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Muscle Oxygen Saturation as a Digital Biomarker to Guide the Return to Play of Athletes Following Anterior Cruciate Ligament Reconstruction

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INTRODUCTION:
Return to play (RTP) protocols for anterior cruciate ligament (ACL) injuries involve full motion, strength, psychological readiness, GPS monitoring, isokinetic testing, and functional testing. However, current RTP criteria lack objective, internal, and continuous data necessary to complement current assessments. The majority of evidence suggests > 9 months is required to regain neuromuscular function and allow for appropriate osseointegration and vascularization of the neoligament into the native environment. Monitoring muscle oxygen saturation (SmO2) levels utilizing wearable sensors enables the collection of objective and internal data to monitor oxygen delivery and consumption in surgical and contralateral limbs during the RTP process. Crum et al. validated the reliability of the SmO2 sensor at low to moderate exercises among 10 healthy cyclists. Statistical analysis showed strong correlations of r=0.842-0.993 for the Spearman's Rank-Order Correlation and r=0.773-0.992 for the Intraclass Correlation between the trials of all participants [1]. We hypothesize that muscle atrophy in the surgical leg following ACL reconstruction (ACLR) results in changes in SmO2.
METHODS:
Currently ongoing is a multi-arm IRB approved study assessing SmO2 levels in the legs of healthy subjects aged 14-22 years (arm 1, n=50) and aged matched patients after ACLR (arm 2, n=50). A standardized workout was created for testing at 6, 9, and 12 -months post ACLR. Sensors are placed on the vastus medialis bilaterally to record SmO2 throughout the study duration. Healthy patients undergo testing once, while surgical patients undergo the testing at 6, 9, and 12 -months post-operatively.
RESULTS:
At present, continuous SmO2 data has been collected on seven healthy subjects and nine patients. The healthy cohort shows no difference in SmO2 levels between the two limbs. Results of the longitudinal trial for ACL patients show the convergence of SmO2 levels during air bike interval sprints, 1-minute air bike sprint, and isometric squat hold exercises over the 6, 9, and 12 -month time periods. ACLR SmO2 levels at the 12 -month trials resemble the healthy cohort.
CONCLUSION:
The change in SmO2 in ACLR patients is likely due to a combination of altered hemoglobin-oxygen unbinding, altered blood delivery, detraining, and muscle atrophy. These changes in SmO2 in the ACLR subjects correlate with improvement in other RTP testing. SmO2 data offer complementary objective data in RTP criteria. Future work will measure key biomarker and physiological data along with patient reported outcome measures on this critical age group. This data will enable an integrative algorithm that physicians and physical therapists can employ to gauge athlete readiness following ACLR with broader implications to other musculoskeletal injuries.
1. Crum, E. M. et al., Validity and reliability of the Moxy oxygen monitor during incremental cycling exercise. European Journal of Sports Science, 2017. 17(8): p. 1037-1043.

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