

# ECCENTRIC MUSCLE ACTIONS PRODUCE 36% TO 154% LESS ACTIVATION THAN CONCENTRIC MUSCLE ACTIONS

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This study evaluated the differences in eccentric and concentric phase muscle activation of variety of muscles during lower body resistance training exercises. Surface electromyography data (EMG) from 12 subjects was analyzed for the eccentric and concentric phases of the squat, deadlift, step-up, and lunge. Data from the test exercises were averaged for the eccentric and concentric phase for each muscle group to produce a comprehensive measure of activation differences between the eccentric and concentric phases. A paired samples *t*-test revealed differences between eccentric and concentric phase activation for all muscles assessed ( $p \leq 0.05$ ). Results demonstrated that during lower body multi-joint exercises the eccentric phase produced 36% to 154% less muscle activation than the concentric phase.

**KEY WORDS:** strength training, resistance training, motor unit recruitment, negative work, muscle contraction

**INTRODUCTION:** Eccentric muscle actions are reported to produce less muscle activation, as measured by electromyography (EMG), than concentric muscle actions under similar loading conditions (Neumann 2002; Zatsiorsky & Kraemer, 2006). These assessments have been typically conducted using isokinetic testing. While differences are known to exist between eccentric and concentric muscle actions, the magnitude of these differences are not clearly understood, especially during multi-joint isotonic resistance training exercises. These differences between eccentric and concentric muscle activation also raises questions about the relative effectiveness of eccentric compared to concentric training and the qualitative differences associated with these muscle actions.

Some evidence comparing eccentric and concentric resistance training shows that eccentric training allows for increased loading and potentially greater adaptation of muscle cross sectional area (Roig et al., 2009). Others report that functional training adaptations are specific to the types of muscle action used in training (Seger & Thorstensson 2005).

Most research examined eccentric compared to concentric differences in muscle activation using isokinetic testing to knee extension (Linnamo et al., 2002; McHugh et al., 2002; Seger & Thorstensson 2005; Westling et al., 1991) or elbow flexion (Fang et al., 2004; Komi et al., 2000; Moritani et al., 1987) exercises. These studies examine the role of muscle length and joint angle (Komi et al., 2000; Linnamo et al., 2002; Moritani et al., 1987), velocity (Westling et al., 1991), loading (Linnamo et al., 2002) cortical activation (Fang et al., 2004), frequency response (McHugh et al., 2002) and assessed preferential activation of fast compared to slow motor units (Komi et al., 2000; Linnamo et al., 2002) between eccentric and concentric muscle actions. These studies also demonstrate that eccentric muscle actions produce greater force than concentric actions (McHugh et al., 2002; Westling et al., 1991) with less muscle activation (Komi et al., 2000; Linnamo et al., 2002; Moritani et al., 1987).

Questions remain about how much difference in muscle activation is present between eccentric and concentric muscle actions and no study has assessed these differences during multi-joint

isotonic resistance training exercises. Therefore the purpose of this study was to compare the levels of eccentric and concentric muscle activation associated with a variety of muscles during lower body resistance training exercises for the purpose of quantifying the magnitude of the difference.

**METHODS:** Subjects included 12 women (mean  $\pm$  SD; age =  $21.00 \pm 1.41$  years; height =  $1.59 \pm 0.28$  m; body mass =  $63.55 \pm 6.89$  kg) who participated in either NCAA Division I, club, or intramural sports and lower body resistance training. All subjects provided informed consent and the university's internal review board approved the study.

Subjects attended one pre-test habituation session and one testing session. Prior to each, subjects participated in a standardized general and dynamic warm up. During the pre-test habituation session, subjects were familiarized with and performed their 6 repetition maximum (6 RM) for the back squat, deadlift, step-up, and forward lunge. All exercises were performed according to the methods previously described (Earle & Baechle, 2008) with the exception that the step-up began on top of the box, so that all exercises started with the eccentric phase and ended with the concentric phase.

Following the 6 RM testing, subjects were familiarized with 4 maximum voluntary isometric contraction (MVIC) tests for the hamstrings, quadriceps, gluteus medius, and gluteus maximus. Approximately 1 week after the pre-test habituation session, subjects returned for the testing session. During this session, subjects performed MVICs for the hamstrings, quadriceps, gluteus medius, and gluteus maximus with contractions held for 6 seconds each. Subjects then were tested by performing 2 full range of motion repetitions of their previously determined 6 RM loads, for each of the test exercises. Randomization of the exercises, limited repetitions, and 5 minutes of recovery were provided between MVICs as well as each test exercise.

Surface electromyography (EMG) was used to quantify muscle activation using a fixed shielded cabled, telemetered EMG system (Myomonitor IV, DeSys Inc. Boston, MA, USA). Data were recorded at sample rate of 1024 Hz using bipolar surface electrodes with  $1 \times 10$  mm 99.9% Ag conductors, and an inter-electrode distance of 10 mm. Electrodes were placed on the longitudinal axis of the medial and lateral hamstrings (MH and LH, respectively) the rectus femoris (RF), the vastus lateralis and medialis (VL and ML, respectively), and the gluteus medius and maximus (GMD and GMX, respectively). A common reference electrode was placed on the lateral malleolus. Electrode placement was chosen in order to assess uni-articular and bi-articular knee extensor and flexor muscles, as well as hip abductors and extensors. Additionally, an electric goniometer was placed on the lateral aspect of the right knee in order to distinguish between the eccentric and concentric phases of the test exercises. Skin preparation included shaving, abrasion and cleansing with alcohol. Elastic tape was applied to ensure electrode placement and provide strain relief for the electrode cables. Surface electrodes were connected to an amplifier and streamed continuously through an analog to digital converter (DeSys Inc. Boston, MA, USA) to an IBM-compatible notebook computer.

All data were filtered with a 10-450 Hz band pass filter, saved, and analyzed with the use of software (EMGworks 3.1, DeSys Inc., Boston, MA, USA). The input impedance was 1015 Ohms and the common mode rejection ratio was  $>80$  dB. Raw data were acquired and processed using root mean square (RMS) EMG with a moving window of 125 ms and were analyzed for seconds 2-3 of the MVICs, and for eccentric and concentric phases for the back squat, deadlift, step-up, and forward lunge. Data from the back squat, deadlift, step-up, and forward lunge were averaged for each muscle group for each subject to produce a comprehensive measure of activation for comparison during the eccentric and concentric phases. All RMS EMG values for each muscle were normalized to the average RMS EMG of the 2 trials of the MVIC.

All data were analyzed with SPSS 18.0 using a paired samples *t*-test to determine differences in

eccentric and concentric phase RMS EMG for each muscle group. The *a priori* alpha level was set at  $P \leq 0.05$  and all data are expressed as means  $\pm$  SD.

**RESULTS:** Results reveal that RMS EMG data, expressed as a composite mean and range from all exercises, is significantly different between the eccentric and concentric phases ( $p \leq 0.05$ ). Data are shown in Table 1.

**Table 1. Composite mean (range) of muscle activation during the squat, deadlift, step-up and lunge, expressed as a percentage of MVIC for the eccentric and concentric phase (N=12).**

MUSCLE	ECCENTRIC PHASE	CONCENTRIC PHASE	DIFFERENCE
LATERAL HAMSTRINGS	0.37 (0.26-0.52)	0.94 (0.59-1.43)	154%
MEDIAL HAMSTRINGS	0.35 (0.23-0.41)	0.66 (0.46-1.01)	80%
RECTUS FEMORIS	0.70 (0.59-0.99)	0.95 (0.78-1.10)	36%
VASTUS MEDIALIS	1.00 (0.75-1.19)	1.68 (1.60-2.15)	68%
VASTUS LATERALIS	0.76 (0.59-0.89)	1.37 (1.17-1.39)	80%
GLUTEUS MEDIUS	0.39 (0.21-0.56)	0.65 (0.36-0.86)	67%
GLUTEUS MAXIMUS	0.89 (0.77-0.97)	1.88 (1.57-2.15)	111%

**DISCUSSION:** This study is the first to quantify the magnitude of differences in muscle activation between eccentric and concentric phases of several muscle groups during a variety of common, (Earle & Beachle, 2008) multi-joint, lower body resistance training exercises. Results demonstrated that mean eccentric compared to concentric differences are considerable larger than those previously found.

Data from the current study are not presented individually for each of the four exercises and seven muscle groups assessed since this would result in 28 comparisons. Since the purpose of the study was to comprehensively assess the magnitude of the differences in eccentric versus concentric activation as a theoretical phenomenon, this study examined a variety of exercises and muscle groups. Previous published studies assessing differences in muscle activation between eccentric and concentric phases were limited to single joint isokinetic knee extension (Linnamo et al., 2002; McHugh et al., 2002; Seger & Thorstensson 2005; Westling et al., 1991) or elbow flexion (Fang et al., 2004; Komi et al., 2000; Moritani et al., 1987) testing. Other studies examining muscle activation during a variety of lower body resistance training exercises did not compare eccentric and concentric activation (Ebben et al., 2009).

Previous research demonstrated approximately 7-31% lower knee extensor EMG in the eccentric compared to the concentric phase of isokinetic knee extension (Westling et al., 1991; Linnamo et al., 2002). In some cases these values were estimated based on the interpretation of figures since numerical data are not reported (Linnamo et al., 2002). Studies examining eccentric compared to concentric differences during isokinetic elbow extension demonstrated approximately 20-30% less muscle activation (Komi et al., 2000), though in some cases no significant differences were found during the portion of the range of motion that resulted in muscles that were significantly longer than resting length, and up to 97% differences at relatively short muscles lengths. Thus, the findings of the current study demonstrate that dynamic, maximal volitional velocity, full range of motion resistance training exercises result in comparatively larger eccentric to concentric muscle activation differences than typically shown in previous studies that used single joint isokinetic testing.

In the present study, multiple muscles and common multi-joint resistance training exercises performed at relatively high training loads and maximal volitional velocity were used to enhance the external validity of the findings. Previous research demonstrated that joint angle, muscle length, and load specific differences are present during single joint isokinetic exercises. The

current study assessed all muscles, exercises, and eccentric and concentric phase differences through the full range of motion of each resistance training exercise, consistent with how these exercises are performed in applied settings.

It is possible that the large differences in eccentric to concentric activation found in this study are present in order to provide higher mechanical efficiency as has been proposed (Moritani et al., 1987) which would be particularly valuable for locomotion. Training with eccentric only loading may result in chronic increases in muscle cross sectional area (Roig et al., 2009) and cortical processing is considerably greater during the eccentric phase (Fang et al., 2004) despite significantly lower levels of activation. Future research in this area should assess differences in eccentric to concentric activation between upper and lower body exercises.

**CONCLUSION:** Results of this study demonstrated that for a variety of lower body multi-joint exercises, concentric activations produced 36% to 154% more muscle activation. This finding helps quantify the nature of the differences between eccentric and concentric muscle actions. Programs designed to stimulate motor unit recruitment should include exercises that include concentric muscle actions and avoid eccentric only training protocols.

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**Acknowledgement:** Travel to present this study was funded by a Green Bay Packers Foundation Grant.