Post-Operative Rehabilitation Protocol: Anterior Cruciate Ligament Reconstruction

Criteria-based, evidence-informed progression with return to sport targeted at 9 months

1. Purpose and Guiding Principles

This protocol guides rehabilitation after primary anterior cruciate ligament reconstruction (ACLR). Progress depends on meeting clinical criteria, not time alone. Priorities include restoring full knee extension, controlling swelling, activating the quadriceps and progressively building strength. Return to sport is gradual and requires strength, balance, agility and psychological readiness.

Return to unrestricted sport is considered at 9 months or later, only when all criteria are met. The surgeon's instructions take priority, and rehabilitation must be tailored to the graft, additional procedures, age, sport and health conditions.

2. Phase Overview

Phase	Typical timing	Primary focus	Key exit criteria
0. Pre-operative	Before surgery	Reduce swelling, restore ROM, strengthen, educate	Full extension, minimal effusion, good quad activation
1. Protection and activation	Weeks 0 to 2	Swelling, extension, quad activation, gait	0 degrees extension, 90 degrees flexion, SLR without lag, normal gait
2. Early strengthening	Weeks 2 to 6	Full ROM, closed-chain strength, balance	Full ROM, no effusion, step-down control, quad index above 50 to 60%
3. Progressive loading	Weeks 6 to 12	Strength, neuromuscular control, cardio	Quad index at least 70%, single-leg squat quality, no effusion
4. Running and impact preparation	Months 3 to 5	Straight-line running, landing, plyometrics	Quad and hamstring index at least 80%, hop tolerance, clean landings
5. Agility and sport-specific	Months 5 to 7	Cutting, deceleration, sport drills	Quad and hamstring index at least 85 to 90%, hop tests at least 85%, agility control
6. Return to sport	Months 7 to 9	Reactive agility, contact, team practice	Full test battery passed at 9 months or later

3. Phase 0: Pre-Operative Preparation

Entering surgery with a quiet, fully mobile knee and good quadriceps strength predicts better post-operative function. Pre-operative rehabilitation should continue until swelling has settled, full extension is present and the patient can walk without a limp.

- Restore full passive and active extension and near-normal flexion.
- Reduce effusion with cryotherapy, compression and elevation, and activity modification.

- Strengthen the quadriceps, hamstrings, hip abductors and trunk, with neuromuscular exercise 2 to 3 times per week.
- Record baseline measures on both limbs: strength, hop tests, KOOS or IKDC, and ACL-RSI. The uninjured limb values are the benchmark for later testing.
- Educate on expected timelines, crutch use, home exercises and the 9-month return-to-sport pathway.

4. Phase 1: Protection and Activation (Weeks 0 to 2)

Goals: control pain and effusion, achieve full passive extension, activate the quadriceps, restore a normal gait pattern and protect the graft and any concomitant repair.

Precautions: follow surgeon weight-bearing and brace instructions (most isolated ACLR patients may bear weight as tolerated). Avoid active open-chain knee extension against resistance and avoid a bolster under the knee that lets the knee rest in flexion.

Component	Prescription
Swelling and pain	Cryotherapy, compression, elevation; monitor with a stroke test or girth measurement
Range of motion	Heel props, prone hangs and passive extension several times daily; flexion progressed to 90 degrees by week 2 with heel slides
Quadriceps activation	Isometric quad sets with neuromuscular electrical stimulation (high intensity, at least 2 to 3 times per week) combined with volitional effort; straight leg raise without extension lag
Gait	Crutches until no limp and good extension control (about 1 to 2 weeks); weight shift and gait retraining
Other	Patellar mobilizations, hip and core exercises, upper body and uninvolved limb exercise

Progress to Phase 2 when: extension equals the other side (0 degrees), flexion is at least 90 degrees, effusion is trace or less, straight leg raise has no lag and gait is normal without crutches.

5. Phase 2: Early Strengthening (Weeks 2 to 6)

Goals: full ROM, normal gait, closed-chain strength, early balance and sustained quadriceps recruitment.

Closed-chain exercise is the foundation (Wright et al., 2008), and short-arc open-chain knee extension (90 to 45 degrees) may be added in a controlled way, as it has been shown to be safe and is more effective for quadriceps recovery than closed-chain exercise alone (Logerstedt et al., 2018). Late-range open-chain extension under heavy load is delayed until the graft has matured, and the surgeon's preferences apply, particularly after bone-patellar tendon-bone graft or quadriceps tendon graft.

- Strength: mini-squats and leg press (0 to 60 degrees), step-ups, bridges, calf raises, hamstring curls (delay resisted curls for 6 to 8 weeks after hamstring autograft), hip abduction and extension. 2 to 3 sets of 10 to 15 repetitions, advancing resistance weekly.
- Balance and proprioception: weight shifting, double-leg to single-leg stance, progressing to unstable surfaces and perturbation. Add dual tasks (ball toss) later in the phase.
- Cardiovascular: stationary bike (low resistance, once flexion allows), upper body ergometer, and pool walking after wounds are healed.
- Continue NMES to the quadriceps if the quadriceps index remains below 80% on testing.

Progress to Phase 3 when: full ROM, no effusion after activity, controlled single-leg stance for 30 seconds, step-down without knee valgus or trunk compensation and normal gait on all surfaces.

6. Phase 3: Progressive Loading (Weeks 6 to 12)

Goals: increase muscle mass and strength, improve neuromuscular control and prepare the knee for running. Muscle hypertrophy and heavy resistance are required, since light-load exercise does not reverse quadriceps atrophy.

- Strength: progress to heavy resistance (about 8 to 12 repetitions at 70 to 80% of 1RM, then 4 to 8 repetitions at 80 to 90% over weeks), covering leg press, squat variations, split squat, Romanian deadlift, hip thrust, step-downs and hamstring curls. Include Nordic hamstring and bridge variations when tolerated. Increase load by about 5 to 10% when the final repetitions are completed with good form.
- Open-chain knee extension: progress to the full range 90 to 0 degrees if there is no anterior knee pain and no effusion, usually after 12 weeks for bone-patellar tendon-bone grafts and sooner for hamstring grafts, with surgeon agreement.
- Neuromuscular control: single-leg squat, lateral lunge, single-leg balance with perturbation and reaching (Y-balance pattern), with feedback on trunk, pelvis and knee alignment.
- Conditioning: cycling and elliptical, with an interval structure to rebuild aerobic fitness.
- Prepare for running with low-level hop preparation: double-leg jumps, small jumps in place, and heel-to-toe drills.

Criteria to begin straight-line running (usually weeks 12 or later; earlier only if all are met and the surgeon agrees): no effusion, full ROM, quadriceps index at least 70%, 5 single-leg squats to 60 degrees with good control, 20 single-leg calf raises and normal walking. Many protocols also expect 10 to 12 consecutive single-leg bridges without compensation.

7. Phase 4: Running and Impact Preparation (Months 3 to 5)

Goals: return to running, graded impact exposure, strength at or above 80% of the other limb and early plyometric competence (Buckthorpe and Della Villa, 2021).

- Running: begin with a walk-jog program on level ground or a treadmill, such as 1 minute of jogging and 2 minutes of walking progressed over several weeks, 3 sessions per week with a rest day in between. Increase volume by no more than about 10 to 20% weekly. Stop and reassess for swelling, pain or limp.
- Plyometrics, low level: double-leg pogo hops, box drops with soft landings, bilateral jumps with a stick-the-landing hold, then single-leg landings. Start with 50 to 80 foot contacts per session and progress gradually, focusing on soft, quiet and aligned landings.
- Strength: continue heavy lower-body work twice weekly. Add single-leg Romanian deadlift, reverse Nordic and lateral band work. Introduce trunk and hip stability work in single-leg stance with moving loads.
- Testing at about 4 to 5 months: strength testing with a handheld dynamometer or isokinetic device, and a landing quality screen (for example the Landing Error Scoring System or a drop vertical jump video analysis). Identify side-to-side deficits and target them.

Progress to Phase 5 when: quadriceps and hamstring strength index is at least 80% of the other limb, no effusion with running and plyometrics, pain-free single-leg hop in place, and good landing mechanics (no excessive valgus, no trunk lean).

8. Phase 5: Agility and Sport-Specific Training (Months 5 to 7)

Goals: restore power, change-of-direction ability and sport-specific skill under controlled conditions.

- Plyometrics, advanced: single-leg hops forward, lateral and diagonal, bounds, drop jumps, then reactive tasks such as responding to a visual cue.
- Agility: ladder and cone drills, shuttle runs, planned cuts at increasing angle and speed (start at 45 degrees and slow, progress to 90 degrees), deceleration training, and then reactive and unanticipated drills.
- Power and strength: Olympic-derivative and loaded jumps if suited to the athlete, heavy compound lifts at 80 to 90% of 1RM, and eccentric hamstring work.
- Sport-specific: non-contact drills, such as passing, throwing, dribbling or stick-handling, with progressive tempo. No contact, no unplanned pivoting in team practice yet.
- Neuromuscular injury-prevention programs (FIFA 11+ or equivalent) integrated 2 to 3 times weekly.

Progress to Phase 6 when: strength index is at least 85 to 90% for quadriceps and hamstrings, hop tests are at least 90% on the first full test, change-of-direction drills are performed without pain or compensation, the knee does not swell after training and the patient reports confidence in the knee.

9. Phase 6: Return to Sport (Months 7 to 9)

Goals: reintroduce full training and competition in staged steps once cleared, building on a completed test battery.

1. Full non-contact team training at game speed (return to participation).
2. Contact or reactive drills and modified scrimmage with limited minutes.
3. Full practice, then match play with graduated minutes (for example 25%, 50% and 75% of usual game time over successive weeks).
4. Unrestricted competition (return to performance) once the athlete has completed several full matches without symptoms or setbacks.

Return to pivoting or contact sport is not cleared before 9 months, even if every test is passed earlier (Grindem et al., 2016). Athletes who reach criteria early should keep building strength, power and sport skill until the 9-month date.

10. Return-to-Sport Test Battery

The full battery is performed at or after 9 months, and a pre-screen at roughly 6 to 7 months identifies deficits early. All measures compare the operated limb with the uninjured limb, expressed as a limb symmetry index (LSI = operated divided by uninjured, times 100). Because the uninjured limb may itself be deconditioned, absolute and body-mass-normalized values and pre-injury baselines should also be considered (Wellsandt et al., 2017).

Domain	Test	Passing standard
Quadriceps strength	Isokinetic at 60 degrees per second, or isometric peak torque at 60 to 90 degrees of flexion	LSI at least 90%; ideally at least 3.0 Nm per kg isometric
Hamstring strength	Isokinetic or isometric peak torque	LSI at least 90%; hamstring to quadriceps ratio of at least 0.6 on the operated side
Hop performance	Single hop for distance, triple hop, crossover hop, 6-metre timed hop	LSI at least 90% on each test (Noyes et al., 1991), with equal landing quality

Domain	Test	Passing standard
Dynamic balance and proprioception	Lower Quarter Y-Balance Test (anterior reach), single-leg stance and perturbation tasks	Anterior reach difference less than 4 cm; composite score at least 94% of limb length (Plisky et al., 2006); no loss of balance
Agility and change of direction	T-test, Illinois agility test, 505 drill, planned and reactive cutting	Times within 10% of the uninjured-side or normative values for the sport; no valgus or trunk lean
Landing and jump quality	Drop vertical jump, Landing Error Scoring System	Good landing score (fewer than 5 errors) and no dynamic knee valgus
Power and reactive strength	Countermovement jump, reactive strength index	At least 90% symmetry and sport-appropriate values
Patient-reported function	KOOS (Sport and Recreation, QOL) or IKDC subjective form	At least 90% (KOOS) or at or above age and sex norms (IKDC)
Psychological readiness	ACL-Return to Sport after Injury scale (ACL-RSI)	Score of at least 65 (Webster and Feller, 2018); confident and willing to return
Clinical findings	Swelling, ROM, ligament examination, pain	No effusion, full ROM, no pain, stable Lachman and pivot shift

If any item falls short, the athlete is not cleared. Targeted training continues for 4 to 6 weeks, and only the failed domains are retested. Surgeon and clinician make the final decision jointly with the athlete.

11. Individualizing the Protocol

Situation	Adjustment
Meniscal repair	Limit weight bearing and flexion beyond 90 degrees for about 4 to 6 weeks, avoid deep loaded flexion and twisting for about 12 weeks, and delay running until about 4 to 5 months per surgeon
Meniscectomy	Usually faster progression; manage effusion closely
Bone-patellar tendon-bone autograft	Anterior knee pain and quadriceps deficit are common; emphasize extension ROM, patellar mobility and gradual open-chain loading
Quadriceps tendon autograft	Prolonged quadriceps strengthening and activation work; monitor thigh swelling and tendon site
Allograft	Consider a slower graft-loading progression and a later return to sport
Adolescent or skeletally immature athlete	Surgeon-specific guidance; high re-injury risk justifies the full 9 months or longer and strict test criteria
Concomitant ligament, cartilage or lateral extra-articular procedures	Follow the more conservative restrictions for that procedure

12. Monitoring, Load Management and Red Flags

Rehabilitation load should be monitored at each session and between sessions. Swelling, pain, ROM and next-day soreness guide progression, and training volume should not increase by more than about 10 to 20% per week.

Refer back to the surgeon promptly for: a fever or wound drainage, a hot, swollen, red calf or a calf that is painful (possible deep vein thrombosis), persistent loss of extension (more than about 5 degrees at 4 to 6 weeks), recurrent effusion, a mechanical block or locking, a sense of giving way, or a sudden pop with swelling.

13. After Return to Sport

Risk of a second injury remains elevated for at least 2 years. Athletes should continue heavy strength training at least twice weekly, maintain a neuromuscular injury-prevention program in their warm-up, retest strength and hop symmetry at 12 and 24 months, and manage load during the first competitive season. Regular follow-up should include checks for new swelling, pain, or loss of confidence.

14. References

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