COMPARISON OF MUSCLE ACTIVITY DURING STEP UPS AND SINGLE LEG SQUATS

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The purpose of this study was to evaluate muscle activity of the vastus lateralis (VL), rectus femoris (RF), vastus medialis (VM), biceps femoris (BF), gluteus maximus (GM), gluteus medius (GME), adductors (A), and gastrocnemius (G) during step ups (SU) and single leg squats (SLS). Subjects were 12 weight trained adults. Muscle activity was averaged by root mean square and normalized to maximum isometric contractions. Repeated measures ANOVA results revealed interaction effects ($p<0.05$) of lift and phase (eccentric/concentric) for VL-, RF-, VM-, GME-, and A-activity. Significant main effects ($p<0.05$) between lifts were observed for BF-, GM-, and G-activity while all but RF-activity had a main effect ($p<0.05$) for phase. The SU appears to be more ideal for activating the quadriceps while the SLS is more appropriate to activate the hamstrings and gluteals.

KEY WORDS: lower extremity, strength training, muscle activity

INTRODUCTION: The use of functional lower extremity exercises has become more prevalent in strength training programs. Functional exercises are ones that attempt to mimic demands of sports movements (Keogh, 1999; Henry, 2011). Typically, for the lower extremity, they are often exercises that create a disproportionate loading of one limb while the other limb stabilizes the movement, such as the lunge, or exercises that require single support; thus, increasing stabilizing efforts, such as the step up (SU). Some functional exercises, such as the single leg squat (SLS), can be performed in either unbalanced loading or single support depending on the placement of external loading.

Compared to the extensive amount of research available on traditional exercises such as the squat, there is relatively limited research on functional lower extremity exercises. Ebben and colleagues (Ebben, 2009; Ebben et al., 2009; Fauth et al., 2010) have evaluated both the lunge and SU compared to the more traditional squat and deadlift exercises while Simenz, Garceau, Lutsch, Suchomel, & Ebben (2010) have evaluated variations of the SU. In these studies, the box used for the SU was a standardized 45.7 cm box. The fixed height of the box would have required participants to have different knee angles at the lowest point of descent of the lift and could have affected muscle recruitment as depth of squat has been shown to increase muscle activity (Wretenberg, Feng, Lindberg, & Arborelius, 1993). Single leg squats have been evaluated in un-loaded (Bourdreau et al., 2009) and dumbbell loaded (Escamilla et al., 2009), but not in barbell loaded conditions.

Most studies of lower extremity exercises have focused on activation of the quadriceps and hamstrings (Wretenberg et al., 1993; Wilk, Moorman, & Andrews, 1996; Wretenberg, Feng, & Arborelius, 1996: Ebben & Jensen, 2002; Ebben, 2009; Ebben et al. 2009). One of the proposed benefits of functional exercises is the increased recruitment of stabilizing muscles such as muscles of the hip. While studies have evaluated the recruitment of the primary abductors of the hip (gluteus maximus (GM) and gluteus medius (GME)) (Fauth et al., 2010; Simenz et al., 2010), no known studies have evaluated the adductors (A) that would also need to be activated to provide stabilization during a single support exercise. Furthermore, no known studies have evaluated the activity of gastrocnemius (G), an ankle stabilizer, during functional lower extremity exercises.

The purpose of this study was to evaluate muscle activity of the VL, RF, VM, BF, GM, GME, A, G during SU and SLS. The SU was selected as it could be evaluated with a standardized starting knee angle and the SLS was selected due to no known studies evaluating it with barbell resistance.

METHODS: Fourteen men who regularly engaged in lower extremity training volunteered for this study. Two participants did not complete all portions of the study and were removed from analysis. Thus, 12 participants (mean ± SD, age 22.5 ± 1.2 y, height 174 ± 6 cm, mass 80.2 ± 6.0 kg, body fat 9.4 ± 2.5 %, SU maximum 90.9 ± 12.3 kg, SLS maximum 84.8 ± 11.3 kg) are reported. The study was approved by the institution's internal review board.
Participants completed two testing sessions. The first session determined 1 repetition maximums (1RM) for the SLS and SU for the right leg. Order of exercise was randomized and a 10 minute rest was provided between maximums. Participants warmed up for 5 minutes on a cycle ergometer at a self-selected rate and resistance. The 1RMs were determined using Wilson, Newton, Murphy, & Humphries`s (1993) protocol. Box height for SU was set at a height where the participants had 90° angles at the right knee when the foot was on top of the box and there was a 90° angle at the ankle. Box height varied from 38.7 cm to 41.3 cm. Participants started on the ground and performed the concentric portion first for the SU. The same height box was used for support of the left leg during the SLS. Participants were instructed to place their heels on a marker and the box was moved to a position where the participants could descend so the right knee was at a 90° angle and the box would not come in contact with the left shin (Figure 1).

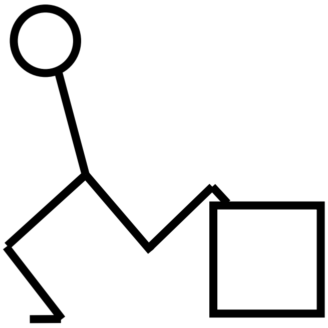

Figure 1. A diagram of the single leg squat box placement

The second session took place a minimum of 48 hours after the first session. Upon arrival, the participants' skin over the VL, RF, VM, BF, GM, GME, A, and G, was shaved and swabbed with rubbing alcohol prior to placement disposable 9 mm pre-gelled bipolar silver-silver chloride electrodes (Noraxon USA, Inc, Scottsdale, Arizona) on right side of the body. Electrodes were placed using the landmarks outlined by Perroto (2005). Additionally, a reference electrode was placed on the clavicle. After warm up on a cycle ergometer, participants performed maximal voluntary isometric contractions (MVIC) using standardized protocols (Kendall et al., 2005). Three 5-second MVICs were performed for each muscle. One minute rest was allowed between isometric contractions. The middle 3-seconds of the MVIC were used as reference muscle activity. A 20 minute recovery was allowed after completion of all MVICs. Participants were fitted with reflective markers and then completed three repetitions of both SU and SLS at 70% of their 1RM. The order of exercise was the same as the 1RM order for each participant. A metronome was set to regulate a cadence of 1-second for both the eccentric (ECC) and concentric (CON) phases. A minimum of a minute rest was allowed between repetitions.
EMG was collected using a MYOPAC telemetric system (Run Technologies, Mission Viejo, CA) instrumented to a Vicon 460 motion analysis system (Vicon, Centennial, CO). Gain was set at 1000 while input impedance was one megaohm and common mode rejection ratio was 110 dB minute at 60 Hz. Analog data were recorded at 1080 Hz. Data were analyzed using Noraxon Myoresearch XP version 1.06.64 software (Noraxon USA Inc. Scottsdale, AZ) and quantified by means of a root mean square (RMS) algorithm. Video data were recorded at 120 Hz. Start and finish of each phase, ECC and CON, were determined with the Vicon system. The RMS values of all three trials were averaged and normalized to the average value of the three MVICs.

Normalized EMG data were analyzed using 2 X 2 (lift X phase) repeated measures ANOVAs for each muscle. Statistics were performed using Statistical Packages for Social Sciences (SPSS) v. 17.0 (IBM, Armonk, NY). The *a priori* alpha level was set at P <0.05 and all data are expressed as means ± SD.

RESULTS: Results revealed interaction effects (p<0.05) of lift and phase for VL-, RF-, VM-, GME-, and A-activity (Table 1). For all interaction effects, paired t-tests were performed comparing lifts at the specific phase only (e.g., SU ECC vs SLS ECC, but not SU ECC vs SU CON or SU ECC vs SLS CON). This was done to limit the number of statistical tests performed and because all muscles except the RF had a significant main effect for phase. Significant main effects (p<0.05) between lifts were observed for BF-, GM-, and G-activity.

Table 1. Normalized Muscle Activity during Eccentric and Concentric Phases of the Step Up and Single Leg Squat (SLS) (N=12)

Muscle	Eccentric		Concentric	
	Step Up	SLS	Step Up	SLS
Vastus Lateralis*#	0.97±.0.49$	1.38±0.56	1.84±0.86$	1.52±0.42
Rectus Femoris*	0.43±.0.19	0.46±0.24	0.63±0.27$	0.48±0.29
Vastus Medialis*#	0.80±0.40$	1.07±0.39	1.43±0.59	1.22±0.48
Biceps Femoris**#	0.18±0.09	0.32±0.16	0.44±0.16	0.65±0.26
Gluteus Maximus**#	0.24±0.11	0.47±0.21	0.91±0.52	1.05±0.40
Gluteus Medius*#	0.45±0.26	0.60±0.43	0.97±0.63	0.90±0.86
Adductors*#	0.72±0.44$	0.89±0.51	1.07±0.83	0.98±0.65
Gastrocnemius**#	0.37±0.22	0.40±0.24	0.40±0.16	0.59±0.37

* = significant (p<0.05) interaction effect between lift and phase
** = significant (p<0.05) main effect for lift
# = significant (p<0.05) main effect for phase
$= significant (p<0.05) difference between SLS (same phase only)

DISCUSSION: The SLS had significantly greater BF-, GM-, and G-activity even though less absolute weight was lifted suggesting greater stabilization requirements for the SLS. The greater BF and GM activation may be beneficial for athletes with poor quadriceps to hamstring strength ratios (Simenz et al., 2010).

In general, the SU had lower muscle activity during the ECC phase. This is most likely due to the participants allowing their support leg to relax during the SU ECC phase and relying on their left leg to absorb the force of landing off of the box. However, the SU had greater muscle activity during the CON phase, and, as validated by the significant interaction effects of the VL, RF, VM, GM, & A, a greater increase in muscle recruitment during the CON phase. These results highlight the importance of emphasizing proper technique when performing weighted SU since increased loading of the left leg on landing could increase the risk of injury.

One surprising finding was the limited RF-activity for both the SU and SLS. The RF crosses both the hip and the knee and thus must be inhibited compared to the VL and VM. This study used 70% of 1RM. It may be that at such a relatively low level of stress, the VL and VM can allow for RF inhibition that would not be possible at higher levels of stress. However, even in maximal isometric squat efforts, the RF will exhibit lower normalized activity compared to the VL and VM (Holt & Bruenger, unpublished data).

Muscle activity values were similar to Ebben et al. (2009) and Fauth et al. (2010). Differences in muscle activity between this current study and these previous studies could be attributed to: 1) greater depth during the SU. As mentioned previously, these two studies had a standardized box height of 45.7 cm which was greater than the height used by any participant in this study (38.7-41.3 cm). Greater depth of squat has been shown to increase muscle activity (Wretenberg et al., 1993). 2) These two studies used, in theory, a higher percentage of 1RM. Both studies used a 6RM which would equate to 80-85% of 1RM (Baechle and Earle, 2008).

CONCLUSION: The SU appears to be more ideal for recruitment of the quadriceps while the SLS is more appropriate to recruit the hamstrings and gluteals. Athletes and coaches should emphasize a controlled descent during the SU to avoid excessive stress during landing.

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