

A Virtual Reality Protocol for Improving Rehabilitation Outcomes Following ACLR

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INTRODUCTION: The anterior cruciate ligament (ACL) plays a significant role in knee stability and movement by preventing excessive tibial rotation and anterior tibial translation. This ligament has relevance in general human gait and locomotion, but notably, it is often evaluated in the context of common sports injuries. ACL injuries are among the most common ligament injuries, with over 120,000 cases occurring in the USA annually.¹ Current treatment for a full ACL tear involves surgical ACL reconstruction (ACLR), in which an allograft or autograft tendon is acquired from the medial hamstring or patellar tendon to restore gross anatomical function. A limited number of studies have investigated the role of virtual technology in ACL rehabilitation using Nintendo Wii Fit, immersive VR, and sports-specific immersion, but yield varied results on its benefits compared to traditional physical therapy.² Here, we describe an adjunct VR rehabilitation program designed for orthopedic and neurological therapy that may improve ACL functional outcomes following surgical reconstruction. By quantifying and delivering real-time feedback on metrics like balance, range of motion, functional movement, divided attention, reaction time, and memory, this new VR protocol can potentially improve ACLR outcomes compared to standard therapy.

METHODS: This project utilizes VAST.Rehab, an interactive motion-tracking software system specifically designed for orthopedic rehabilitation therapy. The system provides an immersive and customizable virtual environment, with a multitude of interactive games correlated to motor and cognitive tasks. We developed two unique exercise phases, emulating the traditional ACLR rehabilitation protocol proposed by Massachusetts General Brigham Sports Medicine.³ Desired motions were adapted to align with the respective balance, strength, endurance, and range of motion specifications indicated for each phase in traditional post-operative therapy (Figure 1). For the initial optimization of this protocol, we utilized data from 9 healthy volunteers. Subjects performed two 15-minute workout sessions, corresponding to weeks 3-5 and 6-8 post-op. Data on range of motion, functional movement, divided attention, and memory were obtained.

RESULTS SECTION: In the first phase designed for rehabilitation weeks 3-5 post-op, the control cohort demonstrated average accuracy functional movement scores for standing lateral balance (77%), R/L lateral leg raise (71%), L leg kick (64%), R leg kick (62%), seated lateral foot swing (82%), standing L hip abduction (83%), standing R hip abduction (98%), standing L knee raise (85%), and standing R knee raise (85%). For the second exercise phase correlating to weeks 6-8 post-op, subjects demonstrated functional movement scores for seated knee raise (95%), standing L lateral leg raise (67%), standing R lateral leg raise (76%), and planted standing torso balance (48%). Additionally, we observed the range of motion for L lateral leg raise (88°) and R lateral leg raise (86°), divided attention task success (53.4%), standing L cross-body kick reaction time (1347 msec), standing R cross-body kick reaction time (1200 msec), and squat symmetry (0.54 cm right-lean). Select functional movement exercises are depicted in Figure 2.

DISCUSSION: VR rehabilitation can potentially improve strength and mobility outcomes and reduce recovery time following ACLR. We have optimized an engaging, customizable VR rehabilitation method to take advantage of technological advances in motion sensing and quantitative feedback metrics. In the future, this system may have benefits for at-home patient use, reducing the need for physical therapist monitoring yet increasing quantitative feedback of progress thresholds. At this stage, we have validated the proof of concept for the data tracking but require further optimization to emulate traditional therapy more accurately. There are several limitations with this VR method, including the motions available with the VAST.rehab system, notably, lack of calf raise exercises and alternative games for knee flexion and extension. Another notable limitation is its role as a supplemental therapy. Because VR therapy depends on detectable motor exercises, the early phase of recovery involving passive movement, supine orientation, and knee mobilizations will not be translatable. At present, the stages of recovery applicable to VR are limited by detection capability of the motion sensor and programmed exercises. Nonetheless, the protocol described here can potentially be a valuable adjunct therapy in ACL rehabilitation.

SIGNIFICANCE/CLINICAL RELEVANCE: Studies evaluating ACLR have demonstrated an increased post-operative rotational and translational knee laxity compared to the contralateral, healthy knee following reconstruction. Improvement of post-operative ACL knee function may require adapted physical therapy such as virtual reality (VR) technology, which may allow for improved real-time feedback on range of motion, reaction time, and functional movement—thereby expediting recovery and return to sport or baseline mobility.

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IMAGES AND TABLES:

Figure 1:

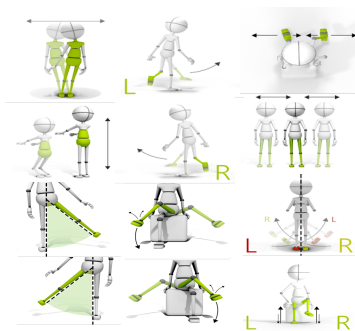


Figure 2:

