BACK MUSCLE FATIGUE DURING SUBMAXIMAL INTERMITTENT ISOMETRIC CONTRACTIONS: THE INFLUENCE OF NEUROMUSCULAR ACTIVATION PATTERNS

[1] Christian Larivière, [2]Denis Gravel, [2]Bertrand Arsenault, [3]Denis Gagnon and [4]Phillip Gardiner
[1]Occupational Health and Safety Research Institute Robert-Sauvé, Montreal, Canada, [2]Research Center, Montreal Rehabilitation Institute, Montreal, Canada; [3]Faculty of Physical Education , University of Sherbrooke, Canada, [3]HLHP Research Institute, University of Manitoba, Winnipeg, Canada; email: larchr@irsst.qc.ca

INTRODUCTION

Three groups of factors are known to explain muscle endurance: (1) anatomical factors (muscle mass and composition, capillary-zation), (2) physiological factors (hormones, enzymes, energy stores), and (3) neuromuscular activation patterns (NMAP). However, NMAP (variable activation of motor units within and between muscles, etc.) has rarely been quantified using indices derived from surface electromyography (EMG). This would help to estimate the role of NMAP when muscles fatigue. The aim of this study was thus to quantify the relationship between the NMAP of synergist muscles and fatigue using different EMG indices.

METHODS

Seventy-four subjects (43 males and 31 females; age: 20-55 yrs) performed 3 maximal voluntary contractions (MVC) and a fatigue test while standing in a static dynamometer measuring L5/S1 moments [1]. Surface EMG signals were collected from 4 pairs of back muscles (multifidus at the L5 level, iliocostalis lumborum at L3, and longissimus at L1 and T10). The fatigue test, assessing absolute endurance (90 Nm load), consisted of repeating an 8-s cycle extension task (1.5 s ramp to reach 90 Nm + 5 s plateau at 90 Nm + 1.5 s rest). For all subjects, a familiarization session (MVCs + 10 min. fatigue test) was followed by a test session (MVCs + fatigue test to exhaustion or 60 min). A subsample of 31 subjects (19 males and 11 females) performed a 3rd session, but the fatigue test was performed to exhaustion using a relative load (41% MVC), thus assessing relative endurance.

Strength was defined as the peak MVC while our fatigue criterion was defined as the time to reach exhaustion either during the absolute ($Tend_{abs}$) or relative ($Tend_{rel}$) fatigue test. For each plateau, the time-series of the RMS amplitude (125 ms) of the EMG signals were computed. The EMG RMS time-series (first 5 min) were used to quantify NMAP between back synergists using 2 types of EMG indices (Ind1 and Ind2 adapted from [2]), both accounting for the effect of fatigue on EMG RMS (linear trends in the EMG time-series were removed). Ind1 basically reflects the variation in EMG activity of each muscle while Ind2 quantify the alternating activity between 2 muscles. Ind2 being the proportion of time of alternating activity (P_{ALT}) times the amplitude of this activity, P_{ALT} was also studied separately. For Ind2 and P_{ALT}, various pairs of muscles (homolateral and contralateral) were assessed.

RESULTS AND DISCUSSION

$Tend_{abs}$ values of subjects (27 males and 27 females) who reached exhaustion before 60 min (median = 14.4 min; range: 2.7-56.7 min), $Tend_{rel}$ values (median = 8.7 min; range: 2.0-24.3 min) as well as Ind1 and Ind2 indices (not P_{ALT}) were first log-transformed to obtain normal distributions. From the **absolute endurance protocol (load = 90 Nm;** session 2; n = 54 subjects**)**, the associations (Pearson correlation) between the EMG indices and $Tend_{abs}$ were all significant ($P < 0.05$) and ranged between -0.29 and -0.61 (positive sign for P_{ALT}). Higher Pearson correlations were observed between the EMG indices and *Strength* (range: -0.38 to –0.81; positive sign for P_{ALT}). Stepwise regression analyses revealed that the EMG indices (2 to 4 selected depending on the model) can explain 57% of $Tend_{abs}$ and 68% of *Strength*. From the **relative endurance protocol (load = 41 % MVC**; session 3 ; n = 31**)**, few EMG indices (6/38) were significantly correlated to $Tend_{rel}$ and only three correlated with *Strength*. In the regression models, EMG indices explained only 29% of $Tend_{rel}$ and 22% of *Strength*. To verify whether Ind1, Ind2 and P_{ALT} were sensitive to the progression of fatigue, these indices were computed for each 25% interval of the absolute fatigue test to exhaustion (n = 54 subjects). The one-way ANOVAs for repeated measures (4 time-intervals) showed, but only for Ind1 and Ind2, a significant ($P < 0.05$) increase across intervals (fatigue effect).

It can be speculated that P_{ALT} was more specific to measure alternating activity while Ind1 and Ind2 was more sensitive to EMG amplitude variations due to the recruitment of motor units (due to force or fatigue increase). In fact, the negative association between Ind1 and Ind2 indices and *Strength* during the absolute endurance protocol showed that Ind1 and Ind2 increase proportionally with the relative load. Hence, *Strength* being a predictor of absolute endurance ($R^2 = 0.31$), negative associations between these indices and $Tend_{abs}$ were expected. During the relative endurance protocol, the relative load being equal across subjects, the relations between the EMG indices and $Tend_{rel}$ or *Strength* almost disappeared, except for some P_{ALT} indices. The differential effect of fatigue on Ind1-Ind2 versus P_{ALT} suggest that EMG amplitude variability increased but alternating activity was stable as fatigue progressed.

CONCLUSIONS

The quantification of NMAP using surface EMG is complex but can reveal relations with the strength and endurance of an individual, particularly during an absolute endurance protocol.

REFERENCES

1. Larivière C, et al. *Clin Biomech* **16,** 80-83, 2001.
2. van Dieen JH, et al*. Eur J Appl Physiol* **66,** 70-75, 1993.

ACKNOWLEDGEMENTS

This project was co-funded by the Occupational Health and Safety Research Institute Robert-Sauvé (IRSST) of Quebec and the Canadian Institutes for Health Research (CIHR).