Effect of Various Practical Warm-up Protocols on Acute Lower-Body Power

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Abstract

Buttifant, D and Hrysomallis, C. Effect of various practical warm-up protocols on acute lower-body power. *J Strength Cond Res* 29(3): 656–660, 2015—The purpose of this study was to compare the acute effect of box squats with barbell (BBSquat), box squats with elastic resistance bands (BandSquat), and static stretches (SStretch) on external power during a 20-kg weighted jump squat. Twelve male athletes performed each of the 3 warm-up protocols on separate occasions in a randomized order. Weighted jump squat power was assessed using a linear position transducer attached to the bar of a Smith machine. Jump power was measured pre-warm-up and 5 and 10 minutes post-warm-up protocol. The BBSquat protocol involved 3 sets of 3RM, BandSquat involved 3 sets of 3 repetitions using highest resistance elastic bands, and the SStretch protocol comprises two 30-second stretches for muscles of the lower limbs. Jump power significantly increased from pre-warm-up to 5 and 10 minutes post-warm-up for both the BandSquat and BBSquat protocols. There was no statistical difference in power values between BandSquat and BBSquat. Power output significantly decreased from pre-warm-up to 5 and 10 minutes post-warm-up for the SStretch protocol. The BandSquat was just as effective as BBSquat in augmenting acute jump power. The SStretch was detrimental to jump performance. A practical warm-up using relatively inexpensive and portable equipment such as elastic resistance bands was just as effective as a warm-up protocol that requires more substantial and less transportable equipment such as a squat rack and associated free weights. The BandSquat warm-up may be considered more accessible for athletes at various competition levels.

Key Words weighted jump squat, post-activation potentiation, elastic resistance

Introduction

The general purpose of a warm-up for training or competition is to assist in the physiological preparation for the increase in activity intensity so as to optimize performance and reduce injury risk (1,35). Different activities may be included as part of the warm-up: low-intensity aerobic exercise, stretching, dynamic drills, and, more recently, moderate (60–85% 1 repetition maximum [1RM]) or high-intensity (>85% 1RM) resistance exercises (32). Research to establish optimal warm-up protocols is a relatively recent occurrence so there are limited data to indicate which warm-up procedures are ideal for particular activities or athletes (21,22).

Acute static stretching has generally been shown to adversely affect maximal strength and explosive muscle performance (26), particularly from longer duration stretches (15). This negative affect has been reported for various levels of athletes, range of ages, and both genders (26). The mechanisms by which static stretching may impair power generation have not been fully elucidated but it has been proposed to be associated with decreased musculotendinous stiffness (24) or diminished capacity to recruit motor units (19). Although the short-term effects of static stretching have not been seen to be beneficial to performance in most cases, negative effects have not been reported in some studies, probably associated with low dosage, whole body, or multi-segment performance measures (10,16,18). Further research on the negative effect of static stretching on multi-segment motion is warranted considering that many athletes still incorporate stretching in warm-ups despite the paucity of positive effects.

Moderate- or high-intensity resistance exercises, such as loaded squats or leg press, elicit a post-activation potentiation (PAP) that may initially enhance power output during jumping (31,34) and sprinting (33,36). Post-activation potentiation is when a strength conditioning exercise precedes a more dynamic exercise or activity with similar movement patterns, leading to an improved performance in the main activity (7). Post-activation potentiation may also be the mechanism of warm-ups with lower intensity overloads using equipment like weighted vests in some athletes (5,29). The postulated mechanisms for the PAP occurrence include phosphorylation of myosin regulatory light chains

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and increased recruitment of higher threshold motor units within the activated muscles (30). Previous studies (6,31,36) have used equipments such as squat racks and leg press machines, which although effective are not easily portable or affordable to all levels of sporting participation. It has been claimed that in most competitive situations, it is probably not feasible to provide the time or equipment to perform moderate- or high-intensity efforts to elicit PAP (4). These limitations may be overcome by equipments such as elastic resistance bands that are relatively inexpensive and can be taken to competition venues to be used immediately before commencement of competition. Resistance bands also differ from free weights and many machines by providing variable resistance, which is increased toward the end range of motion as the bands undergo elongation. It is unknown if an easily administered warm-up protocol with moderate-intensity resistance bands is as effective as high-intensity barbell squats in augmenting short-term power production.

The purpose of this study was to investigate the acute effect of 3 different warm-up protocols on power production during a weighted jump squat (WJS) test. It is hypothesized that an elastic resistance band squat protocol would be just as effective as a heavy barbell squat protocol and both of these would be superior to a static stretching protocol.

Methods

Experimental Approach to the Problem

Each participant first performed a generic warm-up protocol that consisted of 5 minutes of low-intensity jogging on an indoor synthetic track. On 3 separate occasions, during the same time of day and in random order with at least 3 days between the different protocols, the participants performed 3 specific warm-up protocols: elastic resistance band box squat (BandSquat), barbell box squat (BBSquat), and a series of static stretches (SStretch). The BandSquat and BBSquat protocols involved 2 low-intensity warm-up sets of 10 repetitions before completing 3 sets of a predicted 3RM for BBSquat and 3 repetitions of BandSquat using the highest resistance bands. Participants were permitted 2-minute recovery between each set. The BandSquat group performed box squats using 2 "Monster 41" Power Bands (Iron Edge, Melbourne, Australia) placed under each foot and looped over the contralateral shoulder. The participants were instructed to control their descent and then attempt to ascend as quickly as possible, the intent was to try and move the resistance as rapidly as possible. Each band can provide a resistance range of 390 N (40 kg) to 880 N (90 kg) (14). To gauge the level of resistance encountered from elongation during the BandSquat, the bands were placed around a steel rod positioned underneath calibrated digital scales (Tanita BWB-600; Tanita Corporation, Tokyo, Japan) and the exercise was performed on the scales with similar band configuration and movement. The bands underwent elongation equivalent to the average shoulder height of the participants, which was 160 cm. The scale reading was initially tared with a test participant crouched on the scales so as not to generate any tension in the bands. The participant then ascended to the predetermined height and the kilogram reading was recorded.

The box squats were performed to a depth of about 90° of knee flexion; participants were instructed to arch their back, keep their chest and eyes forward, squat down to contact the box completely with their buttocks while maintaining muscle activation during the brief contact stage and then try to ascend as quickly as possible. Dynamic loaded squats were chosen as the moderate- or high-intensity exercise before WJSs because it has been suggested that the movement pattern of the warm-up activity should closely match the power exercise to optimize PAP (30). All participants were experienced with BBSquat, BandSquat, SStretch, and WJS. The SStretch protocol involved two 30-second static stretches of the muscles of the lower limbs: seated hamstring, standing quadriceps, seated gluteal, and standing calf (13).

Weighted jump squats were conducted before the specific warm-up protocols and at 5 and 10 minutes following. The WJSs were performed on a Smith machine with the 20-kg barbell placed across the top of the participant's shoulders. Each participant was instructed to jump as high as possible keeping the bar in contact with their shoulders. During the test, each participant completed 2 separate jumps with a brief pause between each jump. A GymAware (Kinetic Performance Technology, Canberra, Australia) linear position transducer was used to calculate the external power applied to the barbell (17), which was used to indicate lower-body power production. The execution of WJSs with the GymAware transducer attached to the guided barbell of a Smith machine has been shown to produce greater reliability of power values than jumps with the transducer attached to a wooden stick or free barbell (12). GymAware uses variable rate sampling with level crossing detection to capture data points. It then limits (down samples) this to a maximum of 50 points per second. This differs to a traditional 50-Hz continuous sampling system as position points are time-stamped with a high-resolution (35 microseconds) time value. This sampling method involves that data are only recorded during movement and the data are not filtered (9). GymAware software calculated external power applied to the bar by the athlete from the formula: power = force × velocity. The net vertical force applied to the bar was calculated from the product of bar mass and vertical acceleration calculated from the second derivative of the transducer position data. Vertical velocity of the bar was calculated from the first derivative of the position data (8,27). The validity of a linear position transducer to measure related jump performance parameters was previously established by comparing its mean force and peak force with data simultaneously collected from a force platform and found $r = 0.86–0.96$ (3). The intertrial reliability of the GymAware data for mean power determined during pilot work was intraclass correlation coefficient = 0.85. The bar mass of 20 kg was entered into the

Table 1. Mean (*SD*) power for weighted jump squats.*

Warm-up	Pre-warm-up (W)	5 min Post (W)	Change from pre	10 min Post (W)	Change from pre	Change from 5 min (%)
BandSquat	529 (106)	592† (106)	+12%, $d = 0.59$	599† (103)	+13%, $d = 0.67$	+1
BBSquat	505 (72)	564† (107)	+12%, $d = 0.66$	578† (108)	+14%, $d = 0.68$	+2
SStretch	540 (92)	510† (94)	−6%, $d = 0.32$	519† (86)	−4%, $d = 0.24$	+2

*BandSquat = band box squat; BBSquat = barbell box squat; SStretch = static stretches; d = Cohen's effect size.
†Statistically significant difference to pre warm-up at $p \leq 0.05$.

calculation of power. Comparisons were made between the same participant across the different protocols, eliminating the necessity for body mass to be included in the power calculation. The highest mean power value of the 2 trials of each athlete was used for subsequent analysis. Mean power, being the average rate of doing work over the concentric lift phase, has been found to be slightly more reliable for WJSs than peak power (28) and also suggested by the GymAware manufacturers (23).

Subjects

Twelve semiprofessional Australian Rules male footballers were recruited and provided informed consent. The project was approved by the Collingwood Football Club Sport Science Department. The average age, height, body mass, and 3RM BBSquat of the participants was 21 ± 2 years (range 18 to 24), 187 ± 6 cm, 86 ± 11 kg, and 127 ± 16 kg, respectively.

Statistical Analyses

Statistical analyses involved 2-way repeated-measures analysis of variance with post hoc paired t-tests. Significance level was chosen as $p \leq 0.05$.

Results

The mean power values from the WJSs are depicted in Table 1; the data satisfied the requirements for normality. There were no significant differences in power output pre-warm-up for the 3 different protocols ($p > 0.05$). The main effect of time was significant ($F_{2,22} = 20.9$, $p < 0.001$), power values significantly increased from pre-warm-up to 5 and 10 minutes post-warm-up for both the BandSquat and BBSquat protocols and decreased for SStretch. The main effect of warm-up type was also significant ($F_{2,22} = 3.64$, $p = 0.043$) with SStretch being significantly different to BandSquat and BBSquat at 5 and 10 minutes post-warm-up. There was no difference in power values between BandSquat and BBSquat at any time point. The interaction effect was significant after Huynh-Feldt adjustment ($F_{2.022,22.25} = 12.033$, $p < 0.001$); the type of warm-up had a significant effect on power output at 5 and 10 minutes post-warm-up with the SStretch protocol being least beneficial. The load encountered during the BandSquat condition was approximately 101 kg at full extension for participants of mean height compared with an average load of 127 kg encountered during the BBSquat.

Discussion

The present study found that moderate- to high-intensity box squats performed with elastic resistance bands or free weights were effective in significantly enhancing vertical jump power. Mean WJS power was significantly increased at 5 and 10 minutes post-warm-up for both BandSquat and BBSqaut protocols with similar percentage increase in mean power. All the participants increased acute power after the squat exercises with resistance band or barbell. This finding illustrates that a practical warm-up protocol with elastic resistance bands is just as effective as a protocol that involves equipment that is less portable, more expensive, and possibly less practical before or during breaks in competition. The current study found improvements in acute power of 12–14% and of moderate effect size (d = 0.59–0.68). Direct comparisons of the magnitudes of any improvement with others studies are difficult because of differences in jumping protocol and measured parameters. An early study (34) found that 5 repetitions of a 5RM back squat increased weighted (19 kg) jump squat height by 3%. Another study (31) showed that 5 repetitions of 85% 1RM back squat increased average, peak jump height, and peak ground reaction force of 7 consecutive jump squats by 5–6%.

There are a number of factors that may influence power augmentation from PAP after a warm-up protocol: intensity and volume of the warm-up, rest period length and training status of the participants (32). Athletes in the current study used an intensity of 3RM for BBSquat, which equates to approximately 90% 1RM for resistance trained athletes (2). It has previously been found that both moderate- (70%) and high-intensity (93% 1RM) squats similarly enhanced jump performance in resistance trained participants; however, the high-intensity workload may prolong the duration of the potentiation (20). The load encountered during the BandSquat condition was approximately 101 kg at full extension for participants of mean height, which was less than the average load of 127 kg encountered during the BBSquat. In affect, BBSquat were performed with approximately 90% 1RM load, whereas BandSquat were performed with a load approximating 70% 1RM. Despite the disparity in intensity, BandSquat were shown to be just as effective as BBSquat in increasing acute WJS power and there was no difference at 5 and 10 minutes post-warm-up.

The current study found PAP at both 5 and 10 minutes post-warm-up. A recent meta-analysis of the effect of rest period length on jumping performance found that a rest interval range of 0–3 minutes had a detrimental effect on jump performance, a range of 8–12 minutes was beneficial, whereas a 4- to 7-minute rest interval did not generally show a change (7). If the rest period is too short, then the negative influence of fatigue will probably outweigh the value of PAP, and if the period is too long, then PAP will likely be dissipated. There seems to be window of time where PAP outweighs fatigue and consequently enhances performance. The results of the current study revealed that a rest interval of 5–10 minutes was beneficial to power production.

The warm-up protocol that involved stretching produced a significant reduction in WJS power 5 and 10 minutes post-warm-up. This decrement in acute power performance is in agreement with some previous research (11,25), although this finding may not be universal with a recent meta-analysis concluding that the effects on muscle power were unclear (26). When individual data from the present study are examined, 11 of the 12 participants displayed a reduction in mean power. One participant showed a slight increase (4%) in jump power post-SStretch. This highlights the fact that not all athletes will respond similarly to a given protocol and static stretching may not be detrimental to all athletes. Consideration may need to be given to individualized warm-up protocols because it has also been stated that there may be individual differences in response to PAP (20). The training status of the participants may influence the magnitude of PAP with greater strength associated with experienced resistance-trained athletes inducing a greater PAP response than less trained participants (7,20). There were no significant correlations between 3RM absolute or relative squat weight with changes in WJS power in the current study, possibly because the participants were all experienced with resistance training.

Although the findings of this study may have important practical applications, limitations need to be noted. The determination of the physiological mechanisms for power enhancement or decrement was beyond the scope of this project. The participants were high-caliber male team sport athletes and it is unclear if the magnitude of the results would be reflective of those of other athletes. It is recommended that further research is required to extent the present results with a range of athletes, larger sample size, and further exploration of any potential individualized responses (21,22).

The findings of this project using a cohort of semi-professional Australian Rules male footballers found that a warm-up protocol comprising moderate-intensity BandSquat was just as effective as high-intensity BBSquat in augmenting loaded WJS power at both 5 and 10 minutes post-warm-up. There were no statistical differences in power values generated between the 2 squat protocols at any of the periods. These protocols may be of value to many athletic endeavors that require optimal lower body power, particularly at the commencement of training or competition. The SStretch protocol had a negative effect on jump power on all but 1 participant and should generally be avoided unless individual data suggest that it is not detrimental.

Practical Applications

Both a high-intensity BBSquat and moderate-intensity BandSquat warm-up protocol were effective in increasing acute jump power at 5 and 10 minutes post-warm-up. The SStretch warm-up protocol was generally found to be detrimental to acute jump power and should not be encouraged in preparation for events that require optimal lower-body power and not excessive flexibility. The BandSquat warm-up protocol is more viable for most levels of sporting participation because the equipment is more portable and affordable than that normally required for the BBSquat protocol. Although this project was conducted with athletes who participate in Australian Rules football, the findings may be applicable and relevant to a number of athletic pursuits, contributing to optimal preparation before training or competition.

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References

1. Bishop, D. Performance changes following active warm up and how to structure the warm up. *Sports Med* 33: 483–498, 2003.
2. Brechue, WF and Mayhew, JL. Lower-body work capacity and 1RM squat prediction in college football players. *J Strength Cond Res* 26: 364–372, 2012.
3. Cronin, JB, Hing, RD, and McNair, PJ. Reliability and validity of a linear position transducer for measuring jump performance. *J Strength Cond Res* 18: 590–593, 2004.
4. Docherty, D and Hodgson, MJ. The application of postactivation potentiation to elite sport. *Int J Sports Physiol Perform* 2: 439–444, 2007.
5. Faigenbaum, AD, McFarland, JE, Schwerdtman, JA, Ratamess, NA, Kang, J, and Hoffman, JR. Dynamic warm-up protocols, with and without weighted vest, and fitness performance in high school female athletes. *J Athl Train* 41: 357–363, 2006.

6. Gourgoulis, V, Aggeloussis, N, Kasimatis, P, Mavromatis, G, and Garas, A. Effect of a submaximal half squats warm-up program on vertical jumping ability. *J Strength Cond Res* 17: 342–344, 2003.
7. Gouvea, AL, Fernandes, IA, Cesar, EP, Silva, WA, and Gomes, PS. The effects of rest intervals on jump performance: A meta-analysis on post-activation potentiation studies. *J Sports Sci* 31: 459–467, 2013.
8. Gowitzke, BA and Milner, M. *Scientific Bases of Human Movement* (3rd ed.). Baltimore, MD: Williams & Wilkins, 1988. pp. 58–59.
9. GymAware sampling methodAvailable at: http://kinetic.helpdocsonline.com/userfiles/1050/1547/ckfinder/files/FactSheets/sample.pdf. Accessed July 29, 2014.
10. Hirayama, K. Acute effects of an ascending intensity squat protocol on vertical jump performance. *J Strength Cond Res* 28: 1284–1288, 2014.
11. Holt, BW and Lambourne, K. The impact of different warm-up protocols on vertical jump performance in male collegiate athletes. *J Strength Cond Res* 22: 226–229, 2008.
12. Hori, N and Andrews, WA. Reliability of velocity, force and power obtained from the Gymaware optical encoder during countermovement jump with and without external loads. *J Aust Strength Cond* 17: 12–17, 2009.
13. Hrysomallis, C, Buttifant, D, and Buckley, N. Flexibility. In: *Weight Training for Australian Football.* Melbourne, Australia: Lothian Books, 2006. pp. 119–126.
14. Iron Edge. Available at: http://www.ironedge.com.au/store/1-x-monster-41-power-band-black.html. Accessed December 16, 2013.
15. Kay, AD and Blazevich, AJ. Effect of acute static stretch on maximal muscle performance: A systematic review. *Med Sci Sports Exerc* 44: 154–164, 2012.
16. Knudson, D, Bennett, K, Corn, R, Leick, D, and Smith, C. Acute effects of stretching are not evident in the kinematics of the vertical jump. *J Strength Cond Res* 15: 98–101, 2001.
17. Knudson, DV. Correcting the use of the term “power” in the strength and conditioning literature. *J Strength Cond Res* 23: 1902–1908, 2009.
18. Knudson, DV, Noffal, GJ, Bahamonde, RE, Bauer, JA, and Blackwell, JR. Stretching has no effect on tennis serve performance. *J Strength Cond Res* 18: 654–656, 2004.
19. Leone, DC, Pezarat, P, Valamatos, MJ, Fernandes, O, Freitas, S, and Moraes, AC. Upper body force production after a low-volume static and dynamic stretching. *Eur J Sport Sci* 14: 69–75, 2014.
20. Lowery, RP, Duncan, NM, and Loenneke, JP. The effects of potentiating stimuli intensity under varying rest periods on vertical jump performance and power. *J Strength Cond Res* 26: 3320–3325, 2012.
21. Mandengue, SH, Miladi, I, Bishop, D, Temfemo, A, Cisse, F, and Ahmaidi, S. Methodological approach for determining optimal active warm-up intensity: Predictive equations. *Sci Sports* 24: 9–14, 2009.
22. Mandengue, SH, Seck, D, Bishop, D, Cisse, F, Tsala-Mbala, P, and Ahmaidi, S. Are athletes able to self-select their optimal warm up? *J Sci Med Sport* 8: 26–34, 2005.
23. Peak power or mean power… What parameter should I measure and why?Available at: http://kinetic.helpdocsonline.com/userfiles/1050/1547/ckfinder/files/FactSheets/Peak_Mean.pdf. Accessed July 29, 2014.
24. Ryan, ED, Beck, TW, Herda, TJ, Hull, HR, Hartman, MJ, Costa, PB, Defreitas, JM, Stout, JR, and Cramer, JT. The time course of musculotendinous stiffness responses following different durations of passive stretching. *J Orthop Sports Phys Ther* 38: 632–639, 2008.
25. Samuel, MN, Holcomb, WR, Guadagnoli, MA, Rubley, MD, and Wallmann, H. Acute effects of static and ballistic stretching on measures of strength and power. *J Strength Cond Res* 22: 1422–1428, 2008.
26. Simic, L, Sarabon, N, and Markovic, G. Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scand J Med Sci Sports* 23: 131–148, 2013.
27.. Sports Physics–What is power and how can it be measuredAvailable at: http://kinetic.helpdocsonline.com/userfiles/1050/1547/ckfinder/files/FactSheets/What_is_power.pdf. Accessed July 29, 2014.
28. Taylor, KL, Cronin, J, Gill, ND, Chapman, DW, and Sheppard, J. Source of variability in iso-inertial jump assessments. *Int J Sports Physiol Perform* 5: 546–558, 2010.
29. Thompsen, AG, Kackley, T, Palumbo, MA, and 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* 21: 52–56, 2007.
30. Tillin, NA and Bishop, D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Med* 39: 147–166, 2009.
31. Weber, KR, Brown, LE, Coburn, JW, and Zinder, SM. Acute effects of heavy-load squats on consecutive squat jump performance. *J Strength Cond Res* 22: 726–730, 2008.
32. Wilson, JM, Duncan, NM, Marin, PJ, Brown, LE, Loenneke, JP, Wilson, SM, Jo, E, Lowery, RP, and Ugrinowitsch, C. Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training. *J Strength Cond Res* 27: 854–859, 2013.
33. Yetter, M and Moir, GL. The acute effects of heavy back and front squats on speed during forty-meter sprint trials. *J Strength Cond Res* 22: 159–165, 2008.
34. Young, WB, Jenner, A, and Griffiths, K. Acute enhancement of power performance from heavy load squats. *J Strength Cond Res* 12: 82–84, 1998.
35. Zeno, SA, Purvis, D, Crawford, C, Lee, C, Lisman, P, and Deuster, PA. Warm-ups for military fitness testing: Rapid evidence assessment of the literature. *Med Sci Sports Exerc* 45: 1369–1376, 2013.
36. Zois, J, Bishop, DJ, Ball, K, and Aughey, RJ. High-intensity warm-ups elicit superior performance to a current soccer warm-up routine. *J Sci Med Sport* 14: 522–528, 2011.