Electromechanical delay in a wrist flexor at various force levels for a power-grip tracking task.

A.C. Laing, M.B. Frazer, R.W. Norman
Faculty of Applied Health Sciences, University of Waterloo, Waterloo, Canada

Introduction

The purposes of this study were to determine: 1) the electromechanical delay (EMD) of the wrist musculature, and 2) if level of force output affects the EMD. These muscles are involved in various tool grasp/hand manipulation tasks that require widely varying levels of effort. The literature does not include EMD studies of the wrist musculature during gripping tasks. Therefore, it is useful to know if, and how, different levels of grip force affect the EMD. The values of EMDs in the literature span a range from approximately 40 to 140 ms, and differences in reported EMD durations of up to 300% exist for the same muscle under identical conditions. Proposed factors responsible for the EMD include: time for action potential propagation, release of calcium from sarcoplasmic reticulum, cross-bridge formation, and stretching of the muscle series elastic component (Norman and Komi, 1979).

Methods

Six healthy males and one female participated. Subjects performed dominant-hand gripping tasks, composed of 4s cyclical isometric finger flexion contractions, using an instrumented dynamometer, guided by a 1Hz sinusoidal force target displayed on an oscilloscope. To ensure that the rate of force development required to perform the 1 Hz gripping task remained constant at each force level, an absolute force range of 47 N was maintained in each condition. Five trials at each of three randomly assigned force levels (low: 47 to 94 N, medium: 141 to 188 N, high: 234 to 281 N) were recorded.

Raw surface EMG from the flexor digitorum superficialis (FDS), the target waveform (produced by a function generator), and the finger force applied against the dynamometer, were sampled at 2048 Hz. The raw EMG was band-pass filtered from 20 to 500 Hz, and then full-wave rectified. Dual-pass low-pass filters were used to condition the signals without phase shifts (EMG cut-off of 3.74 Hz: net fourth-order, zero phase lag, cut-off frequency = 3 Hz. Force cut-off of 37.41 Hz: net fourth-order, zero phase lag, cut-off frequency = 30.0 Hz). For each trial, a cross-correlation was performed between the full-wave rectified, filtered EMG and the applied force. EMD was defined as the time lag at which the correlation coefficient peaked (cf. Vos et al., 1990). Figure 1 illustrates how EMD was determined.

![Figure 1: Rectified Raw, and Filtered EMG of the flexor digitorum superficialis, and finger force production vs. time for a dynamic gripping task. An example of the Electromechanical Delay (EMD) calculation is shown.](image-url)
Results

Group averaged electromechanical delays of 112, 121, and 141 ms were observed at low, medium, and high force levels, respectively (Figure 2). A repeated measures ANOVA found no significant differences between the EMDs measured at different force levels (Figure 2).

Discussion

The EMDs for the flexor digitorum superficialis (112 to 141 ms) were at the upper end of the wide range of reported durations (40 to 140 ms) for muscles as diverse as the knee extensors, triceps brachii and biceps brachii. It has been proposed that the most important factor in the EMD is the stretching of the muscle series elastic component (Norman and Komi, 1979). One possible explanation for the longer than average EMD for the FDS compared to other muscles lies in its anatomical structure. The flexor digitorum superficialis’ relatively long insertion tendon compared to its muscle belly length could result in more stretching of the series elastic component, and thus longer EMDs, compared to other shorter musculo-tendon complexes within the body.

The EMDs determined from this study did not depend on the level of applied force. In order to attribute any EMD differences directly to variation in force level, this study ensured a constant rate of force generation across conditions by maintaining an absolute 47 N force range at each force level. These results contrast the findings of Vos et al (1991), who observed 98 vs. 107 ms EMDs for subjects that performed cyclic (1.5 Hz) isometric knee extensor contractions for the ranges of 0 - 70% MVC and 0 - 50% MVC, respectively. One of
their explanations for this observation was that “in conditions which demand more force production, the muscle tendon is much less compliant”. Presumably, the increased stiffness induced by the higher force levels translated into less stretch of the series elastic component (SEC), resulting in a smaller electromechanical delay. However, stiffness is modulated by factors other than level of force. Another possible explanation for Vos et al’s observations is rate of force development. In conditions that require faster rates of force development, the muscle tendon is much less compliant compared to conditions requiring slower rates of force development. Although not stated in their discussion, the requirement of maintaining a 1.5 Hz pattern over a larger force range (0 - 70% vs. 0 - 50% MVC) should result in a higher rate of force development for their higher force condition. This would also affect muscle-tendon compliance, and may contribute to the difference in EMDs observed by Vos et al.

As mentioned previously, the literature reports a wide range of EMDs, in some cases for the same muscle under identical conditions. Why is this range so large? One observation is that EMDs seem to depend on the method used to measure them. At least three protocols have been reported: calculation from EMG and accelerometer data during ballistic movements; from EMG and force data during ballistic movements; and isometric tracking tasks cross-correlating EMG and force output (as used in this study). Thus, care should be taken when comparing EMDs from different muscles, and EMDs determined with different measurement protocols.

In conclusion, the EMDs of the flexor digitorum superficialis ranged from 112 to 141 ms, which is at the upper end of the range of values reported in the literature for other muscles. Based on this study, and the work of Vos et al (1991), further studies should be performed that investigate the importance of rate of force development in modulating the EMD. In addition, systematic investigation of EMDs in muscles with different anatomical structures/functions is required to assist in determining the exact mechanisms responsible for the EMD. Finally, it is suggested that distinct terminology be developed to refer to the output of the different measurement protocols used to determine EMDs.

References

