



Rehabilitation After ACL Reconstruction



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Philosophy of Rehabilitation

Rehabilitation, as it applies to the recovery period from Orthopaedic Surgery, is a process that aims to enhance and restore functional ability to the affected limb or joint. The first tenet of this must be to do no harm, hence, as this applies to ACL reconstruction, the aim is to try and restore full function, over a period of time, without damaging or loosening the graft.

The initial aim is to get through the first 6 - 8 weeks with a graft that remains tight, but with near full extension of the knee, and minimal swelling. This implies a good deal of rest, to allow the knee joint to recover and to allow the swelling to go down, yet whilst maintaining extension (getting the knee straight). It does not imply exercise or strengthening work, all of which can loosen the graft, and all of which can be worked on after the ends of the graft have healed into the bone (6 - 8 weeks for patella tendon, 10 - 12 weeks for hamstring tendon).

Whilst it is appealing to try and keep the leg strong during the recovery phase, the reality is that, this has not been shown to allow an earlier return to sport. What has been shown however, particularly with hamstring grafts, is that there can be a loosening of the graft with excessive and repetitive activity, and that loose grafts, in turn, are more likely to fail in the longer term.

Program Design

In designing a rehabilitation program which tries to achieve the conflicting aims of full function and return of strength, with maximal protection of the graft during its weak phase, the following must be taken into account:

1) The union of the graft into the bony tunnels occurs by 6 - 8 weeks with a patella tendon construct and by 10 - 12 weeks with a hamstring tendon construct. This junction is more likely to be broken down by high repetition of moderate loads rather than one particular incident. Care must be taken in this period therefore,

to avoid activities that load the ligament excessively and repetitively.

Activities such as walking are more likely to damage a graft than a fall. This is because each step, particularly during the phase when the leg is extended out in preparation for the next step, and at the start of the next phase when it impacts at heel strike, leads to a sudden rise in the tension within the graft. This means that there is a pulling on the ends of the graft with each step which, if performed often enough, will lead to a gradual loosening of the graft. For this reason, crutches are used for the first 4 - 6 weeks. They reduce the number of steps taken, and should be used full time for the first two weeks, and thereafter for any longer walks (outside the house) up until the 4 - 6 week mark. Less steps means that the graft is pulled on less, and hence, is less likely to loosen.

2) The graft is dead and must undergo a process of revascularisation whereby a new blood supply grows into it. As the ends heal into the bone, new blood vessels start to progress down the graft. They initially appear on the surface, but eventually move into the depths of the graft as well. This process begins as early as the first week, and continues to occur out until about 18 months. Even then, small changes continue to occur within the graft such that, according to some authors, it is not fully mature until about 3 years post surgery. However, by 9 months, most of the changes have occurred, and hence, a good percentage of people are starting to return to sport by about this time.

3) The dead collagen cells in the graft must be slowly replaced by new living cells so that the graft is functional again. The new collagen is type 4 and comes from the synovial lining tissue of the joint. It is not type 1 like the original ligament, and hence, no graft is ever as strong as a normal ligament. Nevertheless, the injury rate to the other knee remains higher (in most studies) than the re-injury rate to the same knee, and this is thought to be due to the fact that a good number of injuries occur in individuals who have weaker than normal ligaments in the first place. Because of

this, and because the re-injury rate (overall 5% but higher in younger individuals) is compatible with the introduction and return to twisting and turning sports, if adequate recovery time is allowed, return to previous types and levels of sport is allowed.

4) Graft 'stretch-out' is a phenomenon that occurs, usually in the first 4 months. It most probably represents either a gradual failure of fixation, or sequential graft fibre failure, rather than actual stretch out. Sequential fibre failure probably occurs because of rupture of the tightest fibres with repetitive load and, once these have ruptured, the next tightest fibres are at risk. By 4 months this seems to be less of a problem, probably because of increasing graft strength, and possibly because of a remolding of the fibres within the graft. Repetitive impact loading activities, such as running, may therefore begin at about this time.

Our experience over the years, where different protocols have been tried and observed, is that running at 3 months may cause some graft loosening, but by 4 months this is uncommon.

5) Return to sport requires a successful surgical outcome and a return of confidence in the knee. Return of confidence is an individual phenomenon which probably relates to the return of proprioception: that being a knowledge of where the knee is in space. The original ACL contains nerves and sensors that tell the brain where the knee is in space, and what it is doing. The graft does not have these nerves and sensors in it, and it seems that the recovery of this sensation relies on the rest of the knee picking up the slack. This takes time, and it seems to be different in each individual; albeit that full recovery, where upon the knee feels normal again, does not usually occur until about 15 months post surgery.

Interestingly, proprioceptive recovery does not seem to correlate to the degree of clinical success of the procedure: that is, how stable the knee feels when examined. Things that help recovery are: time, training and proprioceptive aids (such as a soft tissue knee brace that pulls on the skin to provide increased feedback). Without sufficient recovery, as judged by a return of confidence in the knee, actual sport (competition sport as against training) should not be undertaken.

6) The literature contains many rehabilitation protocols. A good many are motivated by the thought that more aggressive rehabilitation leads to an earlier return to sport. Whilst this has been demonstrated in some studies, experience would suggest that the safe time to return to sport, a time when proprioception is adequate, is still around the 9 month mark. In addition, the very few papers that have looked at minimal therapy in the early weeks (not no therapy, but rather a self guided program to maintain range whilst protecting the graft), suggest outcomes compatible with the more aggressive protocols. The swelling settles more quickly,

the knee motion is regained more easily, and the risk to the graft is less.

7) The type of ACL graft is important. Many of the rehabilitation protocols, including the so called 'Accelerated Rehabilitation' protocol of Shelbourne, were designed for open surgery using patella tendon grafts. Firstly, with open surgery, there is a need to overcome the pain of the procedure just to regain range. Such pain is then, in itself, self protective of the graft, however, the down side is that this limits the ability to regain a good range of motion in the early weeks. Hence, to some extent, these protocols have less application in arthroscopically aided procedures that are inherently less sore, and where pain may not be sufficient to lead the patient to overly protect the knee.

Secondly, and perhaps more importantly, these protocols were developed for the use of patella tendon grafts which, by their very nature, allow for stronger fixation to the bone compared to a hamstring graft. This means that, in the first 6 weeks or so, a hamstring graft needs more care and protection than does a patella tendon graft.

It can be seen therefore, that rehabilitation in the first 2 - 3 months is slower for a hamstring graft than for a patella tendon graft. This is something that needs to be taken into account, along with the advantages and disadvantages of each graft in the longer term, and the timing of surgery (in or out of season etc.), when selecting a graft in the first instance.

8) No one protocol is satisfactory for all players and any adapted protocol should be used only as a guideline for comparing an individual with the average. Every player will have his or her own set of problems, and most will need individual attention from a physical therapist at some point.

Overarching principles

The worst case scenario is that the graft becomes loose or damaged early on, leading to some laxity and a loss of stability in the longer term. In general, and against what might be thought:

If the knee is sore and hard to fully straighten, the graft is almost certainly intact. Hence, rehabilitation can be more intense. If it becomes stiffer, and still more motion is lost, supervision by an experienced therapist will be necessary. Occasionally, if it becomes very tight, and progressively so, it may indicate some capsulitis (similar to frozen shoulder), in which case some other treatment (e.g. oral cortisone) may be needed. This will need review by your surgeon.

If the knee is not overly sore and easily straightens, it is likely that the graft has loosened off a bit. This is not the time to think that the knee is doing very well, but rather, it is a time to be very careful, and to decrease all exercises and stretching. The plan, in this circumstance, is to protect the graft for 2 - 3 months, or until such

time as it is apparent that the graft is going to be alright. If, in the first 6 weeks, there is some concern about the looseness of the graft, it can be examined with the arthroscope with a view to tightening it up. If this is deemed necessary, it should be done earlier rather than later: and certainly before the graft is well healed into the tunnels.

Bracing the knee with a hinged splint has not been shown to protect the knee in the first weeks. Although commonly used in the 1980's, it has since been shown to slow down the recovery of range of motion. On the other hand, it is sometimes useful to brace the knee in full extension, just allowing passive flexion to be maintained with a 3 - 4 times a day, out of splint, regimen. This is most usually done where graft fixation is thought to be poorer than usual, (osteoporosis - soft bones etc.), and it is usually at the tibial end. In reality, whilst uncommon, this is a much more likely event in females than males, and more so in older patients. When used, the splint is usually just continued for 2 - 3 weeks, maintaining good extension of the knee whilst providing some limited protection.

Kinetic Chain Exercises

These come in 2 varieties, closed and open. The difference is that, in closed a kinetic chain, the quads force that pulls against the ACL, is balanced by the hamstring force: hence, there is a co-contraction of these muscles which neutralizes the force in the graft. This then means that, these exercises can be done early on in the recovery phase, knowing that there will be minimal stress being put on the graft. Most of these are static, or minimally dynamic, exercises done with the foot on the ground and the knee somewhat bent.

Open kinetic chain exercises are where the quads force is resisted by the graft alone and not the hamstrings. The quads pull the tibia forwards, and the ACL is the hinge for that motion. Hence, in open chain exercises, the graft can be exposed to significant force. This type of exercise is thus only introduced later in the rehabilitation program and, initially, these exercises are performed with the knee between 40° and 90° only. As the knee becomes straighter, the force in the graft rises further: hence, open kinetic chain exercises, with the knee in the 0 - 40° range, are the last strength exercises to be introduced.

The primary aims of the first six weeks are:

1. To decrease the swelling as fast as possible. This primarily means rest, and particularly in the first week. In that period of time the player will have a range of motion program which he will have been given in hospital. This should not be exceeded.
2. To regain passive extension (getting the knee straight). This is done from day one and it is the single most important part of any rehabilitation program. The knee does not need to be straight all the time, but rather, 3 - 4 times a day, it should

be straightened by sitting on the floor and putting a small towel under the heel, letting the knee sag back. If this cannot be achieved, or if the ability to straighten it is lessening, then some help from your therapist will be needed.

3. To gain initial graft fixation. This means no moderate or high loads under repetitive conditions in this time frame. The use of crutches, as described above, is thought to be helpful.
4. Exercise to keep fit starting from the 1 - 2 week period. This means upper body work, swimming with a pull buoy etcetera.
5. Towards the end of this period some exercise bike riding is allowed. Mostly this is with the good leg and at low pressures.

The goals of the second six weeks are:

1. Walking without a limp should have been achieved by this time
2. Bike riding is increased on a weekly incremental basis, starting at low pressures and a 1k distance equivalent, and building up to 10 - 15k by the end of the period. Build up occurs incrementally on a weekly basis, depending on progress, and limited by swelling.
3. Kicking with swimming is allowed, increasing pressure as for bike riding. Transition from a pull buoy such that, initially just 1 or 2 laps a session are kicked, but increasing that number over the 6 week period to where almost every lap is kicked. Small training fins are allowed for this but hard kicking is not. Initially it may be best to just use a fin on the good leg because this is an open chain type exercise which does put some stress on the graft.
4. With hamstring grafts, hamstring stretches and curls may be done after 8 weeks. Before this time there is a risk of sustaining a tear of the hamstring muscle belly.
5. Closed kinetic chain exercises (exercises designed not to stress the ACL graft) can be increased in intensity. This usually requires a physiotherapy assistance.
6. Proprioceptive training begins so that, by the end of the period, mini-tramp and wobble boards can be incorporated.

The goals of the second three months are:

1. Hard bike riding / rowing limited only by swelling
2. Open kinetic chain exercises introduced
3. Power training begins with limited extension (90-40°) and increasing to full extension at 4 months

4. *Weights to failure are not allowed in this period*
5. *Jogging begins at four months if swelling is minimal. Initially this is on flat ground and in straight lines. Jogging on soft surfaces (such as sand) is not allowed until the end of this period because of the twisting and turning involved. Jogging down slopes is not allowed until 5 - 6 months.*
6. *When straight line running is good, then proprioceptive training is introduced. This includes running in circles, figure '8's, zig-zags, etcetera. This is the most important phase because this type of activity not only helps return to sport, but is has been shown to decrease subsequent ACL rupture or re-rupture. Note that strength and quads / hamstring strength balance has never been proven to be associated with a decrease in injury even though it forms part of all return to sport protocols.*

The 6 - 9 month period

1. *Preparing to return to sport. This can be any time after six months but is more usually nearer the 9 month mark. It very much depends on both the player and the sport that is being returned to.*
2. *The player must be confident. This is an individual thing and occurs between 6 and 12 months. Generally it can be judged by watching the player in action. If there is hesitation and guarding then he should not be allowed to play.*
3. *The PEP program (You Tube), which has been expressly designed to both prepare the injured knee and to protect the other knee, should be attempted and mastered.*
4. *The best training for any player looking to return to match level is training itself, so this is encouraged.*
5. *By 5 months the player should be taking part in non contact skills with the team and these can be built up as confidence increases*
6. *Use of a ball to take the focus off the knee and onto the ball is necessary as part of proprioceptive re-training. The development of this subconscious reflex movement is essential in regaining confidence.*
7. *Use of a soft tissue knee brace to aid proprioception is helpful. It does not hold the knee together, and*

hence, does not need struts or straps. What it does do is to pull on the skin when the knee is moved, hence providing extra feedback about the position of the knee to the brain. This in turn increases confidence. A simple thermoskin will do.

8. *Single leg hop tests may be the best judge of ability to return to sport at this time.*

Setting individual parameters

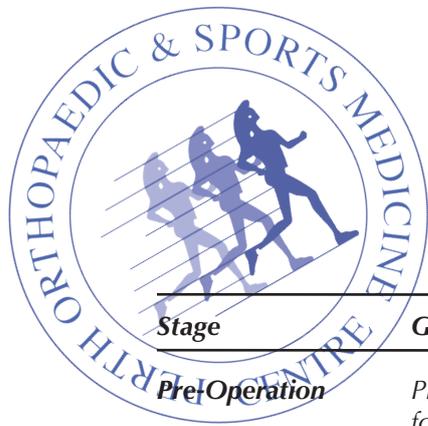
This is the role of the physical therapist and must be based on the progress of the player within the overall guidelines of the program. Each six week period should be assessed, and realistic aims for the player should be given, so that he can work towards these in the period allowed.

It is important not to overestimate a players ability to reach certain levels of function, and modifications of the program should be made if swelling or other problems ensue.

Chondral damage / Osteo-arthritis

Damage to the bearing surface of a joint (the chondral lining) is a permanent injury for which there is no good treatment. Whilst some healing of a damaged area may be achieved with time, and perhaps with prolonged non-weight bearing (6 - 8 weeks full time on crutches), that healing is with fibro-cartilage (scar tissue) and not hyaline cartilage (normal joint lining tissue). Therefore, whilst the defect in the joint surface may seem to partly heal early on, some defect (pot-hole) will always remain, and the fibro-cartilage tissue, which is not as robust as hyaline cartilage, will tend to break down under load. Hence, any defect, even if stable initially, will tend to get larger with time.

If the damage is significant, the longer term is one of progressive degeneration which, ultimately, ends up with osteotomy (bone re-alignment to unload the damaged area) or knee replacement. For this reason, those with significant areas of damage, particularly where the meniscal cartilage has been damaged and partly lost as well, will be advised never to undertake impact loading type activities. Hence, their rehabilitation will be directed towards smoother impact type exercises like cycling, rowing, swimming, cross trainers etc., rather than towards impact loading type activities such as running and prolonged walking.



General Protocol After ACL Reconstruction

Stage	Goals	Treatment Guidelines
Pre-Operation	Preparation for Surgery	Plan to operate on a pain free knee with full extension No surgery on stiff tight knees - leads to complications This may take time to settle - weeks or even months
Day 1 - 14 Early post operative phase	Pain control Swelling control Full knee extension Master crutches	Overnight in hospital to maximise pain control Physio review in the morning for instruction Practice achieving full knee extension, towel under heel This must be done at least 3 times per day Check on ability to use crutches Partial weight bearing on crutches when walking May put full weight on the leg when standing Patella mobilisation to maintain movement Gentle co-contractions to begin VMO strengthening No hamstring stretching until 8 weeks - may tear muscle
Week 2 - 6 Mid post operative phase	Minimize swelling General fitness Begin to walk normally	Continue to use crutches for any long walks Off crutches for short walks around the house or office Continue to work on getting full knee extension Try to maintain some fitness without stressing the knee Swim with a pull buoy, upper body work Try not to overdo knee work to decrease swelling Rest for periods of time helps speed up the resolution Gentle exercise bike riding at 4 weeks, minimal pressure Keep seat lower than normal to decrease stress on the graft Some closed chain activities if knee allows No active hamstring contractions or stretching, other than to allow full knee extension
Week 6 - 12 Late post operative & early exercise phase	Increase strength Proprioceptive work Preparation for next stage	Increase swimming and bike riding Plan to ride the equivalent of 10 - 15k by week 12 Plan to kick full time by 12 weeks, wean off pull buoy Harder closed kinetic chain exercises becoming more dynamic, including supervised partial 2 legged squats and lunges Try to walk normally but not for exercise Introduce early proprioceptive activity, walking cones, figure 8's and similar Use basketball whilst doing proprioceptive training, taking the eyes of the knee and onto the ball After 8 weeks, begin hamstring strengthening Activity is guided by the degree of swelling Continue to maintain fitness with swimming etc.
Month 3 - 6 Strength and recovery phase	Focused strength work Advanced proprioceptive work Running Sport specific activities	Open chain exercises begin, starting in the knee flexion range of 40-90° but progressing to full range by 5 months Running begins at 4 months, initially in straight lines, on the flat, firm even ground Proprioceptive training advanced to be done at running speed Lateral movements, sidestepping and twisting introduced Agility work, shuttle runs and ball work By 6 months, if able, commence PEP program (You Tube) Look at the FIFA 11+ program and incorporate with PEP Gluteal strength work, particularly in knee flexion to help with landings Learn to land with deeper knee flexion and on toes with leg rotated out (decreases re-injury, especially in girls)

Month 6 - 9 Sport specific training and preparation to play phase	<p>Improve fitness</p> <p>Improve strength</p> <p>Improve proprioception</p> <p>Return to sports training</p>	<p>Increase running distances</p> <p>Work on sport specific fitness</p> <p>Practice with PEP and FIFA programs to decrease recurrence</p> <p>Use these as a daily routine and as a warm up for any sport specific training</p> <p>Use soft tissue brace to aid proprioception</p> <p>Plan to return to sport when confidence has returned - usually 9 months</p>
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Month 9 - 15 Return to sport phase	<p>Begin actual sport not just training</p> <p>Continue to train knee</p>	<p>Ease into actual sport as confidence allows</p> <p>If not confident, do not play - this means that proprioceptive recovery is not adequate</p> <p>Single leg hop tests may be the best predictor of ability to play</p> <p>Continue with PEP and FIFA programs as warm up</p> <p>At 9 months the knee will start to free up and feel less tight</p> <p>Full proprioception to where the knee feels normal usually takes about 15 months</p>
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FIFA / PEP examples

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| 1) Warm up - 50m each | Forward jogging, speed not important, shuttle run, backwards running |
| 2) Stretching - 30sec, 2 reps | Calf, quads, figure 4 hamstring, inner thigh, hip flexor |
| 3) Strengthening | Walking lunges - 20m, 2 sets, Russian hamstring - 10 reps, 3 sets
Single toe raises - 30 reps each side |
| 4) Plyometrics - 20 reps each | Lateral hops over 10 - 15cm cone, forward / backward hops over cone,
Single leg hops over cone, vertical jumps, scissor jumps |
| 5) Agilities - 40 - 50m each | Shuttle run forwards and backwards, diagonal run, bounding run |

References:

- PEP Program** https://www.youtube.com/watch?v=t_yz7yWLo5o
https://www.youtube.com/watch?v=tb_boG53efg
- FIFA Program** https://www.youtube.com/playlist?list=PL-W9Gn-XDQ_pleE4mo1mgBb4OwyGc0UGU

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A randomized controlled trial to prevent non-contact anterior cruciate ligament injury in female collegiate soccer players.

Gilchrist J1, Mandelbaum BR, Melancon H, Ryan GW, Silvers HJ, Griffin LY, Watanabe DS, Dick RW, Dvorak J.

Abstract

Neuromuscular and proprioceptive training programs can decrease contact anterior cruciate ligament injuries; however, they may be difficult to implement within an entire team or the community at large.

Randomized controlled trial (clustered); Level of evidence, 1.

Participating National Collegiate Athletic Association Division I women's soccer teams were assigned randomly to intervention or control groups. Intervention teams were asked to perform the program 3 times per week during the fall 2002 season.

Results

Sixty-one teams with 1435 athletes completed the study (852 control athletes; 583 intervention). The overall anterior cruciate ligament injury rate among intervention athletes was 1.7 times less than in control athletes (0.199 vs 0.340; $P = .198$; 41% decrease). Non-contact anterior cruciate ligament injury rate among intervention athletes was 3.3 times less than in control athletes (0.057 vs 0.189; $P = .066$; 70% decrease). No anterior cruciate ligament injuries occurred among intervention athletes during practice versus 6 among control athletes ($P = .014$). Game-related non-contact anterior cruciate ligament injury rates in intervention athletes were reduced by more than half (0.233 vs 0.564; $P = .218$). Intervention athletes with a history of anterior cruciate ligament injury were significantly less likely to suffer another anterior cruciate ligament injury compared with control athletes with a similar history ($P = .046$ for non-contact injuries).

Conclusion

This program, which focuses on neuromuscular control, appears to reduce the risk of anterior cruciate ligament injuries in collegiate female soccer players, especially those with a history of anterior cruciate ligament injury.