Human Movement Science 40 (2015) 24–37

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Acute effects of dynamic exercises on the relationship between the motor unit firing rate and the recruitment threshold ☆,☆☆

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ARTICLE INFO

Article history:

PsycINFO classification:
2330
2540
4160

Keywords:
Concentric exercise
Eccentric exercise
Linear regression analysis
Motor unit firing rate
Recruitment threshold

ABSTRACT

The aim of this study was to compare the acute effects of concentric versus eccentric exercise on motor control strategies. Fifteen men performed six sets of 10 repetitions of maximal concentric exercises or eccentric isokinetic exercises with their dominant elbow flexors on separate experimental visits. Before and after the exercise, maximal strength testing and submaximal trapezoid isometric contractions (40% of the maximal force) were performed. Both exercise conditions caused significant strength loss in the elbow flexors, but the loss was greater following the eccentric exercise ($t = 2.401$, $P = .031$). The surface electromyographic signals obtained from the submaximal trapezoid isometric contractions were decomposed into individual motor unit action potential trains. For each submaximal trapezoid isometric contraction, the relationship between the average motor unit firing rate and the recruitment threshold was examined using linear regression analysis. In contrast to the concentric exercise, which did not cause significant changes in the mean linear slope coefficient and *y*-intercept of the linear regression line, the eccentric exercise resulted in a lower mean linear slope and an increased mean *y*-intercept, thereby indicating that increasing the firing rates of low-threshold

☆ The authors declare that all experiments on human subjects were conducted in accordance with the Declaration of Helsinki and that all procedures were carried out with the adequate understanding and written consent of the subjects.
☆☆ No conflicts of interest or funding are declared by the authors related to the completion of this project and manuscript.

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http://dx.doi.org/10.1016/j.humov.2014.11.011

motor units may be more important than recruiting high-threshold motor units to compensate for eccentric exercise-induced strength loss.

1. Introduction

Most dynamic muscle contractions involve both shortening (concentric) and lengthening (eccentric) of the muscles. In addition to obvious differences in the biomechanics of these movements, repeated concentric muscle actions lead primarily to fatigue but with little muscle damage, whereas repeated eccentric muscle actions cause both fatigue and muscle damage (Weerakkody, Percival, Morgan, Gregory, & Proske, 2003). Therefore, it is possible that the combination of muscle fatigue and muscle damage following eccentric exercise may contribute to greater strength loss compared with that following concentric exercise (Warren, Lowe, & Armstrong, 1999). Furthermore, eccentric muscle actions require a unique motor control strategy compared with isometric or concentric muscle actions (Enoka, 1996; Madeleine, Bajaj, Sogaard, & Arendt-Nielsen, 2001). The most notable difference is that eccentric muscle actions require lower levels of muscle activation for a given force level than concentric and isometric muscle actions (Bigland & Lippold, 1954). In addition to the differences stated above, eccentric exercises also appear to have different acute effects on the manner in which the central nervous system controls the neural drive (Madeleine, Samani, Binderup, & Stensdotter, 2011) and motor unit activity (Dartnall, Nordstrom, & Semmler, 2008, 2011; Dartnall, Rogasch, Nordstrom, & Semmler, 2009). Motor unit recruitment regulation and modulation of the motor unit firing rates are two fundamental features that regulate force production (De Luca, 1985; Falla, Lindstrom, Rechter, & Farina, 2010; Farina, Fosci, & Merletti, 2002; Farina, Holobar, Merletti, & Enoka, 2010; Hu, Rymer, & Suresh, 2013b, 2014b). Thus, studying the relationship between these two factors may help us to understand potential changes in neuromuscular function following dynamic exercise.

Recent developments in surface electromyography (sEMG) decomposition technology have greatly improved the ability to examine motor control strategies (De Luca, Adam, Wotiz, Gilmore, & Nawab, 2006; Kleine, Blok, Oostenveld, Praamstra, & Stegeman, 2000; Kleine, van Dijk, Lapatki, Zwarts, & Stegeman, 2007; LeFever & De Luca, 1982; LeFever, Xenakis, & De Luca, 1982; Merletti, Farina, & Gazzoni, 2003; Merletti, Holobar, & Farina, 2008; Nawab, Chang, & De Luca, 2010). By contrast, early studies (Bigland & Lippold, 1954; Lindsley, 1935) of motor unit function were forced to use intramuscular electromyography (EMG) methods to record single motor unit activities, such as needle and/or fine wire electrodes. The disadvantages of these methods are that they are invasive, they can only detect the activities of a few motor units, and they are restricted to low level muscle contractions. However, the sEMG decomposition technology developed by De Luca et al. (2006) is noninvasive and capable of detecting the activities of up to 40 motor units during strong contractions. It is also important to note that the accuracy of this decomposition algorithm is generally greater than 95% (De Luca & Nawab, 2011; Nawab et al., 2010). A recent study confirmed the high accuracy of this decomposition algorithm (Hu, Rymer, & Suresh, 2014a) and suggested that the use of this algorithm to decompose sEMG signals is valid and reliable (Hu, Rymer, & Suresh, 2013a; Hu et al., 2014a).

De Luca and colleagues (De Luca & Erim, 1994; De Luca, LeFever, McCue, & Xenakis, 1982a, 1982b) also used the relationship between motor unit firing rates and their recruitment thresholds to study motor control strategies. A recent study by De Luca and Hostage (2010) used linear regression analyses to examine this relationship in three different muscles with various levels of isometric contractions, thereby indicating that there was an inverse relationship between the average motor unit firing rate and the recruitment threshold for each muscle at each force level. This finding is consistent with the "onion skin" organization of motor unit firing rates described in previous studies (De Luca & Erim, 1994; De Luca et al., 1982b), which states that at any specified force level, the firing rates of earlier recruited (low-threshold) motor units are larger than those of later recruited (high-threshold)