SUBMAXIMAL NORMALIZING METHODS TO EVALUATE LOAD SHARING CHANGES IN REPETITIVE UPPER EXTREMITY WORK

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INTRODUCTION

The anatomy of the shoulder allows multiple load distribution strategies between muscles thus load-sharing adaptations to fatigue are expected. The relationship between EMG and muscle force changes with muscle fatigue, making the interpretation of load sharing relationships between muscles challenging when workers are exposed to repetitive demands (McDonald et al, 2015; Tse et al, 2015). Two common methods for normalization include using a maximum voluntary exertion (MVE) or a submaximal reference exertion (RVE); the latter may be better suited to estimate sub-maximal loads (Jonsson, 1982). The purpose of this investigation was to evaluate the efficacy of normalizing EMG data to repeated, static, submaximal exertions to mitigate the fatigue artifact in EMG amplitude, to better reflect load sharing.

METHODS

Twenty right hand dominant men completed repetitive simulated work tasks, in 60-second work cycles, until exhaustion. Surface EMG (Trigno, Delsys Inc., Natick, MA, USA) was recorded from 11 muscles for a complete work cycle every 3 minutes. Every 12 minutes, participants completed a series of 4 submaximal (30% MVC) and 1 maximal reference exertions. The series of four reference exertions were selected to activate all of the included muscles (Boettcher et al, 2008). Submaximal forces were recorded with a force transducer (Mark-10, Copiague NY) and a manual goniometer confirmed each posture. EMG data were recorded for 3 seconds after achieving the target force. This cycle continued until one of the termination criteria was met: 1) participant declared they could no longer continue, 2) participant was no longer able to complete the work tasks, 3) participant was no longer able to maintain the 30% MVC force level for any of the 4 reference exertions.

Fatigue was defined as an 8% or greater decrease in median power frequency between reference exertions. Linear envelope EMG was used for the amplitude analysis (2nd order, dual-pass BW filter, fc = 4 Hz). Reference contraction EMG data were used in 6 normalizing methods including a Standard Normalizing Method (SNM) (normalized to initial reference exertion) and 5 novel methods (Figure 1).

EMG from one of the work tasks (drill task) was used to evaluate the methods. The novel methods included: (i) Fatigue Only (FON): When myoelectric fatigue was present, the following 12 work cycles were normalized to that reference exertion. All muscles/work cycles not exhibiting signs of fatigue were normalized to the initial reference exertion. (ii) Linear (LMN) and (iii) Cubic (CMN) Models: A least squares regression model was used to create linear and cubic functions to predict the submaximal EMG amplitude for every third minute. The predicted value was then used to normalize the corresponding work task EMG. (iv) Points Forward (PFN): Each reference exertion was used to normalize the 12 work cycles completed after it. (v) Points Forward/Backward (PFBN): Each reference exertion was used to normalize the 6 work cycles completed before it and the 6 work cycles completed after it.

Random slope, random intercept mixed effects models were used to identify differences between participants and between the normalization methods. All novel methods were compared to the Standard Normalizing Method. Pearson product moment correlations assessed how well the predicted points from the linear and cubic normalization models fit the reference exertion data.
RESULTS AND DISCUSSION

Participants performed the work cycles for 57-240 minutes, completing between 5-20 sets of reference exertions. The muscles that displayed signs of myoelectric fatigue and the time points where fatigue appeared differed between participants. Shoulder flexion strength decreased from 108.8 ± 24.0 N to 77.6 ± 28.6 N.

The significant differences between the novel methods and the SN method were dependent on the muscle and the number of time points in the analysis. Statistically significant changes were consistent between the FO method and LMN and CMN methods (p < 0.05). The amplitude of posterior deltoid muscle was significantly lower when normalized to these 3 methods than when normalized to the standard method (Figure 2). There were more muscles with significant differences from the SN method with the PFN and PFBN methods.

Correlation analysis showed that the predicted cubic model points correlated better to the actual data points than the linear predicted values.

Figure 1: Schematic representation of the 6 normalizing methods (1) SN, (2) FON, (3) LMN, (4) CMN, (5) PFN, (6) PRFN. Circles represent mean EMG data during from reference exertions and the black arrows/lines depict which time points are normalized to each reference exertion.

Figure 2: Adjusted predictions of the 6 normalization methods with 95% confidence interval for the posterior deltoid muscle.

CONCLUSIONS

The purpose of this analysis was to develop a method to reduce fatigue artifacts in EMG data, thus results of the PFN, PFBN and FON methods are of interest. These methods are dependent on the local reference data and subject to any variability/fluctuations in these data. The cubic and linear model methods produced results that are consistent with the fatigue only normalizing method, however may be less susceptible to small local fluctuations. Based on the correlation findings, we believe that the Cubic Model Normalizing method has promise as a novel method to mitigate the effects of muscle fatigue on EMG amplitude and improve our understanding of load sharing changes with repetitive work.

REFERENCES