

Guidelines for Post-operative Rehabilitation of ACL Repair with the *Internal Brace*[™]: A Criterion-Based Approach.

These guidelines have been developed to assist the rehabilitation clinician in their decision-making with patients who have undergone surgical repair of the anterior cruciate ligament (ACL) using the *Internal Brace*[™] augmentation method. This is described by Mackay et al. 2015 and demonstrated at the following web link: https://www.arthrex.com/resources/video/sH_u8jqzQkGFgAFA0HRHKA/acl-primary-repair-with-internalbrace-ligament-augmentation . Historically with an ACL reconstruction, consideration had to be given to the autograft donor site, graft biological healing timeframes and a sense of uncertainty over the early tensile strength of the graft when planning the rehabilitation process (Manal & Snyder-Mackler 1996). Further advancements in rehabilitation guidelines have followed with a greater focus on early mobilisation but with the use of criteria to advance patients rather than being constrained by biological healing time-frames (Adams et al. 2012).

Repair of the ACL using the *Internal Brace*[™] provides immediate protection to the ligament repair in the form of a 'check rein'. Furthermore, the in situ *Internal Brace*[™] has been shown to demonstrate comparable tensile strength to a healthy ACL, the rehabilitation professional can take confidence, particularly in the early stages of rehabilitation, allowing for early mobilisation thus avoiding stress-shielding the repair and utilising mechanotransduction to stimulate an optimal biological healing process of the original ACL tissue. It is our experience that typically patients do not have the same degree of iatrogenic effects of surgery that are often witnessed in traditional ACL reconstruction (i.e. less effusion, less pain, less quadriceps atrophy) once again allowing for earlier progression through the rehabilitation phases.

The guidelines below are specifically intended to be used with patients who have undergone an **isolated ACL *Internal Brace*[™] repair**. It is important to note that these guidelines are 'criterion-based' in terms of progression through the phases and while minimal timeframes for progression are presented, it is essential that the criteria for commencing each phase are demonstrated prior to progressing. The important point to bear in mind is that the original ACL tissue is preserved and repaired with the IB providing a 'check rein' support if the ACL is taken into maximal tension, thus protecting the repair. Furthermore, since there is no donor site morbidity, normally the patient will have far less post-operative pain and swelling therefore quads function is well preserved. This all means that typically patients will be able to progress faster through rehabilitation.

Often the main limiting factor is concurrent pathology (i.e. meniscus, OCD, MCL) rather than the ACL itself. It is very common for co-pathologies to exist and often surgical procedures to address these issues will be undertaken concurrently. Short discussions of common concurrent knee injuries to consider alongside ACL *Internal Brace*TM repair are presented below.

Additional Ligamentous Injury

The **medial collateral ligament of the knee (MCL)** is commonly injured in combination with the ACL. When treated non-operatively, the severity of the MCL injury will determine the rate of progression through rehabilitation, however there should be no significant deviation from the guidelines presented below, albeit higher grade MCL injuries may delay progression by several weeks. If traditional surgical repair of the MCL is conducted concurrently with ACL repair patients may be required to use crutches for 5 weeks and wear a brace to minimise flexion for 6 weeks (Osti et al. 2010). However, with the *Internal Brace*TM method also available for MCL repair such post-operative limitations can be avoided and early mobilisation can be achieved and rehabilitation can follow that outlined in these guidelines.

For **multi-ligament instability** (in the case of motor vehicle accidents or catastrophic sports injuries), typically 6-8 weeks of immobilisation is recommended following stabilisation surgery (Edson 2006). Early surgical intervention for such injuries has demonstrated more favourable results than delayed surgical repair (Levy et al. 2009) and with the potential for the use of *Internal Brace*TM principles to be applied in such procedures, earlier mobilisation can be applied and therefore an accelerated recovery would be anticipated when compared with a more conservative post-operative approach. In such situations however, due to the complex nature of multi-ligamentous injuries of the knee, rehabilitation guidance should be taken from the surgeon and will almost certainly result in more prolonged rehabilitation phases when compared with an isolated ACL repair.

The **anterolateral ligament (ALL)** has been discussed in more detail within the orthopaedic community recently (Claes et al. 2013). This structure is associated with the Segond fracture commonly observed in the presence of an ACL rupture and biomechanically is thought to be a secondary tibiofemoral rotatory restraint. While the ALL may not routinely be reinforced surgically, the *Internal Brace*TM procedure can be applied to the ALL to improve tibio-femoral rotatory stability in the presence of ACL rupture/repair and may be beneficial in young female athletes, hypermobile patients, and in chronic or revision cases (Mackay et al. 2015). This will allow the rehabilitation clinician greater confidence in progressing the patient and therefore should not significantly affect the guidance outlined below.

Previously, **revision ACL reconstruction (RACLR)** rehabilitation guidelines were modified to account for concerns over potential fixation issues and complications from previous procedures. The use of the *Internal Brace*TM during RACLR procedures once again can provide greater confidence in the rehabilitation process. In the situation where the surgeon is utilising the *Internal Brace*TM in a revision of a previous ACL reconstruction using an autograft, the *Internal Brace*TM will provide immediate support to the repaired graft thus allowing early mobilisation. In the event of a primary repair of the ACL using the *Internal Brace*TM succumbing to subsequent injury, the surgeon can convert to a traditional ACLR procedure but again can strengthen the repair with the *Internal Brace*TM which should allow early mobilisation, however consideration must therefore be given to the donor site within the rehabilitation process.

Meniscal Injury

Typically when a partial medial menisectomy is performed concurrently with ACL surgery, modifications to the rehabilitation are not specifically required (Adams et al. 2012). However, clinicians may see that there is a slightly greater effusion and discomfort in the first phase of the rehabilitation process which may delay progression to phase 2 by a few weeks but should not have a significant impact on the overall rehabilitation process.

Meniscal repairs are commonly conducted concurrently with ACL repair. It is advised that weight bearing flexion is limited to 45 degrees for 4 weeks and up to 90 degrees from weeks 5-8 to avoid placing excessive load on the posterior horn where meniscal repairs are most commonly conducted (Starke et al. 2009). There is no limitation on extension range. Otherwise the rehabilitation can follow the isolated ACL *Internal Brace*[™] repair guidelines including return to running criteria.

Chondral Defects

With the advancement of the surgical management of osteochondral defects (OCD) over recent years, there are various procedures available to surgeons to address identified defects. As such, the rehabilitation clinician should always take instruction from the surgeon on any local protocols or guidelines. For smaller OCD, debridement may be the intervention of choice and therefore weight bearing as tolerated with crutches is advised for 3-5 days post-operatively with no other modifications (Reinhold et al. 2006). If a microfracture procedure is carried out, a greater degree of protection will be required. Patients may require the use of crutches from 2-8 weeks after surgery depending on pain, effusion, surgeon preference, and the location and size of the lesion (Reinhold et al. 2006). Starting weight bearing exercises (wall slides) will be delayed in phase 1 where phase 2 will commence once the patient is walking without crutches, pain is minimal and effusion is grade 1+ or less. In the situation where surgical repair of an OCD is undertaken (i.e. osteochondral autograft transfer), the rehabilitation professional should refer to the operating surgeon for guidance. The same criterion-based rehabilitation process and return to sport criteria outlined for ACL repair should be adopted in the presence of all concurrent OCD procedures.

Guidelines for Post-operative Rehabilitation of ACL Repair with the *Internal Brace*™

Phase 0: Pre-op				
Criteria for beginning phase Meets surgical criteria for internal brace augmentation				
Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
Aim to maintain full extension. Limit flexion to 90	PWB 1-2 elbow crutches	<ul style="list-style-type: none"> Choose exercise, resistance & equipment after establishing severity, irritability and nature of injury Assume unstable knee Body weight open chain quads exercises and lower limb triple extension with theraband resistance Hamstring & calf stretching Glute and core maintenance exercises as able 	<ul style="list-style-type: none"> Protect unstable knee Reduce swelling Maintain quads function Maintain/maximise knee extension Maintain Glute and torso function 	<ul style="list-style-type: none"> Rest leg and elevate where possible when not performing exercises Ice the knee for 20min approx. 5 times per day Use crutches as indicated Wear tubigrip or other compression garment throughout the day and remove at night.

Phase 1: Initial Post-op (Days 1-7)				
Criteria for beginning phase				
Successful operative outcome Assumes no or minimal additional structural pathology i.e. meniscal or MCL repair Surgeon in agreement with post-operative protocol				
Testing				
ROM				
Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
Normal hyperextension-100 degrees flexion	1 elbow crutch if required for comfort and gait normalisation. Reduce in stages depending on pain and gait pattern	ROM <ul style="list-style-type: none"> Active ROM challenging flexion and extension within phase limits Passive knee extension – patient (prone hangs) and practitioner administered Patellar mobilisations Posterior chain soft-tissue release work Calf & hamstring stretches Ankle pumps Exercise bike up to 10min low resistance STRENGTH & CONTROL <ul style="list-style-type: none"> Quads setting / Inner range quads / ASLR / long-arc quads Wall slides (0-45°) Calf raises Hamstring strengthening with resistance band or similar NWB hip control/strengthening – focus on extension and ABDuction Core/trunk conditioning without lower limb loading Gait education and drills PROPRIOCEPTION/BALANCE <ul style="list-style-type: none"> Low grade knee proprioception / joint position sense exercises 	<ul style="list-style-type: none"> Good control of pain Grade 1+ effusion or less Walking without crutches Reinstate optimal gait pattern Achieve full knee hyperextension Maintain quads activation Maintain hip/pelvis and trunk control & stability 	<ul style="list-style-type: none"> Rest the leg and elevate as much as possible when not performing physiotherapy exercises Ice the knee for 20min approx. 5 times per day Use crutches as indicated Wear tubigrip or other compression garment throughout the day and remove at night. No crossing legs, running, jumping, twisting/pivoting. No loaded open chain quads – unloaded only.

Phase 2: Early Post-op(from 1 week)

Criteria for beginning phase

Able To walk without crutches | Knee ROM full hyperextension to 100° | Pain reducing | Effusion grade 1+ or less

Testing

ROM

Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
Full hyperextension 110-120 degrees flexion	FWB	ROM <ul style="list-style-type: none"> Maintain previous ROM exercises Continue with passive mobilisations and soft-tissue release as indicated Increase exercise bike up to 15min still low resistance STRENGTH & CONTROL <ul style="list-style-type: none"> Maintain previous phase Introduce light open chain quads loading 90-60deg (i.e. 1-2kg ankle weight) as pain and effusion dictate Progress wall slides to 60° flexion as pain allows Light resistance-based closed chain knee extension (i.e. Pilates reformer supine leg press) Small step-up work – avoid eccentric-biased step-down Supine hamstring bridges Supine glute bridges Core / trunk conditioning can include lower limb loading as tolerated PROPRIOCEPTION/BALANCE <ul style="list-style-type: none"> Static single leg stance on stable base – ensure good pelvis/hip positioning Double leg stance with arm movements +/- eyes closed on unstable base (i.e. balance pad/cushion) 	<ul style="list-style-type: none"> Minimal pain Trace effusion or less Begin reciprocal stair ascending and descending 	<ul style="list-style-type: none"> Rest the leg and elevate as much as possible when not performing physiotherapy exercises Ice the knee for 20min approx. 5 times per day No crossing legs, running, jumping, twisting/pivoting.

Phase 3: Intermediate Post-op (from week 3)

Criteria for beginning phase

Flexion within 30° of uninvolved side and full hyperextension | Effusion Trace or less | Achieving stairs reciprocally with good pattern | Completing full rehabilitation exercises from Phase 2 competently and without pain

Testing

ROM | KOOS (Symptoms, Pain & ADLs) at end of phase

Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
<p>Full hyperextension</p> <p>120-130 degrees flexion</p>	FWB	<p>ROM</p> <ul style="list-style-type: none"> Maintain previous ROM exercises Continue with passive mobilisations and soft-tissue release as indicated Graded progression of exercise bike up to 30min with increasing resistance <p>STRENGTH & CONTROL</p> <ul style="list-style-type: none"> Graded progression of open chain quads loading as clinically indicated progressing from 90-0 deg Progress closed chain loading (i.e. wall squats 0-90deg > BW squats > BW split squats > lunges) Supine Pilates reformer work can commence jump-board work for early landing NM control Progression of step work via increased step height and lateral movements Introduce shallow single leg squats up to 45 degrees knee flexion Advancement of hamstring loading (i.e. Swiss Ball curls including fast eccentrics) SL supine glute bridges Continue core / trunk conditioning <p>PROPRIOCEPTION/BALANCE</p> <ul style="list-style-type: none"> Single leg stance with arm movements +/- eyes closed on unstable base (i.e. balance pad/cushion) Side-stepping, carioca and other entry level agility exercises 	<ul style="list-style-type: none"> Full ROM Introduce agility exercises Sufficient neuromuscular control to commence running program in next phase KOOS (Symptoms & stiffness; Pain; Function & daily living) >75% by end of phase 	<ul style="list-style-type: none"> Ensure symmetrical patterning on squat and lunge-based activities Monitor pain and effusion levels in response to introduction of new activities No running

Phase 4: Late Post-op (from week 5)

Criteria for beginning phase

Flexion within 20 deg of uninvolved side | Maintaining full hyperextension | Effusion Trace or less | KOOS (Symptoms & stiffness; Pain; Function & daily living) >75% | Completing full rehabilitation exercises from Phase 3 competently and without pain

Testing

ROM | KOOS (Symptoms & stiffness; pain; daily living) at end of phase | Open chain quads/knee extension strength at end of phase

Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
Aim for full ROM – no restrictions	FWB	<p>ROM</p> <ul style="list-style-type: none"> Continue with previous ROM exercises if there is a perception of 'tightness' or 'stiffness' or a tendency to clinically stiffen <p>STRENGTH & CONTROL</p> <ul style="list-style-type: none"> Graded progression of open chain quads loading as clinically indicated Advance lunge activities (i.e. multi-directional) Progress closed chain loading (i.e. graded back squat with barbell – 50% range ensuring excellent eccentric control) Progress single leg squat depth up to 90 degrees knee flexion Commence standing landing control exercises (i.e. landing from step, mini jumps) Continue with / advance hamstring, bridge, trunk work <p>PROPRIOCEPTION/BALANCE</p> <ul style="list-style-type: none"> Single leg – progress level of difficulty and consider sports-specific components (i.e. throw/catch) Progress agility work into tight space movement drills and introduce 'cutting' movements (i.e. figure of 8's, squares) 	<ul style="list-style-type: none"> Full ROM KOOS (Symptoms & stiffness; Pain; Function & daily living) >95% Open chain quadriceps strength >80% uninvolved side 	<ul style="list-style-type: none"> Patient to use 'Soreness rules' (see below) to guide rehab intensity and frequency Monitor kinetic chain ROM and control (i.e. ankle dorsiflexion range & pelvic/hip control) to prevent anterior knee overload No running

Phase 5: Transitional Phase (from week 8)

Criteria for beginning phase

Full ROM | No Effusion | KOOS (Symptoms & Stiffness; Pain; Function & daily living) >95% | Completing full rehabilitation exercises from Phase 4 competently and without pain

Testing

KOOS (Function, sports & recreation) at end of phase | Open chain quads/knee extension strength at end of phase | Y-Balance Test – at end of phase | Hop Testing – at end of phase

Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
Full	FWB	<p>ROM Maintain through lower limb kinetic chain</p> <p>STRENGTH & CONTROL</p> <ul style="list-style-type: none"> Graded progression of open chain quads loading as clinically indicated Progress closed chain loading (i.e. graded increase back squat load & depth; consider introducing Olympic lifts if part of patients normal training) Progress landing control exercises (i.e. increased step height; develop single leg landing control; add rotational or external perturbation components) Commence slide board work if indicated for patients sport Continue with / advance hamstring, bridge, trunk work <p>PROPRIOCEPTION/BALANCE</p> <ul style="list-style-type: none"> Advanced gility circuits with multi-components (i.e. steps, speedladder, balance pads, cones – mix static with dynamic stability) <p>RUNNING PROGRAM Commence the running program outlined below.</p>	<ul style="list-style-type: none"> KOOS (Function, sports & recreation) >75% Open chain quadriceps strength >90% uninvolved side Y-Balance Test – composite score >85% Hop testing (single, triple, x-hop, timed lateral, timed forward 6m) > 85% 	<ul style="list-style-type: none"> Patient to use 'Soreness rules' (see below) to guide rehab intensity and frequency Monitor kinetic chain ROM and control (i.e. ankle dorsiflexion range & pelvic/hip control) to prevent anterior knee overload

Phase 6: Sport-specific (from week 12)

Criteria for beginning phase

Full ROM | No Effusion | KOOS (Function, sports & recreation) >75% | Completing full rehabilitation exercises from Phase 4 competently and without pain

Testing

KOOS (Function, sports & recreation) at end of phase | Y-Balance Test – at end of phase | Hop Testing – at end of phase

Range of Motion	Weight Bearing	Exercise	Goals	Guidelines/Restrictions/Precautions
Full	FWB	<p>ROM Maintain through lower limb kinetic chain</p> <p>STRENGTH & CONTROL</p> <ul style="list-style-type: none"> Graded progression of open chain quads loading as clinically indicated Progress closed chain loading (i.e. graded increase back squat load & depth; consider introducing Olympic lifts part of patients normal training) Progress landing control exercises (i.e. add plyometric components) Continue with / advance hamstring, bridge, trunk work Add more advanced cutting/twisting/turning movements with progressive exposure to training drills. Start with few variables and progress towards open play <p>PROPRIOCEPTION/BALANCE</p> <ul style="list-style-type: none"> Agility circuits with multi-components – advance to reflect sport-specificity <p>RUNNING PROGRAM</p> <p>Once the running program is completed – advance to develop relevant components of sport-specific function i.e. increased straight line speed or interval-type.</p>	<ul style="list-style-type: none"> KOOS (Function, sports & recreation; Total score) >95% Open chain quadriceps strength >95% uninvolved side Y-Balance Test – composite score >95% Hop testing (single, triple, x-hop, timed lateral, timed forward 6m) > 95% 	<ul style="list-style-type: none"> Patient to use 'Soreness rules' (see below) to guide rehab intensity and frequency Monitor kinetic chain ROM and control (i.e. ankle dorsiflexion range & pelvic/hip control) to prevent anterior knee overload Patient must adequately demonstrate sport-specific training and sport-specific testing may be indicated to determine return to play readiness alongside the Phase 6 goals.

Soreness Rules

1. Soreness during warm-up that continues	2 days off, drop down one level
2. Soreness during warm-up that goes away	Stay at level that led to soreness
3. Soreness during warm-up that goes away but returns during the session	2 days off, drop down one level
4. Soreness the day after session (not muscle soreness)	1 day off, do not advance program to next level
5. No soreness	Advance 1 level per week or as instructed by physiotherapist

Running Progression

	Treadmill or Outdoors	Track
Level 1	0.2 km walk; 0.2 km jog x 10 (4 km)	Jog straights /walk bend (4 km)
Level 2	0.2 km walk; 0.4 km jog x 7 (4.2 km)	Jog straights / jog 1 bend every 2 nd lap (4km)
Level 3	0.2 km walk; 0.6 km jog x 5 (4 km)	Jog straights / jog 1 bend every lap (4 km)
Level 4	0.2 km walk; 0.8 km jog x 4 (4 km)	Jog 1.75 laps / walk 1 curve (2 km)
Level 5	Jog full 4 km	Jog all laps (2km)
Level 6	Jog 5 km	Jog 5km
Level 7	Jog 6 km	Jog 6 km
Level 8	Alternate between running and jogging every 0.5 km x 6	Alternate between running on the straights and jogging on the bends (6km)

Perform no more than 4 times in 1 week and no more frequently than every 2nd day. Do not progress more than 2 levels in a 7 day period. Based on running program proposed by Adams et al. (2012).

References

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