

# Integrating the Evidence and Clinical Expertise in the Shared Decision and Graduated Return to Sport Process: A Time Series Case Study after Anterior Cruciate Ligament Rupture and Reconstruction

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## Learning Point of the Article:

Integrating the available evidence and the clinical expertise of all relevant stakeholders into a shared decision and graduated RTS process after ACL rupture and reconstruction is feasible and successful.

## Abstract

**Introduction:** Rehabilitation following anterior cruciate ligament (ACL) rupture is often characterized by a large discrepancy between the available scientific evidence and its implementation into practice.

**Purpose:** We aimed to research, selectively rate, and transfer the available evidence to the return to sport (RTS) process after ACL rupture adopting an athlete time series case study design.

**Case Report and Methods:** The participant is a male athlete aged 33 who was diagnosed with an isolated right-sided total ACL rupture. Knee arthroscopy using semitendinosus tendon plastic (×4) was performed. For rehabilitation, a graded and shared decision RTS algorithm was derived from the existing evidence and all relevant decision-makers expertise. Starting with basic functional abilities and range of motion, the functional ability at each stage had to be achieved before the next stage was aimed. The corresponding therapeutic focus (in addition to standard therapy) was adopted to reach this goal. Functions to be tested were as follows: Knee function confidence, dynamic balance, isometric and isokinetic strength/torque testing, as well as jumping ability (single-leg hop and triple crossover hop for distance).

**Results:** RTS was reached (Level 3) 5 months and (Level 2) 10 months post-surgery.

**Conclusion:** Integrating the available evidence and the clinical expertise of all relevant stakeholders into a shared decision and graduated RTS process after ACL rupture and reconstruction was feasible and successful. Particularly, multiple functional measurements in a time series approach to determine the actual rehabilitation focus seem promising.

**Keywords:** Return to play, return to sports, functional healing, ligament healing, case report.

## Introduction

A rupture of the anterior cruciate ligament (ACL) is a serious hazard for health and career advance in sport. Following ACL reconstruction, affected athletes display high risks of sustaining an ipsilateral rerupture or contralateral subsequent injury, in particular, in the 2 years following the rupture/reconstruction [1, 2]. A considerable risk for the development of osteoarthritis is further given [3]. These severe potential consequences highlight the importance of a rehabilitation process focusing on a safe return to sport (RTS) procedure with a low risk for

reruptures and secondary health problems.

The RTS after ACL reconstruction is defined as the process of restoring body function and guiding the athlete back to training, sports practice, and competition with a low rerupture risk [4, 5]. Psychosocial readiness as well as functional restoration and ligamentous healing represent the essential criteria for the completion of this process. Most importantly, the decision as to whether RTS is achieved should be undertaken in a shared (inclusion of all relevant stakeholder and guidelines) and stepwise (process-orientated graded RTS) process [4, 5].

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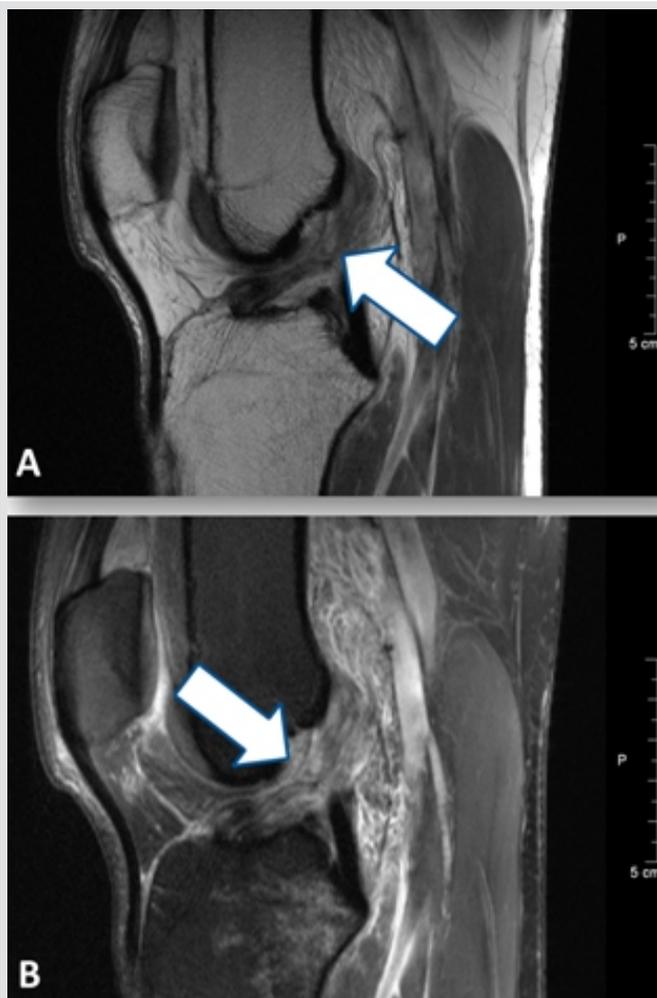
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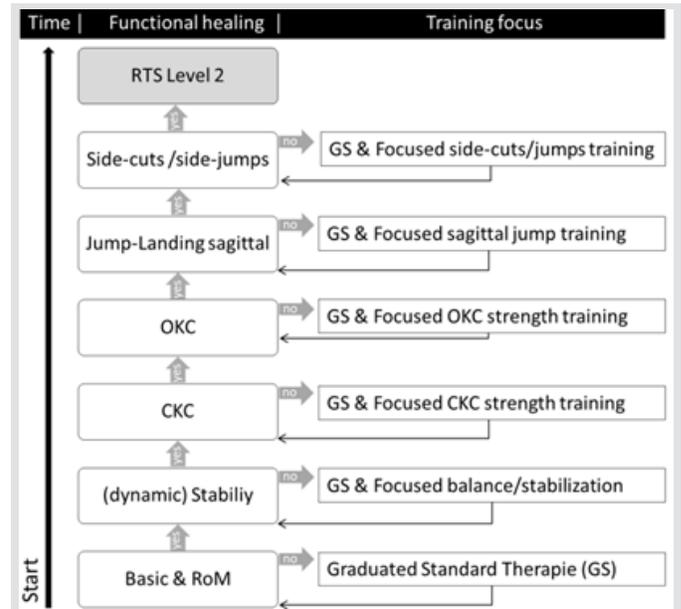
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**Figure 1:** (a and b) Radiological diagnosis, sagittal-lateral, 1.5-tesla magnetic resonance imaging, Siemens Magnetom, Siemens, Germany. Findings: (1) Post-traumatic bone bruises at dorsal proximal tibia,(2)articular effusion in recessus suprapatellar is, (3)condition after anterior cruciate ligament rupture, proximal, and middle third,(4)partial tear lateral ligament (first opinion) versus no lateral ligament involvement (second opinion),(5)lateral edema soft tissue swelling,(6)lateral meniscus intact (first opinion) versus small basic longitudinal dorsal tear (second opinion). Medial meniscus intact,(7)posterior cruciate ligament intact,(8)(Doubtful) retinaculum patellar laterale.

Decisions should, thus, be made based on the integration of the available evidence and guidelines, the stakeholders' clinical experience, and the athletes own preferences [6].

Evidence for both, the graduated shared process [7] and the value of tests for the assessment of functional restoration/healing [8, 9], is available in the biomedical scientific literature. Yet, in semi-professional sports, both are rarely applied in practice [10] and often, one single stakeholder takes the RTS decision. Further, only one single assessment is commonly performed at the hypothetical end of the RTS process [7]. Instead of this highly subjective approach, the performance of multiple measurements, aiming to monitor and verify the course of the RTS process, may be more promising [7]. Conclusively, a large discrepancy between the existing and available evidence and their implementation into practice is observable. Against this background, we aimed to research, selectively rate, and transfer the evidence on the RTS process



**Figure 2:** The graded RTS algorithm used in the present study for RTS to Level 2 after ACL reconstruction. Starting with basic abilities and flexibility (RoM) , a certain functional ability (healing) must be reached before the next step can be aimed. The corresponding therapeutic focus (on top of standard therapy) is adopted to reach this goal. The algorithm is contextually based on the work of Logerstedt et al. [16], Davies et al. [17], and Wilk and Arrigo [18]. CKC: Closed kinetic chain, OKC: Open kinetic chain, RTS: Return to sport.

after ACL rupture, using an athlete timeseries case study design.

### The Medical Problem

#### Patient (case) information

The participant included is a male athlete aged 33 (at the time of ACL rupture). His occupation was (mostly) sedentary. Condition was post-left Achilles tendon total rupture and subsequent reconstruction in May 2016.

The cases' main sporting activity was triathlon, on a semi-professional level, until 2015. His maximal oxygen uptake capacity (VO<sub>2</sub>max) at this time was 68 ml/min/kg of body weight, which can be interpreted as average for elite endurance athletes, or as excellent for the normal population [11]. Running, swimming, and bicycling (the components of triathlon) are all rated as lower level (Level 3) knee stressing [12]. [12]. In addition to his main sport, the case further performed strength training (Level 2--3), and occasional bouldering and skiing (Level 2). No sporting activities including Level 1 load (pivoting, hard cutting manoeuvres) were part of the activities performed.

The mechanism of injury was as follows: During skiing on March 3,rd 2017 (15 days prior to before reconstruction, day -- 15), the participant experienced a painful right leg flexion with valgus and external rotation and reported subsequent pain, swelling, and knee instability (Lachman positive at first investigation). On March 5,th 2017 (day --13), descending a flight of stairs, he witnessed right knee flexion with anterior tibia translation including giving way sensation and knee



subluxation. Overall, both main ACL rupture mechanisms described in literature occurred [13] and may have jointly or isolated caused the ACL tear.

### Clinical findings

The patient was presented to the first orthopaedic specialists' clinic on March 9,th 2017 (day --9) and visited a second physician one 1 week later. The two clinical diagnoses are described in Table 1.

### Imaging findings

The therapeutic recommendations, based on clinical examination and imaging (Fig. 1) were as follows: The first specialist found no acute surgery indication and recommended to perform a conservative rehabilitation (6 weeks) using a 90° restricted orthosis. A 7-week-follow-up was scheduled to decide on final conservative/reconstructive therapy. The second opinion (and patient's decision) was immediate surgical reconstruction and subsequent rehabilitation.

### Surgery procedures

Surgery was performed on the April 18,th 2017 (day 0); ICD-code: 5-813.4. The right knee arthroscopy specifics' were as follows: Resection ACL stump – semitendinosus tendon plastic (x4x) – interference screw x2x- –dog-bone. Following pre-operative preparation, the surgery procedure and post-operative processings were uncomplicated. The patient was discharged from stationary treatment on April 21,st 2017 (day 3). Outpatient rehabilitation was recommended using standard medication, partial (20 kg) right leg weight weight-bearing, standard post-surgery therapy, and RTS (bicycling after 6 weeks, jogging after 3 months, depending on functional performance all activities after 6 months).

### Evidence-Based RTS return to sport Process Deduction and Methods

The present study was conducted and written in accordance with the standard recommendations for clinical case reporting [14]. Its objective was to develop and adapt a shared and graduated RTS return to sport process, integrating all relevant decision-makers and the available scientific evidence on functional RTS criteria. For each study included into decision-making, the evidence level (LoE) was rated using the scale provided [15]. Therapeutical focus decisions were taken based on the results of the diagnostical assessment's values.

### Graded RTSReturn to sport process

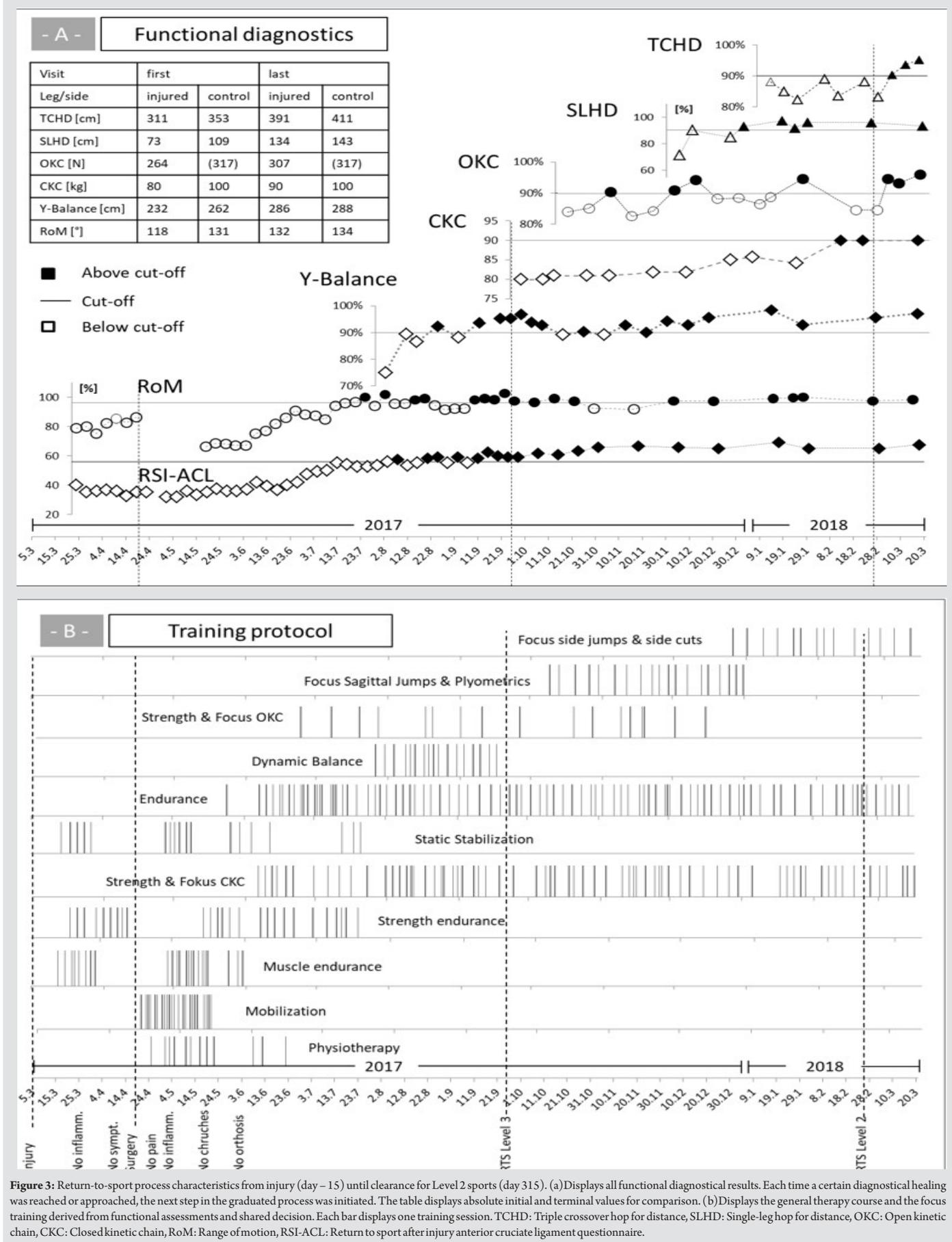
Adopting a stepwise/graduated RTS process after ACL reconstruction, using repeated/continoustests functional testings for the assessment of functional healing is state-of-the-art according to recent reviews [6, 9] (LoE: 1a). The authors of the reviews highlight that, in the absence of top-level evidence RTS-criteria, the best available evidence should be used. In a recently published narrative review (LoE: 4), Dingenen and Gokeler [7] elegantly highlighted the importance of diagnostic assessments to monitor criterion-based rehabilitation. A gradual and periodized RTS process should, thus, be established after ACL reconstruction [7]. On a consensus expert opinion level, such a graded RTS algorithm exists, both for RTS after general knee injuries [16] (LoE: 5) and after ACL reconstruction [17,18] (LoE: 5). The integration of these guidelines and the cases' return-to-level-2-sports aim led to the graded RTS process adopted in our case. It is displayed in Figure (Fig. 2). Each time, a certain functional ability (healing) must be reached before the next step can be aimed.

### Shared decision-making

Each step of the stepwise RTS process should further be based on shared decision-making [7] (LoE: 4). This RTS decision process completion is recommended to be undertaken including all relevant stakeholder and guidelines [4, 5] (LoE: 2b). Decisions should be made based on the integration of the available evidence and guidelines, the stakeholders' clinical experience, and the athletes own preferences [6] (LoE: 4). In our case, one expert for graded RTS after ACL rupture using functional tests (DN), two experts on rehabilitation contents and scheduling (JW, and FK), and three physicians to rate ligamentous wound healing (TE, WB, and treating orthopaedic specialist) participated in the shared decision process. Further, the athlete/patient himself was integrated in each step and decision. As the patient is a physician, his expertise in this field was integrated as well during each step. Thus, the patient participated in the decision process two-fold. Beyond the stepwise RTS model used, all relevant guidelines on diagnostic assessments and therapy/rehabilitation were integrated.

### Diagnostic assessment

Each functional ability (healing) to be achieved during the RTS process was mirrored by an accurate diagnostic test. Based on the multitude of tests available in literature, tests were selected using the following hierarchical grading: (1). Validity in mirroring the target functional ability,- (2). Prospectively validated predictive value for an ACL-re-rupture, and(3). Sufficient test reliability and objectivity. Top-level evidence, based on prospective cohort studies, for all three requirements



**Figure 3:** Return-to-sport process characteristics from injury (day -15) until clearance for Level 2 sports (day 315). (a) Displays all functional diagnostical results. Each time a certain diagnostical healing was reached or approached, the next step in the graduated process was initiated. The table displays absolute initial and terminal values for comparison. (b) Displays the general therapy course and the focus training derived from functional assessments and shared decision. Each bar displays one training session. TCHD: Triple crossover hop for distance, SLHD: Single-leg hop for distance, OKC: Open kinetic chain, CKC: Closed kinetic chain, RoM: Range of motion, RSI-ACL: Return to sport after injury anterior cruciate ligament questionnaire.



**Table 1: Clinical findings. Each finding is described and rated as follows: If clinical diagnosis was performed (yes/no) and, if performed, if finding is reported/confirmed (yes/no). Where applicable, the quantitative finding is reported**

Finding	Visit 1 – first opinion		Visit 2 – second opinion	
	Done	Found/reported	Done	Found/reported
Right knee joint, skin intact, bruising, moderate edema	Yes	Yes, given	Yes	Yes, given
Peripheral sensitivity, circulation, motor activity	No		Yes	Yes, intact
Patella mobility and percussion pain sensitivity	Yes	Yes, given	No	
Pressure pain lateral joint line, pressure pain sensitivity lateral and medial	Yes	Yes, negative	Yes	No, not reported
Steinmann I	Yes	Yes, negative	Yes	No, not reported
Steinmann II lateral	Yes	Yes, positive	Yes	Yes, positive
Lateral ligament laxity	Yes	Yes, positive	Yes	Yes, unknown
Lig. laterale in extension 0–1+	Yes	Yes	Yes	No, not reported
Lachman test	Yes	Yes, positive	Yes	Yes, positive
Posterior drawer	Yes	Yes, negative	Yes	Yes, negative
Sagittal plane passive range of motion extension-neutral-flexion [°]	Yes	5–0–90	Yes	0–0–117

was found for subjective knee-strain-related confidence (basic) testing, isokinetic strength testing at 60°, 180°, and 300°/s open kinetic chain (OKC), as well as for hop test symmetry at single-leg hop (jump-landing sagittal plane) and triple crossover hop for distance (side cuts/side jumps) [19, 20] (LoE: 1b) [21, 22] (LoE: 2b). We complemented the test by basic assessments; the subsequently selected tests are characterized in [Table 2].

The eight-repetition maximum (8RM) for CKC assessment was selected due to the lower functional and mechanical stress imposed on the tissue (particularly, in comparison to the one-repetition maximum 1RM) and because it can be performed at an earlier stage of the rehabilitation phase. We further decided to measure isometric strength instead of isokinetic torque due to the availability of the respective device at the study conduction site. However, additionally, isokinetic assessments at 60°/sec, 180°/sec, and 300°/sec were performed with a three-month interval using a dynamometer (Biodex System 3 Pro, Biodex Medical, Shirley, NY, USA). For the measurements, the participant was positioned in an upright seating. The pelvis as well as the thigh of the tested leg were fixed with Velcro straps

to minimize secondary movement. The opposite hip was fixed at 90° flexion to limit pelvic and lumbar motion and the knee axis was aligned with the rotational axis of the dynamometer. This here described setup has been shown to be valid [32].

For interpretation and RTS-decision-making at each stage, percentage differences between the affected and the non-affected limb in functional outcomes like such as strength, range of motion (RoM), neuromuscular performance, and jumping performance (limb symmetry indices ([LSI]) are commonly used. Side-to-side deficits of <10% [33] (LoE: 4) [19] (LoE: 1b) [34] (LoE: 1b) or <15% [6] (LoE: 4) [8, 9] (LoE: 1a) are recommended. For the present case, an LSI of 10% was selected for all functional outcomes (side symmetry for decision of proceeding to the next step). Recently, estimated preinjury capacity (EPIC) levels instead of LSIs were proposed to be more sensitive in predicting a second ACL injury [20]. They are calculated comparably to the limb symmetry but taking the current value for the injured and a value assessed as quickly as possible after the injury for the unaffected limb into account. As, on the one hand, LSI may overestimate knee function [20], but,

on the other hand, performing jumps directly after injury is of high risk in our opinion, we chose to assess EPIC at a 10% level for OKC only. For the other functional outcomes, LSI was kept as an outcome.

All diagnostics were aimed to be performed twice a week. Once a functional ability goal (cut-off-value, LSI or EPIC) was reached for the first time and once a shared consensus was reached that the next therapeutic step would be possible, the successive step of healing diagnostics was initiated. If the cut-off for a single outcome was reached in three consecutive measurements, the functional ability was considered as healed and the next step in the graded RTS algorithm was taken.

As affected athletes display high risks of sustaining an ipsilateral re-rupture or contralateral subsequent injury, in particular, in the two 2 years following the rupture/reconstruction [1, 2], a two 2-year monitoring for subsequent ACL and other injuries followed.

### Therapeutic interventions

#### Pre-habilitation

Actual approaches in the rehabilitation process increasingly recommend pre-operative rehabilitation. Pre-operative rehabilitation (Prehab) is beneficial to patients with ACL anterior cruciate ligament injury [35] (LoE: 1a-). As Prehab improvements are discussed to be clinically relevant and adverse events occurred only in 3.9% of the patients [36] (LoE: 2b-), it might be of particular relevance after ACL rupture. Low-

level evidence (3b) further supports the relevance of Prehab on RTS-rates [35, 37].

#### Rehabilitation/therapy

Standard rehabilitation strategies were conducted according to Grade A recommendation guidelines [18, 38]. They consisted of:

1. Reduction of inflammation (cooling, inflammation phase, days 0–2/5), followed by
2. Pain reduction and mobilization (during proliferation phase at days 2/5) [38, 39] and
3. Functional enhancement training based on standard training [18, 38] (LoE: 1a), tissue repair/wound healing stages, and clinical expertise integration. The standard training mostly contained CKC strength training and stabilization/balance exercises. The CKC training [40] (LoE: 1a-) was performed gradually, starting from local muscle endurance training without lactate accumulation (31–100 repetitions), strength endurance training (12–30 repetitions), to maximal strength training (8–11 repetitions per set). Each training unit consisted of three sets for all major muscle groups and lasted between 30 and 60 minutes. OKC Open kinetic chain exercise (e.g., knee extension with proximal resistance) was initiated 8-week post-operative, following the same graduated algorithm. Although a recently published systematic review highlights that OKC may be started already at 4 weeks post-operative (at limited RoM) [41], we kept the 8 weeks between surgery and OKC initiation.

**Table 2: Functional abilities to be reached before the next step in the RTS process can be reached. Each ability is described by the corresponding test, its test quality criteria, conduction, and the (positive) decision criteria**

Function	Test instrument	Test quality criteria	Conduction	(Positive) decision criteria
Basic (psychological)	Questionnaire RSI-ACL (return to sport after injury– ACL)	High reliability (Cronbach's alpha=0.92) [23]; highly valid and reliable [24]	Ten 11-point Likert scale questions on fear/confidence on knee during sport	Total score value >56 [25]
Basic (RoM)	Electrogoniometer (FIXKIT, Germany)	High concurrent validity correlations [26]	Passive knee RoM in prone lying	Side symmetry of >97%
Dynamic Balance	Y-balance test (Y balance test kit, functional movement systems, USA)	Good interrater test-retest reliability, acceptable level of measurement error [27]	Single-(test) leg standing, other leg must be moved anterior, posterior lateral, and posterior medial as fast as possible without losing postural control. Composite score is calculated by adding all three single values	Composite score side symmetry
CKC	Eight-repetition maximum in leg extension (life fitness leg press, Brunswick Cooperation, USA)	Excellent reliability (ICC[(1,2)]>0.9) [28].	Participant sits in a leg press; warm-up, 3–5 trials to find the weight which can be moved exactly 8 times over the full RoM	Side symmetry
OKC	Isometric open chain system (M3 Schnell Diagnosis, Germany)	Strong reliability [29]	Upright sitting, warm-up, 3 trials maximal isometric knee flexion at 105° knee angle	Side symmetry
Jump sagittal	Single-leg hop for distance	Reliable and valid for patients following ACL reconstruction [30]	Participants jump from behind a line with one leg only as far as possible without losing stability at landing	Side symmetry
Side jumps	Triple crossover hop for distance following [31]	Reliable and valid for patients following ACL reconstruction [30]	Participants jump medial-lateral-medial over a 15-cm line from behind a line with one leg only as far as possible without losing stability at landing	Side symmetry

RSI-ACL: RTS after injury questionnaire, RoM: Range of motion, OKC: Open kinetic chain, CKC: Closed kinetic chain, ICC: Intraclass correlation coefficient



Stabilization/Balance balance training (local-global; static-dynamic), mobilization, and (as addition) endurance training were performed following the standards. Standard training was performed twice a week. The focus training, based on the functional healing derived from the functional tests, was also performed twice a week.

### Results

All diagnostics, their processing and the rehabilitation procedures performed, are shown in (Fig. 3).

The patient infrequently used electrostimulation and blood flow restriction as further training stimuli. The accompanying isokinetic torque assessment was performed 3 and 6 months post-surgery. Three months post-surgery, quadriceps torque was 168 N for the unimpaired and 80 N for the reconstructed leg (LSI = 48%) at 60°/s, 112 N versus 81 N (72%) at 180°/s, and 84 N versus 63 N (75%) at 300°/s. Six months after reconstruction, torque was 232 N for the uninvolved versus 196 N for the reconstructed (84%) at 60°/s, 163 N versus 156 N (96%) at 180°/s, and 119 N versus 112 N (94%) at 300°/s.

There were no recurrence, revision, or reinjury during the follow-up period until May 20, 2019 (24 months post-surgery; day 747).

### Discussion

We aimed to integrate the evidence and our own clinical expertise into a shared decision and graduated RTS process after ACL rupture and reconstruction in a 33-year-old semi-professional Level 2 and Level 3 athlete. Our multiple measurements and time series approach to identify and adjust the rehabilitation focus was successful and feasible. The athlete successfully returned to sports after 5 months (Level 3) and after 10 months (Level 2).

The duration until RTS success in our case is, compared to studies using functional criteria, slightly above average. In contrast, Welling et al. [42] recently found only a low percentage of athletes passing all functional RTS criteria at both 6 and 9 months after ACL reconstruction. Further, our case showed considerable improvements in all functional outcomes measured even after the RTS decision. This is in contrast to a cohort study of Nawasreh et al. [43]: In this study, the authors found that most participants who had not passed the functional LSI cutoffs after 6 months did not pass them 12 and 24 months post-surgery, either. This result is another intriguing hint that our functional healing diagnostic-based rehabilitation was successful. In practice, of course, the frequency of tests implemented in our case may not be feasible in most settings. As our functional tests showed no large inter-measurement

differences and all of them are investigated to be reliable, a lower frequency of testing can be considered valid in practice. The tests and rehabilitation itself should further be adapted to the setting, athlete, and type of sport specifics. The number of functional tests applied is, in contrary, not reducible in our opinion, as each of them reflects a specific functional capacity. This has recently been proven on a statistical basis [44]. In their study, the authors aimed to statistically avoid test redundancy. They developed a statistically driven feasible diagnostics battery with the objective to reduce the high quantities of diagnostic tests proposed in literature. Conclusively, one-leg postural control, isokinetic knee extension strength, and hop performance (one-leg hops, side hops) were recommended [44]. Isokinetic measurements continue to represent the gold standard of assessing joint torque/muscle strength. Due to our setting specifics, we were not able to assess dynamic torque at a high frequency. The results of the isokinetic testing in between (all 3 months), however, highlight the validity of the frequently performed isometric OKC assessment as they were, at the time both were measured, not different with respect to the LSI. In training, nevertheless, OKC exercises (both standard and focus) were performed sparse. A reason for this may be found in the low OKC training device availability in most training and rehabilitation centers. Further, CKC focus training was, likewise, performed sparse. The latter was due to the high frequency of CKC exercise in general/standard rehabilitation.

### Conclusion

Integrating the available evidence and the clinical expertise of all relevant stakeholders into a shared decision and graduated RTS process after ACL rupture and reconstruction was feasible and successful. Future study is warranted to investigate the effects of the evidence and clinical expertise, integrating shared decision and graduated RTS process adopting a randomized controlled design.

Integrating the available evidence and the clinical expertise of all relevant stakeholders such as the patient itself, the surgeon, physiotherapists, movement scientist, and exercise therapists into a shared decision and graduated RTS process after ACL rupture and reconstruction is feasible and successful. Especially, performing repetitive functional measurements in a time series approach to determine the actual rehabilitation focus seem promising.

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