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SPATIAL DISTRIBUTION OF SURFACE EMG AMPLITUDE DURING SELECTIVE ACTIVATION OF DORSAL FOREARM MUSCLES

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SUMMARY

The aim of this study was to investigate the spatial distribution of EMG amplitude over the forearm during isometric contractions of selected muscles. Ten subjects performed isometric efforts (wrist extension, radial and ulnar deviation, elbow flexion, extension of the metacarpo-phalangeal joint of the middle, ring and little finger). Surface EMG signals were collected by applying 128 electrodes over the proximal portion of the dorsal forearm, and EMG amplitude maps were obtained from the monopolar signals. The active area was tracked and changes of its position in different tasks were analyzed. Significant differences were found along both the proximal-distal ($P<0.01$, $F=35.83$) and the medio-lateral direction ($P<0.01$, $F=125.92$). Post-hoc analyses disclosed that most of the effort combinations could be distinguished with a higher statistical significance in the medio-lateral axis. Others, such as wrist extension vs. radial deviation and middle vs. ring finger extension, could only be discriminated along the proximal-distal direction. This study showed that each effort was associated to a specific surface EMG amplitude distribution, and that different wrist/finger efforts could be discriminated by using high-density surface EMG.

INTRODUCTION

Due to the multiple degrees of freedom required for the highly sophisticated wrist and hand movements, many muscles with different lines of action origin from the elbow region and run through the forearm reaching the insertions at the wrist and hand level. As these muscles differ for architectural features [1] and function [2], it is of critical importance to appropriately separate their EMG signals when forearm muscle patterns of activation are investigated. The aim of this study was to identify the spatial distribution of surface EMG amplitude associated to isometric efforts performed to selectively activate muscles of the dorsal, proximal forearm.

METHODS

Ten healthy subjects performed a set of selective, isometric efforts: 1) wrist extension, radial and ulnar deviation at 20% of the maximal voluntary contraction; 2) elbow flexion against manual resistance; 3) metacarpo-phalangeal joint extension against gravity, lifting the middle, ring or little finger. Surface EMG signals were collected with a grid of 128 electrodes with 10mm inter-electrode distance placed on the dorsal portion of the forearm. Electrodes were organized in 12 rows by 8 columns (radial side) plus 8 rows by 4 columns (Figure 1). Amplitude (root mean square, RMS) maps were computed from the monopolar EMG signals by averaging 3 seconds long epochs.

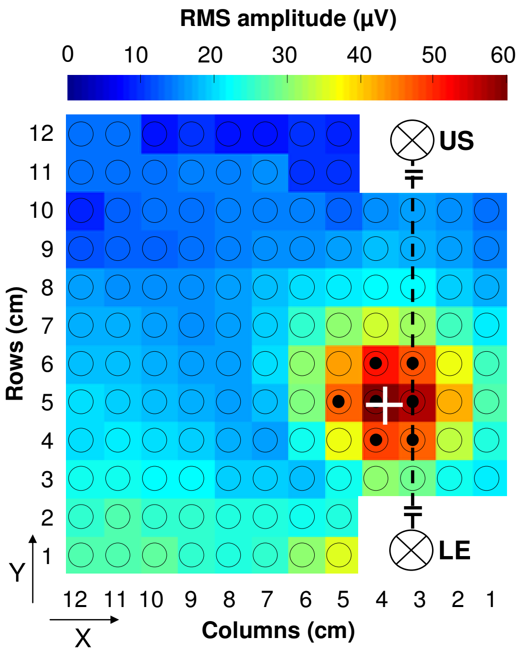

Figure 1: Example of the segmentation process. The RMS map corresponds to a selective middle finger extension. The dotted channels are those automatically selected by the segmentation algorithm [3], the white cross is the barycenter of the selected area. US = Ulnar styloid; LE = Lateral epicondyle.

An automatic algorithm based on Watershed segmentation [3] was then used to identify which channels were included in the portion of the grid with a relevantly high EMG activity. For each effort, the position of the active area was quantified by computing the barycenter of these channels. An example of this process is shown in figure 1. The effect of the direction of the force exerted was separately tested on X- and Y-coordinate (medio-lateral and proximal-distal respectively) with an analysis of variance (ANOVA) . The Holm-Sidak test was used for post-hoc analyses.

RESULTS AND DISCUSSION

Each muscle could be distinguished from the others in at least one direction (proximal-distal direction: P<0.01, F=35.83; medio-lateral direction: P<0.01, F=125.92); results of post-hoc comparisons are shown in table 1. In each contraction, the amplitude distribution matches closely with the anatomical region of the main agonist (figure 2). Most muscles could be discriminated considering either coordinate, but some could only be distinguished along the proximal-distal axis (e.g: extension and radial deviation, middle and ring finger extension).

Advantages in such a precise spatial localization of the EMG source might have been provided by the detection modality chosen; differently from classical single differential detection, monopolar EMG signals show their highest amplitude value above the innervation zone [4], which is a relatively small portion of the muscle fiber. If compared to the single differential EMG amplitude distribution, which is mainly related to travelling potentials along the muscle fibers, the monopolar distribution provides a smaller number of channels representative of muscle activity.

The spatial distribution of EMG activity during wrist extension and radial deviation was significantly different. As these two movements have already been used in the literature to selectively activate the two heads of the extensor carpi radialis [5, 6], the results of this study suggest that the EMG activity of extensor carpi radialis brevis vs longus can be separated by using non-invasive electrodes, at least during selective, isometric efforts. This might be useful in the investigation of upper limb, work-related disorders.

CONCLUSIONS

Each of the efforts tested in this study was associated to a specific spatial distribution of surface EMG amplitude; the position of the barycentre of segmented monopolar maps was effective in discriminating these efforts.

ACKNOWLEDGEMENTS

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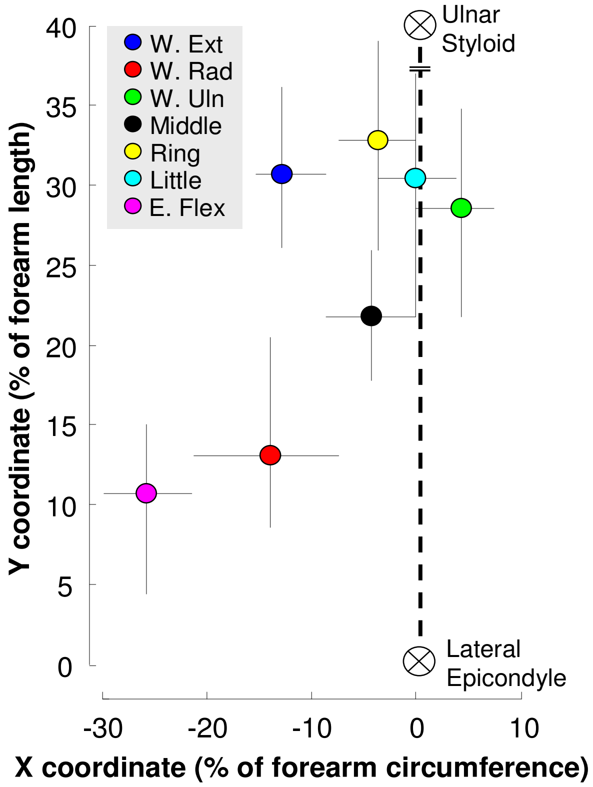

Figure 2: Areas identified during the different efforts. For each effort, all the X- and Y-coordinate of the selected channels were pooled together; each colored circle is the X- and Y- median of those distributions, vertical and horizontal lines are the 25th – 75th percentiles. All the coordinates are normalized with respect to forearm length (Y) or forearm circumference (X).

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Table 1: Post-hoc comparison between each couple of efforts. The values reported in each cell of the table are the t value of the Holm-Sidak post-hoc test. Cells in the top-right portion of the table refer to comparison of the X-coordinate (medio-lateral) of the barycentre for each couple of efforts, whereas cells in the bottom-left refer to the Y axes (proximal-distal). For each couple, the value referring to the coordinate which best discriminated the two efforts is highlighted in bold.

Y\X bar.	W. EXT	W. RAD	W. ULN	E. FLEX	MIDDLE	RING	LITTLE
W. EXT		1,5	**12,90****	**10,64****	**5,42****	**6,63****	**9,77****
W. RAD	**7,58****		**14,40****	**9,14****	**6,92****	8,13**	**11,27****
W. ULN	0,77	6,81**		**23,54****	**7,48****	**6,26****	**3,13****
E. FLEX	9,44**	1,85	8,67**		**16,06****	**17,27****	**20,41****
MIDDLE	4,05**	3,53**	3,28**	5,38**		1,214	4,35**
RING	1,37	**8,95****	2,13	10,80**	**5,42****		**3,14****
LITTLE	0,32	7,91**	1,09	9,76**	**4,38****	1,04	

Along X

Along Y

* = P < 0.05. ** = P < 0.01.