this study were to assess whether the BPU is responsive to PAPE after a bench press conditioning exercise, and to evaluate the effect of ROM conditions on BPU performance in college-aged males. Contrary to our initial hypothesis, no BPU measures were significantly greater than the pre-test, demonstrating that neither full ROM nor partial ROM had a PAPE effect. Further, the VLT bench press had a detrimental effect on some of the post-test BPU measures. Only displacement, work, and mean velocity were significantly different between bench press ROM conditions. The differences in metrics at 2- and 12-minutes post-test and general trends suggest partial ROM may provide less fatigue than full ROM, allowing for a faster return to baseline in impulse and peak power. This may be due to the involved skeletal muscle contracting repeatedly at shorter lengths, which has shown to be less fatiguing than longer muscle lengths for a similar relative force output (21). A limited number of studies have assessed upper-body PAPE with the bench press throw and used velocity-based repetition control bench press as the conditioning exercise (19, 42, 43). To our knowledge, only one study compared the effects of bench press with different ROM on subsequent bench press throw PAPE (19), and one study compared the impact of ballistic or non-ballistic concentric-only bench press on subsequent push-up performance (4). However, no studies to date have investigated the use of velocity-based repetition control bench press with different ROM conditions on BPU performance. Additionally, this study used a self-selected partial ROM performed with a standard barbell resulting in an average displacement difference of 8 cm (3.15 inches).

Similar to other published data (25), the partial ROM condition produced less displacement, and subsequently lesser mean velocity. Although our average mean velocity difference was only 0.02 m/s, it was consistent enough to reach significance with a moderate effect size (d = 0.633). This may indicate that less fatigue was accrued during the partial ROM, as the volume-load between the conditions were similar. The partial ROM bench press does not have to contend with the energy required to accelerate the bar off the chest, reach an initial peak velocity, decelerate, and then reach a second peak velocity as is the case with full ROM (25). Additionally, as the peak velocity between ROM conditions was not different, the greater mean velocity of the full ROM indicates a greater time was spent at a higher velocity through the full ROM. Perez-Castilla et al. (2021) investigated the number of full ROM bench press repetitions completed at 75% 1RM with a VLT of 15% and varied grip widths. The medium grip width reported was 0.58 ± 0.04 m and 150% of the biacromial width, compared to our 0.60 ± 0.06 m that was 158% of biacromial width (36). Despite utilizing a heavier load and a lower VLT, our cohort completed a similar number of repetitions (4.67 ± 1.03) to Perez-Castilla's participants (4.6 ± 1.7 repetitions) with a comparable grip (36). Although both studies had similar inclusion criteria, our group displayed greater relative strength (1.19 ± 0.21 vs 0.97 ± 0.19 1RM/body mass, respectively), likely indicating a higher training status, which can impact repetitions to VLT.

While there is lack of evidence underpinning the mechanisms that contribute to PAPE, we can assume in this study that fatigue inhibited performance enhancement by exceeding factors that potentiate (3). The BPU may not be responsive to PAPE or may require a different stimulus other than heavy bench press. Contrary to our hypothesis, a performance enhancement did not occur in the post-test BPU and was even lower in the post-test in some cases. The results of this study align with Bodden et al. (2019), who investigated the effects of ballistic and non-ballistic concentric only bench press on plyometric push-up performance in resistance trained men. Their subjects used a self-selected hand placement for the push-ups which was similar to the BPU and compared effects to a crossover control group. Both ballistic and non-ballistic bench press conditions proved to be detrimental to impulse over the course of post-testing. The authors concluded their bench press protocol possibly caused too much acute fatigue, which involved increasing the load intensity over 4 sets to finish with 3 repetitions at 70% and 2 repetitions at 90% 1RM (4). Our subjects showed similar relative strength level (1.19, ranged from 0.81 to 1.58) to their sample (1.3, ranged from 1.04 to 1.67), possibly contributing to the similar results. The authors suggested future studies use a lighter load as the conditioning exercise (4), and it is possible that the stimulus from 80% 1RM at 10% VLT was too similar.

The results of this study somewhat contradict similar studies that showed PAPE occurred with the bench press throw. Tsoukos et al. (2021) found that after one set of 80% 1RM bench press, the 10% VLT group and 30% VLT group similarly (+7–8%) enhanced the bench press throw in mean propulsive velocity. However, the 10% VLT group saw increases early in the recovery, while the 30% VLT showed a delayed response and increasing near 10 minutes post-test. Additionally, for peak velocity the 10% VLT saw similar increases, but the 30% VLT was not statistically different (42). As strength may have a role to play in achieving a PAPE effect, the average reported 80% load from Tsoukos et al. (2021) was 87.3 kg, compared with our 81.94 kg. With the strength discrepancy, we also had more average repetitions and a greater volume-load for our comparable full ROM condition which could have influenced the results. Following this, Krysztofik et al. (2022) used a similar methodology with the 10% VLT and analyzed the effects of bench press ROM on the bench press throw PAPE response. They found that the standard bar provided the best enhancement of bench press throw performance when compared to the cambered bar, reverse cambered bar, and control group. Despite the cambered bar having the greatest ROM (and the reverse cambered bar the least ROM), the authors concluded that the standard barbell ROM was superior possibly because it is most similar to the bench press throw (19). It can be concluded then that accumulating fatigue can delay or detract from the PAPE effects, and ROM has some effect on PAPE.

It is possible that the bench press and BPU are too mechanically dissimilar to see a PAPE effect in the latter. While the BPU and regular push-up exercise differ slightly, literature on regular push-up exercises may be informative. Despite the bench press being an open chained exercise and the push-up being a closed chained exercise, evidence shows no major difference in the muscle activity or kinetics between the two (15, 44). However, almost twice as many push-ups were performed by men and women compared to a bench press with similar resistance (1). This has been attributed to distance the center-of-mass travels in a bench press being higher compared to a push-up, as the center-of-mass on the human body is close to the mid-section (1). Related to the center-of-mass differences the mass supported during the push-up at the top has been reported as 67% of total body mass and 75% at the bottom (29). While not part of the main analysis, post-hoc examination of the force during the stable down position of the BPU during this study showed similar results. Averaged across all trials, the system weight was about 77% relative to body mass, and 67% relative to the recorded 1RM. This highlights the relative intensity between the bench press and the BPU, where the BPU may require more relative strength to overcome. Additionally, the push-up may require more core musculature activation to maintain a relatively straight torso, compared to the bench press lying with torso and head supported (1,11). Calatayud et al. (2014) reported greater muscle activity in pectoralis major, anterior deltoid, triceps brachii, and serratus anterior for a 85% 1RM bench press, and greater muscle activity in the rectus abdominis and external oblique for a regular push-up (6). This greater activation during the bench press may have contributed to acute fatigue (1) for BPU performance, and the additional requirement of core stability may have also been detrimental. The bench press throws in previous studies (19,42) may be superior in responding to PAPE because the open-chain bench press conditioning exercise progressed to a more stable smith machine for the throws performed at a lighter intensity relative to the BPU.

This study has several limitations to consider. While we utilized a randomized crossover with pretest-posttest design, we did not have an isolated control condition which may have been more revealing. This study did not separate stronger and weaker participants, and the weaker participants may have reduced any possible PAPE effects for the BPU. While the stretch-shortening cycle was utilized to a limited extent on the bench press, it was not utilized for the BPU possibly adding to the dissimilarity between movements. Additionally, the BPU hand width was standardized while the bench press grip was self-selected, which may have affected PAPE effects. Load selection was based on the 1RM performed at full ROM, which could have influenced the relative intensity and number of repetitions performed during the partial ROM condition. The use of vertical force has been questioned due to the positional nature of the push-up (10), however we used recommended variables for a push-up force plate analysis (9, 10). The present study also examined only male participants, which reduces any applicable results for females. Lastly, the landing impact forces after each BPU could have influenced subsequent BPU performance and added undue fatigue for the following trials. Future investigations will seek to establish whether there is a strength cut point at which individuals do or do not experience PAPE, whether the BPU has predictive capability to track strength performance over time, and assess PAPE differences between males and females.

Neither full nor partial ROM bench press has a potentiating effect on BPU when performed at 80% 1RM with 10% VLT. Practitioners seeking an upper-body PAPE effect for the BPU should seek other options. Alternatively, those who wish to reduce bench press ROM for their athletes (such as those with shoulder limitations or athletes in throwing sports) can do so without fear of an additional negative performance effect. Partial ROM can be utilized as an alternative movement which achieves similar peak velocities while requiring less overall work and likely less fatigue. Practitioners can program ROM based on need and/or preference, rather than according to performance outcome.

ACKNOWLEDGEMENTS

This study received internal department funding. None of the authors report a conflict of interest. The authors would like to thank the participants for their time and effort in this study.

REFERENCES

1. Alizadeh S, Rayner M, Mahmoud M, Behm D. Push-ups vs. bench press differences in repetitions and muscle activation between Sexes. J Sports Sci Med 19(2): 289–297, 2020.

2. Bartolomei S, Nigro F, Ruggeri S, Lanzoni IM, Ciacci S, Merni F, Sadres E, Hoffman JR, Semprini G. 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.

3. Blazevich AJ, Babault N. Post-activation potentiation versus post-activation performance enhancement in humans: historical perspective, underlying mechanisms, and current issues. Front Physiol 10: 1359, 2019.

4. Bodden D, Suchomel TJ, Lates A, Anagnost N, Moran MF, Taber CB. Acute effects of ballistic and non-ballistic bench press on plyometric push-up performance. Sports 7(2): 47, 2019.

5. Bogdanis GC, Tsoukos A, Veligekas P. Improvement of long-jump performance during competition using a plyometric exercise. Int J Sports Physiol Perform 12(2): 235–240, 2017.

6. Calatayud J, Borreani S, Colado JC, Martin F, Rogers ME. Muscle activity levels in upper-body push exercises with different loads and stability conditions. Physician Sportsmed 42(4): 106–119, 2014.

7. Clark RA, Bryant AL, Humphries B. An examination of strength and concentric work ratios during variable range of motion training. J Strength Cond Res 22(5): 1716–1719, 2008.

8. Clark RA, Humphries B, Hohmann E, Bryant AL. The influence of variable range of motion training on neuromuscular performance and control of external loads. J Strength Cond Res 25(3): 704–711, 2011.

9. Dhahbi W, Chaabene H, Chaouachi A, Padulo J, Behm DG, Cochrane J, Burnett A, Chamari K. Kinetic analysis of push-up exercises: a systematic review with practical recommendations. Sports Biomech 21(1): 1-40, 2018.

10. Dhahbi W, Chaouachi A, Cochrane, J, Chèze, L, Chamari, K. Methodological issues associated with the use of force plates when assessing push-ups power. J Strength Cond Res 31(7): e74, 2017.

11. Eckel TL, Watkins CM, Archer DC, Wong MA, Arevalo JA, Lin, A, Coburn JW, Galpin AJ. Bench press and pushup repetitions to failure with equated load. Int J Sports Sci Coach 12(5): 647–652, 2017.

12. Finlay MJ, Bridge CA, Greig M, Page RM. Upper-body post-activation performance enhancement for athletic performance: a systematic review with meta-analysis and recommendations for future research. Sports Med 52(4): 847–871, 2022.

13. García-Pallarés J, López-Gullón JM, Muriel X, Díaz A, Izquierdo M. Physical fitness factors to predict male Olympic wrestling performance. Eur J Appl Physiol 111: 1747–1758, 2011.

14. Gomo O, Van Den Tillaar R. The effects of grip width on sticking region in bench press. J Sports Sci 34(3): 232–238, 2016.

15. Gottschall JS, Hastings B, Becker Z. Muscle activity patterns do not differ between push-up and bench press exercises. J Appl Biomech 34(6): 442–447, 2018.

16. Hopkins WG. How to interpret changes in an athletic performance test. Sportscience 8: 1–7, 2004.

17. Kang H. Sample size determination and power analysis using the G*Power software. J Educ Eval Health Prof 18: 2021.

18. Krzysztofik M, Golas A, Wilk M, Stastny P, Lockie RG, Zajac A. A comparison of muscle activity between the cambered and standard bar during the bench press exercise. Front Physiol 11: 875, 2020.

19. Krzysztofik M, Trybulski R, Trąbka B, Perenc D, Łuszcz K, Zajac A, Alexe DI, Dobrescu T, Moraru CE. The impact of resistance exercise range of motion on the magnitude of upper-body post-activation performance enhancement. BMC Sports Sci Med Rehabil 14(1): 1-8, 2022.

20. Larsen S, Gomo O, Van Den Tillaar R. A biomechanical analysis of wide, medium, and narrow grip width effects on kinematics, horizontal kinetics, and muscle activity on the sticking region in recreationally trained males during 1-RM bench pressing. Front Sports Act Living 2: 229, 2021.

21. Lee SCK, Braim A, Becker CN, Prosser LA, Tokay AM, Binder-Macleod SA. Diminished fatigue at reduced muscle length in human skeletal muscle. Muscle Nerve 36(6): 789–797, 2007.

22. Lockie RG, Callaghan SJ, Moreno MR, Risso FG, Liu TM, Stage AA, Birmingham-Babauta SA, Stokes JJ, Giuliano DV, Lazar A, Davis DL. An investigation of the mechanics and sticking region of a one-repetition maximum close-grip bench press versus the traditional bench press. Sports 5(3): 46, 2017.

23. Mangine GT, Serafini PR, Stratton MT, Olmos AA, VanDusseldorp TA, Feito, Y. Effect of the repetitions-in-reserve resistance training strategy on bench press performance, perceived effort, and recovery in trained men. J Strength Cond Res 36(1): 1–9, 2022.

24. Mann JB, Ivey PA, Sayers SP. Velocity-based training in football. Strength Cond J 37(6): 52–57, 2015.

25. Martínez-Cava A, Morán-Navarro R, Hernández-Belmonte A, Courel-Ibáñez J, Conesa-Ros E, González-Badillo, JJ, Pallarés JG. Range of motion and sticking region effects on the bench press load-velocity relationship. J Sports Sci Med 18(4): 645–652, 2019.

26. Martínez-Cava A, Morán-Navarro R, Sánchez-Medina L, González-Badillo JJ, Pallarés JG. Velocity- and power-load relationships in the half, parallel and full back squat. Journal of Sport Sciences 37(10): 1088–1096, 2019.

27. Massey D, Vincent J, Maneval M, Moore M, Johnson JT. An analysis of full range of motion vs. partial range of motion training in the development of strength in untrained men. J Strength Cond Res 18(3): 518–521, 2004.

28. Mendonça TP, Aidar FJ, Matos DG, Souza RF, Marçal AC, Almeida-Neto PF, Cabral BG, Garrido ND, Neiva HP, Marinho DA, Marques MC. Force production and muscle activation during partial vs. full range of motion in paralympic powerlifting. PLoS One 16(10): e0257810, 2021.

29. Mier C, Amasay TAL, Capehart S, Garner H. Differences between men and women in percentage of body weight supported during push-up exercise. Int J Exerc Sci 7(2): 161–168, 2014.

30. Mookerjee S, Ratamess N. Comparison of strength differences and joint action durations between full and partial range-of-motion bench press exercise. J Strength Cond Res 13(1): 76–81, 1999.

31. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1–8, 2019.

32. Nichols IA, Szivak TK. Effects of different hand widths on plyometric push-up performance. J Strength Cond Res 35: S80–S83, 2021.

33. Orange ST, Metcalfe JW, Liefeith A, Marshall P, Madden LA, Fewster CR, Vince RV. Validity and reliability of a wearable inertial sensor to measure velocity and power in the back squat and bench press. J Strength Cond Res 33(9): 2398–2408, 2019.

34. Pérez-Castilla A, Garcia-Ramos A. Evaluation of the most reliable procedure of determining jump height during the loaded countermovement jump exercise: Take-off velocity vs. flight time. J Strength Cond Res 32(7): 2025–2030, 2018.

35. Pérez-Castilla A, Jerez-Mayorga D, Martínez-García, D, Rodríguez-Perea Á, Chirosa-Ríos LJ, García-Ramos A. Comparison of the bench press one-repetition maximum obtained by different procedures: Direct assessment vs. lifts-to-failure equations vs. two-point method. Int J Sports Sci Coach 15(3): 337–346, 2020.

36. Pérez-Castilla A, Jukic I, Haff GG, García-Ramos, A. The bench press grip width does not affect the number of repetitions performed at different velocity loss thresholds. Int J Environ Res Public Health 18(3): 1057, 2021.

37. Prieske O, Behrens M, Chaabene H, Granacher U, Maffiuletti NA. Time to differentiate postactivation "potentiation" from "performance enhancement" in the strength and conditioning community. Sports Med 50(9): 1559–1565, 2020.

38. Sánchez-Medina L, González-Badillo, JJ. Velocity loss as an indicator of neuromuscular fatigue during resistance training. Med Sci Sports Exerc 43(9): 1725–1734, 2011.

39. Stahl CA, Mann JB, Lockie RG, Dawes JJ. Comparison of estimated-1RM and 225-lb (102-kg) bench press performance between starters and non-starters among a NCAA Division I college football team. Int J Phys Educ Fit Sports 8(4): 64–75, 2019.

40. Stanton R, Doering TM, Macgregor C, Borges N, Delvecchio L. Validity of a contact mat and accelerometric system to assess countermovement jump from flight time. Meas Phys Educ Exerc Sci 23(1): 39–46, 2019.

41. Stock MS, Beck TW, Defreitas JM, Dillon MA. Relationships among peak power output, peak bar velocity, and mechanomyographic amplitude during the free-weight bench press exercise. J Sports Sci 28(12): 1309–1317, 2010.

42. Tsoukos A, Brown LE, Terzis G, Veligekas P, Bogdanis GC. Potentiation of bench press throw performance using a heavy load and velocity-based repetition control. J Strength Cond Res 35: S72–S79, 2021.

43. Tsoukos A, Brown LE, Veligekas P, Terzis G, Bogdanis GC. Postactivation Potentiation of bench press throw performance using velocity-based conditioning protocols with low and moderate loads. J Hum Kinet 68(1): 81-98, 2019.

44. Van Den Tillaar R. Comparison of kinematics and muscle activation between push-up and bench press. Sports Med Int Open 3(03): E74–E81, 2019.

45. Wang R, Hoffman JR, Sadres E, Bartolomei S, Muddle TW, Fukuda DH, Stout JR. Effects of different relative loads on power performance during the ballistic push-up. J Strength Cond Res 31(12): 3411–3416, 2017.

46. Wang R, Hoffman JR, Sadres E, Bartolomei S, Muddle TW, Fukuda DH, Stout JR. Evaluating upper-body strength and power from a single test: The ballistic push-up. J Strength Cond Res 31(5): 1338–1345, 2017.

47. Weakley J, Morrison M, García-Ramos A, Johnston R, James L, Cole MH. The validity and reliability of commercially available resistance training monitoring devices: a systematic review. Sports Med 51: 443–502, 2021.

48. Weakley J, Ramirez-Lopez C, McLaren S, Dalton-Barron N, Weaving D, Jones B, Till K, Banyard H. The effects of 10%, 20%, and 30% velocity loss thresholds on kinetic, kinematic, and repetition characteristics during the barbell back squat. Int J Sports Physiol Perform 15(2): 180–188, 2020.

49. Zimmermann H, Macintosh B, Dal Pupo J. Does postactivation potentiation (PAP) increase voluntary performance? Appl Physiol Nutr Metab 45(4): 349–356, 2020.