MULTI-CHANNEL SURFACE ELECTROMYOGRAPHY CHARACTERISTICS DURING MAXIMAL DYNAMIC CONTRACTIONS

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SUMMARY
Multichannel surface electromyography (sEMG) was applied to examine differences in mean motor unit characteristics as a function of joint angle during maximal lengthening (eccentric) and shortening (concentric) contractions of elbow flexors. Depending on muscle length, eccentric contraction showed higher force with less motor unit activity, despite of higher mean muscle fiber conduction velocity (CV). Therefore, the control strategies of motor units differs between the maximal dynamic contractions. Furthermore, the differences seem to be dependent on the elbow joint angle.

INTRODUCTION
It has been shown with standard sEMG that during a maximal eccentric contraction there is less motor unit activity despite higher contraction force as compared to a maximal concentric contraction [1]. This illogicality has been partly explained by a failure of voluntary muscle activation [2] possibly due to some inhibition at spinal level [3]. At the present, it is very difficult to measure activity of individual motor units during maximal dynamic contractions. However, with multi-channel sEMG it is possible to extract not only the mean muscle activity, but also information about the physiological characteristics of the active motor units, such as CV, which has been shown to correlate well with motor unit twitch torque [4].
The aim of the present experiment was to extract further evidence of differences in motor control strategies during maximal dynamic contractions with multichannel sEMG.

METHODS
Thirty-six healthy male volunteers (age 27.3±3.6 years, weight 79.8±11.7 kg and height 181.2±6.0 cm) performed maximal voluntary contraction (MVC) tests for eccentric and concentric contractions. These tests were done for elbow flexors of the right arm, on a motorized isokinetic dynamometer (angular velocity was 60 °/s, range of motion was between 65° and 175°, when 180° corresponds to full extension, Figure 1a).
Multi-channel sEMG signals were detected from the short head of the biceps brachii muscle with a linear array of 8-electrodes (5 mm inter-electrode distance, Spes Medica, Battipaglia, Italy) and amplified with 2048 samples/s (3-dB bandwidth, 10–750 Hz, 12 bit A/D converter, EMG-USB, LISiN - OT Bioelettronica, Torino, Italy, Figure 1b).

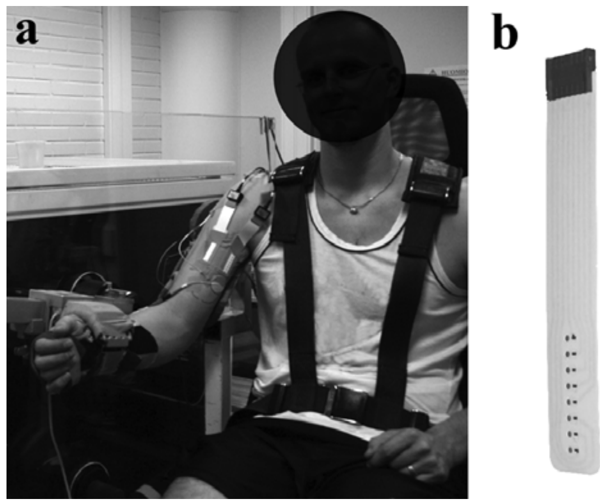

Figure 1: Measurement setup (a) and 8-electrode sEMG array (b) which was applied over the short head of the biceps brachii muscle.

Root mean square (RMS) was calculated separately for each seven bipolar channels. Mean frequency of the power spectral density (MNF) was calculated similarly. Mean muscle fiber conduction velocity (CV) was estimated with a method which is based on based on three adjacent channels (triplets) in the longitudinal direction of the muscle [5]. This was done in ten steps of 10° along the range of motion (from 70° to 170°). This gives a 183 ms time window for each step. Paired t-test was applied separately for each 10° step with a $p<0.05$ significance level.

RESULTS AND DISCUSSION
Force production. On average eccentric MVC (353±74 N) was higher than the concentric one (290±73 N, $p<0.001$). This was the case almost throughout the range of motion (Figure 2).
sEMG variables. On average RMS did not differ significantly between the concentric (346±140 µV) and eccentric MVCs (331±132 µV). However, at the largest elbow joint angles (from 120° onwards) showed higher RMS values during the concentric MVC than during eccentric one ($p<0.05$ - 0.001, Figure 2). Despite of this, both MNF (average MNF and angles from 80° to 120°, $p<0.01$–0.001) and CV (average CV and angles from 80° to 150°, $p<0.05$–0.001) values were

higher during the eccentric MVC as compared to concentric MVC (Figure 2).

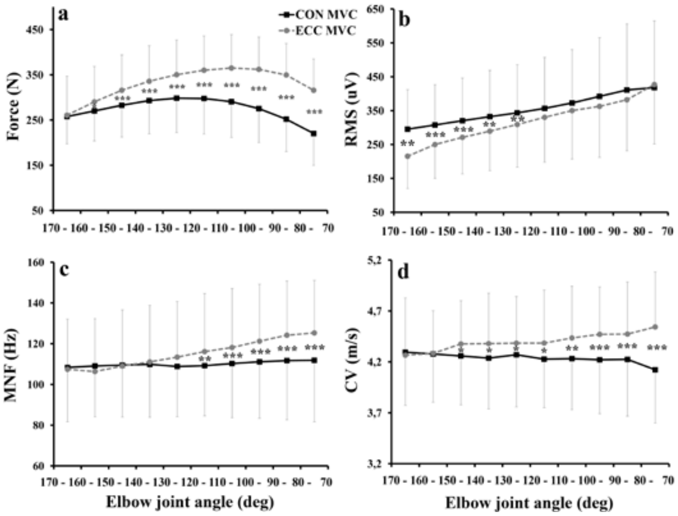

Figure 2: Average force (a), RMS (b), MNF (c) and CV (d) during concentric (CON) and eccentric (ECC) MVCs in respect to ten 10° elbow joint angle steps along the range of motion. ***=p<0.001, **=p<0.01 and *=p<0.05 between contraction types at corresponding angle. Error bars indicate standard deviation.

The current results support the previous findings of higher force production with less motor unit activity during eccentric MVC than during concentric one [1]. In addition, during eccentric contraction some sign of inhibition was observed at the descending limb of the force-length curve (Figure 2), possibly due to proprioceptive feedback from joint receptors and/or Golgi tendon organs [3]. Surprisingly, CV and MNF were significantly higher during eccentric MVC as compared to concentric MVC at the ascending limb of the force-length curve. Furthermore, CV remained higher well beyond the point of optimal force production angle (Figure 2), as did the force production itself. This could be explained by a selective cortical activation of high threshold fast-twitch motor units and/or inhibition of low threshold slow-twitch motor units due to increased recurrent inhibition as suggested by Nardone et al. [6]. Although, the selective recruitment of motor units lacks evidence during maximal contractions [7] it has been shown with electroencephalography that movement-related cortical potentials exhibit greater amplitude during maximal eccentric contraction than concentric one [9]. Furthermore, it is known that different motor tasks may have different cortical origin even though performed by the same group of muscles [9]. In addition to aforementioned, the current results further support the idea that the two maximal dynamic contraction types can be considered as two distinct tasks from the motor control strategy perspective.

CONCLUSIONS

It can be concluded that the control strategy of motor units differs between concentric and eccentric MVCs and is dependent on the muscle length. Inhibition of the motor units during eccentric MVC seems to be emphasized at the descending limb of the force-length curve of the elbow flexors. Interestingly, clear differences in the control strategies of the motor units between the dynamic MVCs were detected at the ascending limb of the force-length curve, even though no differences in the mean muscle activity were detected.

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