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Muscle activity during leg strengthening exercise using free weights and elastic resistance: Effects of ballistic vs controlled contractions

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ABSTRACT

The present study's aim was to evaluate muscle activity during leg exercises using elastic vs. isoinertial resistance at different exertion and loading levels, respectively. Twenty-four women and eighteen men aged 26–67 years volunteered to participate in the experiment. Electromyographic (EMG) activity was recorded in nine muscles during a standardized forward lunge movement performed with dumbbells and elastic bands during (1) ballistic vs. controlled exertion, and (2) at low, medium and high loads (33%, 66% and 100% of 10 RM, respectively). The recorded EMG signals were normalized to MVC EMG. Knee joint angle was measured using electronic inclinometers. The following results were obtained. Loading intensity affected EMG amplitude in the order: low < medium < high loads ($p < .001$). Ballistic contractions always produced greater EMG activity than slow controlled contractions, and for most muscles ballistic contractions with medium load showed similar EMG amplitude as controlled contractions with high load. At flexed knee joint positions with elastic resistance, quadriceps and gluteus EMG amplitude during medium-load ballistic contractions exceeded that recorded during high-load controlled contractions. Quadriceps and gluteus EMG amplitude increased at flexed knee positions. In contrast, hamstrings EMG amplitude remained constant throughout ROM during dumbbell lunge, but increased at more extended knee joint positions during lunges using elastic resistance. Based on these results, it can be

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concluded that lunges performed using medium-load ballistic muscle contractions may induce similar or even higher leg muscle activity than lunges using high-load slow-speed contractions. Consequently, lunges using elastic resistance appear to be equally effective in inducing high leg muscle activity as traditional lunges using isoinertial resistance.

1. Introduction

Musculoskeletal disorders occur commonly in the working population as well as in sports and recreational exercise. Among a representative sample of 5600 blue- and white-collar workers the prevalence of severe pain was 33% and 29% in the neck/shoulders, 33% and 25% in the low back, and 16% and 12% in the knees, respectively (Andersen, Mortensen, Hansen, & Burr, 2011). Such types of pain causes individual suffering and increases the risk for long-term sickness absence (Andersen, Clausen, Mortensen, Burr, & Holtermann, 2011; Andersen, Kjaer, et al., 2008). During recent decades high-intensity strength training has gained increasing popularity in the rehabilitation of musculoskeletal disorders. While athletes commonly use leg-exercises to strengthen lower limb muscles, rehabilitation strategies in work-setting environments typically have focused on low back and upper extremities only (Coury, Moreira, & Dias, 2009). As a possible explanation, leg strengthening exercises may be more difficult to perform in a work-setting environment. Thus, a strong need seems to exist for the development of effective leg strengthening exercises that are easy to implement both in workplace and athletic settings and feasible for rehabilitation and prophylactic prevention of musculoskeletal disorders.

The forward lunge is a unilateral leg exercise involving substantial knee and hip extensor activity. Clinicians have implemented the forward lunge as an effective leg rehabilitation exercise after ACL injury and knee surgery (Alkjaer, Simonsen, Magnusson, Aagaard, & Dyhre-Poulsen, 2002; Mattacola, Jacobs, Rund, & Johnson, 2004) and the forward lunge may also serve important diagnotic purposes (Thorlund, Damgaard, Roos, & Aagaard, 2012). Furthermore, evaluation of electromyographic (EMG) activity has shown that the forward lunge involves high muscle activity ranging from 70–150% of MVC in the quadriceps, gluteus and hamstring muscles (Ebben et al., 2009; Jönhagen, Halvorsen, & Benoit, 2009; Pincivero, Aldworth, Dickerson, Petry, & Shultz, 2000; Thorlund et al., 2012), respectively, depending on the external load, movement velocity and the magnitude of body deceleration/acceleration. Accordingly, Jönhagen et al. (2009) recently observed that the high-velocity jumping forward lunge is associated with higher EMG activity in the rectus femoris, biceps fermoris and lateral gastrocnemius compared with the walking forward lunge.

Sakamoto and Sinclair (2012) recently investigated EMG and median power frequency (MPF) during varying lifting speeds and intensities using isoinertial bench press manoeuvres, and observed greater EMG amplitudes for faster and heavier lifting whereas MPF was similar during all conditions. Whether similar mechanisms are present in resistance training using elastic bands remains uninvestigated.

Resistance training is typically performed using training machines or free weight exercises (Andersen et al., 2006; Andersen, Andersen, et al., 2008). In recent years, elastic resistance bands have gained popularity because of their low cost, simplicity, versatility, and portability. While elastic resistance has shown to be equally effective in strengthening smaller muscles in the neck, shoulder and arm compared to free weight training (Andersen et al., 2010; Andersen, Saervoll, et al., 2011), their proficiency for effectively stimulating larger and stronger muscles of the lower extremities remains questionable. In addition, the EMG – joint angle relationship that is well described for conventional isoinertial strength exercises (i.e., Andersen et al., 2006) remain largely unexplored for elastic resistance exercise.

The purpose of the present study was to evaluate EMG activity during leg strengthening exercises using either elastic or conventional isoinertial resistance while examining the effects of varied movement velocity (controlled vs fast) and modulations in external loading intensity. We hypothesized that lunge exercise performed with elastic bands would induce similar EMG activity as lunge exercise performed with isoinertial resistance (dumbbells).