THE EFFECT OF SQUAT DEPTH ON MUSCLE ACTIVATION IN MALE AND FEMALE CROSS-COUNTRY RUNNERS

Joshua Gorsuch, Janey Long, Katie Miller, Kyle Primeau, Sarah Rutledge, Andrew Sossong, and John J. Durocher

Department of Physical Therapy, St. Francis University, Loretto, PA, USA

KEYWORDS: EMG, resistance training, strength

INTRODUCTION: The squat is a closed-chain lower body exercise that is regularly performed by many athletes. The squat has been shown to increase strength of the rectus femoris, biceps femoris, gastrocnemius (Isear et al., 1997) and erector spinae (Nuzzo et al., 2008). Squats of different depths have been shown to alter muscle activation in male weight lifters (Caterisano et al., 2002), but the findings may not be directly applicable to runners. Therefore, we chose to examine both male and female runners and and multiarticular muscles that often fatigue while running. Muscle activation during parallel and partial squats has not been examined in runners. Hanon et al. (2002) reported that the rectus femoris and biceps femoris are among the first muscles to fatigue in runners. The gastrocnemius becomes increasingly important for running uphill (Sloniger et al., 1997), and the lumbar erector spinae can help runners to maintain upright posture and decrease the risk of injury to the hamstrings (Hoskins & Pollard, 2005).

The purpose of this study was to determine the effect of squat depth on muscle activation in both male and female collegiate cross-country runners. This may help athletes and coaches to determine which squat depth is most effective. We hypothesized that the parallel squat would increase extensor muscle activity (i.e. hamstrings and erector spinae). Furthermore, we sought to determine if changes in muscle activity were different between males and females.

METHODS: Twenty Division I cross-country runners, 10 males (mean ± SD; age = 19.2 ± 1.2 years, height = 176.8 ± 4.8 cm; body mass = 66.2 ± 8.0 kg; bodyfat percentage = 9.0 ± 3.5 %) and 10 females (age = 19.9 ± 1.2 years, height = 166.7 ± 4.7 cm; body mass = 55.9 ± 4.4 kg; bodyfat percentage = 19.7 ± 4.2 %) volunteered to serve as participants for the study. Informed consent and Institutional Review Board approval were obtained prior to the study.

Participants completed an orientation session that included body composition assessment, detailed instructions for the partial and parallel squats, joint angle assessment via a standard goniometer, and a 10 repetition maximum (RM) assessment for each squat condition. Before testing for their 10 RM, participants performed a warm-up of light cycling for 5 minutes on a stationary bike followed by 2 minutes of rest. Each participant's 10RM was then determined within 3 sets.

Electromyography (EMG) testing occurred within 7 to 10 days after the orientation session. The order of trials on the EMG testing day was randomized by a coin toss with heads indicating partial squat first and tails indicating parallel squat first. Participants completed 6 repetitions for each squat condition in a randomized order with their 10 RM loads. Partial and parallel squats were designated as 45 and 90˚ at the knee joint respectively. Repetitions were paced by a metronome set at 60 Hz. Cadence was 1 second down and 1 second up for the partial squat and 2 seconds down and 2 seconds up for the parallel squat. Electromyography was performed on the right rectus femoris, biceps femoris, lumbar erector spinae, and lateral head of the gastrocnemius during each condition. A BioPac Systems (Goleta,CA) EMG unit was used to record muscle activity. Sampling rate was 2000 Hz, and all data were integrated using the root mean square method and averaged over 100 samples. High-pass and low-pass filters were set at 30 and 500 Hz respectively.

Data were analyzed with SPSS 17.0 using repeated measures ANOVA procedures with gender and squat condition as fixed factors. Significant differences were set as $p < 0.05$.

Table 1. Subject Descriptive Characteristics.

Characteristic	Partial Squat	Parallel Squat
10 RM (kg)	78.4 ± 20.4	51.2 ± 14.0*
Hip Joint Angle (degrees)	50.0 ± 12.5	94.6 ± 16.2*
Ankle Joint Angle (degrees)	77.7 ± 7.9	69.7 ± 7.9*

*Significantly different than partial squat condition ($p < 0.01$). Joint angles were measured with a standard goniometer during the orientation session, and knee joint angles were confirmed during EMG testing.

RESULTS: Rectus femoris and erector spinae activity were significantly higher during the parallel squat condition ($p < 0.05$). Biceps femoris and gastrocnemius activation was similar between the partial and parallel squats. No significant differences existed between males and females when examining the interactions between squat condition and gender.

Table 2. Millivolts of Muscle Activity Determined by EMG.

Muscle	Partial Squat	Parallel Squat
Rectus femoris	0.142 ± 0.050	0.177 ± 0.065*
Biceps femoris	0.066 ± 0.044	0.075 ± 0.056
Erector Spinae	0.133 ± 0.050	0.163 ± 0.050*
Gastrocnemius	0.053 ± 0.018	0.049 ± 0.018

*Significantly different than partial squat condition ($p < 0.05$)

DISCUSSION: The primary findings of this investigation are that the rectus femoris and erector spinae activity are significantly higher during the parallel squat when compared to the partial squat. This increase in muscle activation can be attributed to greater ranges of motion at the hip, knee, and ankle joints. Because the rectus femoris fatigues early (Hanon et al., 2002) and the erector spinae aids in maintaining an upright posture (Hoskins & Pollard, 2005), these findings could be of importance to runners.

Despite using a significantly lighter load during parallel squats, rectus femoris and erector spinae activity increased. Parallel squats could benefit runners by reducing compressive forces on the spine while maintaining, or increasing, muscle activity compared to partial squats. Runners may avoid poor running technique and premature fatigue of the rectus femoris by performing parallel squats (Hanon et al., 2002). By increasing erector spinae strength during the parallel squat, runners can benefit by maintaining more upright postures. Weakness in erector spinae can contribute to excessive trunk flexion and exacerbate the risk of hamstring injury during the terminal swing phase of running (Hoskins & Pollard, 2005).

CONCLUSION: Cross-country runners should focus on performing parallel squats to maximally activate the rectus femoris and erector spinae muscles. This increase in muscle activation can be achieved while using a reduced load during the parallel squat versus the partial squat.

REFERENCES:

Casterisano, A., Moss, R.F., Pellinger, T.K., Woodruff, K., Lewis, V.C., Booth, W., & Khadra, T. (2002). The effect of back squat depth on the EMG activity of 4 superficial hip and thigh muscles. *Journal of Strength and Conditioning Research,* 16(3), 428-432.

Hanon, C., Thépaut-Mathieu, C., & Vandewalle, H. (2005). Determination of muscular fatigue in elite runners. *European Journal of Applied Physiology,* 94, 118-125.

Hoskins, W., & Pollard, H. (2005). The management of hamstring injury- part 1: issues in diagnosis. *Manual Therapy*, 10, 96-107.

Isear, J., Erickson, J., & Worrell, T. (1997). EMG analysis of lower extremity muscle recruitment patterns during an unloaded squat. *Medicine and Science in Sports and Exercise,* 29(4), 532-539.

Nuzzo, J., McCaulley, G., Cormie, P., Cavill, M., & McBride, J. (2008). Trunk muscle activity during stability ball and free weight exercises. *Journal of Strength and Conditioning Research,* 22(1), 95-102.

Sloniger, M., Cureton, K., Prior, B., & Evans, E. (1997). Lower extremity muscle activation during horizontal and uphill running. *Journal of Applied Physiology,* 83(6), 2073-2079.