EMG CHARACTERISTICS OF DYNAMIC KNEE EXTENSIONS DETERMINED BY COMBINED MUSCLE MODELLING AND WAVELET ANALYSIS

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INTRODUCTION

Maximum effort movements are common in sport and surface EMG can be used to investigate their neural characteristics. The amplitude of the EMG signal is generally taken to represent the level of muscle activation (De Luca, 1997). However, EMG signals recorded under dynamic conditions are difficult to interpret due to their non-stationarity and the influence of several factors in addition to neural strategy (Farina et al., 2004). Numerous studies have reported EMG amplitude to vary with movement velocity in a multitude of ways.

The objective of this study was to quantify the effects of fibre length and contraction velocity on the surface EMG characteristics of maximum effort knee extensions, through combining time–frequency processing of the EMG signals with a muscle model of the contractions. Given the added dimension in resolution obtained from the time–frequency analysis, neglecting the muscle model would hamper the interpretation of time dependent EMG data as the length, velocity and position of the muscle fibres at any given time would be unknown.

METHODS

Eight strength trained male volunteers who gave informed consent participated in the study (age 27.5 ± 5.0 yrs, body mass 81 ± 11 kg, height 1.77 ± 0.05 m). Maximal effort knee extensions were conducted on a Cybex NORM dynamometer (CSMI, USA). The protocol comprised of isometric contractions at five crank angles spanning 15 to 75° (0° = full extension), followed by eccentric–concentric contractions at preset crank velocities ranging from ±50 to ±300° s⁻¹, as described by Yeadon et al. (2006).

EMG signals from the rectus femoris (RF), vastus medialis (VM), and vastus lateralis (VL) were recorded using an active bipolar electrode system (Biovision, Germany). Synchronous dynamometer and EMG signals were recorded at 2 kHz. The dynamometer data were used in a Hill-type muscle model to give the force, length and velocity characteristics of the VM, VL and RF. The EMG signals were processed using the continuous wavelet transform (CWT) time–frequency method to give the instantaneous amplitude and mean frequency. This employed a complex Morlet wavelet (Wavelet Toolbox in Matlab) with wavelet shape parameters specifically selected to give the required resolution in frequency, time and angle. The amplitudes were normalised (AMPN) based on their values at the isometric location of peak force. The effects of contraction velocity and fibre length were assessed using two-way repeated measures ANOVAS (SPSS, v13.0) with a significance level set at p = 0.05.

RESULTS AND DISCUSSION

For a fixed joint angle the fibre length varied considerably with contraction velocity, especially for the RF (Figure 1). Fibre length
and contraction velocity simultaneously affected the AMPN, supporting the inclusion of both parameters and the contour maps used to present the results (Figure 1). These length and velocity effects were muscle specific, and differed for the RF compared to the vastii. For eccentric contractions the AMPN of the vastii decreased significantly ($p \leq 0.05$), by $15 - 20\%$, with increasing lengthening velocity from -25 to -100 mm s$^{-1}$. For concentric contractions the AMPN of the vastii decreased significantly, by $15 - 25\%$, with fibre shortening from 100 to 70 mm. Across all contraction velocities and knee extensors the mean frequency (MNF) increased significantly, by $5 - 15\%$, across the fibre shortening length range. The MNF was not affected by either eccentric or concentric contraction velocity.

**Figure 1.** AMPN – length – velocity and MNF – length – velocity results for the VM, VL and RF. The white lines represent a fixed joint angle of 50°.

Simultaneous decreases in AMPN with increases in MNF in regions of the contour graphs suggest that the increase in MNF is more likely to be associated with changing fibre length rather than neural strategy. The two areas of reduced AMPN have previously been observed in studies of maximal knee extensions (e.g. Westing et al., 1991 and Aagaard et al., 2000) and linked to neural protection mechanisms. The AMPN results for the RF differed to those for the vastii. The muscle model may help to identify possible reasons for these differences. Notably that the fibre kinematics for this muscle showed the greatest differences to those of the joint.

**CONCLUSIONS**

Both fibre length and contraction velocity affected the EMG characteristics of maximal knee extensions, and in a muscle specific manner. Hence, including both these parameters has allowed for a more complete understanding of the results compared to previous studies that investigated contraction velocity alone. In particular, the AMPN contour graphs illustrated that the effect of shortening velocity is dependent on the region of the graph under investigation. Inconsistencies across previous studies may have resulted from the different angle ranges employed, leading to differing operating regions on the contour graphs.

**REFERENCES**


