PROPORTIONAL AND SIMULTANEOUS ESTIMATION OF COMBINED FINGER MOVEMENTS FROM HIGH-DENSITY SURFACE EMG

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BACKGROUND

In order to mimic the dexterity of the human hand, modern hand prostheses allow control of individual fingers. However, proportional and simultaneous control of individual fingers using myoelectric signals is still to be achieved. For practical application, it is important to minimize the number of sensors and the amount of calibration data. The aim of the present study was to test the feasibility of estimating finger forces during both single and combined finger movements using a training set of only 6 motions and a reduced set of electrodes.

METHODS

Five subjects performed 19 flexion movements: 5 individuated finger flexions, and 14 combinations of 2 to 5 fingers. The finger forces were measured using the Amadeo robot (Tyromotion GmbH, AT), and the surface electromyography (EMG) was recorded through a 256-channel high-density electrode grid (OTBioelettronica). Ridge regression was applied to simultaneously predict the forces of all fingers. The only movements used in the training were the single finger flexions, and the simultaneous flexion of all fingers. The quality of estimation was evaluated by computing the root mean square error (RMSE) between the estimated and desired force normalized (nRMSE) to the maximum of the desired force. The regression was performed using a full set of electrodes and reduced sets comprising 48 and 24 electrodes. The statistically significant difference was tested using a one-way ANOVA ($p<0.05$).

RESULTS

The average nRMSE for the training data and full electrode set was 0.12±0.03, and there was no significant difference in the quality of estimation between the fingers. However, the performance decreased ($p<0.001$) when using less electrodes (48 electrodes: 0.20±0.04; 24 electrodes: 0.22±0.04). The estimation of the finger forces during combined motions (test data) resulted in nRMSE of 0.40±0.12, and the performance was significantly better ($p=0.003$) for the ring finger (0.33±0.08) compared to the thumb (0.49±0.12). There was no difference in the quality of estimation for the combined motions when reducing the number of electrodes.

CONCLUSION

The study showed that the finger forces can be estimated proportionally and simultaneously using a simple method and a reduced training set. However, the average precision of estimating combined finger movements was not high, and the estimation of the thumb proved to be the most difficult of all the fingers. This likely reflects an increased role of intrinsic muscles in thumb control. Remarkably, reducing the number of electrodes did not significantly decrease the performance for the combined movements.