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Effect of Hip Abduction Maximal Voluntary Isometric Contraction on Lumbar Motion and Power Output During the Back Squat

Christopher F. Kelly, Adam M. Gonzalez*, Robert W. Spitz, Katie M. Sell, Jamie J. Ghigiarelli
Department of Health Professions, Hofstra University, 110 Hofstra Dome, 220 Hofstra University, Hempstead, NY 11549, USA
Corresponding Author: Adam M. Gonzalez, E-mail: Adam.gonzalez@hofstra.edu

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ABSTRACT

Background: Post-activation potentiation (PAP) is a neuromuscular phenomenon that has been shown to augment muscular force generating attributes as well as neural and sensory recruitment. While PAP has demonstrated to acutely enhance muscular performance during high-intensity activities, the effect of PAP on lumbopelvic kinematics under load remains unknown. **Objectives:** The purpose of this study was to examine the potential PAP effect of a hip abduction maximal voluntary isometric contraction (MVIC) on lumbar motion and power output during the barbell back squat. **Methods:** Nine resistance-trained men (22.9±2.3 y; 85.0±13.8 kg; 174.3±5.1 cm) performed a set of 5 repetitions of the barbell back squat using 80% one-repetition maximum with and without a hip abduction MVIC prior to performance. Experimental and control trials were randomized and counterbalanced among participants. MVIC was carried out via manual long-lever hip abduction. During the back squat exercise, lumbar motion analysis was performed using wireless motion-sensor technology, and power output was assessed via an accelerometer. **Results:** No significant differences were observed between trials for lumbar flexion range of motion (ROM) (p=0.32), lumbar flexion maximum deviation (p=0.32), lumbar lateral flexion ROM (p=0.81), lumbar lateral flexion maximum deviation (p=0.98), lumbar rotation maximum deviation (p=0.70), average peak power (p=0.98), or average mean power output (p=0.99) during the squat protocol. **Conclusions:** Implementation of a manual long-lever hip abduction MVIC prior to the back squat exercise did not significantly alter lumbar motion or augment power output in resistance trained males.

Key words: Isometric Contraction, Lumbar Motion, Exercise, Accelerometry, Back Squat

INTRODUCTION

Post-activation potentiation (PAP) is a phenomenon by which muscular performance may be acutely heightened following a previous contraction executed at a relatively high intensity (Tillin and Bishop, 2009). The physiological basis for PAP is not completely understood; however, the mechanism behind this phenomenon is thought to result from increased recruitment of higher order motor units (Xenofondos et al., 2015). While various types of pre-exercise stimuli have been implemented to induce muscle potentiation, there does not appear to be an ideal protocol to consistently provide a potentiating effect (Wilson et al., 2013). Nevertheless, PAP techniques typically involve the use of maximal voluntary contractions. While PAP-based warm-up protocols have demonstrated to augment force exerted by a muscle, it has been hypothesized that the stimulus may also be beneficial for neuromuscular recruitment related to spinal stability and parallel performance (Kibler et al., 2006, McGill, 2001, McGill, 2007, Robbins, 2005, Stevens et al., 2007). A warm-up protocol for the maintenance of dynamic spinal stability under load may have important application for athletes performing resistance exercise or high-intensity movements. When performing axial-loaded exercises such as the barbell back squat, athletes may experience external forces that exceed the load bearing capacity of an in vivo spinal system. Moreover, subtle departures (e.g. as little as 2 degrees of extension and/or flexion) from neutral alignment increase compressive loads and have been shown to negatively affect internal moment and ensuing performance (Dolan et al., 1995, Schoenfeld, 2010). Instability of this nature may reduce the capacity of the spinal system to disseminate force leading to suboptimal performance and an increased risk for injury (Schoenfeld, 2010, Panjabi, 2003, Panjabi, 1992, Wallden, 2009). A great deal of research has attempted to identify methods to elicit PAP through conditioning activities during warm-up routines (Tillin and Bishop, 2009, Wilson et al., 2013). Furthermore, practical methods with reduced need for specialized equipment are particularly appealing for athletes. A pre-exercise stimulus consisting of a sustained maximal voluntary isometric contraction (MVIC) has demonstrated viable application. MVIC has been shown to produce acute enhancement in variables such as rate of force development, sprint times, and jumping power (French

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et al., 2003). Furthermore, isometric contraction of lumbar and postural muscles may improve internal stabilization (Kisner et al., 2017). Acute and chronic exposure to isometric contractions may modulate muscle stiffness and augment muscular activity allowing the spine to maintain proximal stability while under load (Kibler et al., 2006, Burgess et al., 2007, Kubo et al., 2001, Lee and McGill, 2017). While MVIC appears to elicit improvements in muscle force-generating attributes, the effect of an MVIC on postural stability and lumbar motion has not been thoroughly investigated (McGill, 2001). Thus, the aim of this investigation was to examine the effect of a hip abduction MVIC on lumbar motion and power output during the back squat exercise. We hypothesized that performing the hip abduction MVIC prior to the barbell back squat would reduce excessive lumbar range of motion, via enhanced muscle stiffness about the lumbopelvic complex, with a potential to augment power output.

METHODS

Participants

Nine resistance-trained men (22.9±2.3; 85.0±13.8 kg; 174.3±5.1 cm) participated in this randomized, counterbalanced, crossover-design research study. Inclusion criteria included being recreationally active and having at least 1 year of resistance training experience. Further inclusion criteria required the participant to be familiar with the barbell back squat exercise. Participants had 5.4±2.2 years of resistance training experience and an average maximum back squat of 145.2±37.6 kg. All participants were free from injury and provided an informed consent prior to participation in this study. The research study was conducted according to the Declaration of Helsinki and approved by the Hofstra University Institutional Review Board prior to participant enrollment.

Maximal Strength Testing

Strength testing occurred at least 72 hours prior to experimental trials. Following a standardized warm-up protocol, participants performed a one-repetition maximum (1RM) strength test for the barbell back squat exercise. The 1RM test was performed using methods previously described (Hoffman, 2006). Participants performed two warm-up sets using a resistance of approximately 40-60% and 60-80% of his perceived maximum, respectively. The 1RM was then determined by applying a prediction formula based on the number of repetitions performed to fatigue using a fixed weight (Brzycki, 1993). All testing was completed under the supervision of a National Strength and Conditioning Association–certified strength and conditioning specialist (CSCS). A successful barbell back squat repetition required the participant to descend to a thigh parallel position defined by the trochanter head of the femur reaching the same horizontal plane as the superior border of the patella.

Experimental Trials

Participants reported to the laboratory for two trials. The experimental trial and control trial were counterbalanced between participants. Prior to each trial, participants were instructed to refrain from resistance training for a minimum of 48 hours and to abstain from the use of stimulants (e.g. caffeine) for a minimum of 4 hours prior to reporting to the HPL. Following the placement of wireless motion-sensors, participants completed a general and specific warm-up. The general warm-up consisted of 10 body weight squats, body weight walking lunges, dynamic walking hamstring stretches, and dynamic walking quadriceps stretches. For the specific warm-up, participants performed one set of 8 repetitions using 40% 1RM and one set of 4 repetitions using 60% 1RM separated by 2 minutes of rest. The participant then rested for 5 minutes. During the control trial, participants began the squat protocol immediately. During the experimental trial, participants performed a hip abduction MVIC prior to the squat protocol. The barbell back squat protocol consisted of a single set of 5 repetitions using 80% 1RM. Proper range of motion (i.e. thigh parallel position) was encouraged and monitored during the squat protocol. By reason of the relatively high-intensity load implemented, cadence of repetitions was not strictly controlled, however participants were instructed not to pause between repetitions.

Hip abduction MVIC

The hip abduction MVIC was carried out through unilateral manual resistance and quantified using a hand-held dynamometer (MicroFET 2, Hoggan Health Industries, Inc, West Jordan, UT). Participants were set up in a standardized, side lying position on a table, and a researcher facilitated a single set of long-lever isometric hip abduction by applying manual resistance following procedures set forth by Hislop et al. (2013) (Figure 1). The participants were instructed to maintain maximal exertion against the resistance for 5 seconds. Subsequently, the participant was immediately instructed to turn over and the same protocol began on the contralateral limb. Hip abduction MVIC peak and mean force were recorded. Participants began the squat protocol immediately following a 1 min rest period.

Movement Analysis

All participants wore a wireless motion-sensor technology that tracks and measures movement in real-time (ViPerform™, DorsaVi, USA). This system consists of two wireless motion-sensors that measure three-dimensional movement and a wireless recording device that captures the sensor data. Data were sent in real time to a computer via bluetooth and recorded for later analysis. One motion-sensor was placed across the posterior superior iliac spine and the second sensor was placed superiorly using a template to allow for consistent sensor placement. Sensors were adhered using disposable adhesive pads. This arrangement allows three-dimensional isolation of the lumbar spine and pelvic components (Figure 2). Prior to the squat exercise, a "baseline" was established with participants standing in their normal upright posture with feet at shoulder width apart. During the squat exercise, range of motion (ROM) and maximum deviation (i.e. maximum value from baseline) data were assessed.

Figure 1. Hip abduction maximal voluntary isometric contraction (MVIC) protocol

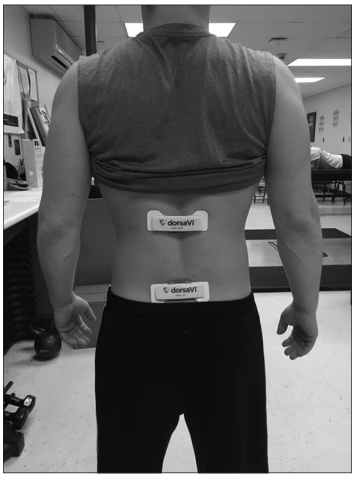

Figure 2. Motion sensor placement

ROM variables assessed the full range of motion throughout the movement (e.g. 10° flexion with 10° extension would yield a ROM of 20°). Data included lumbar flexion ROM and maximum deviation, lumbar lateral flexion ROM and maximum deviation, and lumbar rotation max deviation. The average was calculated for each set of 5 repetitions and used for subsequent analysis. The system software has displayed good inter-tester ($ICC_{2,1}$>0.86) and intra-tester reliability ($ICC_{2,1}$>0.89) for lumbar movements (Ronchi et al., 2008) and excellent concurrent validity with standard errors of measurement of 0.9° [95 % confidence interval (CI)=±1.8°] for the sagittal and 1.8° (95 % CI=±3.6°) coronal planes [46] relative to the "gold standard" Optotrak 3D-motion tracking system (NaturalPoint Inc. Corvallis, Oregon USA) (Charry et al., 2011).

Power Measures

Power output during the barbell bench press exercise was measured for each repetition with a Tendo™ Power Output Unit (Tendo Sports Machines, Trencin, Slovak Republic). The Tendo™ unit consists of a transducer attached to the end of the barbell, which measures linear displacement and time to calculate peak and average barbell velocity. Power was calculated from the barbell load entered into the microcomputer and barbell velocity detected by the unit. Prior to the investigation, intraclass correlation coefficient ($ICC_{3,1}$), standard error of the measurement ($SEM_{3,1}$), and minimal difference (MD) values for barbell velocity values measured by the Tendo™ unit during a single repetition ($ICC_{3,1}$=0.91, $SEM_{3,1}$=0.04 m·sec^{-1}, MD=0.09 m·sec^{-1}) were determined in 10 resistance-trained men (26.8±3.5 years; 92.6±6.5 kg; 180.5±6.6 cm) demonstrating that the Tendo™ unit has high test-retest reliability. Peak and mean power outputs were recorded for each repetition, and average peak and mean power was calculated for each set of 5 repetitions.

Statistical Analysis

Prior to statistical procedures, all data was assessed for normal distribution (Shapiro-Wilk), homogeneity of variance, and sphericity. Paired *t*-tests were utilized to determine the effect of the hip abduction MVIC on lumbar motion and power output during the back squat. Significance was accepted at an alpha level of $p \leq 0.05$, and all data are reported as mean ± standard deviation.

RESULTS

During the experimental trial, the participants right leg hip abduction MVIC produced a peak and mean force of 25.9±2.0 kg and 20.6±1.9 kg, respectively, while the participants left leg hip abduction MVIC produced a peak and mean force of 23.9±2.8 kg and 19.1±2.3 kg, respectively. No significant differences were noted between right and left leg hip abduction MVIC for peak (p=0.11) or mean force (p=0.15). Lumbar motion analysis and power output during the barbell back squat are depicted in Table 1. No differences were observed between trials in lumbar flexion ROM (p=0.32), lumbar flexion max deviation (p=0.32), lumbar lateral ROM (p=0.81), lumbar lateral max deviation (p=0.98), or lumbar rotation max deviation (p=0.70) during the squat protocol. Additionally, no differences were observed between trials in average peak power (p=0.98) or average mean power output (p=0.99) during the squat protocol.

DISCUSSION

The primary purpose of this study was to investigate the effect of hip abduction MVIC on subsequent lumbar motion and power output during the barbell back squat exercise. To the best of our knowledge, this appears to be the first study to evaluate lumbar motion following the implementation of a long-lever isometric hip abduction with application of manual resistance. Therefore, it was the primary intent of this investigation to implement a practical MVIC protocol and examine the effect through the lumbopelvic complex during the barbell back squat exercise. Our findings indicate that the application of a manual long-lever hip abduction MVIC prior to the back squat exercise did not result in significant alterations in lumbar motion or power output in resistance trained males. A properly functioning spinal system should

Table 1. Lumbar motion analysis and power output during the barbell back squat

	Experimental Trial	Control Trial	p-value
Lumbar flexion ROM (°)	24.7±5.9	21.7±6.4	0.32
Lumbar flexion maximum deviation (°)	21.8±5.2	19.0±6.3	0.32
Lumbar lateral flexion ROM (°)	6.3±1.9	6.0±2.9	0.81
Lumbar lateral flexion maximum deviation (°)	4.4±1.0	4.4±2.5	0.98
Lumbar rotation maximum deviation (°)	3.1±1.1	3.3±1.1	0.70
Average peak power (W)	978.0±341.5	981.1±322.9	0.98
Average mean power (W)	584.6±188.6	585.6±183.4	0.99

ROM=range of motion; W=watts

be capable of managing the instantaneous demand of dy-namic perturbation whilst optimizing muscle force-generating capacity with a relatively low prospect for injury. When an in vivo spinal system is under load and operating outside of neutral zone, instability may exacerbate compressive, shear, and tensile forces (Panjabi, 1992, Wallden, 2009, Adams and Dolan, 1995). Therefore, an effective warm-up strate-gy targeting neuromuscular efficiency prior to axial-loaded exercise may offer application for injury-mitigation, stabil-ity, and performance. A pre-exercise MVIC may modulate muscle stiffness and augment muscular activity allowing the spine to maintain proximal stability while under load (Kibler et al., 2006, Burgess et al., 2007, Kubo et al., 2001, Lee and McGill, 2017). For example, Lee and McGill (2017) recent-ly showed that isometric training exercises could induce immediate changes in core stiffness, which may transiently influence performance and injury resilience. Additionally, core and isometric hip strengthening may improve dynamic postural control (Jackson et al., 2017, Sadeghi et al., 2013). Previous investigations have administered various MVIC protocols prior to assessing an athletic endeavor, however lit-tle is known regarding the value of a simple isometric muscle action for the acute enhancement of spinal stability during dynamic resistance exercise (French et al., 2003, Güllich and Schmidtbleicher, 1996, Hamada et al., 2000, Hodgson et al., 2005). A maximum trunk flexion ROM of 60° has been re-ported during the back squat exercise (Norkin and White, 2016), with a significantly greater degree of hyperextension when subjects lifted at heavier loads (>60% 1RM) attributed to a compensatory action to stabilize the body from falling forward (Walsh et al., 2007). Lumbar deviations have been reported between 5.9-22.1° during the back squat in previ-ous investigations (Walsh et al., 2007, McKean et al., 2010). In the current study, the manual long-lever hip abduction MVIC applied in the current study did not exert significant changes in lumbar flexion, lateral flexion, or rotational ROM during the barbell back squat exercise.

Across the current body of research, the MVIC stimulus has been carried out under several different protocols, differ-ing in contraction type, duration, rest-interval, and specific movement patterns (French et al., 2003, Güllich and Schmidt-bleicher, 1996, Hamada et al., 2000, Hodgson et al., 2005). Findings appear to indicate a strong relationship between the PAP response, fatigue, and pre-load volume (French et al., 2003). In summary, the PAP effect appears to be diminished if inadequate recovery time is provided between the MVIC stimulus and the subsequent power test. Whereas, when fa-tigue is correctly modulated, the MVIC protocol may confer athletic enhancement. Under conditions where contraction time and fatigue are balanced (i.e., MVIC ≤10-seconds) a heightened neural environment has been shown to augment skeletal muscle force-generating characteristics, along with sensory-related control of short-term muscle action (French et al., 2003, Trimble and Harp, 1998, Vandervoort et al., 1983, Lorenz, 2011). For example, Baudry and Duxhateau (2007) found a large increase in twitch-potentiation follow-ing a 6-second MVIC of the adductor pollicis along with a 9-24% increase in isometric rate of force development within 2 minutes of the intervention. Folland et al. (2008) also demonstrated an augmented twitch-potentiation at the quadriceps femoris following a 10-second MVIC; howev-er, performance measures were not enhanced following the intervention. Rate of force development has shown to either remain unchanged, or decrease, when assessed immediately following a potentiation stimulus (Güllich and Schmidtble-icher, 1996). Similarly, in the current study, the administra-tion of the hip abduction MVIC 1 min prior to performing the back squat exercise did not augment power output during the barbell back squat exercise.

While the results of the current study indicate that the implementation of a manual long-lever hip abduction MVIC prior to the back squat exercise does not significantly alter lumbar motion in resistance trained males, we recognize that our methods are accompanied with limitations and fur-ther research is warranted to determine effective strategies to manage spinal mechanics under load. The ability to draw conclusions from our small sample (n=9) of recreationally trained men using a single load (80% 1RM) may be limit-ed. Additionally, the abduction protocol implemented in the current study does not follow a similar kinematic and kinetic sequence compared to the back squat; therefore its ability to translate to the spinal system during the performance of the back squat remains in question. However, several investiga-tions have highlighted the influence of the dynamic stabi-lizers of the hip on lumbopelvic function, especially during closed-chain exercise (Kibler et al., 2006, Bobbert and Van Zandwijk, 1999, Nadler et al., 2002). While a side-lying iso-metric abduction has shown to activate muscles that facil-itate spinal stability, including the gluteus medius, gluteus minimus, and quadratus lumborum (Cynn et al., 2006), no single muscle has been recognized as most important for the lumbar spine stability (Cholewicki and Vanvliet Iv, 2002). Thus, other practical strategies employing different volume parameters, contractions, and rest times should be investigated. Currently, a 7-12 minute recovery interval has been suggested to optimally enhance the potentiation response to exercise (Wilson et al., 2013, Gouvêa et al., 2013). In the current study, a 1-minute rest was allotted between the pre-conditioning contraction and the performance measure. It is plausible that a greater rest period may be warranted to accommodate the fatigue theory associated with the potentiating mechanisms. Additionally, it has been suggested that the potentiation effect is more sensitive in experienced individuals (Wilson et al., 2013, Gouvêa et al., 2013), therefore MVIC protocols may be more applicable in elite, competitive strength/power athletes (e.g. powerlifters). Further research should also investigate twitch-potentiation and muscle activation, along with spinal mechanics following such MVIC protocols.

CONCLUSION

In conclusion, the application of a manual long-lever hip abduction MVIC prior to the back squat exercise did not significantly alter lumbar motion or augment power output in resistance trained males. Following a maximal exertion hip abduction MVIC against manual resistance for 5 seconds, no significant differences were observed in lumbar flexion ROM and maximum deviation, lumbar lateral flexion ROM and maximum deviation, or lumbar rotation max deviation during a squat protocol consisting of a single set of 5 repetitions using 80% 1RM. Additionally, no significant differences were noted for peak or mean power during the squat protocol. Future research is encouraged to determine practical MVIC protocols to not only improve performance outcomes, but also lumbar kinematics.

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