RETURN-TO-PLAY CRITERIA FOLLOWING ACL RECONSTRUCTION SURGERY: A CASE STUDY OVER NINE-MONTHS

Steven Leigh

School of Kinesiology, Marshall University, Huntington WV, USA

This case study investigated changes in an injured athlete's function, gait kinematics and parameters, and strength over nine months of ACL rehabilitation. The participant completed laboratory assessments at 6, 12, 24, and 36 weeks post-op, which included a functional outcome questionnaire, a gait evaluation with an electromagnetic tracking system and force plates, and a strength test with an isokinetic dynamometer. Left to right side differences in function, gait kinematics and parameters, and strength were assessed non-parametrically. Results indicated persistent strength disparities and dysfunction at terminal knee extension, even when return-to-play was approved clinically. Kinematics may be useful to guide a continuing rehabilitation program. Strength measures appear to be the most useful for describing rehabilitation progress and effectiveness.

KEYWORDS: Rehabilitation, Function, Knee Kinematics, Coordination, Strength.

INTRODUCTION: An anterior cruciate ligament (ACL) tear is one of the most common non-contact injuries in sports. They tend to occur during quick deceleration, landing, and pivoting movements, and are more common in female athletes compared with their male counterparts (Hewett, 2008; Yu Dai, Herman, Liu, Garrett, & Yu, 2012). Physical conditioning, muscular strength, biomechanical movement patterns and motor control strategies, sports skill levels, and footwear and surface have been proposed as external factors that may be modifiable to decrease future injury risk, and may account for the greater injury rates seen in female athletes (Hewett, 2008; Stevenson, Beattie, Schwartz, & Busconi, 2015).
ACL rehabilitation typically lasts six to nine months before the injured athlete is prepared for a return to sports participartion. ACL rehabilitation programs have been developed to return the athlete to play, reduce their risk of re-injury, and minimize long-term, degenerative problems, such as knee osteoarthritis. This is achieved by restoring pre-injury range of motion and muscular strength levels, and by creating sustained changes in movement patterns and motor control strategies. The content of these ACL rehabilitation programs includes: stretching exercises, strength training, balance and landing control tasks, general agility training, and sport-specific technique drills (An, Park, & Lee, 2015; Benjaminse, & Otten, 2011; Bien & Dubuque, 2015; Sousa et al., 2017). There is alignment, therefore between modifiable external risk factors and the content of ACL rehabilitation programs.
Return-to-play criteria are used to guide an injured athlete through an ACL rehabilitation program and back to sports participation following reconstructive surgery (Bien & Dubuque, 2015). These criteria are a mix of subjective opinion and numeric measures and include: clinical outcomes, such as pain, range of motion, and presentation, functional movement and balance test scores, and isokinetic strength levels (An, Park, & Lee, 2015; Benjaminse, & Otten, 2011; Bien & Dubuque, 2015; Sousa et al., 2017). These criteria are not applied consistently across rehabilitation programs, however, and threshold or cutoff values have not been identified. Following ACL reconstruction and rehabilitation, not all athletes return to sports participation, and of those who do about 25% sustain a repeated knee injury (Hewett, Di Stasi, & Myer, 2013; Sousa et al., 2017). Reasons given for not returning were pain, persistent knee problems, and fear of re-injury (Flanigan, Everhart, Pedroza, Smith, & Kaeding, 2013). These findings suggest that ACL rehabilitation programs were not wholly effective at reducing the risk of re-injury, or were not followed for long enough for the strength and modified movement pattern changes to become permanent. Objective and specific criteria for return-to-play remain undetermined. The aim of this case study was to investigate changes in functional outcomes, gait kinematics and parameters, and strength, as an athlete participated in nine months of rehabilitation following ACL reconstructive surgery. We hypothesized that each variable would indicate a difference between the healthy and injured

side, and that the magnitude of the difference would indicate each variable's usefulness as a descriptor of rehabilitation progress and effectiveness.

METHODS: With ethical approval and informed consent, a female rugby player (age = 20 years, 1.68 m, 65.8 kg) who had recently undergone ACL reconstructive surgery agreed to have her rehabilitation monitored. She sustained a non-contact injury during a rugby training session when she hyperextended her left knee, ruptured her ACL, and tore both menisci. An orthopedic surgeon repaired her ACL arthroscopically using autograft tissue from her left semitendinosus tendon. Her meniscus tears were not repaired.
The participant attended physical therapy and then sports-specific training sessions three times per week for nine months following her surgery. She met with the orthopedic surgeon who performed the reconstructive surgery at 9 days, and 6, 12, and 36 weeks post-op where the surgeon approved activity milestones, such as clearance to walk or run. These decisions were made clinically following questions about knee pain, sensation, and range of motion. For the first 9 days the participant's knee was immobilized in a brace and she used a wheelchair for total non-weight bearing. For weeks 2-6 she walked with crutches with decreasing use over time. The rehabilitation focus was increasing range of motion with graft protection, and exercises were passive or single joint e.g. knee extension and stationary bike riding. At 6 weeks post-op she was cleared to walk by the orthopedic surgeon, and the rehabilitation focus shifted to gait and balance re-training, and exercises were light strength training emphasizing terminal knee extension. At 12 weeks post-op she was cleared to run by the orthopedic surgeon, and the rehabilitation focus shifted to dynamic activity, and exercises were moderate strength training emphasizing bilateral movements and coordination. At 24 weeks post-op the rehabilitation focus shifted to sports preparation, and exercises were power and agility training emphasizing deceleration and change of direction. The participant was cleared to return-to-play by the orthopedic surgeon 36 weeks post-op.
Laboratory assessments were performed at 6, 12, 24, and 36 weeks post-op. There were no pre-injury data. During each assessment, the participant completed three sets of tasks to assess functional outcomes, gait kinematics and parameters, and strength. Functional outcomes were measured by clinical tests that examined lower extremity joint alignment, mobility, and pain subjectively by a physical therapist, and section and aggregate percentages from the participant completing a Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire. Kinematics were measured during a lower body gait analysis. The participant walked overground for 10 trials whilst her lower extremity positions and orientations were recorded at 200 Hz by electromagnetic motion trackers (Polhemus, Colchester, VT) placed on her sacrum, lateral thighs, anterior shanks, and feet. Ground Reaction Forces (GRF) for one foot strike of each trial (5 left, 5 right) were recorded at 2 kHz using a force platform (Bertec, Columbus, OH). Gait parameters (step length, cadence, stance:swing), GRFs, and joint angles and angular velocities were calculated, temporally normalized, and averaged using custom written MatLab software (Natick, MA). Phase portraits of knee angle-angular velocity were calculated as representations of knee joint coordination. Strength was measured with an isokinetic dynamometer (Biodex, Shirley, NY). The participant completed ten repetitions each of bilateral knee flexion and extension at 30, 60, 90, and 120 degrees/second, and peak flexion and extension torques were recorded.
Graphs of vertical GRF, knee kinematics, and knee joint coordination, normalized and averaged over the gait cycles, were produced to assess asymmetries and dysfunction qualitatively. The non-parametric Kruskal-Wallis *H* test was used to evaluate differences in gait parameters, knee kinematics, and strength between the healthy right and injured left sides statistically. All analyses were conducted using IBM SPSS Statistics version 22, with significance set *a priori* at $\alpha = 0.05$.

RESULTS: Clinical tests conducted 6 weeks post-operation indicated some pain and limited range of motion. These symptoms were absent on all other assessment dates. The KOOS scores showed a moderate level of knee function after being cleared to walk, then increased over the next 6 weeks, and then plateaued (Table 1). Step length ($H = 3$, $p = 0.081$), cadence

(H = 0.021, p = 0.885), and stance:swing (H = 0.750, p = 0.375) were consistent between right and left sides, with a trend of increasing time in stance phase (Table 1). Peak knee valgus (H = 4.083, p = 0.042) was asymmetric between right and left sides on each assessment date (Figure 1). Peak GRF (H = 2.083, p = 0.146) and peak knee extension (H = 0.021, p = 0.883) were not different statistically. All kinematic measures, including knee joint coordination, demonstrated dysfunction on each assessment date qualitatively (Figure 1). Strength was consistently greater for the right side in both flexion and extension on each assessment date (H = 5.330, p = 0.021) (Table 1).

Table 1: Functional Outcome, Gait Characteristics, and Strength Measures of an Athlete at 6, 12, 24, and 36 Weeks Post ACL Reconstructive Surgery

Week	KOOS (%)	Step Length (m)		Cadence (steps/min)		Stance:Swing		Peak Knee Ext Torque (NM)		Peak Knee Flex Torque (NM)	
		R	L	R	L	R	L	R	L	R	L
6	64.3	0.48	0.45	50	49	62:38	62:38	88.5	30.1	36.8	15.4
12	84.5	0.44	0.43	51	51	62:38	61:39	99.5	50.2	54.4	23.7
24	81.5	0.44	0.37	44	45	68:32	64:36	79.7	47.3	48.0	22.6
36	86.3	0.50	0.41	47	46	72:28	67:33	72.4	56.5	42.4	28.4

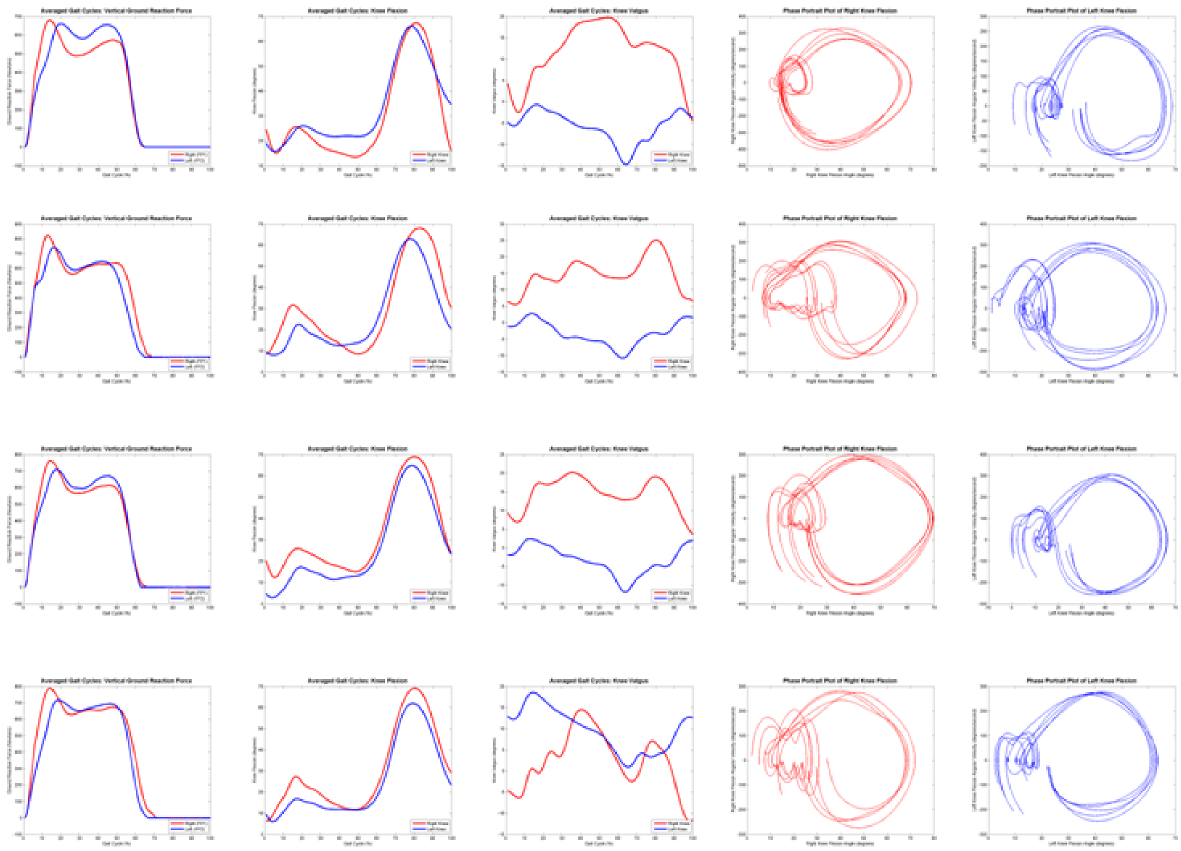

Figure 1: GRF, Knee Flexion, Knee Valgus, Right Knee Phase Portrait, & Left Knee Phase Portrait Normalized to Gait Cycle at 6, 12, 24, and 36 Weeks Post ACL Reconstructive Surgery.

DISCUSSION: Functional outcomes, gait kinematics and parameters, and strength measures varied throughout the nine months of ACL rehabilitation. The participant was cleared to return-to-play by the orthopedic surgeon 36 weeks post-op, and the clinical and functional outcome tests indicated this time was appropriate. The more sophisticated kinematic and strength measures, however, showed continuing asymmetry and dysfunction at 36 weeks. The clinical and functional outcome tests appear to demonstrate a ceiling effect. They may lack the sensitivity to small changes in function as an athlete progresses through their rehabilitation program.

The qualitative comparisons of gait kinematics and joint coordination results indicate persistent dysfunction between 10° and 0° left knee extension (Figure 1). The week 36 gait test results of right-left step lengths differing by 20%, and stance:swing of 70:30 not the normal 60:40 suggest a limping gait (Table 1). Gait re-training and terminal knee extension were the focus of the rehabilitation program from week 6 to week 12, but dysfunction is present at the time the athlete was cleared to return-to-play. These results suggest the shift of rehabilitation focus towards dynamic activities may have been made too early.

There were strength disparities between the injured and healthy sides throughout the 36 weeks of rehabilitation. The difference between left and right sides decreased over time, but this was partly due to a decrease in strength on the healthy side (Table 2). In combination with the altered right knee joint coordination seen in the phase portraits (Figure 1), these results may reflect a changing motor control strategy as the participant relearned to walk and run. Similar to the findings of Sousa *et al.* (2017), athletic patients may be at significant risk of contralateral ACL injury related to their increased activity level and participation in sports preparation exercises. Given their clear trend, strength measures may be the most useful variable for describing rehabilitation progress and effectiveness.

CONCLUSION: One injured athlete’s changes in function, gait kinematics, and strength were investigated over nine months of an ACL rehabilitation program. They returned-to-play 36 weeks post-op, which functional outcomes indicated was appropriate, but kinematics showed continued asymmetry and dysfunction. Strength appeared to be a sensitive criterion for determining return-to-play, and may indicate risk for a repeat or contralateral injury.

REFERENCES

An, K. O., Park, G. D., & Lee, J. C. (2015). Effects of acceleration training 24 weeks after anterior cruciate ligament reconstruction on proprioceptive and dynamic balancing functions. *Journal of Physical Therapy Science, 27*(9), 2825-2828.

Benjaminse, A., & Otten, E. (2011). ACL injury prevention, more effective with a different way of motor learning? *Knee Surgery, Sports Traumatology, Arthroscopy, 19*(4), 622-627.

Bien, D. P., & Dubuque, T. J. (2015). Considerations for late stage ACL rehabilitation and return to sport to limit re-injury risk and maximize athletic performance. *International Journal of Sports Physical Therapy, 10*(2), 256-271.

Dai, B., Herman, D., Liu, H., Garrett, W. E., & Yu, B. (2012). Prevention of ACL injury, part I: Injury characteristics, risk factors, and loading mechanism. *Research in Sports Medicine*, *20*(3-4), 180-197.

Flanigan, D. C., Everhart, J. S., Pedroza, A., Smith, T., & Kaeding, C. C. (2013). Fear of reinjury (kinesiophobia) and persistent knee symptoms are common factors for lack of return to sport after anterior cruciate ligament reconstruction. *Arthroscopy, 29*(8), 1322-1329.

Hewett, T. E. (2008). Predisposition to ACL injuries in female athletes versus male athletes. *Orthopedics, 31*(1), 26-28.

Hewett, T. E., Di Stasi, S. L., & Myer, G. D. (2013). Current concepts for injury prevention in athletes after anterior cruciate ligament reconstruction. *American Journal of Sports Medicine, 41*(1), 216-224.

Stevenson, J. H., Beattie, C. S., Schwartz, J. B., & Busconi, B. D. (2015). Assessing the effectiveness of neuromuscular training programs in reducing the incidence of anterior cruciate ligament injuries in female athletes: A systematic review. *American Journal of Sports Medicine*, *43*(2), 482-490.

Sousa, P. L., Krych, A. J., Cates, R. A., Levy, B. A., Stuart, M. J., & Dahm, D. L. (2017). Return to sport: Does excellent 6-month strength and function following ACL reconstruction predict midterm outcomes? *Knee Surgery, Sports Traumatology, Arthroscopy, 25*(5), 1356-1363.