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Personalized sensor-based classification of ACL reconstructed patients using machine learning is affected by muscle strength and symmetry

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Purpose: Early identification of subtle, sub-clinical, aberrant motion characteristics in patients with ACL reconstructed knees can inform rehabilitation and return to sports decision making. Wearable sensors enable characterization of movement in native sport and activity environment. Personalized injury classification may be helpful in making objective healthcare decisions regarding return to physical activity after injury or surgery to optimize patient safety. The ability to accurately classify patients with ACL reconstructed knees (ACLR) is not perfect and may be influenced by strength recovery over the course of rehabilitation. For example, ACLR patients may be less accurately classified as strength and symmetry recover during rehabilitation thereby indicating good outcomes and healthy lower extremities. The purpose of the study to use a machine learning algorithm to classify patients with ACL reconstructions using inter-limb movement variability from sensor data during walking and jogging and to compare knee extension strength and symmetry between those patients who were accurately classified and those who were not. Our hypothesis is that patients who are accurately classified will be weaker and less symmetric.

Methods: We evaluated 84 patients (23.5±10.2Yr, 172.6±9.6cm, 73.4±16.7kg, IKDC=79.7±13.2) with primary, unilateral and uncomplicated ACLR at approximately 6 months from index surgery. All participants walked for 5 minutes at 3 mph and jogged for 3 minutes at 6mph on a treadmill. Subjects were fitted with 5 wireless sensors (Shimmer3 IMU Unit, Dublin, Ireland) secured bilaterally on the wrists and ankles and around the waist at the sacrum. Accelerations from the sensors were continuously monitored during the walking and jogging trials. The multi-dimensional time-varying biomechanical data captured by the sensors were processed to generate a graphical model and matrices to represent the cause-and-effect relationship in inter-limb movement. The matrices extracted from the sensor data were used to train machine learning algorithms and then these trained algorithms were used to classify participants as ACLR. We then measured normalized peak isokinetic torque (90deg/s) using a dynamometer (Biodex System 4, Shirley NY) bilaterally and calculated limb symmetry and compared those patients who were correctly classified with those who were not using t-tests

Results: Patients who were correctly classified during walking were weaker (1.6±.46Nm/kg vs. 1.45±.44, P=.006) and less symmetric (66.1±19.4% vs. 74.5±16.8%, P=.048) than those who were incorrectly classified. However, during jogging there were no differences in strength (1.61±.46Nm/kg vs. 1.45±.44Nm/kg, P=.15) or symmetry (65.7±16.3% vs. 72.1±19.6%, P=.13) between groups.

Conclusion: Personalized classification of patients with ACL reconstruction using wearable sensor-based movement variability during walking only is influenced by quadriceps strength and strength symmetry. This study is an initial step in laying the framework for the clinical use of instrumented measures of movement variability and machine-learning algorithms to better understand recovery from ACL reconstruction and making informed return to activity decisions.