Muscle synergy residuals are necessary for accurate prediction of task progress

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Introduction

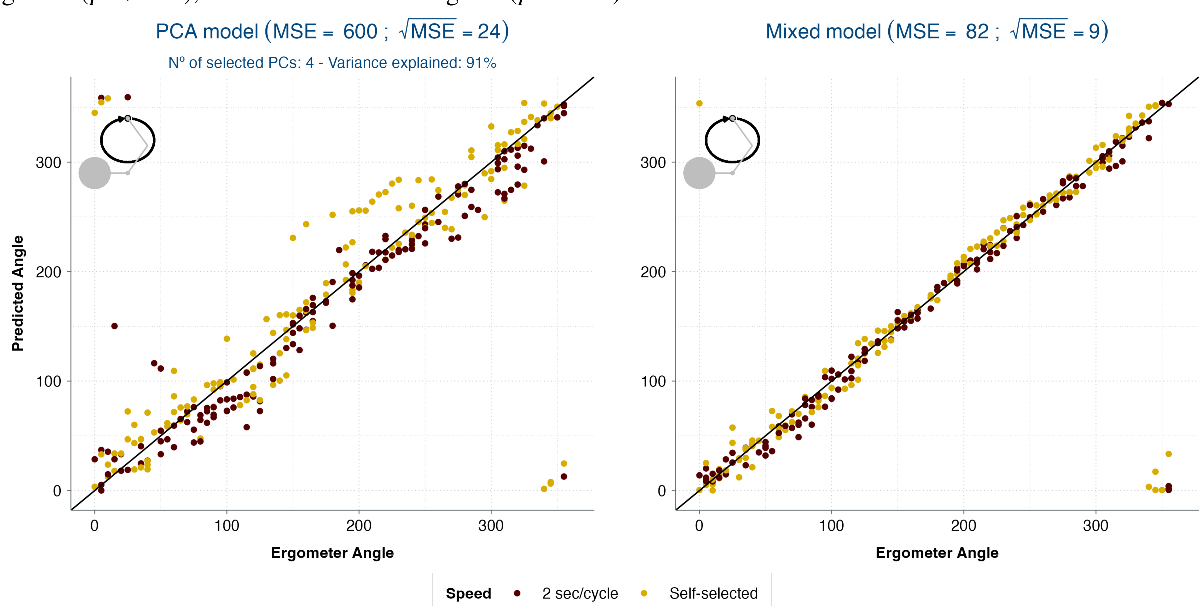
Dimensionality reduction techniques are often applied to electromyographic (EMG) recordings to calculate basis functions that quantify muscle coordination strategies. Usually, muscle synergies are defined using these dimensionality reduction techniques from the basis functions that account for 90% of variance in the original signal. However, the residual activity (remaining 10%) is not entirely random and can inform the execution of motor tasks. To test the importance of residual activity to capture the fine features of upper-arm cyclical motion, we compared the task progress prediction error based on (i) EMG activity and (ii) after its dimensionality reduction.

Methods

Eleven participants (5 males, 7 females), with a mean age of 37.3 ($\pm$ 14.2) years were evaluated using a horizontal ergometer (reaching-like cyclical motion), while electrodes were placed on seven muscles of their right upper extremity: *Long* and *Short heads of biceps*, *Anterior*, *Middle* and *Posterior deltoid*, *Lateral head of triceps*, *Upper Trapezius*. Each participant executed 30 repetitions at two speeds: self-selected and two seconds per cycle. EMG signals were filtered, then rectified and normalized to maximal contraction in each trial (over the 30 repetitions). Muscle activity was averaged over five degree intervals between 0 to 360º. To estimate task progress, a *mixed effects model* was fitted using cross validation (k=5), where *task progress* (ergometer angle) is estimated based on EMG signals of the seven muscles and after dimensionality reduction using principal component analysis (PCA). Four PCs accounted for 91% of EMG signal variance, and were used as predictors.

Results

Root mean squared error (RMSE) of task progress prediction based on dimensionality reduction was 24º, while RMSE based on EMG signals was 9º. Statistical differences were found between observed and predicted ergometer angle (task progress) using PCA ($p < 0.01$), but none from EMG signals ($p = 0.21$).



Discussion

Our results suggest the remaining 9% of variance that was not considered after dimensionality reduction is necessary for accurate prediction of task progress. This raises questions about the utility of synergies for the accurate prediction of reaching kinematics.

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