ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2021; 28(**3**): 217-223
ISSN 2299-9590
DOI: 10.23829/TSS.2021.28.3-6

The influence of rest intervals following low-load countermovement jumps in athletes

VANESSA L. CAZÁS-MORENO[1], KRISTEN C. SNYMAN[2], JAMES J. TUFANO[3], LEE E. BROWN[4]

Abstract
Introduction. **A countermovement jump (CMJ) is a common explosive activity used to measure lower body power. Determining an optimal rest interval may be beneficial in creating a training program to improve performance.** Aim of Study. **To investigate the post-activation potentiation (PAP) effect of different low-load, high-intensity CMJs on subsequent bodyweight CMJs.** Material and Methods. **On four different occasions, 18 athletes (age: 19.61 ± 0.98 y; height: 177.69 ± ± 11.35 cm; mass: 80.22 ± 11.96 kg) completed one baseline CMJ followed by a series of low-load, high-intensity CMJs (0%, 10%, and 20% of their back squat one repetition maximum [1RM]) and one control condition without a CMJ (NJ). For each low-load intervention, participants completed 1 set of 6 CMJs, except NJ where participants stood for 20-seconds. Then, participants performed single CMJs at 8 different rest intervals following the experimental and control conditions. Three, 4 × 9 (condition [NJ, 0%, 10%, and 20%] × time [baseline, 0.5-min, 1-min, 2-min, 4-min, 6-min, 8-min, 10-min, and 12-min]), and three, 4 × 2 (condition × time [baseline and peak]) repeated measures analysis of variance were used to analyze jump height (JH), estimated power (eP), and flight time (FT) via a jump mat.** Results. **There were no protocol × time interactions. However, there was a significant ($p < 0.05$) main effect for time for FT, where FT was longer at 2-min than 10-min, and FT was longer at 4-min than 8-, 10-, and 12-min. Peak JH, eP, and FT values were all significantly greater than baseline.** Conclusions. **A single warm-up jump may enhance jump performance and other low-loads investigated in this study. The effectiveness of a low-load PAP response may be highly dependent upon the individuals. Thus, a greater focus on individualized PAP programming is needed.**

KEYWORDS: power, warm-up, post-activation potentiation, PAP.

Received: 7 March 2021
Accepted: 19 May 2021

Corresponding author: vlcazasmoreno@gmail.com

[1] Tennessee State University, Human Performance and Sport Science, Nashville, United States
[2] Concordia University, Health and Human Performance, Chicago, United States
[3] Charles University, Department of Physiology and Biochemistry, Prague, Czech Republic
[4] California State University, Kinesiology, Fullerton, United States

Introduction

Post-activation potentiation (PAP) is a phenomenon that occurs after performing a specific priming activity that may lead to a heightened ready state prior to performing a powerful movement [3, 6, 19, 28]. Therefore, PAP is considered to be a sport- or activity-specific extension of an otherwise general warm-up that can elicit supramaximal levels of explosive movement [3, 12, 15, 16, 30]. Although, the exact mechanisms underlying this phenomenon are not completely known, it is well documented that PAP is likely related to the contractile history of skeletal muscle [3, 13, 14, 22, 28, 29]. It has been suggested that phosphorylation of the myosin regulatory light chain (MRLC), excitability of the spinal cord reflex, and muscle spindle/presynaptic and postsynaptic changes are all potential factors that may enhance performance [3, 13, 14]. Thus, the specific contractile activity performed before an explosive task is likely to impact the likelihood of a PAP effect taking place.

Post-activation potentiating tasks are often performed by completing a brief bout of high- load, high-intensity movement prior to performing a bout of light, explosive activity [1, 18, 28, 29]. It has been suggested that performing high-loaded activities may induce fatigue [1, 3, 6, 18, 19, 28], thereby impacting subsequent performance. Despite this potential fatigue-effect, literature suggests the potentiation effect may outlast fatigue, and once this priming load-induced fatigue subsides, an increase in overall explosive performance may occur for a short period of time [29]. There is also evidence that negative loading (i.e., assisted exercise whereby the priming activity is performed with a load lighter than the performance load) can also induce a beneficial PAP effect on jumping, sprinting, and swinging motions [3, 6, 8, 19]. Therefore, both heavy and negative loading patterns may have beneficial effects on performance, there may be additional activity-specific stimuli with the ability to induce a PAP response. Heavy loading may induce fatigue and negative loading often requires specialized equipment that may not be practical in many strength and conditioning settings. Thus, a practical load and specific movement priming activity that does not result in significant fatigue, but can quickly induce.

PAP shortly after the priming activity, could be performed readily in the field. A practical non-fatiguing PAP application would be desirable to the strength and conditioning practitioner or athlete to possibly enhance acute explosive performance.

Rest interval prescription might be as important as load and intensity of the priming activity [5, 10, 20, 29]. At low-loads, a short rest interval 1- to 2-minutes (min) may be enough to augment subsequent explosive performance. For example, it has been reported that improvements in low-load, high intensity plyometric activity occurred following 2-minutes of rest [5]. In addition, Read et al. (2013) revealed as little as one-minute of rest led to a significant ($p < 0.05$) 2.2% increase explosive performance. Yet, excessive rest (10-min) at low-loads may be too long to observe any potentiating effect on jump performance (pre: $43.94 \pm \pm 5.28$ cm; post: 44.70 ± 6.45 cm) [10]. Previous evidence suggests (6, 10, 20) that shorter rest intervals may be optimal to increase the likelihood of potentiation and ultimately performance. However, there is evidence that PAP responses may be highly individualized and that some individuals may peak early, while others late. Thus, there is a need to investigate a range of rest intervals at low-loads and high intensities to determine the optimal range.

Jump performance also appears to be elicited to a greater extent in those who have a higher degree of anaerobic training [17, 25]. In addition, there is evidence that individuals with higher absolute and relative strength may benefit from this phenomenon [6, 17]. Previous evidence [17] suggests that these individual differences may impact the time to peak performance around a PAP stimulus. For example, at high-load, high-intensity activity, individuals with a higher relative strength appear to potentiate closer to the PAP intervention, in comparison to those with a lower relative strength [17]. It is unknown if this same pattern of peak performance can be applied to a low-load, high-intensity sport-specific intervention such as the counter-movement jump (CMJ).

Although previous research has investigated the effect of low-load PAP protocols, these protocols differed in specific task, rest interval between PAP stimulus and performance, and individual training status [17]. Additional research is needed to determine an appropriate priming activity prescription to increase the likelihood of a PAP using a low-load priming activity across various loads and rest intervals for its effect on bodyweight (BW) CMJ performance in college-aged athletes.

Aim of Study

Therefore, the aim of the study was to determine whether different low-load (0%, 10%, and 20% of 1RM back squat) CMJ could induce PAP on subsequent BW CMJ across a 12-min rest interval range. Based on the findings of Chattong et al. [5] who reported a significant ($p < 0.05$) increase in jump height (post-intervention: 22.99 ± 3.35 in; pre-intervention: 22.69 ± 3.37) performance after a low-load intervention, it is hypothesized that there would be differences across conditions and time from baseline to one or more post-test jump performances and that group peak performance would likely occur closer to the potentiating stimulus, especially in those with higher levels of relative strength [3, 17].

Material and Methods

A mixed factor design investigated the influence of different low-load CMJs on subsequent bodyweight CMJ performance. On separate days, participants completed 1 maximal effort baseline CMJ. After 1-min of rest, participants performed either a control condition that included 20-s of standing without jumping, or 1 set of 6 CMJs. During the 1 set of 6 CMJs, participants jumped with only their BW (0%) or with 10% (10%)

or 20% (20%) of their back squat 1RM [5, 9]. The order of the conditions were randomized. Participants completed one CMJ at nine different time points for each of the following conditions (0.5-, 1-, 2-, 4-, 6-, 8-, 10-, and 12-min). Dependent variables analyzed included: CMJ height (JH), flight time (FT), estimated power output (eP). An a-priori power analysis to calculate sample size determined that in order to detect a significant effect size of 0.40, with an alpha of 0.05, and a power of 0.80, a minimum of 16 participants would be required. Potential significant effect size were calculated using investigations that measured similar variables [5, 6, 8, 20]. Twenty collegiate athletes from team sports such as football and men and women's basketball (FB, MBB, WBB, respectively) were recruited for this study. Two dropped out, resulting in a total of 18 athletes for our study (Table 1). Each participant demonstrated proper technique during the testing session to ensure the participant was able to safely perform the necessary exercises. Exclusionary criteria for participants included a history of any lower body musculoskeletal or orthopedic injuries within the last six months. There was no concern with women completing this exercise protocol while on their menstrual cycle [11], as research has shown it has no effect on jumping capabilities, nor significant differences of potentiation between men and women [29].

Table 1. Descriptive characteristics for anthropometrics and relative strength (rStrength) by sport

	Men's football	Men's basketball	Women's basketball
N	4	5	9
Age (y)	19.75 ± 0.96	20.60 ± 1.14	19.00 ± 0.00
Mass (kg)	82.04 ± 4.85	87.90 ± 13.81	75.14 ± 11.51
Height (cm)	176.85 ± 1.22	190.99 ±11.12	170.67 ± 6.73
Body fat (%)	9.95 ± 1.41	10.06 ± 5.87	22.94 ± 4.67
rStrength ($kg \cdot kg^{-1}$)	1.49 ± 0.20	1.13 ± 0.23	1.08 ± 0.24

Visit 1: Familiarization and one repetition maximum testing

All testing was completed in a strength and conditioning facility. Visit 1 consisted of familiarization and 1RM testing. First, each participant read and signed the institutionally approved informed consent document upon arrival to the facility; any questions were answered at this time. Then, a general warm up (GWU) was demonstrated for the participants to complete and use when instructed prior to the familiarization and intervention days: 10 jumping jacks, 10 BW squats, 5 walking knee hugs to full range of motion of plantar-flexion per leg, 5 forward lunges per leg, and 5 straight leg marches per leg [3, 15]. After the GWU, familiarization of CMJs were completed on the jump mat. Participants were instructed to begin in a standing and upright on the jump mat, with their arms above their head. Participants were instructed to stand on the jump mat. The investigated provided a countdown: "3.. 2.. 1.. Go!" On "Go", participants began to rapidly squat down to their self-selected depth by flexing the hip and knees while simultaneously swinging their arms down and behind their hips. Immediately following the downward/eccentric phase, participants explosively jumped, swinging their arms above their head (concentric phase). Two, 15-sec of rest periods were given between 3 jumps (18). Test-retest reliability was conducted of the jump mat for CMJ performance (JH, eP, and FT). Intraclass correlation coefficients (ICC) and 95% confidence intervals (CI) were calculated based on a mean-rating (k = 3), absolute-agreement, 2-way mixed-effects model (ICC = = 0.816-0.990, CI = 0.948 for jump mat JH; ICC = 0.966- -0.998, CI = 0.991 for eP; and ICC = 0.824-0.989, CI = = 0.945 for FT). Intraclass correlation coefficient ranges demonstrated good to excellent agreement indicating a high degree of agreement utilizing the jump equipment for CMJ performance. Following the CMJs, 10-min [23] sitting recovery was provided. After the recovery period, 1RM testing began and proper technique of the back squat was evaluated at this time.

One repetition maximum (1RM) testing of lower body strength: back squat (BS)

Following the wash-out period, the 1RM testing protocol was implemented in order to determine the appropriate intervention loads. The National Strength and Conditioning Association has published a standardized method to measure a 1RM of the back squat exercise [12]. Comfort and McMahon [7] demonstrated paired sample t-test, and no significant differences occurred between two trials of 1RM back squat (ICC = 0.994, $p < 0.001$) and an excellent reliability (0.978). If the 1RM back squat was not attained within 5 sets, retesting was scheduled on a separate day. This completed the familiarization and baseline-testing day.

A standard Olympic barbell (20 kg), universal exercise power rack and safety bars was used during the 1RM back squat. For the low-load CMJ conditions, the load of a standard adjustable weighted vest (Mir Vest Inc., San Jose, CA) was individualized and adjusted to the appropriate weight for each loaded intervention (10% and 20%); weight vest was not worn during the no-load condition. Measurement of CMJ height, flight time and estimated power was determined by a jump mat (Swift Performance, Northbrook, IL) [21]. The equation to estimate power associated with the jump mat was the Harman formula:

$$\text{Estimated power (W)} = 21.2 \times \text{jump height (cm)} + 23.0 \times \text{body mass (kg)} - 1393$$

Visits 2-5
Upon arrival to the weight room, participants completed the GWU as done on day one. One-min after the GWU, one maximal effort baseline CMJ was completed prior to each PAP intervention. In addition to the three intervention conditions (0%, and 10%, and 20% of 1RM BS), participants completed a NJ condition. On this day, participants completed the GWU, 1-min of rest, one maximal CMJ, followed by standing for 20-sec (time of intervention and walking over to the jump mat), and then performed one post-CMJ at each time interval. All conditions were implemented in a randomized order (NJ, 0%, and 10%, and 20% of 1RM BS) by selecting conditions randomly from a basket.

Loaded countermovement jump, PAP intervention
The no-load or low-load, high-intensity CMJ exercise was instructed following the guidelines of the NSCA [12]. Participants began in an upright position, feet with shoulder width apart, with the weighted vest on and velcrowed. Each participant was instructed to use an arm swing and a self-selected depth during the eccentric phase throughout all 6 jumping reps, immediately followed by pushing off the ground to jump. The landing position was the same as the starting position. Each rep of the CMJ was immediately repeated until all 6 reps were completed in a plyometric fashion. After the 1 set was completed, one maximal effort CMJ was performed at 0.5-, 1-, 2-, 4-, 6-, 8-, 10-, and 12-min. Participants were sat during the resting periods. This completed a single visit. The following three sessions were conducted as the first except for the intervention condition implemented in a randomized order.
Three, 4 × 9 (condition [NJ, 0%, 10%, and 20%] × time [baseline, 0.5-min, 1-min, 2-min, 4-min, 6-min, 8-min, 10-min, and 12-min]) and three, 4 × 2 (condition × time [baseline and peak value]) repeated measures analysis of variance (ANOVA) was used to analyze JH, eP, and FT. Bonferroni-corrected dependent sample t-tests were completed where indicated by significant main effects. Greenhouse–Geisser corrections were applied when sphericity was not met according to Mauchly's test of sphericity. Partial eta squared (η_p^2) and Cohen's d (small × 0.20 to 0.49, medium = 0.50 to 0.79, and large = 0.80 and above) effect sizes were also calculated for each ANOVA and t-test, respectively. All confidence intervals were calculated at 95%. For all analyses, an a-priori alpha was set at 0.05 and all statistical analyses were performed using IBM Statistical Package for Social Sciences software (version 25.0, SPSS Inc. Chicago, Il, USA).

Results

Jump height (JH)
The 4 × 9 ANOVA revealed no significant ($p = 0.980$, $\eta_p^2 = 0.028$) condition × time interaction, main effect for condition ($p = 0.411$, $\eta_p^2 = 0.520$), or main effect for time ($p = 0.105$, $\eta_p^2 = 0.120$). Further analysis with a 4 × 2 ANOVA showed no significant ($p = 0.672$, $\eta_p^2 = 0.200$) condition × time interaction or main effect for condition ($p = 0.393$, $\eta_p^2 = 0.053$). There was, however, a main effect for time ($p < 0.001$, $\eta_p^2 = 0.801$), with pairwise comparisons revealing that peak JH values were significantly ($p < 0.001$) greater than baseline values (Table 2). The corresponding effect size (Cohen d) was 0.30, (CI: –0.36; 0.95).

Estimated power (eP)
The 4 × 9 ANOVA revealed no significant ($p = 0.594$, $\eta_p^2 = 0.034$) condition × time interaction, main effect for condition ($p = 0.230$, $\eta_p^2 = 0.084$), or main effect for time ($p = 0.118$, $\eta_p^2 = 0.112$). Further analysis with a 4 × 2 ANOVA showed no significant ($p = 0.673$, $\eta_p^2 = 0.018$) condition × time interaction or main effect for condition ($p = 0.228$, $\eta_p^2 = 0.081$). There was, however, a main effect for time ($p < 0.001$, $\eta_p^2 = 0.623$), with pairwise comparisons revealing that peak eP values were significantly ($p < 0.001$) greater than baseline values (Table 2). The corresponding effect size (Cohen d) was 0.21, (CI: –0.49; 0.90).

Flight time (FT)
The 4 × 9 ANOVA revealed no significant ($p = 0.652$, $\eta_p^2 = 0.037$) condition × time interaction or main effect for condition ($p = 0.253$, $\eta_p^2 = 0.076$). There was, however, a main effect for time ($p = 0.030$, $\eta_p^2 = 0.163$). Pairwise comparisons revealed that FT at 2-min was significantly ($p = 0.031$) greater than 10-min, and FT at 4-min was significantly greater than 8-min ($p = 0.031$), 10-min ($p < 0.001$) and 12-min ($p < 0.001$). Further

analysis with a 4 × 2 ANOVA showed no significant ($p = 0.533$, $\eta_p^2 = 0.018$) condition × time interaction or main effect for condition ($p = 0.406$, $\eta_p^2 = 0.081$). There was, however, a main effect for time ($p < 0.001$, $\eta_p^2 =$ $= 0.623$), with pairwise comparisons revealing that peak FT values were significantly ($p < 0.001$) greater than baseline values (Table 2). The corresponding effect size (Cohen d) was 0.29 (CI: –0.36; 0.92).

Table 2. Jump height (JH), estimated power (eP), and flight time (FT), main effect for time

	JH	eP	FT
Base	44.44 ± 11.41	1366.46 ± 428.63	0.598 ± 0.08
0.5 min	44.44 ± 10.36	1383.86 ± 388.56	0.599 ± 0.08
1 min	45.12 ± 09.80	1394.32 ± 369.86	0.604 ± 0.07
2 min	45.51 ± 09.92	1406.81 ± 376.03	0.605 ± 0.08*
4 min	45.74 ± 10.56	1412.65 ± 385.09	0.608 ± 0.08*ˣ
6 min	44.59 ± 09.90	1387.50 ± 377.07	0.599 ± 0.07
8 min	44.69 ± 09.81	1385.68 ± 376.80	0.598 ± 0.07
10 min	44.18 ± 10.25	1378.63 ± 381.47	0.596 ± 0.07
12 min	44.13 ± 09.90	1375.29 ± 367.58	0.596 ± 0.08
Peak	47.92 ± 11.86^	1455.71 ± 419.78^	0.621 ± 0.08^

Mean ± SD (s)
^ significantly ($p < 0.05$) greater than baseline; * significantly ($p < 0.05$) greater than 10-min; ˣ significantly ($p < 0.05$) greater than 8-, 10-, and 12-min

Discussion

The purpose of this study was to investigate whether different low-load CJMs (0%, 10%, and 20% of 1RM) could induce PAP for subsequent CMJs. There were no differences in jump performance between conditions, including the NJ condition, at any time point. However, individual responses indicated that each subject's peak jump performance was greater than baseline, indicating that all subjects did in fact potentiate at unique time points. Therefore, it seems as though a combination of the GWU, baseline measurements, and a single-set of low-load jumps may have been enough to induce PAP for FT within close proximity (2- and 4-min). This rapid time-dependent change is supported by previous literature [3, 5] showing that potentiation likely appears and disappears quickly when the priming activity is not fatiguing, especially in stronger individuals [5, 8, 27].

The main finding of the present study was that although none of the low-load priming activities potentiated jump performance better than any of the other conditions, each subject did in fact experience their own individualized PAP effect (Figure 1). This finding is in line with previous research showing that PAP seems to be a highly individualized phenomenon [25, 26, 29]. Previous findings [3, 25, 29] have shown that the time to potentiation peak after an explosive priming activity is highly individualized and improvements in jump performance may begin as early as 1-min, but as late as 12-min after an intervention. It has also been reported that the differences in individual responses may be due to prescribed recovery intervals, volume, intensity, and strength level [17, 23, 24, 29]. The approach of recruiting skeletal muscle across the force-velocity spectrum to ultimately improve acute power output may rely greater on established neuromuscular pathways [2] and specific exercise prescription given for the priming activity (intensity and volume).

Highly trained individuals should have improved synchronization and recruitment patterns of the higher-order fibers, and therefore, should have the ability to recruit fibers faster or additional fibers overall [4, 12]. This may be an explanation for augmented jump performance for time, but not condition within the present study. Nevertheless, explosive priming activities appear to elicit a PAP response that is highly individualized, which suggests a trial-and-error approach might be needed to determine the optimal PAP stimulus on an individual basis rather than prescribed from mean responses.

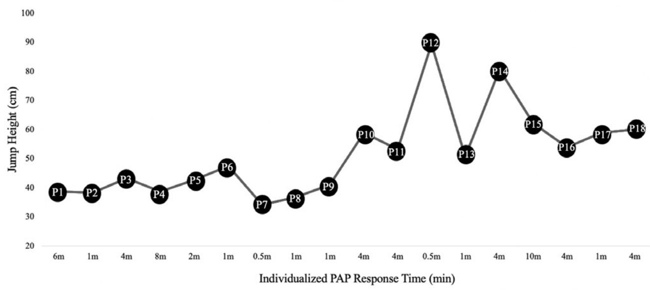

Figure 1. Individual responses by participant (P) for jump height (cm)

Note: m – minute

A time-dependent change in jump performance (FT) occurred, but that response was similar regardless of condition. Previous literature reported early jump performance improvements from 2- to 5-min post-priming activity following no- and low-load conditions [5, 8, 27], which is similar to the current study. Moreover, Chattong et al. [5], Cuenca- Fernández et al. [8], and Turner et al. [27] all had single recovery periods, 2-min, 5-min, and 4-min, respectively, and did not include other post-testing time points, meaning that it is possible potentiation could have occurred before or after these recovery time points. Despite a lack of improvement between no- and low-load conditions before the priming activity, the implemented GWU might have been sufficient stimulus to prime the skeletal muscle and nerves to augment overall performance, even minimally [5, 8]. Further suggesting, regardless of the load priming activity, PAP is highly individualized, and the stimuli might need to be individualized or a self-selected rest interval might be needed to augment a change between conditions for the current population.

The current sample of collegiately trained athletes were similar to those recruited in previous literature [5, 8, 27], suggesting the weighted conditions were not enough to elicit a physiological response that differed from a single baseline jump. Previous research has shown that stronger athletes can potentiate within a shorter period of time than weaker athletes [17, 25, 29]. Furthermore, stronger individuals may require a more intensive priming activity in order to stimulate a PAP response [17, 29]. Considering the athletes in the present study had an average BS 1RM of about 110 to 150% of their body mass, we did not have enough individuals to separate by relative strength into even "strong" or "weaker" categories to determine if there was a unique "strength" effect on the PAP response to the low-volume low-load priming activity used in the present study. Therefore, future studies should investigate whether athletes with different strength levels respond in unique patterns to such low-load protocols. Additionally, it is possible that the stronger athletes would have needed a more fatiguing stimulus in order to encourage PAP. Future research should determine whether a greater volume of low-load exercises could potentiate CMJ performance to a greater extent than in the present study. Despite the inability to compare individuals based on strength characteristics, the findings of the present study are reflective of what is common among team sport athletes. In team sports, athletes commonly have different relative strength levels, where some members are relatively stronger than other members of the same team. The data from current study indicates that there may be impact of relative strength on a PAP performance response. Thus, when utilizing PAP, the relative strength data lends evidence that coaches should assess PAP interventions based on the individual rather than the mean strength of the whole team.

Conclusions

The study demonstrated that individual subjects experienced a PAP effect, and that a GWU alone may be sufficient to stimulate PAP in some individuals. The findings of the present study lend evidence to the notion that a priming stimulus as simple as a GWU may be sufficient to stimulate a rapid PAP response, as most subjects potentiated within 2- to 4-min. Furthermore, there were moderate-to-large effects for peak FT, JH, and eP compared to baseline, indicating that the individualized PAP responses observed in this study likely could be a practical warm-up for jump performance. The results of the present study also provided support to the individualized nature of PAP responses and that individual prescriptions of varying volumes or intensities may be required to maximize effectiveness of a potentiation intervention. Thus, a specific prescription to elicit a PAP response is recommended and should be adjusted based on current status and training abilities to ensure optimal subsequent jump performance.

Although the purpose of this study was to investigate the effects of a single set of low-load jumps on subsequent BW jump performance, increasing the volume of jumps may have resulted in greater potentiation and future studies should investigate the effects of multiple sets of low-load jumps. Furthermore, the influence of relative strength should be investigated to determine whether relatively stronger or weaker individuals respond better to low-load, low-volume priming activities, which may help clarify how potentiation is elicited and best be prescribed.

References

1. Arias J, Coburn JW, Brown LE, Galpin AJ. The acute effects of heavy deadlifts on vertical jump performance in men. Sports. 2016;4(2):22.
2. Brooks GA, Fahey TD, White TP. Exercise Physiology: Human Bioenergetics and Its Applications. Mountain View, CA: Mayfield Publishing Company; 1996.
3. Cazás VL, Brown LE, Coburn JW, Galpin AJ, Tufano JJ, Laporta JW, et al. Influence of rest intervals after assisted jumping on bodyweight vertical jump performance. J Strength Cond Res. 2013;27:64-68.
4. Chandler TJ, Brown LE. Conditioning for Strength and Human Performance. Philadelphia, PA: Lippincott Williams & Wilkins; 2008.
5. Chattong C, Brown LE, Coburn JW, Noffal GJ. Effect of a dynamic loaded warm-up on vertical jump performance. J Strength Cond Res. 2010;24(7):1751-1754.
6. Chui LZF, Fry AC, Weiss LW, Schiling BK, Brown LE, Smith SL. Post activation potentiation response in athletic and recreationally trained individuals. J Strength Cond Res. 2003;17:617-677.

7. Comfort P, McMahon JJ. Reliability of maximal back squat and power clean performances in inexperienced athletes. J Strength Cond Res. 2005;29(11):3089-3096.
8. Cuenca-Fernández F, Smith IC, Jordan MJ, MacIntosh BR, López-Contreras G, Arellano R, et al. Nonlocalized postactivation performance enhancement (PAPE) effects in trained athletes: a pilot study. Appl Physiol Nutr Metab. 2017;42(10):1122-1125.
9. Esformes J, Cameron N, Bampouras TM. Postactivation potentiation following different modes of exercises. J Strength Cond Res. 2010;24:1911-1916.
10. Faulkinbury K, Stieg JL, Brown LE, Coburn JW, Judelson DA. Potentiating effects of depth and box jumps on vertical jump performance in female collegiate volleyball players. J Strength Cond Res. 2010; 24(1).
11. Giacomoni M, Bernard T, Gavarry O, Altare S, Falgairette G. Influence of the menstrual cycle phase and menstrual symptoms on maximal anaerobic performance. Med Sci Sports Exerc. 2000;32(2),486-492.
12. Haff GG, Triplett NT, editors. Essentials of Strength Training and Conditioning. 4th edition. Champaign, IL: Human Kinetics; 2015.
13. Hanson ED, Leigh S, Mynark RG. Acute effects of heavy- and light-load squat exercise on the kinetic measures of vertical jumping. J Strength Cond Res. 2007;21:1012--1017.
14. Hodgson M, Docherty D, Robbins D. Post-activation potentiation: underlying physiology and implications for motor performance. Sports Med. 2005;35:585-595.
15. Jeffreys I. Warm-up and flexibility training. In: Haff GG, Triplett NT, editors. Essentials of Strength and Conditioning. Champaign, IL: Human Kinetics; 2005. pp. 318-350.
16. Jeffreys I. Warm-up revisited – the ‘ramp’ method of optimising performance preparation. UKSCA Journal. 2007; 6,15-19.
17. Jo E, Judelson DA, Brown LE, Coburn JW, Dabbs NC. Influence of recovery duration after a potentiating stimulus on muscular power in recreationally trained individuals. J Strength Cond Res. 2010;24(2),343-347.
18. Lowery RP, Duncan NM, Loenneke JP, Sikorski EM, Naimo MA, Brown LE, et al. The effects of potentiating stimuli intensity under varying rest periods on vertical jump performance and power. J Strength Cond Res. 2012;26(12):3320-3325.
19. Montoya BS, Brown LE, Coburn JW, Zinder SM. Effect of warm-up with different weighted bats on normal baseball bat velocity. J Strength Cond Res. 2009;23(5):1566--1569.
20. Read PJ, Miller SC, Turner AN. The effects of postactivation potentiation on golf club head speed. J Strength Cond Res. 2013;27(6):1579-1582.
21. Rogan S, Radlinger L, Imhasly C, Kneubuehler A, Hilfiker R. Validity study of a jump mat compared to the reference standard force plate. Asian J Sports Med. 2015;6(4): e25561.
22. Sale DG. Postactivation potentiation: role in human performance. Exerc Sport Sci Rev. 2002;30:138-143.
23. Slattery KM, Wallace LK, Bentley DJ, Coutts AJ. Effect of training load on simulated team sport match performance. Appl Physiol Nutr Metab. 2012;37(2):315--322.
24. Thompsen AG, Kackley T, Palumbo MA, Faigenbaum AD. Acute effects of different warm-up protocols with and without a weighted vest on jumping performance in athletic women. J Strength Cond Res. 2007;21(1):52-56.
25. Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. Sports Med. 2009;39(2):147-166.
26. Tobin DP, Delahunt E. The acute effect of a plyometric stimulus on jump performance in professional rugby players. J Strength Cond Res. 2014;28(2):367-372.
27. Turner AP, Bellhouse S, Kilduff LP, Russell M. Postactivation potentiation of sprint acceleration performance using plyometric exercise. J Strength Cond Res. 2015;29(2):343-350.
28. Weber KR, Brown LE, Coburn JW, Zinder SM. Acute effects of heavy-load squats on consecutive squat jump performance. J Strength Cond Res. 2008;22(3):726-730.
29. Wilson JM, Duncan NM, Marin P, Brown LE, Loenneke JP, Wilson SM, et al. Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. J Strength Cond Res. 2013;27(3):854-859.
30. Zatsiorsky VM, Kraemer WJ. Science and practice of strength training. Champaign, IL: Human Kinetics; 2006.