Melbourne ACL Rehabilitation Guide 2.0

A criteria driven ACL rehabilitation protocol and guide for both clinicians and people who have undergone a surgical reconstruction of the Anterior Cruciate Ligament (ACL).

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ACL Rehabilitation Protocol

The ACL rehabilitation protocol featured in this eBook is a guide for both clinicians and people who have undergone a surgical reconstruction of the Anterior Cruciate Ligament (ACL).

You move through the ACL protocol at your own pace, and let the criteria govern how quickly you go, not a pre-determined timeline.

Here are a few tips on how to progress through an ACL rehab protocol with minimal problems:

• Get the knee straight early (within the first 2-3 weeks both post injury and post surgery), and keep it straight. Flexion can progress gradually.
• Use knee pain and knee swelling as a guide. If either or both are increasing, the knee isn't tolerating what you're doing to it.
• Technique is everything. Compensation patterns develop after an ACL tear, so focusing on correct muscle and movement/biomechanical patterns is paramount.
• Build high impact forces gradually. The articular structures in the knee joint will take time to adapt to a resumption of running, jumping and landing.
• Complete your ACL rehabilitation. Once people are back running with no knee pain it's easy to think that it's all done. But the last 1/3 of the protocol is the most important – to help reduce the chance of re-injury, increase the chance of a successful return to sport, and possibly to reduce the likelihood of osteoarthritis down the track.

As much as possible outcome measures that are evidence based have been used, and only tests that can be performed with simple and inexpensive equipment have been included.

Clinicians should use a clinical reasoning approach in prescribing an exercise rehabilitation program and management advice for each phase. This ACL protocol briefly suggests typical exercises for each phase, but programs should always be individualised.

The ACL rehab protocol is broken down into 6 phases, and there's a list of goals and outcome measures that need to be satisfied at the end of each phase to move onto the next one.

The six phases are:

- Pre-op Phase: Injury recovery & readiness for surgery
- Phase 1: Recovery from surgery
- Phase 2: Strength & neuromuscular control
- Phase 3: Running, agility, and landings
- Phase 4: Return to sport
- Phase 5: Prevention of re-injury

ACL Rehab:

Melbourne ACL Rehabilitation Guide

Goal Based

PHASE: **Pre Op** Injury recovery & readiness for surgery

PHASE: **1** Recovery from surgery

PHASE: **2** Strength and neuromuscular control

PHASE: **3** Running, agility and landings

PHASE: **4** Return to sport

PHASE: **5** Prevent re-injury

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Pre-op Phase:

Injury Recovery & Readiness for Surgery

Whilst people may want to have the operation as soon as possible, it's important to allow the knee to settle from the injury and regain a good level of strength and function before surgery.

Recent research has suggested that people who attain full range of motion, good quadriceps and hamstring strength, and minimal swelling prior to surgery have better outcomes than those who don't up to 2 years post surgery.

Exercises and activities during this phase typically include regular icing of the knee to reduce swelling, range of motion exercises, low impact aerobic exercise such as cycling, and a progressive strengthening regime.

Strength exercises should progress in parallel with the clinical condition of the knee. As the pain & swelling settles, and the range of motion increases, strength exercise can progress to include weighted exercises in the gym and jump and land activities such as hopping drills.

Aggressive change of direction activities should be avoided during this phase.

This pre-surgery phase also allows clinicians to gather information that can be used to determine readiness to return to training and sport.

The three most important goals of the Pre-op Phase are;

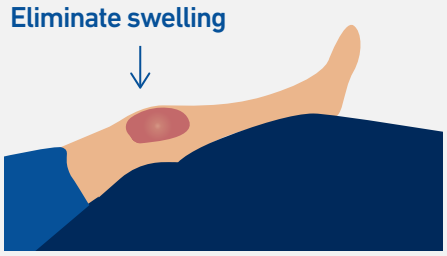
- Eliminate swelling
- Regain full range of motion
- Regain 90% strength in the quads and hamstring compared with the other side

Pre-op Phase

Injury recovery & readiness for surgery

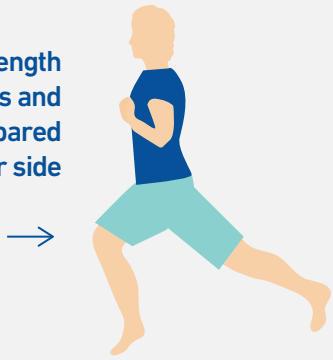
Most important goals

Eliminate swelling



Regain full range of motion

Regain 90% strength in the quads and hamstring compared with the other side



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Injury Recovery & Readiness for Surgery

Pre-op: Outcome Measures and Goals

Outcome Measure	Test Description & Reference	Goal	√
Passive Knee Extension	Supine with a long arm goniometer (Norkin & White, 1995). Bony landmarks: greater trochanter, the lateral femoral condyle, and the lateral mallelous.	0°	○
Passive Knee Flexion	Supine with a long arm goniometer (Norkin & White, 1995). Bony landmarks: greater trochanter, the lateral femoral condyle, and the lateral mallelous.	125^{+}	○
Swelling/ Effusion	Stroke Test (Sturgill et al, 2009) Zero: No wave produced on downstroke Trace: Small wave on medial side with downstroke 1+: Large bulge on medial side with downstroke 2+: Effusion spontaneously returns to medial side after upstroke 3+: So much fluid that it is not possible to move the effusion out of the medial aspect of the knee	Zero – 1+	○
Strength	Hand held dynamometer testing (Mentiplay et al, 2015) Quads: Participant seated and hip and knees flexed at 90°. Dynamometer placed on the anterior aspect of the shank, proximal to the ankle joint. Hamstrings: Participant seated and hips and knees flexed at 90°. Dynamometer placed on the posterior aspect of the shank, proximal to the ankle joint.	90% compared with other side	○
Single Hop Test	Single leg hop test (Reid et al, 2007) Subjects stand on one leg and hop as far forward as possible and land on the same leg. The distance is recorded from toe at take-off to heel at landing with a tape measure which is fixed to the ground. Two valid hops are performed, with the average (mean) of the 2 being used for calculation. A limb symmetry index is calculated by dividing the mean distance (cms) of the involved limb by the mean distance of the non involved limb then multiplying by 100.	90% compared with other side	○

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Recovery from Surgery

ACL reconstruction surgery is traumatic to the knee and a period of rest and recovery is required after the operation. Whilst it's tempting to want to get going and improve strength and range of motion, it's best to let the knee settle for the first 1-2 weeks with basic range exercises, quadriceps setting drills, ice and compression.

Typical exercises and management activities during this phase include regular icing of the knee and graft donor site (usually either the hamstrings, quad or patella tendon), compression of the knee and lower limb, basic quadriceps setting exercises, and gentle range of motion exercises to improve knee extension (straightening) and flexion (bending). Analgesics and other medications should only be used in consultation with your doctor.

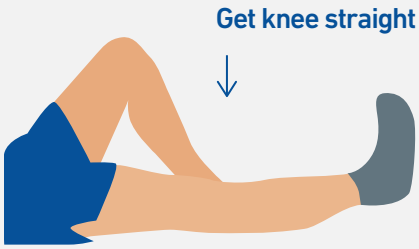
The three most important goals of Phase 1 are:

- Get the knee straight (full extension)
- Settle the swelling down to 'mild'
- Get the quadriceps firing again

Phase 1

Recovery from Surgery

Most important goals



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Recovery from Surgery

Phase 1: Outcome Measures and Goals

Outcome Measure	Test Description & Reference	Goal	√
Passive Knee Extension	Supine with a long arm goniometer (Norkin & White, 1995). Bony landmarks: greater trochanter, the lateral femoral condyle, and the lateral mallelous.	0°	○
Passive Knee Flexion	Supine with a long arm goniometer (Norkin & White, 1995). Bony landmarks: greater trochanter, the lateral femoral condyle, and the lateral mallelous.	125^{+}	○
Swelling/ Effusion	Stroke Test (Sturgill et al, 2009) Zero: No wave produced on downstroke Trace: Small wave on medial side with downstroke 1+: Large bulge on medial side with downstroke 2+: Effusion spontaneously returns to medial side after upstroke 3+: So much fluid that it is not possible to move the effusion out of the medial aspect of the knee	Zero – 1+	○
Strength	Quadriceps lag test *variation (Stillman, 2004) With the patient sitting on the edge of a treatment bed, the therapist takes the relaxed knee into full passive extension. The patient is then required to maintain full active extension of the knee when the therapist removes support.	0 to 5 lag	○

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Strength and Neuromuscular Control

Regaining muscle strength, balance, and basic co-ordination are the goals of Phase 2. This phase usually commences with easy body weight type exercises and progresses into a gym-based regime with a mixture of resistance, balance, and co-ordination exercises.

It's important for clinicians and patients to 'listen to the knee' during this phase and only progress as quickly as the knee will allow. Increase in pain and/or swelling are the two main symptoms that indicate that the knee is not tolerating the workload.

Typical exercises and management activities during this phase include lunges, step-ups, squats, bridging, calf raises, hip abduction strengthening, core exercises, balance, gait re-education drills, and non-impact aerobic condition such as cycling, swimming, and walking. Some clinicians may start some introductory impact type activities such as walk-jogging or mini jumps during this phase, but the bulk of this type of training should be reserved for Phase 3.

The three most important goals of Phase 2 are:

- Regain most of your single leg balance
- Regain most of your muscle strength
- Single leg squat with good technique and alignment

Phase 2

Strength and neuromuscular control

Most important goals

Regain single leg balance

Regain muscle strength

Single leg squat with good control

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Strength and Neuromuscular Control

Phase 2: Outcome Measures and Goals

Outcome Measure	Test Description & Reference	Goal	√
Passive Knee Extension	Prone hang test (Sachs et al, 1989) Subjects lie prone on a treatment bed with the lower legs off the end allowing full passive knee extension. The heel height difference is measured (approx 1cm = 1°	Equal to the other side	○
Passive Knee Flexion	Supine with a long arm goniometer (Norkin & White, 1995). Bony landmarks: greater trochanter, the lateral femoral condyle, and the lateral mallelous.	125^{+}	○
Swelling/ Effusion	Stroke Test (Sturgill et al, 2009) Zero: No wave produced on downstroke Trace: Small wave on medial side with downstroke 1+: Large bulge on medial side with downstroke 2+: Effusion spontaneously returns to medial side after upstroke 3+: So much fluid that it is not possible to move the effusion out of the medial aspect of the knee	Zero	○
Functional Alignment Test	Single leg squat test (Crossley et al, 2011) Subjects stand on one leg on a 20cm box with arms crossed. 5 x single leg squats are performed in a slow controlled manner (at a rate of 2 seconds per squat). The task is rated as "good", "fair" or "poor". For a subject to be rated "good"; • Maintain balance • Perform the movement smoothly • Squat must be to at least 60 degrees • No trunk movement (lateral deviation, rotation, lateral flexion, forward flexion) • No pelvic movement (shunt or lateral deviation, rotation, or tilt) • No hip adduction or internal rotation • No knee valgus • Centre of knee remains over centre of foot	Good	○

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Strength and Neuromuscular Control

Phase 2: Outcome Measures and Goals .. continued

Outcome Measure	Test Description & Reference	Goal	√
Single Leg Bridges	Single leg bridge test *variation (Freckleton et al, 2013) Subjects lie supine on the floor with one heel on a box or plinth at 60cm high. The knee of the test leg is slightly bent at 20° and opposite leg is bent to 90° hip and knee flexion with their arms crossed over chest. Subjects elevate the hips as high as possible and the assessor places a hand at this height. Repeat this action as many times as possible touching the assessors hand each time. The test concludes when the subject is unable to bridge to the original height (assessors hand).	> 85% compared with other side **Hurdle requirement** = >20 repetitions	○
Calf Raises	Single leg calf raises (Hebert et al, 2017) Subjects stand on one foot on the edge of the step and perform a calf raise through full range of motion. Calf raises are performed at 1 repetition every 2 seconds. The test concludes when subjects are unable to move through full range or slow below the cadence outlined above.	> 85% compared with other side **Hurdle requirement** = >20 repetitions	○
Side Bridge Endurance Test	Side bridge test (McGill et al, 1999) Subjects lie on an exercise mat on their side with legs extended. The top foot is placed in front on the lower foot, then subjects lift their hips off the mat to maintain a straight line over their full body length for as long as able. The test (time) ends when the hips return to the mat.	> 85% compared with other side **Hurdle requirement** 30 seconds	○
Single Leg Squat	Single Leg Rise Test (Culvenor et al., 2016 & Thorstensson et al., 2004) Subjects sit on a chair (or a plinth) with test leg bent to 90deg, and 10cm from edge of chair. With hands folded across the chest, the subject aims to stand up from the sitting position, and sit down as many times as possible.	> 85% compared with other side **Hurdle requirement** >10 repetitions each leg	○
Balance	Unipedal stance test (Springer et al, 2007) Subjects stand on one leg with other leg raised and arms crossed over the chest. The assessor uses a stopwatch to time how long stance is maintained on one leg with a) eyes open, and b) eyes closed. Time ends when; • Arms are used (uncrossed) • Use of the raised foot (touches down or other leg) • Movement of the stance foot • 45 secs has elapsed (maximum time) • Eyes opened on eyes closed trials	**A** (eyes open) 43 seconds **B** (eyes closed) 9 seconds (Normative data for 18-39 year olds)	○

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Strength and Neuromuscular Control

Phase 2: Outcome Measures and Goals - Supplementary Goals

Supplementary goals are considered a bonus for each phase of the ACL rehab protocol and should be strongly encouraged when the patient is returning back to high level jumping, cutting and pivoting sports.

NB: The absence of not performing supplementary tests however, is not considered a "road-block" to the next phase.

Outcome Measure	Test Description & Reference	Goal	√
Single Leg Press	1RM Single Leg Press (Campanholi Neto, José, et al, 2015) This test can be performed in most commercial gymnasiums that have a 45 degree incline leg press. Please ensure an appropriate warm up. Seat position is at 90 degrees to the slide, and the foot should be placed so that the hip is flexed to 90 degrees. A valid repetition is where the weight is lowered to a depth of 90 degrees knee flexion and then extended back to full knee extension.	1.5 x Body Weight (sled + weight)	○
Squat	1RM Squat This test can be performed in most commercial gymnasiums that have a squat rack. Please ensure an appropriate warm up and supervision/spotter whilst performing this test. There are many ways to perform the squat exercise ie. Front Squat, Back Squat, Trap Bar Squat; whichever way you choose to do it, we advise that the person attempts to squat down to 90 degrees knee flexion, and rises up into full knee and hip extension	1.5x Body Weight	○

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Running, Agility and Landings

Phase 3 of this ACL rehabilitation protocol sees a return to running, agility, jumping and hopping, as well as the continuation of a gym based strength and neuromuscular program.

Change of direction training and modified game play can also commence and progress during this phase, although supervision by the clinician is recommended.

The knee should be swelling and pain free during this phase, and an emphasis is placed on correct technique particularly for deceleration tasks such as landing from a jump. It's important to perfect landing and pivoting biomechanics before progressing fully back to sport (Phase 4).

Exercises and activities in Phase 3 typically include agility drills such as slalom running, shuttle runs, and ladder drills. Jumping and hopping exercises usually start with drills such as scissor jumps and single hops and progress to box jumps and single leg landings with perturbations.

It's important that there is some rest and recovery time during this phase as many of the exercises and activities require eccentric muscle activity. Clinicians should watch for signs of overload of the patellofemoral complex in particular.

The three most important goals of Phase 3 are:

- Attain excellent hopping performance (technique, distances, & endurance)
- Progress successfully through an agility program and modified game play
- Regain full strength and balance

Phase 3

Running, Agility and Landings

Most important goals

Attain excellent hopping performance

Complete agility program

Regain full strength and balance

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Running, Agility and Landings

Phase 3: Outcome Measures and Goals

The following hurdle criteria must be met before Phase 3 testing is conducted (see Phase 1 & 2 for test descriptions):

- Full range of motion (prone hang test and knee flexion)
- No effusion/swelling (stroke test)
- A "good" rating on the Single Leg Squat Test (Crossley et al, 2011)
- No side to side difference for the Single Leg Bridge Test, Single Leg Calf Raises, and Side Bridge Endurance Test

Outcome Measure	Test Description & Reference	Goal	√
Single Hop Test	Single leg hop test (Noyes et al, 1991) Subjects stand on one leg and hop as far forward as possible and land on the same leg. The average (mean) distance of 2 valid hops is recorded with a tape measure which is fixed to the ground. Measure from toe at take-off to heel at landing. Arms are free to swing. A limb symmetry index is calculated by dividing the mean distance (in cms) of the involved limb by the mean distance of the noninvolved limb then multiplying by 100.	**1.** >95% compared with other side **2.** Equal to or greater than pre-operative data (best result – affected or non-affected)	○
Triple Hop	Triple Hop Test (Noyes et al., 1991) Subjects are required to hop forwards three consecutive times on one foot. The total distance is measured, and the average (mean) of 2 valid tests is recorded. Measure from toe at take off to heel at landing. Arms are free to swing. A limb symmetry index is calculated by dividing the mean distance (in cms) of the involved limb by the mean distance of the noninvolved limb then multiplying by 100.	>95% compared with other side	○
Triple Cross Over Hop Test	Triple Cross Over Hop Test (Noyes et al, 1991) This test is performed on a course consisting of a 15cm marking strip on the floor which is 6m long. Subjects are required to hop three consecutive times on one foot going in a medial to lateral to medial direction, crossing the strip on each hop. The total distance is measured, and the average (mean) of 2 valid hop tests is recorded. Measure from toe at take-off to heel at landing. Arms are free to swing. A limb symmetry index is calculated by dividing the mean distance (in cms) of the involved limb by the mean distance of the noninvolved limb then multiplying by 100.	>95% compared with other side	○

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Running, Agility and Landings

Phase 3: Outcome Measures and Goals

Outcome Measure	Test Description & Reference	Goal	√
Side Hop Test	Side Hop Test (Gustavsson et al., 2006) Subjects stands on test leg with hands behind the back and jumps from side to side between two parallel strips of tape, placed 40 cm apart on the floor. Subject jumps as many times as possible during 30sec. The number of successful jumps performed, without touching the tape is recorded.	>95% compared with other side	○
Single Leg Squat	Single Leg Rise Test (Culvenor et al., 2016 & Thorstensson et al., 2004) Subjects sit on a chair (or a plinth) with test leg bent to 90°, and 10cm from edge of chair. With hands behind the back, the subject aims to stand up from the sitting position, and sit down as many times as possible.	Hurdle requirement = >22 repetitions both limbs	○
Balance (Dynamic)	Star Excursion Balance Test (Gribble et al, 2012) The star excursion balance test (SEBT) is performed in the anterior, posterolateral, and posteromedial directions. A composite score for all 3 directions is obtained for each leg. A limb symmetry index is then calculated by dividing the mean distance (in cms) of the involved limb by the mean distance of the noninvolved limb then multiplying by 100.	>95% compared with other side	○
Balance (Dynamic)	Cooper & Hughes Sports Vestibular Balance Test Subjects stand on one leg with a small amount of flexion in the hip, knee and ankle, and place their hands on their waist. In this position, two assessments are performed; **1. Side to side** At a rate of 60 beats per minute, subjects repeatedly turn their head from side to side (70-90 degree turn) for a period of 15 seconds. Vision needs to be inline with head position (no visual fixing). **2. Up and down** At a rate of 60 beats per minute, subjects repeatedly tilt their head up and down (looking floor to ceiling) for a period of 15 seconds. Vision needs to be inline with head position (no visual fixing). The test is passed if subjects can maintain single leg stance and do not take their hands off their waist for both assessments	Pass both limbs	○

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Running, Agility and Landings

Phase 3: Outcome Measures and Goals - Supplementary Goals

Supplementary goals are considered a bonus for each phase of the ACL rehab protocol and should be strongly encouraged when the patient is returning back to high level jumping, cutting and pivoting sports.

NB: The absence of not performing supplementary tests however, is not considered a "road-block" to the next phase.

Outcome Measure	Test Description & Reference	Goal	√
Single Leg Press	1RM Single Leg Press (Campanholi Neto, José, et al, 2015) This test can be performed in most commercial gymnasiums that have a 45 degree incline leg press. Please ensure an appropriate warm up. Seat position is at 90 degrees to the slide, and the foot should be placed so that the hip is flexed to 90 degrees. A valid repetition is where the weight is lowered to a depth of 90 degrees knee flexion and then extended back to full knee extension.	1.8 x Body Weight (sled + weight)	○
Squat	1RM Squat This test can be performed in most commercial gymnasiums that have a squat rack. Please ensure an appropriate warm up and supervision/spotter whilst performing this test. There are many ways to perform the squat exercise ie. Front Squat, Back Squat, Trap Bar Squat; whichever way you choose to do it, we advise that the person attempts to squat down to 90 degrees knee flexion, and rises up into full knee and hip extension	1.8 x Body Weight	○

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Phase 4

Return to Sport

Phase 4 ACL rehab should be highly individualised, and exercises and training activities that are usual for the athlete when not injured should be integrated into the regime.

Focus should not only be on getting the knee ready for sport, but the whole person. The knee needs to be stable and strong, with optimal neuromuscular patterning and biomechanics. But the athlete needs to be confident and mentally ready to return to sport, and this will come from repetition of successful training and match play situations.

A background of strength, balance, landing, and agility work needs to be done during this phase (and continue on into Phase 5), but the emphasis of Phase 4 ACL rehab is on progressive training, from restricted to unrestricted, and an eventual return to competition when ready.

So when are people ready to return to sport after an ACL reconstruction?

Current research suggests a minimum of 9 months, however please be guided by your surgeon and sports medicine team. Our suggestion is to allow people back to sport if they have satisfied 3 key criteria:

- Successful completion of the Melbourne Return to Sport Score (>95)
- The athlete is comfortable, confident, and eager to return to sport, as measured by the ACL-RSI and IKDC
- An ACL injury prevention program is discussed, implemented, and continued whilst the athlete is participating in sport. To lower the risk of future injury, evidence supports that injury prevention programs are performed at least 15mins prior to each training session and game.

Phase 4

Return to Sport

Return to sport criteria

95 + on Melbourne Return to Sport Score

←

Athlete is comfortable, confident, and eager to return to sport

→

ACL injury prevention program implemented

←

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Melbourne Return to Sport Scoring Sheet 2.0 (MRSS2.0)

The MRSS2.0 is an assessment tool for return to sport following anterior cruciate ligament reconstruction. There are six components to the test:

- Clinical Examination (10 points)
- IKDC Subjective Knee Evaluation and ACL-RSI (20 points)
- Tampa Scale of Kinesiophobia (hurdle criteria)
- Functional Testing (50 points)
- Assessment of General Fitness (hurdle criteria)
- Functional Testing in a Fatigued State (20 points)

We suggest performing the tests over two sessions at least 3 days apart;

- Session 1 – Part A, B, C, & D
- Session 2 – Part E & F

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Melbourne Return to Sport Scoring Sheet

Part A: Stability, Swelling, & Range

Item	Result	Score	
Effusion		/5	
Stability		/5	
Flexion		/5	
Extension		/5	**Converted**
		/20	/10

Part B: IKDC Subjective Knee Evaluation Form & ACL-RSI

Item	Result	Converted	
ACL-RSI	/100	/10	
IKDC	/100	/10	**Converted**
		/20	/10

Part C: Tampa Scale of Kinesiophobia (TSK-11)

Item	Score	Result	
TSK-11	19 or more	Fail	
	11 - 18	Pass	**Pass / Fail**

Part D: Functional Testing

Item	Result	Score	
SEBT		/10	
Vestibular Balance		/10	
Single Hop		/5	
Triple Hop		/5	
Triple Crossover		/5	
Side Hop		/5	
SL Rise		/10	**Total**
			/50

Part E: General Fitness Testing

Item	Result	
Test 1		
Test 2		**Pass / Fail**

Final Score
/100

Part F: Functional Testing in a Fatigued State

Item	Result	Score	
Single Hop		/5	
Triple Hop		/5	
Triple Crossover		/5	
Side Hop		/5	**Total**
			/20

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Criteria, Questionnaires and Testing Sheets

Part A: Stability, Swelling, & Range

Test	Outcome	Points Awarded
Effusion	**Absent**	5 Points
	Present	0 Points
Stability (Pivot Shift Test)	**Nil**	5 Points
	Grade I	3 Points
	Grade II	1 Points
	Grade III-IV	0 Points
Flexion	**0-5 degrees deficit**	5 Points
	5-20 degrees deficit	3 Points
	20+ degrees deficit	0 Points
Extension (Prone Hang Test)	**0-1cm deficit**	5 Points
	1-5cm deficit	3 Points
	5cm+ deficit	0 Points

Total
/20

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Criteria, Questionnaires and Testing Sheets

Part B: ACL-RSI

1. Are you confident that you can perform at your previous level of sport participation?

Not at all confident	0	10	20	30	40	50	60	70	80	90	100	Fully confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

2. Do you think you are likely to re-injury your knee by participating in your sport?

Extremely likely	0	10	20	30	40	50	60	70	80	90	100	Not likely at all
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

3. Are you nervous about playing your sport?

Extremely nervous	0	10	20	30	40	50	60	70	80	90	100	Not nervous at all
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

4. Are you confident that your knee will not give way by playing your sport?

Not at all confident	0	10	20	30	40	50	60	70	80	90	100	Fully confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

5. Are you confident that you could play your sport without concern for your knee?

Not at all confident	0	10	20	30	40	50	60	70	80	90	100	Fully confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

6. Do you find it frustrating to have to consider your knee with respect to your sport?

Extremely frustrating	0	10	20	30	40	50	60	70	80	90	100	Not at all frustrating
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

7. Are you fearful of re-injuring your knee by playing your sport?

Extremely fearful	0	10	20	30	40	50	60	70	80	90	100	Not fear at all
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

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Criteria, Questionnaires and Testing Sheets

Part B: ACL-RSI

8. Are you confident about your knee holding up under pressure?

Not at all confident	0	10	20	30	40	50	60	70	80	90	100	Fully confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

9. Are you afraid of accidentally injuring your knee by playing your sport?

Extremely afraid	0	10	20	30	40	50	60	70	80	90	100	Not at all afraid
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

10. Do thoughts of having to go through surgery and rehabilitation prevent you from playing your sport?

All of the time	0	10	20	30	40	50	60	70	80	90	100	None of the time
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

11. Are you confident about your ability to perform well at your sport?

Not at all confident	0	10	20	30	40	50	60	70	80	90	100	Fully confident
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

12. Do you feel relaxed about playing your sport?

Not at all relaxed	0	10	20	30	40	50	60	70	80	90	100	Fully relaxed
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Test	Outcome	Points Awarded
ACL RSI	**> 90% = 10/10**	10 Points
	< 90% = 0/10	0 Points

Reference: Webster et al, 2008

Total
/10

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Criteria, Questionnaires and Testing Sheets

Part B: IKDC Subjective Knee Evaluation Form

Test	Outcome	Points Awarded
IKDC	**Raw score** **/100**	
	Divide by 10	/10 Points

Reference: Anderson et al, 2006

SYMPTOMS*:

*Grade symptoms at the highest activity level at which you think you could function without significant symptoms, even if you are not actually performing activities at this level.

1. What is the highest level of activity that you can perform without significant knee pain?
   - 4 ☐ Very strenuous activities like jumping or pivoting as in basketball or soccer
   - 3 ☐ Strenuous activities like heavy physical work, skiing or tennis
   - 2 ☐ Moderate activities like moderate physical work, running or jogging
   - 1 ☐ Light activities like walking, housework or yard work
   - 0 ☐ Unable to perform any of the above activities due to knee pain

2. During the past 4 weeks, or since your injury, how often have you had pain?

Never	0	1	2	3	4	5	6	7	8	9	10	Constant
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

3. If you have pain, how severe is it?

No pain	0	1	2	3	4	5	6	7	8	9	10	Worst pain imaginable
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

4. During the past 4 weeks, or since your injury, how stiff or swollen was your knee?
   - 4 ☐ Not at all
   - 3 ☐ Mildly
   - 2 ☐ Moderately
   - 1 ☐ Very
   - 0 ☐ Extremely

5. What is the highest level of activity you can perform without significant swelling in your knee?
   - 4 ☐ Very strenuous activities like jumping or pivoting as in basketball or soccer
   - 3 ☐ Strenuous activities like heavy physical work, skiing or tennis
   - 2 ☐ Moderate activities like moderate physical work, running or jogging
   - 1 ☐ Light activities like walking, housework, or yard work
   - 0 ☐ Unable to perform any of the above activities due to knee swelling

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Part B: IKDC Subjective Knee Evaluation Form

6. During the past 4 weeks, or since your injury, did your knee lock or catch?

   0 ☐ Yes 1 ☐ No

7. What is the highest level of activity you can perform without significant giving way in your knee?

   4 ☐ Very strenuous activities like jumping or pivoting as in basketball or soccer
   3 ☐ Strenuous activities like heavy physical work, skiing or tennis
   2 ☐ Moderate activities like moderate physical work, running or jogging
   1 ☐ Light activities like walking, housework or yard work
   0 ☐ Unable to perform any of the above activities due to giving way of the knee

Sports Activities:

8. What is the highest level of activity you can participate in on a regular basis?

   4 ☐ Very strenuous activities like jumping or pivoting as in basketball or soccer
   3 ☐ Strenuous activities like heavy physical work, skiing or tennis
   2 ☐ Moderate activities like moderate physical work, running or jogging
   1 ☐ Light activities like walking, housework or yard work
   0 ☐ Unable to perform any of the above activities due to knee

9. How does your knee affect your ability to:

		Not difficult at all	Minimally difficult	Moderately difficult	Extremely difficult	Unable to do
a.	Go up stairs	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
b.	Go down stairs	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
c.	Kneel on the front of your knee	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
d.	Squat	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
e.	Sit with your knee bent	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
f.	Rise from a chair	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
g.	Run straight ahead	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
h.	Jump and land on your involved leg	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐
i.	Stop and start quickly	4 ☐	3 ☐	2 ☐	1 ☐	0 ☐

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Part B: IKDC Subjective Knee Evaluation Form

FUNCTION:

10. How would you rate the function of your knee on a scale of 0 to 10 with 10 being normal, excellent function and 0 being the inability to perform any of your usual daily activities which may include sports?

Function Prior To Your Knee Injury:

Couldn't perform daily activities	0	1	2	3	4	5	6	7	8	9	10	No limitation in daily activities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Current Function Of Your Knee:

Can't perform daily activities	0	1	2	3	4	5	6	7	8	9	10	No limitation in daily activities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Scoring Instructions for the 2000 IKDC Subjective Knee Evaluation Form

Several methods of scoring the IKDC Subjective Knee Evaluation Form were investigated. The results indicated that summing the scores for each item performed as well as more sophisticated scoring methods.

The responses to each item are scored using an ordinal method such that a score of 0 is given to responses that represent the lowest level of function or highest level of symptoms. For example, item 1, which is related to the highest level of activity without significant pain is scored by assigning a score of 0 to the response "Unable to perform any of the above activities due to knee pain" and a score of 4 to the response "Very strenuous activities like jumping or pivoting as in basketball or soccer". For item 2, which is related to the frequency of pain over the past 4 weeks, the responses are reverse-scored such that "Constant" is assigned a score of 0 and "Never" is assigned a score of 10. Similarly, for item 3, the responses are reversed-scored such that "Worst pain imaginable" is assigned a score of 0 and "No pain" is assigned a score of 10. Note: previous versions of the form had a minimum item score of 1 (for example, ranging from 1 to 11). In the most recent version, all items now have a minimum score of 0 (for example, 0 to 10). To score these prior versions, you would need to transform each item to the scaling for the current version.The IKDC Subjective Knee Evaluation Form is scored by summing the scores for the individual items and then transforming the score to a scale that ranges from 0 to 100. **Note:** The response to item 10a "Function Prior to Knee Injury" is not included in the overall score. To score the current form of the IKDC, simply add the score for each item (the small number by each item checked) and divide by the maximum possible score which is 87:

$$\text{IKDC Score} = \left[\frac{\text{Sum of Items}}{\text{Maximum Possible Score}}\right] \times 100$$

Thus, for the current version, if the sum of scores for the 18 items is 45 and the patient responded to all the items, the IKDC.

Score would be calculated as follows:

$$\text{IKDC Score} = \left[\frac{45}{87}\right] \times 100 \qquad \text{IKDC Score} = 51.7$$

The transformed score is interpreted as a measure of function such that higher scores represent higher levels of function and lower levels of symptoms. A score of 100 is interpreted to mean no limitation with activities of daily living or sports activities and the absence of symptoms.The IKDC Subjective Knee Form score can be calculated when there are responses to at least 90% of the items (i.e. when responses have been provided for at least 16 items). In the original scoring instructions for the IKDC Subjective Knee Form, missing values are replaced by the average score of the items that have been answered. However, this method could slightly over- or under-estimate the score depending on the maximum value of the missing item(s) (2, 5 or 11 points). Therefore, in the revised scoring procedure for the current version of a form with up to two missing values, the IKDC Subjective Knee Form Score is calculated as (sum of the completed items) / (maximum possible sum of the completed items) * 100. This method of scoring the IKDC Subjective Knee Form is more accurate than the original scoring method.

A scoring spreadsheet is also available at: www.sportsmed.org/research/index.asp This spreadsheet uses the current form scores and the revised scoring method for calculating scores with missing values.

Total
/10

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Criteria, Questionnaires and Testing Sheets

Part C: Tampa Scale of Kinesiophobia (TSK-11)

People who fail the TSK-11 should not continue with the remainder of the MRSS2.0 testing as return to sport should not be considered. Further time and rehabilitation is required.

		Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1	I'm afraid that I might injure myself if I exercise.	1 ☐	2 ☐	3 ☐	4 ☐
2	If I were to try to overcome it, my pain would increase.	1 ☐	2 ☐	3 ☐	4 ☐
3	My body is telling me I have something dangerously wrong.	1 ☐	2 ☐	3 ☐	4 ☐
4	People aren't taking my medical condition seriously enough.	1 ☐	2 ☐	3 ☐	4 ☐
5	My accident has put my body at risk for the rest of my life.	1 ☐	2 ☐	3 ☐	4 ☐
6	Pain always means I have injured my body.	1 ☐	2 ☐	3 ☐	4 ☐
7	Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening.	1 ☐	2 ☐	3 ☐	4 ☐
8	I wouldn't have this much pain if there weren't something potentially dangerous going on in my body.	1 ☐	2 ☐	3 ☐	4 ☐
9	Pain lets me know when to stop exercising so that I do not injure myself.	1 ☐	2 ☐	3 ☐	4 ☐
10	I can't do all the things normal people do because it's too easy for me to get injured.	1 ☐	2 ☐	3 ☐	4 ☐
11	No one should have to exercise when he/she is in pain.	1 ☐	2 ☐	3 ☐	4 ☐

Test	Outcome	Result	Pass / Fail
TSK-11	**11 - 18**	Pass	
	> 18	Fail	

Reference: Woby et al, 2005

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Criteria, Questionnaires and Testing Sheets

Part D: Functional Testing

Star Excursion Balance Test

	Right	Left	LSI	Points
Anterior			%	/5
Posteromedial				
Posterolateral			LSI	Points
Total			%	/5

Cooper & Hughes Vestibular Balance Test

Item	Pass or Fail	Points Awarded
Side to Side		/5
Up and Down		/5
Total		/10

Single Hop Test

	Right	Left		
Trial 1	cm	cm		
Trial 2	cm	cm	LSI	Points
Mean	cm	cm	%	/5

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Criteria, Questionnaires and Testing Sheets

Part D: Functional Testing

Triple Hop Test

	Right	Left		
Trial 1	cm	cm		
Trial 2	cm	cm	LSI	Points
Mean	cm	cm	%	/5

Triple Cross Over Hop Test

	Right	Left		
Trial 1	cm	cm		
Trial 2	cm	cm	LSI	Points
Mean	cm	cm	%	/5

Side Hop Test

	Right	Left	LSI	Points
Trial 1	reps	reps	%	/5

Single Leg Rise Test (90° knee flexion)

	Right	Left	LSI	Points
Trial 1			%	/5

The single leg rise to fatigue test: Subjects are seated on the edge of a treatment plinth with hips and knees at 90. Arms are to be crossed over the chest. On one leg, subjects are asked to raise to a fully extended knee as many times as possible at a tempo of 2 seconds up, and 2 seconds down. The test is complete when subjects are unable to complete any further squats, or the tempo or form is incorrect. The maximum number of squats are recorded for each leg.

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Criteria, Questionnaires and Testing Sheets

Part D: Functional Testing

Limb Symmetry Index (LSI) Scoring

The Limb Symmetry Index is calculated by dividing the mean distance (cms), or repetitions of the involved limb by the mean of the non-involved limb, and multiply by 100. For the tests that use the limb symmetry index, the following criteria will apply:

Limb Symmetry Index (dominant leg)	Points Awarded	Limb Symmetry Index (non dominant leg)	Points Awarded
97-105	10/10 or 5/5	95-103	10/10 or 5/5
90-96 / 105-110	8/10 or 4/5	85-94 / 103-110	8/10 or 4/5
80-89 / 110-120	6/10 or 3/5	75-84 / 110-120	6/10 or 3/5
70-79 / 120-130	4/10 or 2/5	65-74 / 120-130	4/10 or 2/5
60-69 /130-140	2/10 or 1/5	55-64 / 130-140	2/10 or 1/5
← 60 / 140+	0 points	← 55 / 140+	0 points

Part E: General Fitness Testing

Two sports-specific fitness tests that have previously been performed prior to the ACL injury are to be selected. Such tests could include;

- Beep Test/Shuttle/Yo-Yo Test
- Agility T-Test
- Illinois Agility Test
- Bruce Protocol
- Timed Run
- Sprint Test
- Other

The purpose of running these fitness tests is to ensure people have regained sufficient fitness to allow full return to game play. For both tests, the athlete must attain the same or better result as pre-injury testing. It's pass or fail. If no fitness tests have been previously performed, or baseline data is unavailable, it is suggested that the clinician and athlete discuss two appropriate tests with the coach (and/or fitness staff if available) and acceptable results are mutually agreed.

General Fitness Test

	Results	Pass or Fail
Test 1		
Test 2		

It is suggested that these two fitness tests are performed prior to undertaking Part F: Functional Testing in a Fatigued State.

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Criteria, Questionnaires and Testing Sheets

Part F: Functional Testing in a Fatigued State

Four hopping tests are to be performed in a fatigued state. Athletes are to undertake sports-specific exercise or game/match play until they reach a general fatigue level of;

7/10 on a VAS scale

When athletes have reached this level of general fatigue, the following tests are to be performed in reasonably quick time.

Single Hop Test

	Right	Left		
Trial 1	cm	cm		
Trial 2	cm	cm	LSI	Points
Mean	cm	cm	%	/5

Triple Hop Test

	Right	Left		
Trial 1	cm	cm		
Trial 2	cm	cm	LSI	Points
Mean	cm	cm	%	/5

Triple Cross Over Hop Test

	Right	Left		
Trial 1	cm	cm		
Trial 2	cm	cm	LSI	Points
Mean	cm	cm	%	/5

Side Hop Test

	Right	Left	LSI	Points
Trial 1			%	/5

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Prevention of Re-Injury

ACL injury prevention programs aim to improve the neuromuscular control of individuals during standing, cutting, and landing tasks.

Key components of an injury prevention program should include:

- Plyometric, balance, and strengthening exercises
- That the program must be performed for at least 10mins before every training session and game
- That the program is on going

Five popular injury prevention programs that include exercises to help reduce ACL injuries are available on the web. Five programs are:

- Sportsmetrics Program
- The 11+ Warm Up
- The PEP Program
- The KNEE Program - Netball Australia
- The FootyFirst Program - AFL

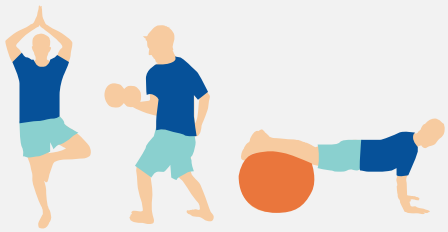
It is highly recommended that athletes continue with an ongoing ACL injury prevention program whilst they continue to play sports.

Phase 5

Prevention of Re-Injury

Successful ACL injury prevention programs include:

Plyometric, balance, and strengthening exercises



A program performed more than once per week

A program that continues for at least 6 weeks

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Bibliography

Anderson, Allen F., et al. "The International Knee Documentation Committee subjective knee evaluation form: normative data." *The American journal of sports medicine* 34.1 (2006): 128-135.

Crossley, Kay M., et al. "Performance on the single-leg squat task indicates hip abductor muscle function." *The American journal of sports medicine* 39.4 (2011): 866-873.

Campanholi Neto, José, et al. "A Single Session of Testing for One Repetition Maximum (1RM) with Eight Exercises is Trustworthy." *Journal of Exercise Physiology Online* 18.3 (2015).

Culvenor, Adam G., et al. "Predictors and effects of patellofemoral pain following hamstring-tendon ACL reconstruction." *Journal of science and medicine in sport* 19.7 (2016): 518-523.

Freckleton, Grant, Jill Cook, and Tania Pizzari. "The predictive validity of a single leg bridge test for hamstring injuries in Australian Rules Football Players." *British journal of sports medicine* (2013): bjsports-2013.

Gribble, Phillip A., Jay Hertel, and Phil Plisky. "Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review." *Journal of athletic training* 47.3 (2012): 339-357.

Grindem, Hege, et al. "Nonsurgical or surgical treatment of ACL injuries: knee function, sports participation, and knee reinjury: the Delaware-Oslo ACL Cohort Study." *The Journal of bone and joint surgery*. American volume 96.15 (2014): 1233.

Grindem, Hege, et al. "Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study." *Br J Sports Med* (2016): bjsports-2016.

Gustavsson, Alexander, et al. "A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction." *Knee Surgery, Sports Traumatology, Arthroscopy* 14.8 (2006): 778-788.

Hébert-Losier, Kim, et al. "Updated reliability and normative values for the standing heel-rise test in healthy adults." *Physiotherapy* 103.4 (2017): 446-452.

Mandelbaum, Bert R., et al. "Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up." *The American journal of sports medicine* 33.7 (2005): 1003-1010.

McGill, Stuart M., Aaron Childs, and Craig Liebenson. "Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database." *Archives of physical medicine and rehabilitation* 80.8 (1999): 941-944.

Mentiplay, Benjamin F., et al. "Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: A reliability and validity study." *PloS one* 10.10 (2015): e0140822.

Norkin, Cynthia C., and D. C. White. "Measurement of joint: A guide to goniometry." (1995): 88-9.

Noyes, Frank R., et al. "A training program to improve neuromuscular and performance indices in female high school basketball players." *The Journal of Strength & Conditioning Research* 26.3 (2012): 709-719.

Noyes, Frank R., Sue D. Barber, and Robert E. Mangine. "Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture." *The American journal of sports medicine* 19.5 (1991): 513-518.

Paterno, Mark V., et al. "Self-reported fear predicts functional performance and second ACL injury after ACL reconstruction and return to sport: a pilot study." *Sports health* (2017): 1941738117745806.

Reid, Andrea, et al. "Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction." *Physical therapy* 87.3 (2007): 337-349.

Sachs, Raymond A., et al. "Patellofemoral problems after anterior cruciate ligament reconstruction." *The American journal of sports medicine* 17.6 (1989): 760-765.

Springer, Barbara A., et al. "Normative values for the unipedal stance test with eyes open and closed." *Journal of Geriatric Physical Therapy* 30.1 (2007): 8-15.

Steffen, Kathrin, et al. "High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial." *Br J Sports Med*(2013): bjsports-2012.

Sugimoto, Dai, et al. "Specific exercise effects of preventive neuromuscular training intervention on anterior cruciate ligament injury risk reduction in young females: meta-analysis and subgroup analysis." *Br J Sports Med* (2014): bjsports-2014.

Stillman, Barry C. "Physiological quadriceps lag: its nature and clinical significance." *Australian Journal of Physiotherapy* 50.4 (2004): 237-241.

Sturgill, Lynne Patterson, et al. "Interrater reliability of a clinical scale to assess knee joint effusion." *journal of orthopaedic & sports physical therapy* 39.12 (2009): 845-849.

Thorstensson, Carina A., et al. "Reduced functional performance in the lower extremity predicted radiographic knee osteoarthritis five years later." *Annals of the rheumatic diseases* 63.4 (2004): 402-407.

Webster, Kate E., Julian A. Feller, and Christina Lambros. "Development and preliminary validation of a scale to measure the psychological impact of returning to sport following anterior cruciate ligament reconstruction surgery." *Physical therapy in sport* 9.1 (2008): 9-15.

Woby, Steve R., et al. "Psychometric properties of the TSK-11: a shortened version of the Tampa Scale for Kinesiophobia." *Pain* 117.1-2 (2005): 137-144.

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