Prehabilitation prior to anterior cruciate ligament reconstruction should include quadriceps strengthening—improving range of motion and balance and proprioception as a minimum. Although the content and duration of prehabilitation varies in the literature, when faced with a delay between diagnosis and surgery, 4-6 weeks of prehabilitation can improve early to mid-term strength and motion and can improve the timing and odds of a patient returning to sport.

**Introduction**

A successful anterior cruciate ligament (ACL) reconstruction surgery and rehabilitation optimizes patient satisfaction, knee stability, and return to sport, while also preventing rerupture. Failure occurs in 5-25% of patients when one considers both graft ruptures and ongoing laxity. The prospect and challenge of going through a revision surgical procedure because of one of these adverse outcomes, with 9-12 months of recovery, obviously must be avoided.

The goals of a physical therapy routine prior to ACL reconstruction, known as prehabilitation, address the most common early deficits after ACL injury: loss of motion, quadricep weakness, and instability. In addition, a prehabilitation program should improve balance, proprioception, and confidence, which helps prevent reinjury or contralateral injury after reconstruction.

**Re-Rupture Rates**

Rerupture rates were evaluated by Samuelsen et al., who performed a meta-analysis, including 47,613 ACL reconstructions [39,768 bone-tendon-bone (BTB) and 7,845 hamstring (HS)] from 25 different studies. Mean follow-up was 68 ± 55 months.

Overall, 2.80% BTB grafts ruptured compared with 2.84% in the hamstring group. Laxity was slightly higher in the BTB group compared to the HS group, but the difference was not significant.1

In a systematic review, Grassi et al. reported as many as 8% of patients undergoing ACL reconstruction will undergo a subsequent revision procedure. Regarding revision ACL reconstruction, when considering the sum of reruptures and objective clinical failures, the proportion of failed revision ACL reconstruction was more than 20% in 5 of the 15 included series in their review.2

Crawford et al. identified 14 studies for review of long-term ACL reconstruction failures. At longer than 10 years clinical follow-up, the reported ACL graft rupture rate was 6.2%, and clinical failure occurred in ~10.3%. At least 1 in 9 patients undergoing ACL reconstruction will have rerupture or clinical failure at long-term follow-up.3

**Return to Sport Rates**

Return to sport after ACL reconstruction, depending on the study, runs around 90%. This means 10% of patients never return to the same level of sports after ACL reconstruction surgery and rehabilitation.4 Webster et al. found that only 24% of individuals returned to their preinjury level of sport, despite 91% reporting preoperatively that they expected to return.5

Graincher and Scherr advocate for an assessment of risk factors to determine whether a prehabilitation program prior to ACL reconstruction would benefit the

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1. Samuelsen et al. (2019) J Bone Joint Surg Am
2. Grassi et al. (2019) Am J Sports Med
3. Crawford et al. (2019) Am J Sports Med
4. Webster et al. (2019) Sports Med
5. Graincher and Scherr (2019) Arthroscopy
patients who underwent the 6 weeks of prehabilitation 15% volume-load each week. The authors found that prescription of 3 sets of 12 repetitions, increasing by 10-
performed both strength and balance exercises, with a
almost nothing prior to ACL surgery. The prehab group
habilitation versus control group subjects who did
a group of subjects that completed 6 weeks of pre-
habilitation can be facilitated.

Before surgery is performed during which pre-
necessary, there is almost always at least a brief period
once there is a determination that ACL surgery is
surgery be delayed in lieu of prehabilitation? After
should the goals of prehabilitation be? (Table 1), Should
injury. Early ACL reconstruction is preferred in elite
athletes for return to sport at a similar level to pre-
jury. Early ACL reconstruction is preferred in elite
athletes in order to avoid ingraining of perception of
instability and giving-way phenomena, so the authors
recommend more analysis of whether prehabilitation
would benefit the athlete so much so as to outweigh
these risks of waiting.6

On the basis of these studies, the scope and scale of
recurrent issues after ACL reconstructions are some-
what daunting when you consider the number of ACL
surgeries performed annually. Anything we can do to
mitigate the risk of reinjury or contralateral injury is
helpful. Therefore, our purpose is to review the current
literature, including options and success, regarding ACL
prehabilitation therapy. There is good support for
optimizing the patients’ knee flexibility, strength, and
proprioception preoperatively and that these pre-
habilitation physical therapy measures will result in a
decrease in ACL reinjury after reconstruction.

Components of Prehabilitation

What is a good prehabilitation routine? What should
be done, when and for how long and how often? What
should the goals of prehabilitation be? (Table 1). Should
surgery be delayed in lieu of prehabilitation? After
reviewing the literature, there does not seem to be
much consensus regarding these questions. However,
when there is a determination that ACL surgery is
necessary, there is almost always at least a brief period
before surgery is performed during which pre-
habilitation can be facilitated.

Shaarani et al. compared outcome measures between
a group of subjects that completed 6 weeks of pre-
habilitation versus control group subjects who did
almost nothing prior to ACL surgery. The prehab group
performed both strength and balance exercises, with a
prescription of 3 sets of 12 repetitions, increasing by 10-
15% volume-load each week. The authors found that
patients who underwent the 6 weeks of prehabilitation
scored significantly higher on the single-legged hop
test, as well as on their self-reported assessment using
the Modified Cincinnati Knee Rating System. These
effects were sustained at 12 weeks postoperatively. The
mean return to sport timeframe was 34.2 weeks for the
prehab group and 42.5 weeks for the control group.7

Grindem et al. recommended a standard pre-
habilitation procedure after isolated ACL rupture for 5
weeks of progressive training, including heavy resis-
tance training, plyometrics, and neuromuscular exer-
cises, aiming at regaining 90% of quadriceps and
hamstring strength and hop performance of the unin-
jured leg before surgery.8

When comparing the Multicenter Orthopedics
Outcome Network (MOON) and Delaware-Oslo ACL
Cohorts, Failla et al. identified better IKDC and Knee
injury and Osteoarthritis Outcome Score (KOOS) scores
and higher return to sport rates 2 years after ACL
reconstruction (ACLR) in patients undergoing preop-
erative rehabilitation with neuromuscular training
compared to those who did not undergo preoperative
rehabilitation. In their assessment, delaying surgery for
10 sessions of prehabilitation could improve functional
knee scores by 12% to 15%. Overall, prehabilitation
seems to be a positive alternative to passive waiting
periods between injury and reconstruction.9

Outcomes of Prehabilitation

A good indicator for potential successful pre-
habilitation is the ability to achieve 80% quadricep
strength compared to the unaffected side. Patients who
achieve this milestone minimize their chance of
persistent strength differences for up to 2 years
postsurgery.10

A systematic review by Giesche et al. evaluated the
benefits of prehabilitation on objective, self-reported
and return-to-sport-specific outcomes, in comparison
to ACL postoperative rehabilitation without pre-
habilitation. They found low-level evidence that sup-
ports the notion that prehabilitation improves return-
to-sports rates and 2-year postoperative knee function.

The time before surgery ranged from 5 to 9 months,
and prehabilitation ranged from 4 to 6 weeks (4.8
weeks average), 2-4 times per week, for a maximum of
75 to 120 minutes. The prehabilitation included lower
limb open- and closed-chain exercises, neuromuscular
training (perturbation, balance, stability, proprioceptive
exercises), quadriceps-focused muscle control, and
coontraction exercises, as well as stretching and range
of motion (ROM) exercises for the lower limb. Some
studies included as part of their prehabilitation regimen:
patellar mobilization, kinesiotaping of the patellofe-
moral joint and plyometrics (single leg hops with soft
landing).

In the various studies, prehabilitation improved
maximal quadriceps torque, single-leg-hop for distance,
and limb symmetry index. There was also improved self-reported knee function, return to sport tended to be faster, and the prehabilitation groups had a higher return-to-sport rate at 2 years postsurgery.\textsuperscript{11}

### Discussion

While prehabilitation seems to be beneficial overall, the results may not endure. Reddy et al. compared the results of 41 patients who were randomly assigned to prehabilitation versus standard rehabilitation protocols in postoperative ACL reconstruction (quadruple hamstring graft). Twenty patients had prehabilitation with goals to decrease pain, swelling and inflammation; to restore range of motion; and to restore muscle strength. The secondary goals of prehabilitation were eliminating antalgic gait and improving neuromuscular control. The prehabilitation regimen included quadriceps-strengthening exercises, mini-squats, straight leg raising, hamstring stretches, ankle pumps, and ice application after exercises. The authors stated that a 4-week program significantly improved knee extensor muscle strength postoperatively and improved knee function by assessing Single Leg Hop Test distance. The prehabilitation group experienced a significantly improved range of motion at 3 and 6 weeks versus the standard rehabilitation group, but there was no difference at 3 and 6 months. There was no statistical difference in Lysholm or IKDC scores between the groups.\textsuperscript{12}

Other studies suggest that prehabilitation is more successful, and benefits may last substantially longer than those found by Reddy et al. Patients who complete prehabilitation may manifest improvements for up to 6 years postoperatively compared to those that do not do a preoperative exercise routine. These improvements apply across knee-related strength, range of motion, function, and outcome measure scores, including Lysholm scores, Tegner activity scores, the lower extremity functional scale, and the functional hop test (Table 2).\textsuperscript{13,14}

| Table 1. Sample ACL Prehabilitation Program Beginning Six Weeks Before Reconstruction |
|----------------------------------|----------------------------------|
| **Phase I**                        | **Phase II**                     |
| (\(\sim 0-3\) weeks)              | (\(\sim 3-6\) weeks)            |
| **Goal**                           | **Goal**                         |
| Normalize ROM                      | Normalize ROM                    |
| Heel slides with strap             | Heel slides with strap           |
| Seated knee flexion stretch        | Seated knee flexion stretch      |
| Prone hangs                        | Prone hangs                      |
| Heel prop                          | Bike                             |
| Semicircles on bike                | Hamstring and gastroc stretches  |
| Hamstring and gastroc stretches    | Manual PROM from PT              |
| Manual PROM from PT                |                                  |
| **Goal**                           | **Goal**                         |
| Decrease Swelling and Inflammation| Decrease Swelling and Inflammation|
| Ankle pumps                        | Ankle pumps                      |
| Post-treatment cryotherapy/squid   | Post-treatment cryotherapy/squid |
| Manual retrograde massage from PT  | Manual retrograde massage from PT|
| **Goal**                           | **Goal**                         |
| Increase Strength                  | Increase Strength                |
| Quad sets                          | Standing TKEs with resistance band|
| SLR 4 way                          | Long-arc quads                   |
| Bridging                           | Squats                           |
| Hamstring curls                    | Hamstring ball curls             |
| Heel raises bilateral              | Heel raises unilateral           |
| Side-lying clamshells              | Sidestepping with TheraBand      |
| Step ups                           | Leg press                        |
| Sit to stand or squats             | Split squats or single-leg squats|
| Wall slides                        | RDLs                             |
| Blood flow restriction             | Blood flow restriction           |
| **Goal**                           | **Goal**                         |
| Improve Balance/Proprioception     | Improve Balance/Proprioception   |
| Single-leg balance                 | Single-leg balance on uneven surfaces|
| Tandem stance                      | Tandem walk                      |
| Double-leg balance on uneven       | Single-leg balance star taps     |
| surface                            |                                  |

Also identify any proximal and distal joint restrictions in range of motion (ROM) and strength, such as hip extension/external rotation, hip flexion/internal rotation, ankle dorsiflexion, and thoracolumbar spine ROM).

If you have a dynamometer, measure unaffected limb open-chain knee extension strength for post-op limb symmetry index.
The authors suggested that return to sport after ACL reconstruction is commonly inadequate because patients aren’t mentally ready despite having achieved a successful functional outcome. Prehabilitation programs don’t commonly address the mental aspect related to ACL rehabilitation.16

Visualization techniques and virtual reality training could be used to boost confidence and mental preparedness for return to sport.

### Conclusion

Although no study seems to provide a consensus on what prehabilitation encompasses, the basic components should include improvement in knee ROM, quadriceps strengthening, and proprioception. The duration can be as short as 3 weeks, but the more successful programs last at least 4-6 weeks. In some patients, it may be beneficial to delay surgery to optimize these knee functions. Benefits of a prehabilitation program (better ROM and quadriceps strength) last at least 6 weeks, but perhaps as long as 6 years with the hope that a vigorous prehabilitation program prevents reinjury or contralateral injury after ACL reconstruction.

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### Table 2. Advantages of ACL Prehabilitation

| Goals and Benefits of ACL Prehabilitation |
|------------------------------------------|
| 1. Restore knee range of motion           |
| 2. Restore lower extremity strength, especially quadriceps |
| 3. Restore knee stability                  |
| 4. Restore balance                         |
| 5. Restore proprioception                  |
| 6. Restore confidence in return to sport   |
| 7. Reduce likelihood of reinjury or contralateral injury |

Yalfani et al. performed a systematic review of 10 studies to examine whether preoperative exercises can affect self-reported knee function outcomes. The authors found that several preoperative programs significantly enhanced self-reported knee function after surgery. They concluded that preoperative rehabilitation, consisting of progressive strengthening and neuromuscular training, followed by a postoperative rehabilitation program, had greater functional outcomes after ACLR and that preoperative rehabilitation should be considered as an addition to the standard of care to maximize functional outcomes after ACLR. The authors discussed that even if ACLR creates good stability, the quadriceps strength defect is reported as one of the limiting elements in returning to preinjury phase, which can last for up to 2 years after surgery.

Preoperative training in this systematic review varied in duration, frequency, and content; mean training was 4 weeks duration (average frequency of 3 times per week), and the content included quadriceps and hamstring strength training; proprioception; and neuromuscular, balance, and gait training. Most of the studies evaluated knee function through questionnaires. Studies reviewed showed that muscle function maximization and ROM deficit minimization preoperatively translate into improved postoperative outcomes. They predicted that with better strength and performance, prehabilitation can prevent reinjury.

They concluded that there was moderate-quality evidence that prehabilitation exercises, based on neuromuscular exercises with strength training could enhance self-reported function and that maximizing quadriceps strength with progressive preoperative exercises should be the focus for therapists, in order to enhance functional outcomes after ACL reconstruction.
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