IMPLEMENTING STABILITY CRITERIA AND WAVELET ANALYSIS TO ASSESS KNEE STABILITY AND MUSCLE ACTIVATION PATTERNS IN ATHLETIC POPULATIONS: IMPLICATIONS FOR ACL INJURIES

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Introduction: An anterior cruciate ligament (ACL) tear is a common knee injury in sports and, despite current prevention research, injury rates are sharply increasing. Lower-extremity muscles stabilize and support the knee during dynamic movements, such as single-leg jump landing (SLJL), to reduce ACL strain. Frequency techniques, commonly used in control theory to assess system stability, may be used to evaluate knee stability and classify biomechanical data into low- and high-risk ACL injury groups. Additionally, wavelet analysis, commonly used to detect abnormalities in biosignals, may be used to isolate underlying relationships between risk groups. The objective is to identify unstable landing biomechanics and to determine potentially harmful differences in muscle function elevating ACL injury risk.

Methods: Experimental kinematic, surface electromyography (sEMG), and ground reaction data were recorded for thirty male Australian football players performing a SLJL and subject-specific simulations were created in OpenSim for each participant [1]. Musculoskeletal models with 37 degrees-of-freedom and 92 muscle-tendon actuators were scaled to each participant's size. Inverse kinematics and a residual reduction algorithm were used to generate dynamically consistent simulations of the weight-acceptance phase of SLJL (peak residuals within 4N and 8Nm).

To evaluate knee stability in the sagittal, frontal and transverse planes, an open-loop transfer model of the joint kinematic and kinetic data was analyzed with Nyquist and Bode diagrams for their encirclement properties and gain and phase dynamics; respectively. Subsequently, a Daubechies wavelet filter divided the sEMG signals into trend and fluctuation sub-signals to uncover features unique to the stable (low-risk) and unstable (high-risk) groups. The aforementioned analyses were performed in MATLAB.

Results and Discussion: Nyquist diagrams assessed sagittal plane knee stability for two participants based on if the (-1, 0) point was encircled (Fig. 1a-b). Visual differences in medial gastrocnemius sub-signals between participants indicate variability in muscle activation patterns in individuals with unstable landing biomechanics.

This methodology provides a novel approach to assessing knee instability in athletic populations. The wavelet analysis enables researchers to detect hidden muscle function in at-risk populations**.** Together, this work contributes to our understanding of ACL injury risk and provides insights to complement current ACL injury prevention research.

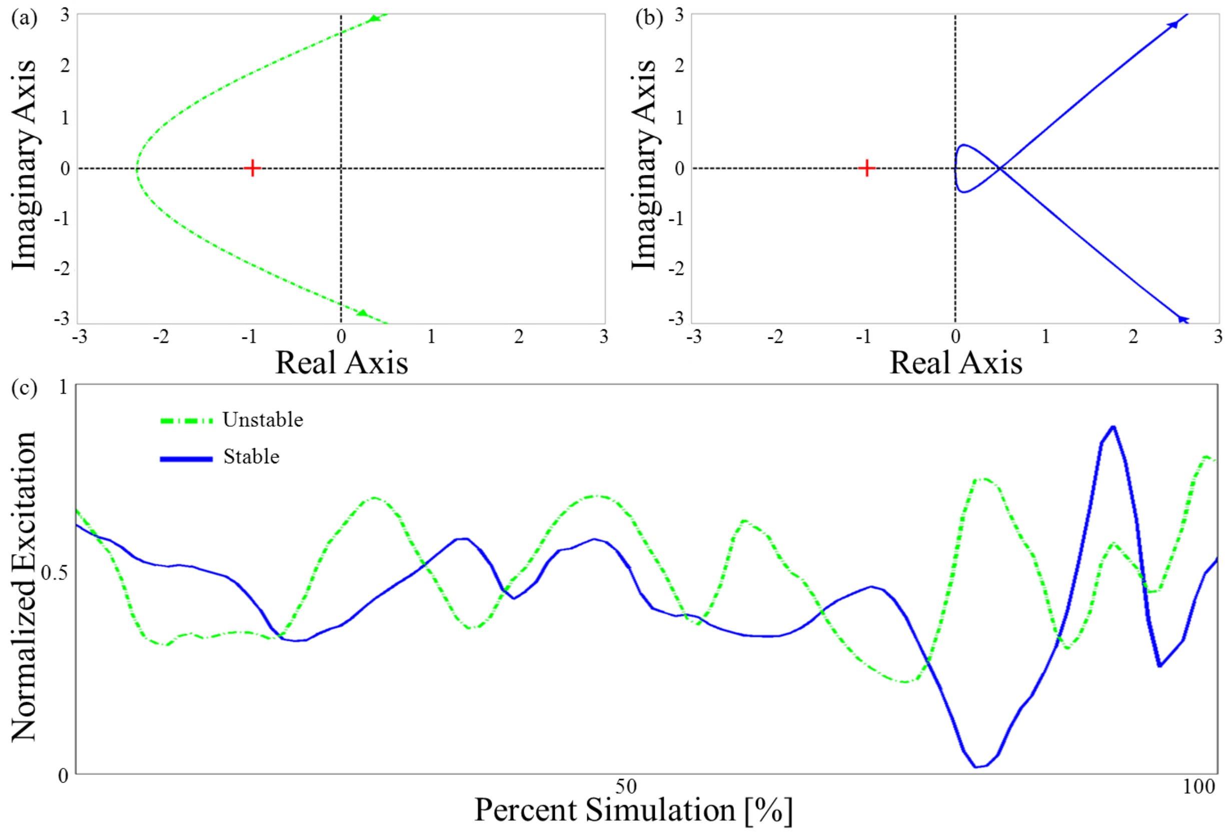

Figure 1: Stability and wavelet analysis of knee flexion angle during the weight-acceptance phase of single-leg jump landing. (a-b) Nyquist diagram displaying the encirclement properties exhibiting unstable (a) and stable (b) sagittal plane knee biomechanics. (c) Daubechies 4 wavelet analysis compared the first trend medial gastrocnemius sEMG sub-signals for the unstable and stable sagittal plane knee biomechanics.

Reference

[1] Donnelly, et. al. (2012). *J. Sports Med.* **46**: 917-22.

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