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Obtaining maximum muscle excitation for normalizing shoulder electromyography in dynamic contractions

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ABSTRACT

Muscle specific maximal voluntary isometric contractions (MVIC) are commonly used to elicit reference amplitudes to normalize electromyographic signals (EMG). It has been questioned whether this is appropriate for normalizing EMG from dynamic contractions. This study compares EMG amplitude when shoulder muscle activity from dynamic contractions is normalized to isometric and isokinetic maximal excitation as well as a hybrid approach currently used in our laboratory. Anterior, middle and posterior deltoid, upper and lower trapezius, pectoralis major, latissimus dorsi and infraspinatus were monitored during (1) manually resisted MVICs, and (2) maximum voluntary dynamic concentric contractions (MVDC) on an isokinetic dynamometer. Dynamic contractions were performed (a) at 30°/s about the longitudinal, frontal and sagittal axes of the shoulder, and (b) during manual bi-rotation of a tilted wheel at 120°/s. EMG from the wheel task was normalized to the maximum excitation from (i) the muscle specific MVIC, (ii) from any MVIC ($MVIC_{ALL}$), (iii) for any MVDC, (iv) from any exertion (maximum experimental excitation, MEE). Mean EMG from the wheel task was up to 45% greater when normalized to muscle specific isometric contractions (method i) than when normalized to MEE (method iv). Seventy-five percent of MEE's occurred during MVDCs. This study presents an 20 useful and effective process for obtaining the greatest excitation from the shoulder muscles when normalizing dynamic efforts.

1. Introduction

Electromyography (EMG) is influenced by many technical, anatomical and physiological factors. To account for many of these factors, EMG is typically normalized to a reference contraction allowing comparisons between individuals and testing sessions. Maximal contractions or efforts are typically used for reference contractions and thus the recorded EMG amplitude is assumed to represent 100% of a muscle's capacity (DeLuca, 1997). For this interpretation, it is paramount that the true maximum activation is determined. Without a true maximum, normalized EMG will be inflated and misrepresent the muscular effort (Lehman and McGill, 1999). Due to the multidirectional action of the shoulder and inherent difficulty isolating specific muscles, proper normalization and interpretation of its EMG is of particular interest. Inconsistencies in determining maximum activity of shoulder muscles have led to concerns about the interpretation of shoulder muscle activity and coordination, especially during dynamic efforts (Clarys, 2000; Morris et al., 1998).

Numerous methods of obtaining maximal muscle activation are found in the literature and have been described by a number of similar terms. The predominant method of obtaining a reference amplitude is to perform a muscle specific maximal voluntary isometric contraction, referred to as either a MVC (Anders et al., 2005; Morris et al., 1998) or more specifically, a MVIC (Sparkes and Behm, 2010; Burnett et al., 2007). MVICs are typically performed at a specified mid-range joint angle, most often citing the need to optimize the muscle force length relationship, and are commonly performed against manual resistance provided by an experimenter or clinician (Ball and Scurr, 2010; Chapman et al., 2010; Chopp et al., 2010; Rouffet and Hautier, 2008; Boettcher et al., 2008; Netto and Burnett, 2006; Hunter et al., 2002; Burden and Bartlett, 1999; Morris et al., 1998, Kelly et al., 1996). Interestingly, EMG amplitude has been observed to be constant with increasing joint angle for the biceps when under constant electrical stimulus (Leedham and Dowling, 1995), as well as the biceps and brachioradialis when under constant tension (Doheny et al., 2008). Other methods of providing resistance include cable systems and isokinetic dynamometers in static mode (Hodder and Keir, 2012; Netto and Burnett, 2006; Hunter et al., 2002). However, to avoid misinterpretation with percent maximum force, or torque, the term "MVE" has been adopted. MVE has been defined as maximal voluntary effort (Shirasawa et al., 2009), exertion (Fischer

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et al., 2011; Granata and Gottipati, 2008; Thelan et al., 1994), electrical activity (Madill and McLean, 2006; Mogk and Keir, 2003; Balogh et al., 1999) or excitation (Hodder and Keir, 2012; Chopp et al., 2010; Meyers and Keir, 2003). In the current communication, we differentiate between the maximum voluntary contraction (e.g. MVC) elicited by muscle excitation and the maximum voluntary excitation (e.g. MVE) itself.

Previous studies have aimed to define standardized MVE tests for the shoulder (Chopp et al., 2010; Boettcher et al., 2008; Kelly et al., 1996). Since fatigue can be a concern when performing a single test for each shoulder muscle, these studies focused on reducing the number of tests necessary to elicit acceptable MVEs. However, their investigations are limited to conventional isometric tests and did not normalize activity from another task to determine the effect on interpretation of the EMG. Despite the wide use of MVEs from isometric contractions for normalizing muscle activity, there is reason to question its utility when investigating dynamic contractions. Many studies have found that during dynamic contractions using an isometric normalization contraction yields normalized EMG values greater than 100% (e.g. Decker et al., 1999; Morris et al., 1998; McGill and Sharratt, 1990; Jobe et al., 1984; Clarys et al., 1983). Normalized EMG over 160% MVIC was reported for the triceps brachii during swimming (Clarys et al., 1983). Activity over 226% MVIC was reported for the serratus anterior during baseball pitching (Jobe et al., 1984), and rotator cuff activity exceeding 300% MVIC has been found during common rehabilitation exercises (Morris et al., 1998). In these studies, the absence of a true MVE is obvious, yet there remains concern for studies examining sub-maximal tasks that may have over-estimated EMG levels but it has gone undetected and perhaps only in specific muscles.

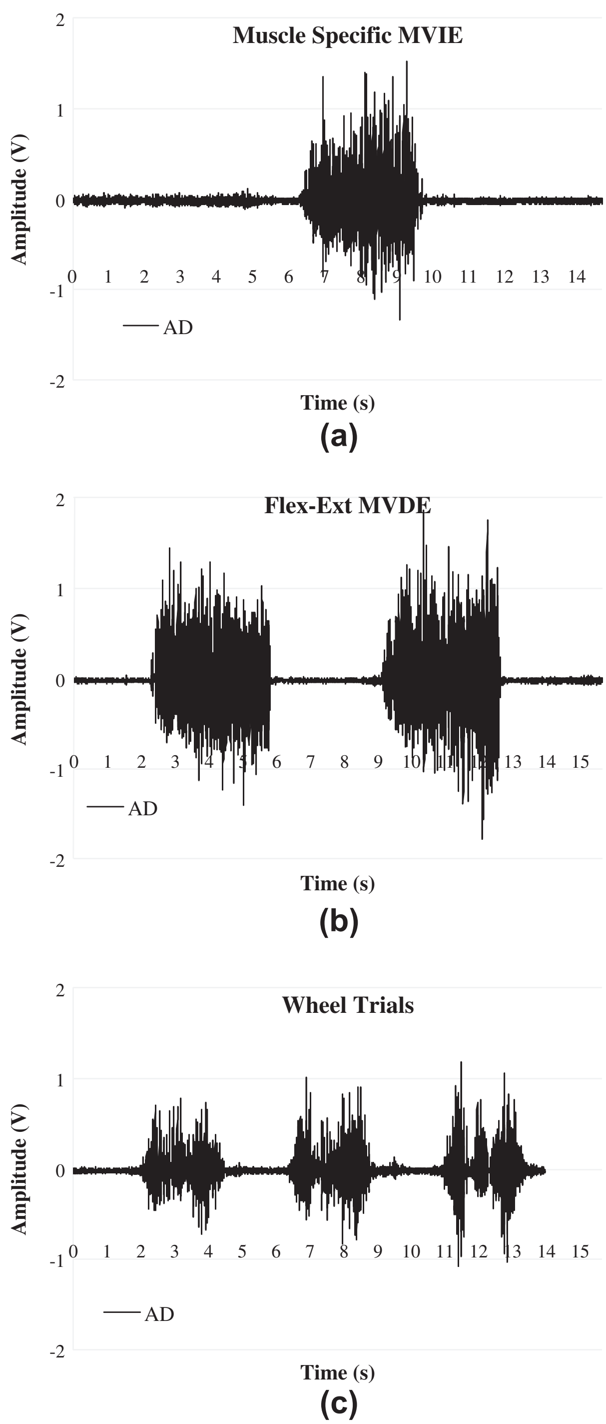

Fig. 1. Raw EMG (V) of the AD of Subject 11 during (a) the muscle specific MVIC, (b) the Flexion–Extension MVDC from 0° to 90° and back to 0°, (c) the wheel task at 120°/s. EMG presented post-amplification. Isometric and isokinetic contractions produced similar excitation levels for the AD. For this subject, the isokinetic contraction resulted in higher excitation.

Noting these issues, researchers have sought to improve the normalization process through the use of dynamic reference contractions. Some have selected muscle specific dynamic movements (Ball and Scurr, 2010; Rouffet and Hautier, 2008; Kyrolainen et al., 2005), while others have used the maximum excitation found in the experimental tasks (Ball and Scurr, 2010; Rouffet and Hautier, 2008; Kyrolainen et al., 2005; Arampatzis et al., 2001; Morris et al., 1998). Sources of variation must be considered when obtaining maximal excitation via isometric and dynamic contractions. In addition to muscle length effects, EMG amplitude may also change with joint angle due a change in the relative positioning of the muscle to the recording electrodes, altering the detection volume. Several studies have found a constant EMG-joint angle relationship in the biceps brachii (Doheny et al., 2008; Kasprisin and Grabiner, 2000; Leedham and Dowling, 1995), brachioradialis and triceps brachii (Doheny et al., 2008). The effect of contraction velocity on EMG amplitude and signal quality is more equivocal (Mathiassen et al., 1995). The EMG-velocity relationship has been found to be constant across velocities of 20°/s to 200°/s in the biceps brachii (Burden and Bartlett, 1999; Komi, 1973). In the lower limb, both uniform (Amiridis et al., 1996; Kellis and Baltzopoulos, 1996) and non-uniform (Amiridis et al., 1996; Kellis and Baltzopoulos, 1996; Bobbert and Harlaar, 1992) relationships have been reported.

The purpose of this study was to determine the best method to obtain maximal muscle excitations. We evaluated the effects of evaluate four methods of obtaining maximal excitation and their effects on normalized EMG amplitude. Maximum excitations were obtained from: (i) muscle specific manually resisted maximal voluntary isometric contractions (MVIC), (ii) any isometric MVIC, $MVIC_{ALL}$), (iii) planar maximum voluntary dynamic concentric contractions (MVDC) using an isokinetic dynamometer, and (iv) any contraction collected during the experiment (including the experimental task, MEE).

2. Methods

2.1. Participants

Twelve healthy men (176.2 ± 9.1 cm; 76.3 ± 11.9 kg; 22.0 ± 1.5 years) who reported no previous shoulder injury and were free of shoulder pain in the last year were recruited from the university population. This study was approved by the Human Research Ethics board at McMaster University. All participants provided written informed consent prior to participating in the study.