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Title

Muscle pre-activation prior to landing in athletes with anterior cruciate ligament reconstruction: detection of EMG onset using artificial intelligence

Keywords:

ACL-R; asymmetry; EMG onset; deep learning; motion analysis

ABSTRACT

Introduction

In Return-to-Sport evaluation of athletes after Anterior Cruciate Ligament Reconstruction (ACL-R), motion analysis of specific tasks, such as Single-Leg Hop (SLH), can provide unique measurements. Muscle pre-activation prior to SLH landing is adopted as a discriminant parameter between ACL-R and control athletes [1]. To detect muscle pre-activation from electromyography (EMG) signals, algorithms for activation-interval detection can overcome the limitations of manual segmentation. Long Short-Term Memory recurrent neural network for Muscle Activity Detection (LSTM-MAD) [2] proved successful, in gait analysis, as a tool for EMG-onset detection based on Artificial Intelligence (AI). LSTM-MAD directly works on raw EMG signals without requiring additional pre-processing or input parameters (e.g., background-noise power and Signal-to-Noise Ratio). The aim of this work is to quantify muscle pre-activation and asymmetry in ACL-R and control athletes, adapting LSTM-MAD to the evaluation of SLH task.

Methods

The EMG activity of 4 lower-limb muscles - Vastus Lateralis (VL), Vastus Medialis (VM), Semitendinosus (ST), and Biceps Femoris (BF) – was acquired bilaterally from 12 ACL-R and 17 control athletes. LSTM-MAD was applied to evaluate muscle pre-activation before initial contact while landing. The median value of the EMG pre-activation across 3 trials was considered for the analysis. A derived parameter - named "pre-

activation asymmetry" - was obtained for each subject, defined as $\left|EMG\ preactivation_{left} - EMG\ preactivation_{right}\right|$. In other words, the asymmetry between the reconstructed and contralateral side of patients was calculated and compared against the "physiological" asymmetry between the dominant and non-dominant side of controls. Two *2-way* ANOVAs with Bonferroni adjustment for multiple comparisons were performed to test differences in muscle pre-activation and pre-activation asymmetry between populations (ACL-R athletes vs. controls) and knee flexor/extensor muscle groups (knee flexors: ST and BF; knee extensors: VL and VM).

Results

Figure 1 shows the muscle activation intervals of a representative ACL-R athlete, and results on ACL-R and control populations.

Statistically significant differences in muscle pre-activation were found between populations (ACL-R: 167±6 ms (mean±SE); controls: 137±5 ms; p<0.001) and muscle groups (knee flexors: 169±5 ms; knee extensors: 135±5 ms; p<0.001). Moreover, pre-activation asymmetry was higher in ACLR athletes compared to controls (ACL-R: 55±6 ms; controls: 29±4 ms; p<0.001) and in knee extensors compared to knee flexors (knee flexors: 29±5 ms; knee extensors: 55±5 ms; p<0.001).

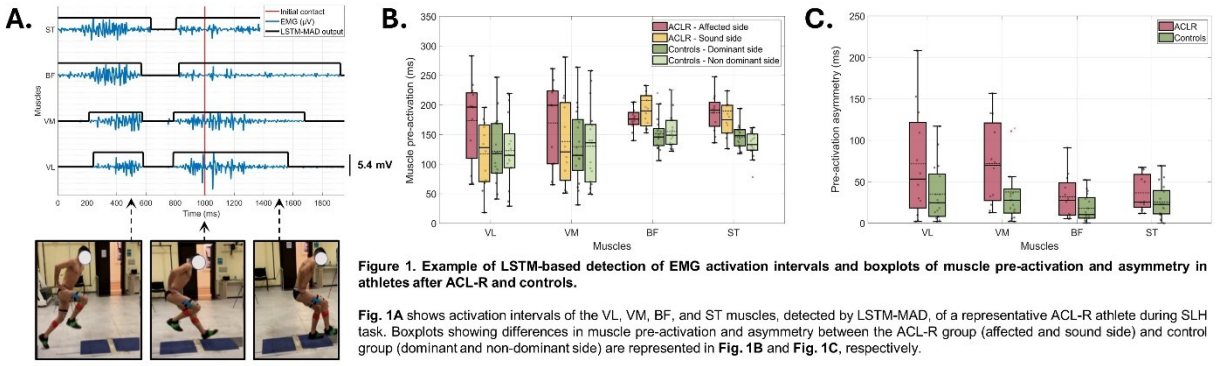

Figure 1. Example of LSTM-based detection of EMG activation intervals and boxplots of muscle pre-activation and asymmetry in athletes after ACL-R and controls.

Fig. 1A shows activation intervals of the VL, VM, BF, and ST muscles, detected by LSTM-MAD, of a representative ACL-R athlete during SLH task. Boxplots showing differences in muscle pre-activation and asymmetry between the ACL-R group (affected and sound side) and control group (dominant and non-dominant side) are represented in **Fig. 1B** and **Fig. 1C**, respectively.

Discussion

AI proved useful in the automatic detection of muscle activity, allowing for the extraction of muscle pre-activation and derived parameters such as pre-activation asymmetry during SLH landing in ACL-R and control athletes.

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