

# REHABILITATION AND RETURN TO SPORTS AFTER ACL RECONSTRUCTION

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Rehabilitation after anterior cruciate ligament injury remains long and costly, and patients continue to expect improvements in evidence-based care. A key clinical task is tailoring the latest evidence into a programme for the patient, to effectively optimise the protocol towards the goal of return to sports (RTS).

Clinicians also need to perform RTS clearance, to evaluate when a patient's risk is acceptably low to recommend that they are ready to return to sporting activity. Currently, approaches combine clinical assessment, functional tests and patient-reported outcomes (PROs). While these tests provide a more detailed understanding of the patient's condition, clinicians must be aware that evidence for RTS criteria are very limited at present.

## REHABILITATION APPROACHES

The purpose of anterior cruciate ligament reconstruction (ACL-R) rehabilitation is

to restore structure and function, while reducing the risks of associated chronic or acute injury, within acceptable time and cost. A typical programme timeline starts with goals of range of motion (ROM) and weight-bearing recovery during the first few weeks, progressing to strengthening and proprioception training up to 3 months, increasing use of exercise and drills up to 6 months, then RTS training from 6 to 12 months. Progress is adapted depending on the patient's individual response, goals and compliance to the programme<sup>1</sup>.

## STANDARD REHABILITATION

Current clinical protocols initially target resolution of pain and effusion, restoration of ROM and limiting the loss of thigh muscular strength. Later phases of rehabilitation generally focus on strengthening of hamstrings and quadriceps to the point of symmetry within 10%. This is usually with isotonic open/closed-chain exercises using

weights or elastic bands and completed via a home programme. For safe aerobic training, ergometer or outdoor cycling may be recommended. Progression is approximately time-based, guided by functional tests before introducing new training types.

The ACL-R rehabilitation evidence base is growing; a systematic review of 54 studies by Wright et al<sup>1,2</sup> found evidence that early weight-bearing and motion are safe and appear beneficial and may help avoid arthrofibrosis. The use of accelerated protocols of 5 to 6 months appear safe based on limited studies, but shorter periods to RTS should be avoided if possible. Bracing was not found to offer advantages over not bracing. Neuromuscular electrical stimulation needed to be used early and with a high intensity to achieve meaningful results. Closed kinetic chain exercises are preferred during the first 6 weeks. Despite this evidence, significant questions



remain and the authors showed that methodological quality of studies is often mixed. A similar conclusion was drawn by van Grinsven et al<sup>4</sup> in a systematic review of 32 studies, while compiling an evidence-based protocol.

Other well-documented clinical protocols are given by Werstine<sup>5</sup>, Adams et al<sup>6</sup> and Bishop et al<sup>7</sup>. However, significant unexplained risks remain at RTS despite these protocols based on strength training, prompting the trend to also include neuromuscular training.

One novel modality that shows promise is eccentric cycle training during ACL-R. In a clinical review, Lepley and Palmieri-Smith<sup>8</sup> support its use for ACL-R rehabilitation. In a review of practices to strengthen quadriceps after ACL-R, Gokeler et al<sup>9</sup> conclude that “eccentric training may be most effective to restore quadriceps strength”. However, both reviews are based on a very limited number of studies, meaning that, while promising, this area requires further study.

#### NEUROMUSCULAR PROGRAMMES

In ACL rehabilitation, neuromuscular training is becoming more common, along with strength training<sup>10</sup>, partly due to the

poor correlation of traditional strength outcomes to patient satisfaction<sup>11</sup>. Also, there is evidence that neuromuscular training reduces primary ACL injury risk<sup>12,13</sup>, particularly for young females<sup>14</sup>. From a meta-analysis of 12 studies, Sugimoto et al<sup>15</sup> calculated a relative risk reduction from neuromuscular training of 73.4% for non-contact ACL injuries and 43.8% for ACL injuries in general. Varied programmes were emphasised, as these had the strongest relative risk reduction. In males, however, similar evidence of reduced risk is scarce and not conclusive<sup>4,16</sup>. In order to make these programmes worthwhile, it is important that screening of high-risk patients is improved and programmes are optimised.

Example preventive programmes are given by Pappas et al<sup>17</sup>, such as the FIFA 11+ programme to reduce injuries in football. These often include progressively challenging balance exercises, to functional activities (e.g. ball catching) on unstable surfaces. Later stages often use explosive hopping and bounding exercises, also known as plyometrics, evaluated on power and landing technique. Landing is an important phase of movement as it is typically when ACL injuries occur<sup>18</sup>,

requiring control, balance and response to perturbations.

Similarly to its use in prevention, neuromuscular exercises improve ACL-R rehabilitation. While modification of risk has not yet been shown, studies show the effect on clinical outcomes. Paterno et al<sup>19</sup> showed improved single-limb stability in young female athletes after 6 weeks of neuromuscular training. Risberg et al compared neuromuscular and strength training groups<sup>20,21</sup>; the neuromuscular group had a better global function visual analogue score (VAS) at 6 months and 1 year (no difference at 2 years), improved Cincinnati score at 6 months and improved pain scores at 1 year. Interestingly, no differences were found in isokinetic strength at any time points. In another trial of proprioceptive vs strength training, Liu-Ambrose et al<sup>22</sup> found that concentric quadriceps and eccentric hamstring strengths of the injured limb increased more in the proprioceptive training group than in the strength group. These examples show how effective neuromuscular training can be in strength outcomes for these patients.

Neuromuscular training is now more common in rehabilitation protocols. In

a clinical commentary, Di Stasi et al<sup>23</sup> recommend neuromuscular training to reduce risk of ACL re-injury. In a recent ACL-R rehabilitation protocol, Bishop<sup>7</sup> emphasises restoring neuromuscular control by stabilisation of knee from above and below (ankle and hip) during phase V (Advanced Activity Phase, 12 to 20 weeks). Based on this evidence, both neuromuscular and strength training is recommended, combining training modalities where possible to improve training efficiency.

RETURN TO SPORT CLEARANCE

RTS clearance is a multi-faceted clinical decision, which must balance the need to clear the patient with their risk of re-injury. There are a wide variety of clinical criteria being used after ACL-R to clear a patient for RTS. At present these are typically developed independently by the clinician or their organisation and are based primarily on their experience. Objective tools could assist the clinician to make more reliable, transparent decisions, but they must always be used in light of the patient’s individual situation.

The challenge is that at present there is a general lack of validated objective tools, standardisation or even clear definitions of RTS terms in the research literature<sup>24</sup>. This is primarily because of a lack of studies which show a particular clearance criterion which indicates risk directly. Two systematic reviews by Barber-Westin & Noyes<sup>25</sup>, and Harris et al<sup>26</sup> have shown that objective criteria for RTS are reported in only 13% (35 of 264) and 10% (5 of 49 studies) of studies, respectively.

For now, clinicians must use reviews of published group means and threshold percentages (from studies and/or registries), and associations between variables, where available. In addition, careful record-keeping of in-house tests and results can assist the clinician to improve their practice. In the longer term, larger prospective studies will be needed to better answer these questions.

SUCCESSFUL OUTCOMES

Rehabilitation is multifactorial, with a range of overlapping goals. To evaluate its success, the clinician must be satisfied that these goals are individually met. Any method that summarises this process by a

TABLE 1	
Consensus outcomes (more than 80% of clinicians agree)	Non-consensus outcomes (less than 80% of clinicians agree)
Absence of knee giving way	Functional tests (75.4% agree)
Return to sport (participation)	Negative pivot-shift (77.8% agree)
Symmetrical quadriceps muscle strength (structure and function)	Laxity <3 mm (72.9% agree)
Absence of knee joint effusion	Absence of radiographic osteoarthritis (36.5% agree)
Symmetrical hamstrings muscle strength (structure and function)	
PROs with clearly defined thresholds for success (activity and participation)	

Table 1: Consensus successful ACL-R outcomes. From Lynch et al<sup>27</sup>.

single average or overall measure runs the risk of missing deficits by compensation in other areas. While the focus is on outcomes at RTS, most protocols use a staged approach, so that any deficits of the previous stage must be resolved before progressing to the next stage. This helps to balance the progress with the risks of more advanced rehabilitation exercises.

CONSENSUS OUTCOMES

With respect to rehabilitation success, clinician surveys provide an important reference. Recently, Lynch et al<sup>27</sup> interviewed 1779 clinicians to identify consensus indicators of a successful ACL-R outcomes, recommended by >80% of clinicians.

PATIENT-REPORTED OUTCOMES

Patient-reported outcome (PRO) questionnaires are easy-to-administer outcome measures, commonly used to evaluate knee function and monitor progress<sup>28-30</sup>. It is recommended that both PROs and functional outcomes be tested, because they have been shown not to be correlated<sup>31</sup>. The following literature specifically relate to the use of PROs for RTS readiness.

In the clinician survey above<sup>27</sup>, PROs were a consensus outcome. The study further asked clinicians about the importance of different PROs and threshold scores for success. For Knee Outcome Scores (KOS), the Global Rating Scale (GRS), the International Knee Documentation Committee (IKDC), Lysholm and Cincinnati scores, the median

reported threshold was 90, while for Knee injury and Osteoarthritis Outcome Score (KOOS) it was 85. In addition, the IKDC questionnaire was particularly recommended because it has the added benefit of a normative data set to compare to age- and gender-matched uninjured people. Logerstedt et al found that using this IKDC normal data, scores below the 15th percentile were good at predicting passing return to activity criteria<sup>32</sup>. The only other PROs found to have been used for RTS were the Global Rating Scale of Perceived Function and the activity-of-daily-living KOS score, as part of the University of Delaware’s return to activity criteria<sup>6,32-34</sup>.

If no thresholds for success or normative data are available, comparison of a patient’s progress with other ACL-R patients can guide management. A clinical review by Lepley<sup>35</sup> investigated deficits using a range of PROs at RTS during 6 to 12 months post-surgery. Average deficits at 6 months were 14% (5 studies) and at 12 months it was 13% (5 studies). The authors emphasise that this data suggests that patients are returning to activity with levels of function that are below clinical recommendations (deficits <10%).

STRENGTH METRICS

Symmetrical quadriceps and hamstrings strength and size are also consensus measures of success, commonly quantified for RTS. However, the threshold of limb symmetry index (LSI) >90% is based primarily on clinical consensus<sup>27</sup> and has





## ***RTS clearance is a multi-faceted clinical decision, which must balance the need to clear the patient with their risk of re-injury for RTS.***



not yet been correlated to prospective RTS or injury-risk data. A recent systematic review of strength measures has also highlighted this lack of evidence<sup>36</sup>. In the one prospective study available, Myer et al<sup>37</sup> tested females for strength before injury, finding no difference in quadriceps or hamstring strength between subsequent ACL injury and matched female controls. This study suggests that strength may not be a predictor of ACL injury in females.

Abrams et al<sup>38</sup> performed a systematic review of strength measures after ACLR. Isokinetic knee extension and flexion peak torque LSI values were by far the most commonly reported. At 6 months, hamstring graft ACL-R patients had extension LSI of  $77 \pm SD14$  and flexion LSI of  $84 \pm SD11$  at  $60^\circ$  per second (10 studies each). At  $180^\circ$  per second, values were  $89 \pm SD8$  and  $86 \pm SD4$ , respectively.

The hamstring-quadriceps (H/Q) ratio is used to assess the balance of strength around the joint. An example of the use of the H/Q ratio in calculating risk was a clinician-friendly nomogram developed by Myer et al, but only for young females<sup>39</sup>. A systematic review of healthy normal H/Q ratios for different isokinetic speeds, stratified by gender<sup>37</sup> has found that H/Q increases with speed for males, but not for females. Individual H/Q ratio values can be compared to these normal values as targets, to indicate possible strength imbalances. However, natural variation in H/Q ratio is present in healthy individuals and clear thresholds of the ratio have not been correlated prospectively with injury risk.

### **FUNCTIONAL TESTING**

Functional testing uses standardised tasks, most commonly jumping and hopping, typically evaluated by degree of symmetry. A wide range of tests and outcomes are used, as reviewed in Abrams et al<sup>38</sup>. In another recent systematic review, it was shown that there is limited and conflicting evidence regarding the reliability, agreement, construct validity, criterion validity and responsiveness of eight commonly-used performance tests<sup>40</sup>. These limitations must be kept in mind when drawing conclusions from functional tests.

#### ***Drop vertical jump test***

Of the functional tests, the drop vertical jump (DVJ) has shown to be clinically useful in evaluating ACL injury risk in female patients<sup>41,42</sup> and the effect of training<sup>23</sup>. In particular, excessive knee abduction moment has been shown to predict ACL injury in females (sensitivity 78%, specificity 73%)<sup>43</sup> and re-injury (sensitivity 92%, specificity 88%)<sup>44</sup>. Using motion capture and force plates, the reliability and validity of kinematics and kinetics has been shown<sup>45</sup>.

To reduce the cost of 3-D methods for clinical application, several approaches have been used. Multiplanar 2-D video methods quantified knee valgus movement and flexion angle for young females for a risk assessment tool<sup>39,46,47</sup>. To improve on this, a single depth camera (Microsoft Kinect®) has been shown to give more accurate results for a similar cost<sup>48</sup>.

#### ***Landing error scoring system***

As an alternative to 3-D motion capture and 2-D video, the Landing Error Scoring System (LESS) scores DVJ landing errors using 17 criteria. Its validity and inter-rater reliability have been shown in a large cohort of 2691 healthy military recruits<sup>49</sup>. This study did not investigate subsequent ACL injury. However, it did show that females had higher number of errors than males, which correlates with their higher risk of ACL injury.

The LESS has also been used for ACL-R. A recent review indicated that, thus far, one study has shown LESS may be useful in predicting ACL injury, while another did not<sup>50</sup>. Bell et al<sup>51</sup> showed that ACL-R participants had higher LESS scores than controls (+1.1 errors,  $p=0.04$ ) and particularly high differences in trunk flexion ( $p=0.002$ ). Kuenze et al<sup>52</sup> performed a similar study, finding that the ACL-R group had 3.2 errors more than the control group ( $p=0.002$ ). Maximal voluntary isometric contraction was also measured and found to be correlated with a lower LESS score, but only in the injured limb ( $r=-0.455$ ,  $p=0.03$ ).

For faster clinical evaluation, Chimera and Warren<sup>50</sup> describe a 10-item real-time version using four jumps (LESS-RT), but this only has one small reliability study available to date. An even shorter test with five items – iLESS – also only has a single reliability study and requires further validation. In a similar ‘abridged LESS’ approach, the Melbourne RTS score (MRSS, discussed below) uses only five of the 17 items of the LESS. It is scored live, not using video recordings. This may seem

TABLE 2

Tests		Weight	RTS Criteria
University of Delaware	Knee Outcome Score-ADLS	Must pass all tests individually	>90%
	Global Rating Scale		>90%
	4 single-leg hop tests		LSI>90
	Quadriceps Index		LSI>90
IKDC		100%	>15th percentile
MRSS	Clinician assessment	25%	None established
	IKDC score	25%	
	Functional testing score	50%	

Table 2: Criteria for RTS.

attractive, but to date no clinical evidence is available to support it. Also, the five items do not seem to align with the most common errors or clear differences from controls<sup>52</sup>. This lack of evidence, mean that real-time/abridged LESS versions should not be used clinically until further research is available.

#### Hop tests

Hop tests are the most commonly-used functional criteria for RTS. Abrams et al<sup>38</sup> performed a systematic review giving normative data for different types of tests. The single-leg hop for distance was the most common, with around 30 studies; at 6, 9 and 12 months, limb symmetry values were 87±6, 90±2 and 92±2, respectively. The cross-over hop, triple hop and six-metre timed hop had about half as many reported studies. For the cross-over hop test, values at 6, 9 and 12 months were 90±4, 91±3 and 92±3, respectively. Four hop tests are part of the University of Delaware's combined method (described below), with LSI thresholds of 90%.

#### Star excursion balance test

The star excursion balance test is recommended by several clinical protocols<sup>34,53,54</sup> and was recently reviewed by Chimera and Warren<sup>50</sup>. It does not yet have a strong evidence base or norms developed for ACL-R patients. However, a promising recent study used Y-balance anterior asymmetry

>4 cm at 12 weeks to identify those who failed single-hop LSI>90 at 6 months, with a sensitivity of 96%<sup>55</sup>. Other studies have shown less clear outcomes<sup>56</sup>. The test is a low-cost, easy-to-implement balance test that is part of the MRSS (see below), but these results should be used with caution in light of the discussed lack of evidence.

#### Functional strength testing

Attempts have been made to quantify closed kinetic chain (functional) strength of the knee for clinical use, rather than open kinetic chain dynamometer values. In the MRSS below, a squat-to-fatigue test is prescribed. However, it is not supported by clinical evidence at present and thus should be used with caution, with the gold standard of dynamometer testing preferred where possible.

#### UNIVERSITY OF DELAWARE COMBINED RTS CRITERIA

In 2000, Fitzgerald et al<sup>57</sup> developed the University of Delaware return-to-activity criteria for nonoperative treatment of ACL injuries. They have been used in ACL-R patients in large studies<sup>23,58</sup> and have been recommended as part of a clinical protocol<sup>6</sup>. They were the only combined set of criteria that were found to have a pre-determined cut-off point, indicating readiness for RTS (Table 2).

#### MELBOURNE RETURN TO SPORTS SCORE

In an attempt to integrate clinician assessment, a PRO (IKDC) and functional testing, the Melbourne Return to Sports Score (MRSS) has been proposed (Table 2). Functional testing included the DVJ, two hop tests, the Y-balance test and a squat-to-fatigue test. It has been shown that in a study of 94 patients, those who returned to sports had significantly higher MRSS<sup>59</sup>. However, this combined score lacks clinical evidence and requires further research to be validated.

#### CONCLUSION

The above rehabilitation approaches help the clinician to better understand the potential of different training types to improve patient outcomes. Clinical, functional and PRO testing all play a role in understanding a patient's progress towards RTS. However, evidence for objective RTS criteria is still limited and must be supplemented by clinical experience in deciding what is best for the patient.

References available at  
[www.aspetar.com/journal](http://www.aspetar.com/journal)

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