# FATIGUE ANALYSIS USING ELECTROMYOGRAPHY DRIVEN MUSCULOSKELETAL TRUNK MODELS

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## Abstract

Muscle fatigue progression is commonly studied using Electromyography (EMG). Although muscle forces can be obtained using EMG-driven neuromusculoskeletal models (EDMM), these do not reflect changes in force generation due to fatigue. Here, we studied trunk muscle forces in 3 participants using EDMM during a fatigue task. We discuss results and model updates needed to obtain realistic muscle forces during fatiguing tasks.

## Introduction

Factory workers are prone to musculoskeletal disorders as a result of increasing likelihood of injury and fatigue progression [1]. Tracking fatigue progression helps understand likelihood of risk in factory workers. Muscle fatigue is a progressive decline in maximal force or power capacity of the muscle [2]. Temporal and frequency analysis methods of EMG were used to study fatigue [3].

EDMM were used to estimate muscle forces during different motor tasks [4]. However, these models did not include fatigue dynamics and therefore, cannot reflect resulting changes in muscle force generating capacity. Realistic muscle force estimation is needed to design bio-protective active exosuits that assist factory workers by preventing excessive loads on the musculoskeletal system. In this study, we analyze a trunk EDMM within the context of a fatiguing task, and study whether the estimated muscle forces were influenced by fatigue.

## Methods

Three participants (Mean (SD) Age: 27.7 (2) years, height: 1.8 (0.05) m, weight: 72 (3) kg) performed an endurance task at 30 ± 5° lumbar flexion until exhaustion while the pelvis was fixed. Motion data was captured using Qualisys (Qualisys Medical AB, Sweden). High Density EMG (HDEMG) was measured using the Refa system (TMSi, The Netherlands). Four 8x8 grids were placed on the right back, each consisting of evenly spaced 64 electrodes 8.5 mm from each other [5]. Kinematic, kinetic, and HDEMG data were synchronized by Qualisys Track Manager software.

Bipolar EMG data for the iliocostalis lumborum (6 cm lateral to L2), longissimus thoracis pars lumborum (3 cm lateral to L1) and pars thoracis (4 cm lateral to T10) muscles on the right were extracted from HDEMG data by differentiating adjacent channels along the muscle line of action. The EDMM was applied to the Lifting Full-Body model within OpenSim 4.3 to extract muscle lengths and force [6].

The Root Mean Square of the amplitude (RMS) was estimated using a moving window (size 60 s with an overlap 30 s) and compared between the EMG and muscle force.

## Results

Change in the RMS from the initial value was identified at two instances (halfway (M) endurance task and at exhaustion (E)) as percent difference (%Δ). The changes per participant are shown in Table 1.

| % Δ | | Sub 1 | | Sub 2 | | Sub 3 | |
|---|---|---|---|---|---|---|---|
| | | M | E | M | E | M | E |
| IL | EMG | -1.5 | 3.6 | 0.6 | 1.5 | 37 | 46 |
| | Force | 0.9 | 5.2 | 27 | 33 | 68 | 34 |
| LL | EMG | -7.9 | -11.7 | 4.5 | -2 | 16 | 34 |
| | Force | -7.5 | -11.5 | 5 | -0.5 | 21 | 33 |
| LT | EMG | -4.1 | 3.8 | -2 | 17 | 11 | 27 |
| | Force | -2.1 | 4.6 | 1.5 | 19 | 15 | 27 |

*Table 1: Iliocostalis Lumborum (IL), Longissimus thoracis pars lumborum (LL) and pars thoracis (LT) measured halfway endurance task (M) and at exhaustion (E).*

## Discussion

We observed that changes in muscle force RMS follows that of EMG (R2>0.9). Although the participants were exhausted at the end of their trials, not all muscles seemed to have fatigued (shown by an increase in EMG RMS) as they performed sub-maximal contraction [7]. In most cases, EDMM based muscle forces increase for subjects due to increase in EMG amplitude and lack of fatigue modelling within the EDMM. Therefore, individualized fatigue models that modulate muscle forces based on the amplitude and duration of contraction during motor tasks must be included in EDMMs.

## References

1. Ma et al, *Int. J Ind. Ergon*, 39:211-220, 2009
2. Enoka et al, *J Physiol*, 5861:11-23, 2008
3. Dimitrova et al, *J. Electromyogr. Kinesiol.*, 13:13–36, 2003
4. Sartori et al, *IEEE Trans. Biomed. Eng.*, 63:879–893, 2016
5. Moya-Esteban et al, *Proc. IEEE RAS EMBS Int. Conf. Biomed. Robot. Biomechatronics*, 2020
6. Beaucage-Gauvreau et al, Comput. Methods Biomech. Biomed. Engin., 22:451-64, 2019
7. Farina et al, *J. Electromyogr. Kinesiol.*, 13:319–32, 2003

## Acknowledgements

This work was supported by EU Horizon 2020 ICT-10 Project SOPHIA (871237).