Electromyographic Investigation of Lower Limb Muscle Fatigue during an Exercise Protocol Simulating the Activity Present in Intermittent Sports

Natalia Glibbery, IBSc degree in Orthopaedic Sciences, MBBS1, Ian McCarthy2, Peter J. Smitham3, Richard Weiler, MBChB, MSc3, Suzie Cro, MSc, BSc4.

1University College London, London, United Kingdom, 2University College London Institute of Orthopaedics and Musculoskeletal Science, London, United Kingdom, 3University College London Hospitals NHS Foundation Trust, London, United Kingdom, 4Medical Research Council Clinical Trials Unit, London, United Kingdom.

Disclosures:
N. Glibbery: None. I. McCarthy: None. P.J. Smitham: None. R. Weiler: None. S. Cro: None.

Introduction: Muscle fatigue development has been the focus of extensive research owing to the fact that it is associated with performance impairment and an increased predisposition to musculoskeletal injuries. It has been proposed that fatigued muscles absorb less energy before stretching to a degree that may cause injuries. Muscle fatigue is also considered to alter neuromuscular and biomechanical function, potentially leading to an increased risk of musculoskeletal injuries. The investigation of fatigue development is particularly important in the sports sector since it accounts for a considerable proportion of injuries. Surface electromyography (sEMG) has been extensively utilized in studies investigating muscle fatigue development, since physiological and biochemical changes occurring in fatiguing muscles are considered to be reflected in the properties of their electromyographic signal, resulting in amplitude or frequency spectrum changes (De Luca, 1984). Past studies investigating the effects of muscle fatigue on the sEMG signal properties have, however, been confined to a laboratory setting, producing results which are inconsistent and not necessarily representative of real life situations. The aim of the present study was, therefore, to investigate the changes in the amplitude of the surface EMG signal, recorded from lower limb muscles of professional football players, as a result of muscle fatigue developing during an exercise protocol conducted in a realistic, sport-specific setting. This would provide a better understanding of the underlying mechanisms of muscle fatigue developing during sports and its role in musculoskeletal injuries, and potentially enable sEMG to be used in the future to detect muscle fatigue development in an effort to predict and prevent injuries and their sequelae.

Methods: Ten male professional football players participated in this study. The present work is a pilot study and hence there is no formal calculation that could be used to estimate the required sample size. The participants of this study were required to perform the Yo-Yo Intermittent Recovery (IR) test level 2, an exercise protocol simulating the intermittent activity present in various sports, on artificial turf. The Yo-Yo IR test consists of 40 meter shuttle runs, interspersed with a 10-second active recovery period, progressively increasing in average speed until the shuttle run cannot be completed in the specified time. The sEMG signal was recorded using wireless sensors, positioned on the gastrocnemii and hamstrings of the participants, while performing the test. The raw sEMG signal recorded from each sensor during the test was filtered and full-wave rectified by calculating the root mean square (RMS) of the signal. It was subsequently analysed by calculating a peak RMS (pRMS) value for each shuttle run, in order to investigate sEMG signal amplitude changes occurring during the Yo-Yo IR test. The statistical significance of the changes occurring in the pRMS values of the sEMG signal was assessed by repeated measures ANOVA. A p-value < 0.05 was considered to indicate statistically significant changes. A treadmill protocol was devised in order to validate the sEMG signal analysis technique used. Six male participants were required to perform two 45-second running trials each, interspersed with a 5-minute rest period to avoid the development of fatigue, on a treadmill. The sEMG signal of the participants was recorded, processed and analysed as described above. The difference between the pRMS values of the sEMG signal recorded during the two trials was investigated in order to assess the repeatability of the sEMG signal analysis technique. The study was approved by the UCL Research Ethics Committee and informed consent was obtained from all participants prior to data collection.

Results: The results of the analysis investigating sEMG signal amplitude changes during the Yo-Yo IR test demonstrated an initial increase in the pRMS values of the signal followed by a decrease continuing until the end of the test, for both gastrocnemii and hamstrings (Figure 1). These changes in the amplitude of the sEMG signal were however determined to be non-significant (p>0.05). A retrospective sample size calculation was conducted, concluding that approximately 100 participants would be required in future studies in order for an 80% statistical power to be attained. The error associated with the sEMG signal analysis technique was expressed using the standard deviation of the difference between the two trials as a percentage of the mean of the two trials and was found to be 10.52%, hence not sufficient to account for the sEMG signal amplitude changes observed during the Yo-Yo IR test.

Discussion: The present study demonstrated the existence of an initial increase followed by a decrease in the amplitude of the sEMG signal, as a result of muscle fatigue developing during an exercise protocol simulating the intermittent activity present in various sports. These changes could be indicative of an initial additional recruitment of fast-twitch type II motor units, in an
effort to compensate for fatigue, followed by a decrease in the myoelectric activity of the muscle, as a consequence of changes in central drive, conduction velocity, excitation-contraction coupling and metabolite accumulation (Al-Mulla et al., 2011). The changes in the sEMG signal amplitude were determined to be non-significant; however, future studies should include a larger sample size in order for a higher statistical power to be attained and hence definite conclusions to be drawn. Further research is still required in order for the exact effects of muscle fatigue on the sEMG signal amplitude to be elucidated.

**Significance:** Determining the effects of muscle fatigue, developing during a sport-specific exercise protocol, on the sEMG signal amplitude is of major clinical significance since it will provide a better understanding of the mechanisms and role of muscle fatigue in musculoskeletal injuries and potentially aid in preventing them. The present research was particularly novel in nature since it allowed for muscle fatigue development and its effects on the sEMG signal properties to be investigated in a realistic, sport-specific setting for the first time, thus laying the foundations on which future research can be conducted.

**Acknowledgments:**


<table>
<thead>
<tr>
<th>Gastrocnemii</th>
<th>Hamstrings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progression of exercise protocol</td>
<td>Progression of exercise protocol</td>
</tr>
</tbody>
</table>

Figure 1 Average pRMS values of the sEMG signal recorded from the gastrocnemii and hamstrings of the ten football players during the Yo-Yo IR test. Error bars have been produced using the standard error of the mean.

**ORS 2014 Annual Meeting**

Poster No: 1415