ACUTE EFFECTS OF DEPTH JUMP VOLUME ON VERTICAL JUMP PERFORMANCE IN COLLEGIATE WOMEN SOCCER PLAYERS

Jennifer L. Stieg, Kimberly J. Faulkinbury, Tai T. Tran, Lee E. Brown, Jared W. Coburn and Daniel A. Judelson

Human Performance Laboratory, Center for Sport Performance, Department of Kinesiology, California State University, Fullerton, USA

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Abstract:

Post-activation potentiation (PAP) has been shown to improve acute power performance. Depth jumps might elicit PAP resulting in improved vertical jump. The purpose of this study was to compare different volumes of depth jumps with rebound as a warm-up for vertical jumping. Seventeen collegiate women soccer players (age: 18.94±.74 yrs, height: 169.35±5.25 cm, mass: 66.07±6.42 kg) volunteered to participate in five testing sessions separated by at least 48 hours. Each subject warmed up on the cycle ergometer, then performed three pre-test countermovement jumps followed by 0, 3, 6, 9, or 12 depth jumps with rebound in random order. Box height was set at the level of the lateral femoral condyle for each subject. Subjects then rested for ten minutes followed by three post-test countermovement jumps. Dependent variables were *Vertec vertical jump height* (VJ) and *relative ground reaction force* (rGRF) measured by a force plate. ANOVA revealed no significant interactions but there was a main effect for time for VJ with pre-test (41.02±4.50 cm) being greater than post-test (40.42±4.30 cm). There were no main effects for rGRF (pre- 24.07±2.48 N/kg; post- 23.73±2.60 N/kg). These results suggest that the volume, box height and/or rest time used in this study were insufficient to elicit PAP and not only failed to increase vertical jump performance but resulted in a decrease. Therefore, it is suggested that collegiate women soccer players do not use depth jumps at knee height with these volumes and rest times as a warm-up in an effort to increase vertical jump performance.

Key words: *post-activation potentiation, force, warm-up*

Introduction

Athletic performance enhancement has long been an integral part of the competitive American sport nature. Athletes and coaches are constantly searching for different modes of training and different combinations of techniques with the goal of finding the best possible routines that result in improved performance. Although there are many variables that may be manipulated to improve performance, recently there has been a major focus on the effects of dynamic and maximal warm-ups on explosive performance (Bradley, Olsen, & Portas, 2007; Burkett, Phillips, & Ziuraitis, 2005; Church, Wiggins, Moode, & Crist, 2001; Gourgoulis, Aggeloussis, Kasimatis, Mavromatis, & Garas, 2003; Hilfiker, Hubner, Lorenz, & Marti, 2007; Mangus, et al., 2006; McMillian, Moore, Hatler, & Taylor, 2006; Scott & Docherty, 2004; Thompsen, Kackley, Palumbo, & Faigenbaum, 2007; Vetter, 2007; Wallmann, Mercer, & McWhorter, 2005).

Athletes often warm up with a short jog followed by static stretching. Previous researchers (Burkett, et al., 2005; Church, et al., 2001; McMillian, et al., 2006) examining the effect of static stretching on vertical jump height have found no change in post treatment performance, while others (Bradley, et al., 2007, Vetter, 2007, Wallmann, et al. 2005) have found a decrease in vertical jump height. Cramer et al. (2004) concluded that this decrease in performance following static stretching may be due to altered viscoelastic properties of muscle as well as neurological factors such as reflex sensitivity. Studies (Burkett, et al., 2005; Gourgoulis, et al., 2003; Markovic, Jukic, Milanovic, & Metikos, 2007; McBride, Nimphius & Erickson, 2005; McMillian, et al., 2006; Thompsen, et al., 2007; Vetter, 2007) have also examined dynamic warm-ups, submaximal warm-ups, heavy load warm-ups and modified depth jumps on vertical jump performance and found mixed results. Although depth jumps are often used in training programs (McClenton, Brown, Coburn, & Kersey, 2008) they are seldom utilized (Hilfiker, et al., 2007), as a catalyst for acute effects on vertical jump height. More recent studies (Burkett, et al. 2005; Gourgoulis, et al., 2003; McMillian, et. al., 2006; Thompsen, et al., 2007) have shown that a dynamic warm-up may be more beneficial in preparing muscles for explosive

movements. This is maybe due to the phenomenon of post-activation potentiation (PAP).

PAP is defined as an increase in force production following a maximal or near maximal muscle action and may be due to phosphorylation of the myosin light chain (Hodgson, Docherty, & Robbins, 2005). Another potential mechanism of PAP could be an increase in $C^{a}_{2}+$ at the cross bridge sites and increased excitability of the alpha motor neuron (Hodgson, et al., 2005). Depth jumps can be considered a form of maximal muscle action and therefore they may elicit PAP. However, it is presently unclear if depth jumps elicit PAP or how many repetitions may be required to maximize the effect. We hypothesize that across a wide spectrum of volumes, there would be an optimal number to elicit PAP. Therefore, the purpose of this study was to compare different volumes of depth jumps with rebound on vertical jump height and relative ground reaction force.

Methods

Participants

Seventeen collegiate women soccer players (age: 18.94±.74 yrs, height: 169.35±5.25 cm, mass: 66.07±6.42 kg) were recruited for this study. Players with current lower extremity injuries or back injuries were excluded. Players participated during their post season, but they were still engaged in strength and conditioning as well as soccer practice at the time data was collected. They were advised to drink plenty of water during testing and to eat on testing days similar food as usual. They were also asked not to engage in static stretching before testing. All subjects read and signed a University approved informed consent document prior to participating.

Instruments and measurements

Vertical jump height (VJ) was measured by the Vertec (Sports Imports, Columbus, OH). A Force Plate (Advanced Mechanical Technology, Inc., Watertown, MA) was used to collect data on ground reaction force which was expressed relative to body mass for further analysis (rGRF). The force plate was connected to a desktop computer running custom LabVIEW data collection and analysis software (version 7.1, National Instruments Corporation, Austin, TX) which sampled at 1000 Hz.

Procedures

Subjects completed five different conditions on five different days, separated by 48 hours to allow complete recovery and to control inter-subject variability. Experimental conditions (0, 3, 6, 9, and 12 depth jumps with rebound) were performed in random order. Subjects warmed up on a cycle ergometer (Monark 868, Varberg, Sweden) for five minutes at 25 Watts at a comfortable cadence at the beginning of each testing day. They then completed three pre-test countermovement vertical jumps with arm swing with 30 seconds rest between jumps while standing on the force plate. Immediately following the pre-test jumps, they performed that day's condition (0, 3, 6, 9 or 12 depth jumps with rebound). Each jump was performed by stepping off a box with one foot, landing with bent knees, then immediately exploding out of the jump with maximal effort using arm swing. The box height was individualized for each subject at the level of their lateral femoral condyle. To encourage maximal effort the Vertec was set up as a visual target and they were asked to try and hit the highest vane achieved during pre-test jumps. Rest time between depth jumps was 10 seconds. Upon completion of the depth jumps, they sat quietly for ten minutes. Previous studies have shown that approximately ten minutes of rest is optimal time for recovery in this type of activity (Chiu, et al. 2003; Kilduff, et al. 2007). After ten minutes they completed three post-test vertical jumps using the same protocol as the pre-test. All testing days were identical with the exception of depth jump volume.

Results

Two 5 x 2 (condition by time) repeated measures ANOVAs revealed no significant ($p>.05$) interactions for either variable. Table 1 shows that VJ

Table 1. Pre-test and post-test scores (mean±SD) for Vertec jump height (cm) across all conditions including condition and time main effects.
**Significantly less than pre-test. #Significantly less than 0, 3 & 6 jumps.*

	Vertec jump height (cm)		Condition Average
	Pre-test	Post-test	
0 jumps	41.31±4.69	40.78±4.44	41.05±4.56
3 jumps	41.91±4.73	41.23±4.11	41.57±4.42
6 jumps	41.16±4.37	40.49±4.41	40.82±4.39
9 jumps	39.74±4.10	39.66±4.56	39.70±4.33 #
12 jumps	41.01±4.63	39.96±3.99	40.49±4.31
Time average	41.02±4.50	40.42±4.30 *	

height demonstrated a significant ($p<.05$) main effect for condition where 9 jumps were less than 0, 3 & 6 but not different than 12 and a main effect for time with pre-test being greater than post-test. Table 2 shows that rGRF revealed no main effects for either condition or time, therefore scores did not change.

Table 2. Pre-test and post-test scores (mean±SD) for relative ground reaction force (N/kg) across all conditions

	Relative ground reaction force (N/kg)	
	Pre-test	Post-test
0 jumps	23.85±2.35	23.66±2.23
3 jumps	24.36±2.35	23.84±2.84
6 jumps	24.73±2.98	23.84±2.41
9 jumps	23.69±2.01	23.47±2.30
12 jumps	23.76±2.72	23.87±3.24

Discussion and conclusions

The purpose of this study was to examine the potentiating effects of different volumes of depth jumps with rebound on vertical jump performance. Depth jumps were hypothesized to induce PAP, resulting in an increase in vertical jump height. However, the results revealed a decrease in VJ height across conditions with no change in rGRF. Since there was no significant interaction of condition and time, it might suggest that rest time or box height, not depth jump volume, played the greatest roles in decreasing vertical jump performance.

The goal in any athlete's training is to enhance performance. Most focus on long-term chronic training programs which largely accomplish this goal. However, as an acute strategy, there is evidence that heavy lifting and maximal effort exercises immediately preceding an activity may enhance performance through PAP (Chiu, et al., 2003; Comyns, Harrison, Hennessy, & Jensen, 2006; Mangus, et al., 2006). This increase in force production may be due to an increase in $C^{a}{}_{2}+$ at the cross-bridge sites and phosphorylation of myosin light chains (Hodgson, et al. 2005). Many of these previous studies have shown equivocal results.

McBride et al. (2005) showed a significant increase in sprint speed following a heavy load squat warm-up, while Young, Jenner and Griffiths (1998) showed a significant increase in vertical jump height following warm-up with heavy load squats, yet Scott et al. (2004) and Mangus el al. (2006) did not. These results may be different than ours due to the volume of warm-up varying between studies as well as the populations measured. McBride et al. (2005) used 3 repetitions of heavy load squats at 90% of the subject's 1RM as well as 3 loaded countermovement jumps with 30% 1RM load. Young et al. (1998), who also found a significant increase, used 5 half-squats with a 5RM load. Scott and Docherty (2004) also used 5RM squats but added a 5RM preparation period prior to the actual squats. This extra preparation period may have caused fatigue resulting in no increase in jumping performance. Similarly, Mangus et al. (2006) used a maximum load of 1RM half-squats and 1RM quarter-squats but were unable to show any significant differences pre-test to post-test although they concluded that individualized results varied. Collectively, these studies suggest that the volume needs to be enough to elicit PAP but not too much that fatigue counters the effects. In our study, 9 depth jumps were significantly less than 0, 3 and 6 jumps but not different than 12 depth jumps which were also less than 0, 3 and 6 but not significantly. This may have been due to a too great volume thereby masking any PAP affects.

Additionally, individual subjects may have indivi-dualized volumes that are specific to their own PAP mechanism (Mangus, et al., 2006). Our present study showed a decrease across conditions, suggesting that either the volume (0, 3, 6, 9 or 12) or the box height (equal to their lateral femoral condyle) may not have been enough to create the high intensity needed to elicit PAP in this sample of collegiate women soccer players. Another possibility is that VJ performance increases may have been masked due to the length of the rest interval. Chui et al. (2003) found greater results 18.5 minutes after the experimental condition in an athletic population, while Kilduff et al. (2007) found the greatest results 8-12 minutes after the experimental condition in another athletic population. The results of our study were not consistent with these studies as we showed a decrease across conditions after ten minutes of rest which may have been due to the fact that we added rebounds to our depth jumps. However, our results are consistent with Jensen and Ebben (2003) who also found a decrease in VJ height and GRF immediately after and no improvement up to four minutes after 5RM squats. Comyns et al. (2006) also found decreases in jump flight time 30 seconds after and six minutes after 5RM back squats with no difference in flight time found at two and four minutes.

Coupled with our box height intensity, the rest time may have been too long in our study, resulting in the muscles no longer being warmed up and thereby decreasing jump height. A study by Bergh and Ekblom (1979) found that greater muscle temperature was positively correlated with power output, muscle strength, jumping and sprinting ability. They also found that decreased temperature could result in negative effects on the same variables. Another study by Gray, Vito, Nimmo, Farina and Ferguson (2006) found similar results, where male subjects performed a six second maximal power output measure on a cycle ergometer after

having their muscle temperatures raised by water immersion and electric blankets. Muscle biopsies taken before and after the power output test showed that muscle fiber conduction velocity and ATP turnover increased with muscle temperature. This would support the findings of our study in that the pre-test jumps were significantly greater than the post-test jumps across all conditions since the post-test jumps were performed following a 10-minute rest period without quantifiable intensity.

Chiu et al. (2003) examined the response of athletic subjects vs. non-athletic subjects to a PAP activity and found that force and power improvements were greater in the athletic subjects. Women collegiate soccer players were recruited in our study in hopes of finding a greater response to the depth jumps. Although our athletic subjects were not compared to a recreationally trained sample, our results demonstrated that athletes did not have a similar response to a PAP activity as did those of Chiu et al. (2003). Instead, our results are more consistent with Hilfiker et al. (2007) who did not find an increase in VJ in elite athletes after 5 drop jumps from 60 cm. It is possible that the depth jump height and/or volume used in our study were not enough to elicit a PAP response. Although the average box height in this study was lower (49.80 cm) than in Hilfiker et al. (2007), we used volumes of 3, 6, 9 and 12 compared to Hilfiker's 5. Also, our study used depth jumps with rebound in hopes of utilizing the stretch-shortening cycle and further stressing the muscles vs. in drop jumps (Hilfiker, et al., 2007) where subjects landed in a squat position. Although our study examined greater volume and utilized rebounding explosive movements compared to Hilfiker et al. (2007), we also did not find an increase in performance.

This study suggests that collegiate women soccer players should not use depth jumps with rebound at knee height with volumes of 3, 6, 9 or 12 and a rest time of 10 minutes as a warm-up prior to performing vertical jumps. Further research is warranted to find the optimal combination of rest time, volume, and box height which results in maximal VJ performance following repeated depth jumps with rebound. In addition, individual differences in rest time, volume and box height should also be investigated in order to design properly specific warm-up protocols.

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Correspondence to:
Lee E. Brown, EdD, CSCS*D, FNSCA, FACSM
Professor, Department of Kinesiology
Cal State Fullerton, Kinesiology
800 N. State College Blvd., KHS 233
Fullerton, CA 92832-6870
Phone: (657) 278- 4605
E-mail: leebrown@fullerton.edu

AKUTNI UČINCI TRENINGA DUBINSKIH SKOKOVA NA IZVEDBU VERTIKALNOG SKOKA KOD SVEUČILIŠNIH NOGOMETAŠICA

Dokazano je da postaktivacijska potencijacija (PAP) poboljšava akutnu eksplozivnu izvedbu. Dubinski skokovi mogu izazvati PAP koja može rezultirati poboljšanjem izvedbe vertikalnih skokova. Cilj je ovoga istraživanja bio usporediti učinke izvedbe različitih volumena dubinskih skokova s odrazom koji su se koristili kao sadržaj zagrijavanja za vertikalno skakanje. Sedamnaest sveučilišnih nogometašica (dobi 18,94±0,74 godina, tjelesne visine: 169,35±5,25 cm, tjelesne mase: 66,07±6,42 kg) dobrovoljno je sudjelovalo u istraživanju koje je uključivalo 5 testiranja s najkraćim razdobljem odmora između različitih volumena od 48 sati. Svaka ispitanica zagrijala se na bicikl ergometru, izvela tri skoka s pripremom prije provedbe testiranja te nakon toga 0, 3, 6, 9 ili 12 dubinskih skokova s odrazom nasumičnim redoslijedom. Visina sanduka s kojega se izvodio saskok bio je podešen na visinu lateralnoga femoralnoga kondila za svaku ispitanicu. Ispitanice su se nakon izvedbe dubinskih skokova odmorile 10 minuta te su nakon odmora ponovno izvodile tri skoka s pripremom. Zavisne varijable bile su *visina vertikalnoga skoka* (VJ) i *relativna sila reakcije podloge* (rGRF) izmjerena pomoću tenziometrijske platforme. Analizom varijance nije utvrđena statistički značajna razlika pri izvedbi različitih volumena dubinskih skokova, ali je utvrđena statistički značajna razlika u prosječnoj visini skoka pri čemu je rezultat u inicijalnom testiranju (41,02±4,50 cm) bio veći od rezultata zabilježenoga u finalnom testiranju (40,42±4,30 cm). Nije utvrđena značajna razlika u *relativnoj sili reakcije podloge* (pre-24,07±2,48 N/kg; post-23,73±2,60 N/kg). Dobiveni rezultati sugeriraju da volumen predopterećenja, visina sanduka i/ili vrijeme oporavka koje se koristilo u ovom istraživanju nije bilo dovoljno da bi se izazvala PAP te zbog toga ne samo da nije zabilježeno povećanje visine skoka, već je navedeni protokol predopterećenja rezultirao smanjenjem visine vertikalnoga skoka. Zbog toga se predlaže da sveučilišne nogometašice za zagrijavanje ne koriste dubinske skokove s odrazom u visini svojih koljena u ovom volumenu i vremenu oporavka kao vježbu predopterećenja za povećanje izvedbe vertikalnih skokova.

Ključne riječi: *postaktivacijska potencijacija, sila, zagrijavanje*