ACL-Related Motor Control Strategies Alterations: Insights from a Muscle-Driven 6-DOF Knee Model

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Summary

This study examines the impact of Anterior Cruciate Ligament (ACL) strain from both kinematic and kinetic perspectives using musculoskeletal models (MSMs) and electromyographic (EMG)-driven methods like Moco to estimate muscle activations (MAs) and forces (MFs) during dynamic movements. Four subjects who underwent ACL reconstruction performed Drop Landing tasks (DLs), and their data captured via motion capture, force platforms, and surface EMG (sEMG) systems. Results indicated that pathological subjects exhibited greater hip external rotation and increased vastus lateralis activation compared to healthy controls. These compensatory patterns likely aim to stabilize the knee and adjust for altered alignment due to ACL injury. The study underscores the importance of understanding these compensatory mechanisms in ACL rehabilitation.

Introduction

In high-intensity sports ACL injuries are among the most common knee injuries. During DL tasks, the knee is subjected to significant stress due to sudden impact and the high forces involved [1]. In this context accurate MSMs are important, as they can estimate internal parameters during dynamic conditions. When pathological conditions, such as ACL strain, and elite athletes are involved, incorporating motor control information (e.g., EMG) becomes crucial [2]. EMG-driven methods, such as Moco [3], help aligning muscle excitation estimates more closely with experimental data. This study examines the impact of an ACL strain injury from both kinematic and kinetic perspectives.

Methods

Four subjects (mean age and BMI: 17.75 ± 2.86 years, 24.73 ± 6.04 kg/m²) that underwent ACL reconstruction were acquired through six BTS cameras (60 Hz), synchronized with two Bertec force platforms (960 Hz) and an 8-channel sEMG system (1000 Hz) during the execution of DLs. sEMG sensors were placed bilaterally respectively on the following muscles: Vastus Lateralis, Semitendinosus, Tibialis Anterior and Gastrocnemius Medialis. IORGait protocol was applied [4]. Data was processed in OpenSim using a 6-degree-of-freedom (DOF) knee MSM [1]. Moco EMG-driven was applied to estimate MAs and MFs. sEMG envelope peaks were calculated. The same acquisition protocol was applied on a cohort of five healthy subjects (mean age and BMI: 25.6 ± 0.49 years, 21.96 ± 1.85 kg/m²). Statistical Parametric Mapping (SPM) [5] were conducted to compare the two groups.

Results and Discussion

Figure 1 reports the kinematics among the available lower limbs' DOFs of the applied MSM. Statistically relevant differences can be noted especially for the hip and the knee.

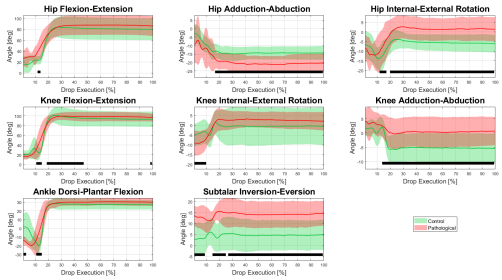

Figure 1: Joint kinematics comparison between control and pathological group: mean ± std. *statistical significance ($p<0.05$)

In Figure 2, the estimated MAs from Moco show that, consistent with the increased hip external rotation observed in pathological subjects, these individuals exhibited higher vastus lateralis activation compared to healthy controls. This is likely a compensatory response to counteract altered knee alignment and maintain stability during dynamic movements.

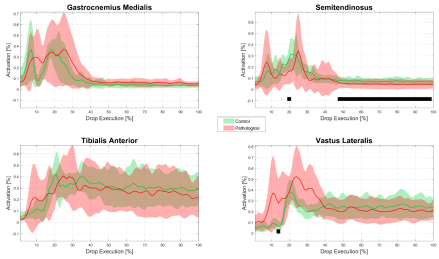

Figure 2: Comparison of Moco estimates (MAs) between the controls and the pathological group : mean ± std. *statistical significance ($p<0.05$)

Conclusions

The results highlight the value of both adopting an enhanced 6-DOF knee MSM and an EMG-driven approach in investigating joint mechanics and MAs patterns in ACL injured subjects. Incorporating these methods in ACL injury screening can improve recovery strategies and reduce the risk of reinjury.

References

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