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Reporting Return-to-Sport Criteria After Anterior Cruciate Ligament Reconstruction Using StaRI: A Single-Site Retrospective Proof-of-Concept Study

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Abstract

Background

More than half of athletes return to sport after anterior cruciate ligament (ACL) reconstruction without meeting return-to-sport (RTS) criteria, contributing to reinjury rates approaching 25%. While extensive literature recommends individual RTS assessment components, few studies document real-world implementation or provide systematic reporting frameworks for clinical protocols.

Purpose

The aim of this study was to demonstrate a systematic approach for reporting implemented RTS criteria using implementation reporting standards, providing healthcare systems a replicable framework for protocol review.

Methods

A retrospective observational study, utilizing the Standards for Reporting Implementation Studies (StaRI), analyzed de-identified electronic medical records from a single sport-specific rehabilitation clinic over a three-year period. Nineteen patient records met the following inclusion criteria: referral after ACL reconstruction, passing of comprehensive RTS criteria, and affiliation with a healthcare system sporting partner. The implemented protocol assessed anthropometric measures, movement screens, strength testing, gait analysis, jump performance, and psychological readiness. The prevalence of subsequent lower extremity injury at one-year follow-up was collected via practitioner phone contact.

Results

Patients achieved RTS clearance at 263 ± 85 days (8.7 ± 2.8 months) post-surgery. The mean age was 17.9 ± 1.7 years, with 5 patients returning to collegiate athletics and 14 to high school athletics. At the one-year follow-up, subsequent injury prevalence was 10.5% (one contralateral ACL rupture, one ipsilateral meniscus injury).

Discussion

This proof-of-concept study demonstrates that comprehensive RTS criteria can be reported using StaRI, describing both the criteria and the clinical context in which they were delivered. While heterogeneity in RTS protocols will persist because of varying resources and populations, standardized reporting methodologies can provide healthcare systems with a replicable model for assessing protocol implementation and informing expansion decisions. Future prospective multi-site studies assessing RTS criteria using frameworks such as RE-AIM may elevate clinical practice and transform ACL rehabilitation toward feasible, evidence-informed care.

Categories: Sports Medicine, Integrative/Complementary Medicine, Orthopedics
Keywords: anterior cruciate ligament (acl), anterior cruciate ligament return to sport after injury (acl-rsi), athletic injuries, return to sport, return to sport after anterior cruciate ligament, return to sport testing, sport injury

Introduction

Rupture of the anterior cruciate ligament (ACL) can be a devastating injury that has a lasting impact on an athlete. Athletes suffering this injury have an 80% chance of returning to their sport but only a 55% chance of returning to the same level of pre-injury performance [1]. Even with a successful return to their sport, three in four individuals will be diagnosed with post-traumatic knee osteoarthritis [2], with one-eighth of these individuals receiving the diagnosis within five years of their injury [3]. These grim outcomes are exacerbated by the occurrence of subsequent ACL injury, which is a concern in this population. One in four athletes suffers an ACL re-injury [4], with athletes in jumping/cutting sports having a 5.7 times greater

chance [5].

Depleted bio-motor abilities and compensatory movement patterns developed in response to injury are likely contributors to the concerning ACL reinjury rate. Return-to-sport (RTS) criteria, instituted by the athlete's rehabilitation provider, assess these risks before the athlete returns to their sport. Multiple studies have reported that more than half of athletes returning from ACL reconstruction return to their sport without passing RTS criteria [6-9]; the consequence is a greater increase in injury risk [8].

Clinical judgment on safe return often relies on unstructured subjective conditions or post-operative timelines rather than organized rehabilitation milestones. This contributes to inconsistent and premature RTS, in which athletes feel compelled to demonstrate readiness before they genuinely achieve the requisite functional capabilities. The literature is abundant with research recommending individual RTS criteria; yet few studies describe how protocols are delivered in clinical practice. Implementation science frameworks and tools can bridge the gap between evidence-based recommendations and clinical adoption. This paper presents a proof-of-concept single-site implementation study that uses the Standards for Reporting Implementation Studies (StaRI) framework [10] for an implemented RTS protocol.

Materials And Methods

Single-site implementation design

A retrospective observational study with implementation elements was conducted in accordance with the StaRI, using de-identified electronic medical records collected over a three-year period. The reporting of clinical characteristics is presented in Table *1*. Patient data analyzed for this study were filtered to include cases that 1) were referred to the clinic after ACL reconstruction surgery, 2) had passed all aspects of the RTS criteria, and 3) were associated with a sporting partner of the healthcare system. As standard clinic practice, providers tagged the records of patients who were affiliated with a sporting partner and passed RTS criteria, and these tags were used to identify records.

Implementation Domain	Description
Clinic purpose	The implementing clinic's purpose is to help patients regain function and independence after illness or injury. Clinic clientele includes patients who participate in competitive athletics at colleges and high schools affiliated with the healthcare system.
Clinic resources	The clinic had athletic flooring with a space with artificial turf. Assessment Tools: Measurement tape, Functional Movement Screen assessment kit, Y-balance assessment kit, dual force plates, handheld dynamometer, treadmill, six and twelve-inch boxes, plyometric boxes, restraining strap, computer tablet for slow-motion video analysis, agility ladders, leg press machine.
Clinic providers	The clinic consisted of nine total staff: eight physical therapists and one athletic trainer. Physical therapists had the SCS certification through the American Board of Physical Therapy Specialties. Implementation was led by the licensed athletic trainer certified through the Board of Certification for Athletic Trainers, who led the conduction of the RTS criteria.
RTS criteria structure	Evaluations were conducted between 3 and 6 months, covering different criteria, with at least three 45- to 60-minute sessions. Further evaluations of specific criteria were conducted in subsequent sessions as needed, at varying time points, depending on patient progression. Assessments, scoring, feedback, and communication with other providers were completed on assessment day.
Timing and frequency of physical therapy	Physical therapy sessions were conducted twice a week for 5-6 months, then reduced to once a week until discharge.
Clinical tailoring	The clinic is tailored to be an accredited space through the JACO.
RTS criteria implementation modifications	When force plates were not available, RTS criteria were modified to substitute with a single-leg vertical jump measured with a Vertec device and a single-leg hop for distance.

TABLE 1: Description of the implementation site and methods for the RTS criteria.

RTS, return-to-sport; SCS, Sports Clinical Specialist; JACO, Joint Commission on Accreditation of Healthcare Organizations

The implementation site was a sport-specific rehabilitation clinic within a hospital system consisting of 21

rehabilitation facilities, 15 of which may encounter patients returning from ACL reconstruction. Details on this site, including staffing, equipment, and operational structure, can be found in Table *1*. As part of standard clinical practice at this facility, all patients presenting with lower-extremity injuries undergo a comprehensive RTS criteria assessment and a one-year follow-up evaluation after clearance. Referrals were made from university and high school athletic trainers working at the locations where the patients train and compete. Subsequent injury prevalence at one year following RTS clearance was obtained via practitioner phone contact documented in clinical notes.

Implemented return-to-sport criteria

RTS criteria assessment protocols and timing varied based on patient progression and specific assessment requirements, with details provided in Table *2*. The Limb Symmetry Index (LSI) for all qualifying tests was calculated as the injured limb's performance divided by the healthy limb's performance, expressed as a percentage of 100% [11]. The clinic instituted the RTS criteria, with the cited literature supporting each criterion. Passing criteria were based on clinical convention or practitioner estimation. The initial evaluation included screening of pelvic tilt [12-14] and leg length [14]. Movement screening protocols consisted of the Functional Movement Screen [15] and Modified Star Excursion Balance Test [16] (Functional Movement Systems, Chatham, VA, USA). Ankle range of motion was evaluated using the ankle dorsiflexion test, performed with the patient in a kneeling lunge position, maintaining 90-degree hip and knee flexion. During testing, patients advanced their knee forward, while the dorsiflexion angle was measured using a smartphone inclinometer application [17]. Ankle function was further assessed through single-leg calf raise testing performed against a wall, with measurements taken of heel-to-floor distance to evaluate bilateral symmetry, and the calf raise repetition test, which required patients to perform 20 consecutive repetitions with heel elevation exceeding 6 cm on the floor, with assessment for pelvic drop throughout the movement [17]. Strength assessment utilized a leg press machine for single-leg one-repetition maximum (1RM) testing, coupled with an endurance strength evaluation consisting of repetitions at 80% of 1RM, with a maximum of 30 repetitions, assessing for LSI [18]. Hamstring and quadriceps strength were assessed in a seated position using a handheld dynamometer (Vald, Newstead, Queensland, Australia). The dynamometer was secured to the distal lower leg with the opposing end anchored to a floor fixture. Testing was conducted with the knee positioned at 90 degrees of flexion and the patient securely stabilized in the seated position [19,20]. Two repetitions were performed in each direction, with passing criteria defined as 90% force symmetry among the hamstrings and quadriceps, and an average hamstring-to-quadriceps ratio between 0.65 and 0.8, based on normative ranges for isokinetic testing [21], which has been shown to carry over to isometric testing [22]. Jump testing consisted of five double-leg and single-leg countermovement jumps performed on force plates (Vald, Newstead QLD, Australia), with symmetry of vertical ground reaction force assessed between limbs at takeoff [23,24]. Hop testing consisted of the triple crossover hop test for distance, using LSI for limb distance covered as the criterion [25]. The assessment criteria included valgus collapse of 10 degrees or less and hip drop of 10 degrees or less throughout the movement sequence. A running gait analysis was conducted at a patient-selected speed on a treadmill, with video assessment of hip drop, knee valgus, foot pronation/supination patterns, and foot strike location, evaluated using a smartphone app (OnForm, Fort Collins, CO, USA) [26]. The Anterior Cruciate Ligament Return to Sport after Injury (ACL-RSI) questionnaire was administered to all patients, with a score of 80% or higher as the passing criterion for psychological readiness to return to sport [27].

RTS Component	RTS Test	Passing Criteria	Supporting Literature
Anthropometric	Pelvic alignment	<10-degree difference between ASIS	Suits, 2021 [12], Mendiguchia et al., 2024 [13]
	Leg length	<2-cm difference in length between limbs	Dei Giudici et al., 2016 [14]
Movement and balance	Functional movement screen	No 0's, 1's, or asymmetries; score > 14	Mokha et al., 2016 [15]
	Y-balance test	>90% composite score; <4-cm difference during the anterior reach; <6-cm difference during posterior reach	Plisky et al., 2006 [16]
	Ankle dorsiflexion	>35 degrees, <5-degree difference	De La Fuente et al., 2018 [17]
Strength	Unilateral calf raise	>90% LSI	De La Fuente et al., 2018 [17]
	Calf strength test	Achieving 20 repetitions on both side	De La Fuente et al., 2018 [17]
	Unilateral leg press 1RM	>90% LSI; can press body weight with each limb	Schmitt et al., 2012 [18]
	Unilateral leg press repetition maximum at 80% 1RM	<3 repetition difference between limbs	Schmitt et al., 2012 [18]
	Isometric hamstring strength at 90 degrees knee flexion	>90% LSI	Schmitt et al., 2012 [18]
	Isometric quadricep strength at 90 degrees	>90% LSI	Schmitt et al., 2012 [18]
	Hamstring/quadricep strength ratio	0.65-0.8	Rosene et al., 2001 [21]
Running gait	Running gait evaluation	Absence of clinician-spotted presence of excessive knee abduction angle, hip drop, foot strike location, or foot pronation/supination	Lussiana et al., 2017 [26]
Jumping analysis	Single-leg countermovement jump	>90% jump height LSI, >90% vGRF symmetry	Lee et al., 2018 [24]
	Double-leg countermovement jump	>90% peak vGRF LSI	Kotsifaki et al., 2023 [23]
	Triple crossover hop	>90% distance LSI	Logerstedt et al., 2012 [25]

TABLE 2: Description of the RTS criteria including passing criteria and supporting literature.

1RM, one-repetition maximum; ASIS, anterior superior iliac spine; LSI, limb symmetry index; RTS, return to sport; vGRF, vertical ground reaction force

Results

A review of electronic medical records identified 20 patient records that met the eligibility criteria. One patient record was excluded due to insufficient follow-up data, resulting in a final sample of 19 records. Patients achieved RTS criteria clearance at 263.3 ± 85.0 days (8.7 ± 2.8 months) post-surgery. Mean age at the time of RTS clearance was 17.9 ± 1.7 years; 5 patients returned to collegiate athletics, and 14 returned to high school sports.

At the one-year follow-up after clearing RTS criteria, one patient suffered a contralateral ACL injury, while

another suffered an ipsilateral meniscus injury, bringing the subsequent injury prevalence to 10.5%. The remaining 17 patients reported no subsequent injuries during the one-year follow-up. Patient characteristics and follow-up results are presented in Table 3.

	Athletic Level	Age at Surgery (Years)	Age at RTS Completion (Years)	Days Post-Surgery at RTS Completion	Injury at the One-Year Follow-Up
Patient 1	High school	14.4	15.2	288	No
Patient 2	High school	15.3	16.1	285	No
Patient 3	High school	17.4	18.0	218	No
Patient 4	College	18.8	19.2	149	No
Patient 5	College	19.2	19.9	229	No
Patient 6	College	19.3	19.8	169	Yes
Patient 7	High school	17.3	17.9	244	No
Patient 8	High school	16.0	16.6	227	No
Patient 9	College	19.0	19.9	329	No
Patient 10	High school	17.5	18.2	236	No
Patient 11	High school	16.3	17.2	323	No
Patient 12	High school	15.4	16.3	317	No
Patient 13	High school	16.8	17.3	164	No
Patient 14	High school	16.4	17.6	420	No
Patient 15	High school	16.2	16.9	257	No
Patient 16	High school	16.6	17.9	477	No
Patient 17	High school	16.9	17.6	278	No
Patient 18	High school	15.6	16.1	169	Yes
Patient 19	College	21.7	22.3	224	No

TABLE 3: Patient characteristics and subsequent injury status at the one-year follow-up.

RTS, return to sport

Discussion

Our retrospective proof-of-concept study demonstrates a systematic approach to reporting implemented RTS criteria by combining implementation reporting standards (StaRI) with clinical context. While numerous studies propose individual RTS criteria, few document real-world implementation within clinical settings. Our methodology provides a replicable framework for healthcare systems to report their RTS protocols. A quantitative descriptor of the protocol reported a 10.5% prevalence of subsequent injury at the one-year follow-up. When such data are available for both patients who do and do not pass RTS criteria, a clinic can estimate whether passing its RTS criteria is associated with subsequent injury risk. This comparison is seldom feasible in practice, as patients who fail RTS criteria often stop receiving services from the clinic, and their outcomes are difficult to obtain. Clinics can still track subsequent injury at follow-up and compare it across revisions of their RTS criteria. Because this is the first report and iteration of this clinic's RTS criteria, this study does not provide a comparison and therefore does not assess effectiveness. Further limitations include the small sample size (n=19), the retrospective design, and the one-year follow-up window, which captures only a portion of the elevated risk period, extending to approximately two years post-surgery [3]. The retrospective design prevented us from reporting individual criterion results and the frequency of equipment substitutions, though a review such as this one shows clinics which data to begin collecting for future insights. Lastly, the clinic's passing cutoffs were based on clinical convention or literature-informed practitioner estimation, which can be refined as criterion results, and outcomes were tracked across revisions. Prospective implementation research should systematically track failure rates, which criteria patients fail most often, time to criterion achievement, and barriers to collecting outcomes for both those who pass and those who return to sport despite not meeting the criteria. Despite limitations, our approach offers healthcare systems a model for documenting existing RTS protocols before they are revised or expanded to additional clinical sites.

Although our study used StaRI reporting standards for implementation research, our retrospective design limited our ability to capture key implementation details. Future studies can employ comprehensive frameworks such as RE-AIM to systematically evaluate Reach (what proportion of eligible patients receive RTS assessment), Effectiveness (additional patient outcomes), Adoption (which clinicians and sites implement the protocol), Implementation (adherence to protocol components), and Maintenance (sustainability over time) across clinical settings [28]. This multi-dimensional evaluation approach would address a critical gap in ACL rehabilitation literature, which predominantly focuses on proposing criteria rather than documenting and evaluating their implementation. Understanding barriers at individual, organizational, and system levels is essential for translating evidence-based assessments into practice.

Conclusions

In this single-clinic review, the StaRI provided a structure for describing a return-to-sport protocol after ACL injury and the clinical setting in which it was delivered. Reporting protocols in this way may help clinics document their RTS criteria and compare outcomes as those criteria are revised.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Acquisition, analysis, or interpretation of data: Paul Mentele

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. University of Louisville IRB and UofL Health's Resarch Office issued approval 811829. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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