INHOMOGENOUS DISTRIBUTION OF EMG REFLEX RESPONSES ACROSS THE SOLEUS MUSCLE: A SINGLE CASE STUDY.

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SUMMARY

The aim of this preliminary study was to investigate whether the delay of reflex responses to external perturbation is represented homogeneously across the soleus muscle of a single subject. Surface EMGs were collected with a grid of 6x4 electrodes from the soleus muscle while perturbations were applied to the waist. Across ten perturbations, the range of delays estimated from each of the 18 channels varied between 22 and 101 ms and likely were influenced by the distribution of motor unit potentials. These results suggest that the timing of muscle onset depends on where the EMGs are collected; undoubtedly, this will influence the estimation of reflex responses in people following stroke.

INTRODUCTION

Surface electromyography has been used extensively to characterise muscle activation in response to externally imposed perturbations during standing. Delay and magnitude of muscle responses are the typical key parameters of interest. These parameters are particularly important to measure in people after stroke, when impairments to postural responses are prevalent. When assessing postural responses using traditional bipolar, surface electromyograms (EMGs), however, it is assumed the signals collected reflect the activity of all motor units within the muscle volume. In his seminal paper, Nashner considered the possibility that the delay estimated from EMGs collected with a single pair of surface electrodes was not representative of the entire gastrocnemius response to standing perturbations [page 20 in ref 1]. Here, we further investigate this issue using high-density surface EMGs. We specifically ask: Does the delay in muscle response depend on where surface EMGs are collected on the grid with respect to the muscle volume? If it does, then, is it statistically different from delays estimated from two electrodes of the grid which are situated in the recommended position for traditional, bipolar electrodes?

METHODS

This preliminary report focuses on the results for EMGs collected from the non-paretic leg of a single subject who was 2 years post-stroke and 70 years of age.

Through a pulley system, forward pulls were applied while subjects stood upright. Pulls corresponded to the dropping of a load equalling 2% of body mass. The load was dropped ten times in succession into a basket rigidly linked to the subject's waist. Once dropped, loads were left in the basket for 15 s and then removed. There was at least 30s between removal of the load and the next load drop. All loads were dropped from the same height (5 cm) with respect to the basket. Single differential, surface EMGs were collected from the calf muscles of both legs with large matrices of electrodes. Twenty-four electrodes (4 x 6 arrangement) were placed over the soleus muscle using ultrasound guidance [2] (Figure 1). The top row of electrodes on soleus was located 2 cm distally from the Achilles tendon-medial gastrocnemius junction. EMGs were amplified and then synchronously digitised with ground reaction forces.

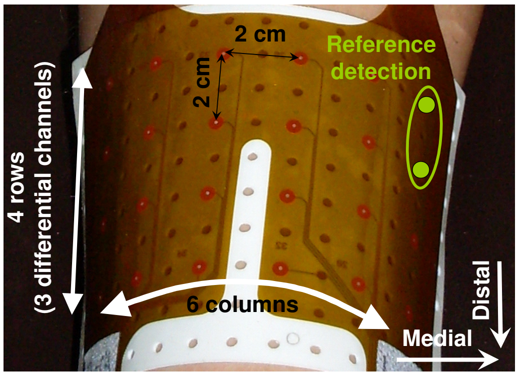

FIGURE 1. Positioning of the grid on the right soleus. The position for the reference detection used to compare with the individual channels is in the proximal-medial portion of the grid (green circle); as recommended by SENIAM [4].

Response delays were calculated as indicated in a previous study [3], for each channel. Individual EMGs were band-pass filtered (25-400 Hz), full-wave rectified and then low-pass filtered (40 Hz). The onset of muscle response detected by each channel corresponded to the time instant when the amplitude of these EMG envelopes was two standard deviations greater than baseline (baseline amplitude calculated for 100 ms starting 150 ms before load drop). The distribution of delays across individual muscle volumes was compared to that obtained from a reference detection (see Fig 1), which is the electrode position recommended for traditional bipolar recordings.

RESULTS AND DISCUSSION

Delay estimates varied markedly across the matrix of electrodes. For the fifth load drop, for example, the delay of EMG responses ranged from 50 ms to 150 ms (Figure 2; perturbation 5). The range of delay estimates varied from 22 ms (perturbation 10) to 101 ms (perturbation 5; N=18 channels). If for a single perturbation one considers the shortest delay as the onset of the reflex response, then, Figure 2 shows that onsets varied from 50 ms (perturbations 4 and 5) to ~140 ms (perturbation 10) and were statistically smaller than the corresponding onset estimates obtained from the reference detection (Figure 2; Wilcoxon rank test; P=0.008; N=10 perturbations). This suggests that the high-density surface EMGs may be able to detect differences across the muscle volume in people after stroke.

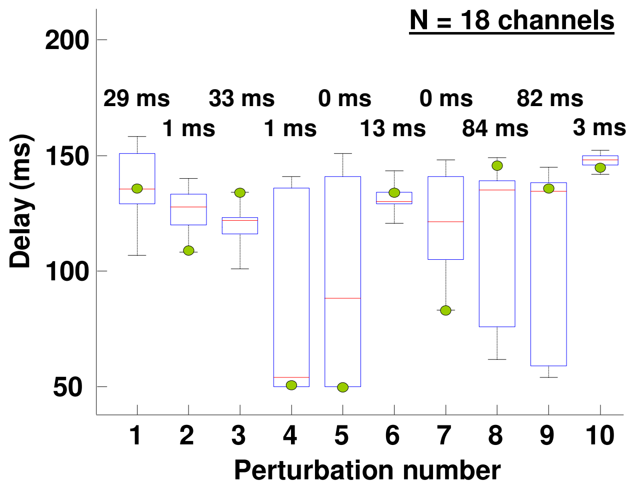

FIGURE 2. Boxplot of the delays in EMG response calculated across the grid for each perturbation. Range (black), interquartile intervals (blue) and median (red) are represented. The green circles indicate the delay obtained from the reference detection. Above each boxplot, the difference between this value and the shortest delay (denoted by the lowest whisker) is reported; the reference detection identified this delay with an error of less than 5 ms in 5 perturbations (perturbation #2,4,5,7,10). In the others, the first response occurred between 13 and 84 ms earlier compared to the traditional, bipolar technique.

Visual inspection of EMG suggests the difference between delays reported in Figure 2 was influenced by soleus motor units being represented differently across the muscle. To illustrate this, EMG envelopes for the first load drop are presented in Figure 3*A*. The EMG envelope for the reference detection (top, right) was different from those observed for other channels in the grid. Interestingly, EMGs collected from two adjacent locations (row 1, column 3 and 4) suggest that different electrodes are likely sampling from different motor units, albeit the delay estimates are similar. This impact of motor unit representation across the grid is exemplified further with the expanded traces in Figure 3B whereby the large motor unit potential observed in row 3 column 6 (~120 ms after the load drop) is not represented in the reference detection EMG; this particular motor unit did not contribute to delay estimates obtained from the reference detection.

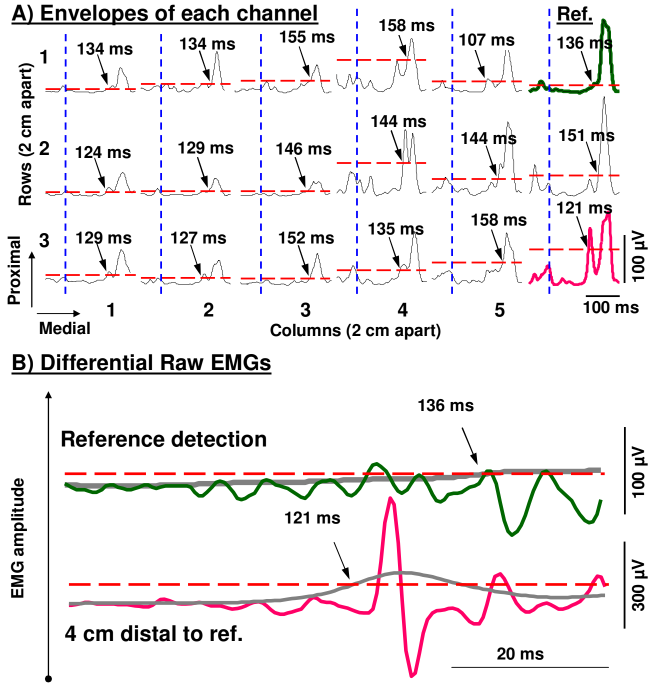

FIGURE 3. A, EMG envelopes for each channel in the grid (dashed blue line: perturbation onset; dashed red line: amplitude threshold; black arrows: delays). B, Expanded differential raw EMGs and envelopes for channels in column 6, row 1 (top, reference detection, green trace) and row 3 (bottom, red trace). Note that the motor unit potential represented in the bottom EMG (which is not recorded in the top EMG) makes the envelope higher than the threshold 15 ms earlier than in the reference detection signal.

CONCLUSIONS

Understanding the muscle response to external perturbations after stroke can be aided by the use of high density surface EMGs. Depending on the position of individual electrodes on the soleus surface, reflex responses might be estimated with highly different delays (differences from 20 - 100 ms). In relation to the muscle volume sampled by our grid, the onset of reflex responses estimated from the reference detection (which simulates a traditional bipolar technique) did not correspond necessarily to those measured across the grid. These results from the non-paretic side of a single subject establish the feasibility of using high density surface EMGs to investigate how postural responses are represented across the soleus muscle volume and are important for future comparisons with the paretic side after stroke.

ACKNOWLEDGEMENTS

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