Neuromuscular Fatigue Estimation from Biomechanical Parameters in Cycling Task

Samira Fazeli Veisari [1*], Atousa Parsaei[1], Shahram Rasoulian[2], Sierra Sweeny[1], Reza Ahmadi[3], Jalal Aboodarda[2], Amin Komeili[1,2,3]
[1]Department of Biomedical Engineering, University of Calgary, Calgary, Canada
[2]Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Calgary, Canada
[3]Department of Mechanical and Manufacturing Engineering, University of Calgary, Calgary, Canada
Email: samira.fazeliveisari@ucalgary.ca

Summary

This study evaluates the potential of frequency-domain biomechanical parameters in predicting neuromuscular fatigue during a pedaling task. The EMG signal of seven lower limb muscles was collected in power-constant and stepwise pedaling tests from 11 healthy participants. The data was analyzed in frequency and time domains, and the correlation of biomechanical parameters to neuromuscular fatigue development was studied. The Mean frequency (MNF) parameter had the highest correlation with neuromuscular fatigue development.

Introduction

Non-invasive estimation of neuromuscular fatigue is a critical area of interest for muscle physiologists, clinicians, sports and biomechanists, and engineers. Accurately predicting muscle capacity offers numerous benefits, including improving patient comfort and optimizing training and rehabilitation programs. Muscle electromyography (EMG) has been used extensively to assess neuromuscular activity. However, its correlation to neuromuscular fatigue development was questioned [1] and supported in the literature [2, 3]. It was argued that factors like intracellular action potential propagation and after-potential magnitude, and various sources of noise significantly influence EMG signals during fatigue. Recent advanced data analytics reported a strong correlation between neuromuscular fatigue and EMG signal [4]. The objective of this study was to explore time and frequency domain EMG parameters and investigate their correlation with neuromuscular fatigue in a cycling task.

Methods

In this study, muscle fatigue refers to performance fatigability rather than perceived fatigability [5]. Eleven recreationally active cyclists (6 females and 5 males; age 24±5 years, height 1.71 ±0.08 m, and body mass 69 ± 9 kg) completed a stepwise cycling test, which was started at a power output of 40 W and increased by 20 W every minute at a constant cadence of 70 rpm. On another day, participants completed a power constant cycling test, where 70% of the maximum cycling power, which was achieved in the step test, was maintained at 70 rpm and continued until task failure. The study protocol was approved by the institutional ethics board (REB#1803). Surface EMG of seven muscles on each lower limb was measured at 2200 Hz, including rectus femoris (RF), vastus medialis (VM) and vastus lateralis (VL), gastrocnemius (GA), long head biceps femoris (BF), tibialis anterior (TA), and soleus (SO). EMG signal parameters were calculated in time-frequency domain, including MNF (Equation1), median frequency (MDF), and area (A). In this equation P(f) is Power spectral density at frequency f.

$$MNF = \frac{\int P(f).f df}{\int P(f) df} \qquad (1)$$

Results and Discussion

The MNF parameter had the largest correlation with neuromuscular fatigue development (Figure 1), making it a particularly promising metric for monitoring fatigue. This finding emphasizes the potential of EMG frequency domain parameters for estimating fatigue development.

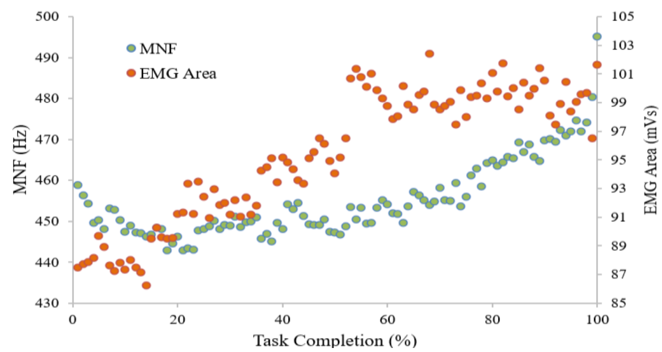

Figure 1: Variation of MNF and EMG area for VL muscle during the power constant test.

Conclusions

This study highlights the potential of the MNF parameter, as a potential indicator of neuromuscular fatigue development during cycling tasks, which can provide a basis for further advancements in noninvasive fatigue monitoring systems. Future research should focus on validating these results for different populations and exploring the validity of the results at different power levels and cadences.

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