

The Physical Root

ACL Reconstruction Exercise Library

Phase-matched exercise options for clinicians and rehabilitation professionals

Purpose

A companion to The Physical Root ACL Reconstruction Rehabilitation Protocol. This library presents exercise options only when they are generally appropriate for the stated time since surgery. Selection still depends on graft type, concomitant procedures, effusion, ROM, symptoms, strength, movement quality, and surgeon restrictions.

Library at a glance

Section	Typical timing	Contents
Readiness	Preoperative	Quiet-knee preparation and baseline capacity
Protection / activation	Day 0 to week 2	ROM, quadriceps activation, protected CKC, gait and trunk/hip
Foundational strength	Weeks 2 to 6	OKC/CKC progression, balance and kinetic-chain control
Progressive strength	Weeks 6 to 12	Machine/free-weight strength, unilateral control, proprioception
Running readiness	Weeks 12 to 16	Impact preparation, running drills and higher-load strength
Power / agility	Months 4 to 9	Plyometrics, deceleration, valgus correction and cutting preparation
Return / maintenance	Months 9 to 12+	Sport exposure, secondary prevention and lifelong strength

How exercises enter the library

- An exercise appears only in the earliest phase in which it is commonly appropriate, then may be continued or progressed in later phases.
- The stated window is a floor, not a deadline. If criteria are not met, remain with earlier options.
- Open-chain and closed-chain training are complementary. Isolated quadriceps loading is retained throughout recovery.
- Dynamic valgus correction is treated as a whole-body motor-control problem involving trunk, pelvis, hip, knee, ankle, task demand, and fatigue.
- A next-day joint response matters more than expected muscular soreness.

1. Selection rules, precautions, and dosage

Before selecting an exercise

- Verify graft source and all concomitant procedures from the operative report.
- Confirm weight-bearing, brace, ROM, loaded-flexion, hamstring, impact, and pivoting restrictions.
- Check extension, flexion, effusion, pain, warmth, gait, and current exercise response.
- Use the ACL protocol progression criteria before advancing to the next phase.

Traffic-light response rule

Response	Interpretation	Action
Green	No joint pain increase; no new warmth or swelling; ROM and gait unchanged the next day	Maintain or progress one variable.
Yellow	Mild symptoms that settle by next morning; transient technique decline late in a set	Repeat same dose, reduce range/load, or increase rest.
Red	Increasing effusion; extension loss; joint pain lasting into next day; buckling; locking; wound or calf concern	Stop progression, regress, reassess, and communicate when indicated.

General dosage bands

Training target	Typical starting dose	Progression
Activation / motor control	5-10 repetitions or 5-10 second holds; multiple brief sessions daily	Improve contraction quality before adding fatigue.
Strength endurance	2-4 sets of 8-15 repetitions; RPE about 5-7/10	Add load when 2-3 repetitions remain in reserve with stable knee response.
Maximum strength	3-5 sets of 3-8 repetitions; RPE about 7-9/10 in later phases	Use only after adequate healing, technique, and objective readiness.
Balance / proprioception	2-4 bouts of 20-45 seconds or 5-10 reaches	Reduce support, narrow base, add reach/perturbation, then add dual task.
Plyometric / agility	Low contacts first; full recovery between quality sets	Progress amplitude, speed, direction, reactivity, and fatigue separately.

Non-negotiable

Do not progress strengthening intensity with increasing effusion or loss of extension. Do not use this library to override a meniscal, cartilage, multi-ligament, osteotomy, or revision-specific restriction.

2. Preoperative readiness library

Typical window: before surgery. Goal: enter surgery with a quiet knee, full extension, minimal effusion, strong quadriceps activation, and realistic expectations.

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Heel prop / ROM	Preoperative	Restore passive extension; heel supported, knee unsupported, relaxed breathing.	Add low-load duration; avoid aggressive pain.
Prone hang / ROM	Preoperative	Extension mobility when tolerated; patella just off table.	Increase duration, not force.
Heel slide / ROM	Preoperative	Flexion recovery; keep heel supported and avoid hip hiking.	Progress range with stable effusion.
Quad set / OKC activation	Preoperative	Maximal quadriceps recruitment; cue posterior knee toward surface.	Add NMES or biofeedback if activation is poor.
Straight-leg raise / OKC	Preoperative	Quadriceps endurance and hip flexor control; no lag.	Add light ankle load only with full control.
Sit-to-stand / CKC	Preoperative	Functional quadriceps and hip strength; symmetrical pressure.	Lower seat or add load.
Box squat / CKC	Preoperative	Squat mechanics and confidence; tripod foot, knee over midfoot.	Increase depth or external load.
Step-up / CKC	Preoperative	Stair capacity; level pelvis and controlled knee.	Increase step height gradually.
Bridge / posterior chain	Preoperative	Hip extensor capacity; ribs down, avoid lumbar extension.	Single-leg or externally loaded variation.
Calf raise / distal chain	Preoperative	Ankle plantar-flexor strength for gait and propulsion.	Single-leg and loaded progression.
Single-leg stance / proprioception	Preoperative	Baseline balance; level pelvis, soft knee.	Add reach or unstable surface.
Palof press / trunk	Preoperative	Anti-rotation control for whole-chain stability.	Increase lever arm or resistance.

Readiness target

Aim for full active/passive extension, trace-to-zero effusion, no straight-leg-raise lag, normalized gait, and quadriceps strength as close as practical to the uninvolved side before surgery.

3. Phase 1 library - protection and activation

Typical window: day 0 to week 2. Exercises below assume uncomplicated primary ACLR and must be modified for concomitant procedures.

ROM, swelling, and quadriceps activation

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Heel prop / ROM	Day 0	Restore extension; heel elevated, knee unsupported.	Longer low-load holds if extension is limited.
Prone hang / ROM	Days 2-7	Extension mobility if incision and comfort permit.	Use only gentle gravity load.
Assisted heel slide / ROM	Day 0	Flexion mobility within restrictions; strap or opposite leg assists.	Increase range without reactive swelling.
Patellar glide / mobility	Day 0-2	Maintain superior/inferior and medial/lateral mobility.	Continue until mobility is symmetrical.
Ankle pump / circulation	Day 0	Distal movement and calf pump; full comfortable range.	Frequent sets while activity is limited.
Quad set / OKC	Day 0	Quadriceps recruitment; visualize patellar lift and full knee straightening.	Add NMES or biofeedback.
NMES-assisted quad set / OKC	Day 0	Improve recruitment with visible contraction.	Increase tolerated intensity, not compensatory movement.
Straight-leg raise / OKC	When lag-free	Quadriceps/hip flexor control; brace per surgeon, knee fully straight.	Add repetitions before ankle load.
Short-arc knee extension / OKC	Days 3-14	Early isolated quadriceps; controlled terminal movement.	Progress range/load if effusion stable.
Low-load long-arc knee extension / OKC	Days 3-14	Isolated quadriceps through surgeon-approved range.	Begin unweighted or light cuff; monitor donor site.

Phase 1 - protected weight bearing and kinetic chain

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Gait training / function	Day 0	Heel strike, knee extension in stance, appropriate device and brace use.	Wean device only with safe, non-antalgic gait.
Double-leg weight shift / CKC	Day 0-3	Graded weight acceptance and confidence.	Increase operative-side loading within restrictions.
Supported mini-squat / CKC	Days 3-14	Co-contraction and early squat pattern; shallow depth.	Increase depth only with control and stable effusion.
Elevated sit-to-stand / CKC	Days 3-14	Functional lower-extremity strength; use hands as needed.	Lower seat, reduce hand support.
Double-leg calf raise / CKC	Days 3-14	Calf pump and gait capacity; even pressure.	Increase repetitions, then bias operative limb.
Glute set / hip	Day 0	Hip extensor activation without knee load.	Transition to bridge.
Bridge / posterior chain	Days 3-14	Hip extension and trunk control; avoid hamstring cramp.	Longer holds or band at knees.
Sidelying hip abduction / OKC	Day 0-3	Hip abductor strength; pelvis stacked, leg slightly behind.	Add band/ankle load.
Prone hip extension / OKC	Day 0-3	Gluteal strength; avoid lumbar extension.	Add knee-bent variation if graft permits.
Adductor squeeze / hip	Day 0-3	Adductor and pelvic control; gentle isometric.	Progress hold time.
Dead bug - arms only / trunk	Days 3-14	Trunk control without lower-limb demand.	Add heel slide when safe.
Staggered stance balance / proprioception	Days 3-14	Early sensory reweighting with hand support.	Reduce hand support or narrow stance.

Phase 1 exit emphasis

Full or near-full passive extension, flexion progressing, stable trace-to-1+ effusion, lag-free straight-leg raise, and safe gait with the prescribed device.

4. Phase 2 library - foundational strength

Typical window: weeks 2 to 6. Begin only when Phase 1 criteria are met and loaded-flexion restrictions allow.

Open-chain and machine options

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Long-arc knee extension / OKC	Weeks 2-6	Isolated quadriceps; protected 90-45 degrees when conservative pathway is needed.	Progress toward full ROM and add cuff weight.
Knee extension machine / OKC	Weeks 2-6	Quantifiable quadriceps loading; controlled tempo.	Increase load 5-10% with stable effusion.
Isometric knee extension / OKC	Weeks 2-6	High recruitment at selected angle; useful when motion is irritable.	Add angles and total contraction time.
Straight-leg raise with load / OKC	Weeks 2-6	Quadriceps endurance; no lag or pelvic rotation.	Increase ankle load or repetitions.
Seated hamstring curl / OKC	Weeks 2-6 if cleared	Knee-flexor strength; lighter/delayed after hamstring graft.	Increase range and load by donor-site response.
Standing hip abduction / OKC	Weeks 2-6	Frontal-plane hip strength and stance control.	Add band, cable, or reduced hand support.
Standing hip extension / OKC	Weeks 2-6	Gluteal strength without deep knee flexion.	Add cable/band resistance.
Hip adduction machine / OKC	Weeks 2-6	Adductor capacity for frontal-plane control.	Increase load while pelvis remains stable.
Seated soleus raise / OKC	Weeks 2-6	Soleus strength for stance and deceleration.	Add external load.
Tibialis raise / OKC	Weeks 2-6	Dorsiflexor capacity and foot clearance.	Increase lever arm or load.

Phase 2 - closed chain, balance, and valgus correction

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Leg press / CKC	Weeks 2-6	Quadriceps/hip strength in permitted ROM; equal pressure.	Increase ROM, then load.
Goblet box squat / CKC	Weeks 2-6	Squat pattern; tripod foot and knee over second/third toe.	Lower box or add load.
Wall squat / CKC	Weeks 2-6	Quadriceps endurance with controlled depth.	Longer hold or lower position.
Low step-up / CKC	Weeks 2-6	Concentric strength and stair control.	Increase height or external load.
Supported split squat / CKC	Weeks 3-6	Unilateral loading; vertical trunk, controlled front knee.	Reduce support, increase depth.
Bridge with band / posterior chain	Weeks 2-6	Hip extension plus abductor engagement.	Loaded or single-leg bridge.
Hip hinge with dowel / kinetic chain	Weeks 2-6	Teach posterior-chain strategy; neutral trunk, shins near vertical.	Add kettlebell RDL.
Lateral band walk / valgus correction	Weeks 2-6	Hip abductor endurance; toes forward, pelvis level.	Heavier band or longer steps.
Band-resisted squat / valgus feedback	Weeks 2-6	External cue for knee-over-foot alignment.	Reduce cue as control becomes automatic.
Single-leg stance / proprioception	Weeks 2-6	Static balance; soft knee, level pelvis.	Add reach, head turn, or foam.
Tandem stance with perturbation / proprioception	Weeks 2-6	Reactive trunk/hip/ankle control.	Progress toward single-leg perturbation.
Palof press / trunk	Weeks 2-6	Anti-rotation control linked to lower-extremity alignment.	Increase lever arm, resistance, or split stance.

Valgus coaching

Use external cues such as “center the knee over the middle toes,” mirror/video feedback, and target-based reaches. Correct the foot, pelvis, trunk, and task demand rather than cueing the knee alone.

5. Phase 3 library - progressive strength

Typical window: weeks 6 to 12. Add load only with full extension, stable minimal effusion, and controlled foundational tasks.

Quadriceps and posterior-chain strength

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Full-ROM knee extension / OKC	Weeks 6-12	Primary isolated quadriceps strength/hypertrophy tool.	Progress sets, load, and eccentric control.
Eccentric knee extension / OKC	Weeks 6-12	Quadriceps eccentric capacity; assist up, control down.	Increase load or slower lowering.
Single-leg leg press / CKC	Weeks 6-12	Unilateral quadriceps/hip strength.	Increase range then load.
Front-foot elevated split squat / CKC	Weeks 6-12	Knee-dominant unilateral loading.	Increase depth, load, or reduce support.
Reverse lunge / CKC	Weeks 6-12	Unilateral control with lower braking demand than forward lunge.	Add load or deficit.
Step-down / CKC	Weeks 6-12	Eccentric quadriceps and frontal-plane control.	Increase step height or load.
Romanian deadlift / posterior chain	Weeks 6-12	Hip extensors/hamstrings; hinge without knee collapse.	Add load, then single-leg.
Hip thrust / posterior chain	Weeks 6-12	Hip extensor maximum strength.	Add barbell/load or unilateral bias.
Hamstring curl machine / OKC	Weeks 6-12 if cleared	Knee-flexor strength across range.	Progress load/tempo; monitor hamstring graft site.
Nordic hamstring - assisted / OKC	Weeks 8-12 if cleared	High-force eccentric hamstring preparation.	Reduce assistance gradually.
Standing calf raise - single leg / CKC	Weeks 6-12	Gastrocnemius strength and propulsion.	Add load and full excursion.
Seated soleus raise - loaded / OKC	Weeks 6-12	Soleus capacity for running/deceleration.	Progress toward heavy sets.

Phase 3 - proprioception and kinetic-chain control

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Star reach / proprioception	Weeks 6-12	Dynamic balance and multi-directional control.	Increase reach distance or reduce visual input.
Y-Balance pattern / proprioception	Weeks 6-12	Standardized reach control; pelvis level, stance knee centered.	Increase reach symmetry and consistency.
Single-leg ball toss / proprioception	Weeks 6-12	Reactive balance with visual/manual challenge.	Change surface, direction, or ball speed.
Single-leg stance perturbation / proprioception	Weeks 6-12	Reactive stabilization through ankle, knee, hip, trunk.	Increase unpredictability.
Lateral step-down / valgus correction	Weeks 6-12	Eccentric control; prevent pelvic drop, foot collapse, knee drift.	Increase height or external load.
Single-leg RDL / kinetic chain	Weeks 6-12	Hip-dominant unilateral control; square pelvis.	Add contralateral load or reach.
Rear-foot elevated split squat / CKC	Weeks 8-12	Unilateral strength and pelvic control.	Increase load or range.
Hip airplane - supported / valgus correction	Weeks 8-12	Rotational hip/pelvic control over stance limb.	Reduce hand support.
Copenhagen plank - short lever / kinetic chain	Weeks 8-12	Adductor and trunk capacity for frontal-plane control.	Long lever or dynamic repetitions.
Side plank with hip abduction / kinetic chain	Weeks 8-12	Lateral trunk and hip abductor capacity.	Long lever or band resistance.
Farmer carry / kinetic chain	Weeks 6-12	Whole-body stiffness and gait control.	Heavier or suitcase carry.
Sled drag - backward / CKC	Weeks 8-12	Quadriceps loading with controllable range and low eccentric demand.	Increase load or distance.

Movement-quality rule

A “perfect knee” is not required on every repetition. Look for a consistent strategy that keeps the center of mass controlled, the foot engaged, the pelvis/trunk organized, and the knee from collapsing under load or fatigue.

6. Phase 4 library - running readiness

Typical window: weeks 12 to 16. Impact exercises require full ROM, trace-to-zero effusion, no daily-activity pain, adequate strength, and controlled single-leg loading.

Impact preparation and running drills

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Pogo - bilateral / plyometric	Weeks 12-16	Ankle stiffness and low-amplitude impact; quiet, rhythmic contacts.	Increase contacts, then amplitude.
Jump rope - bilateral / plyometric	Weeks 12-16	Rhythm, stiffness, and conditioning.	Longer bouts or alternating feet.
Snap-down / landing	Weeks 12-16	Rapid athletic landing position; hips back, knee over foot.	Add arm swing or small drop.
Squat jump and stick / plyometric	Weeks 12-16	Concentric power plus landing control.	Repeated jumps or greater height.
Box jump - low / plyometric	Weeks 12-16	Power with reduced landing height; step down.	Increase box gradually.
Marching drill / running skill	Weeks 12-16	Posture, hip flexion, foot strike, arm rhythm.	A-march then A-skip.
A-skip / running skill	Weeks 12-16	Elastic coordination and front-side mechanics.	Increase speed or distance.
Wall acceleration drill / running skill	Weeks 12-16	Body angle and hip drive without full-speed running.	Single exchange to rapid exchanges.
Walk-jog intervals / conditioning	Weeks 12-16 when cleared	Graded running exposure on level surface.	Increase running time before speed.
Tempo treadmill run / conditioning	After walk-jog tolerance	Steady aerobic running at submaximal pace.	Increase duration, then pace.
Heavy knee extension / OKC	Weeks 12-16	Quadriceps maximum strength; standardized setup.	Use RPE/RIR or tested load.
Heavy split squat / CKC	Weeks 12-16	Unilateral maximum strength and trunk/pelvic control.	Increase load while maintaining depth/control.

Suggested running entry

Full ROM, trace-to-zero effusion, stable lifting response, controlled repeated single-leg squat/step-down, and quadriceps strength approximately 80% or greater, interpreted with absolute strength and graft type.

7. Phase 5 library - power and multidirectional control

Typical window: months 4 to 6. Begin after successful running progression and adequate bilateral landing control.

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Countermovement jump / plyometric	Months 4-6	Vertical power and bilateral force sharing.	Increase intent; monitor asymmetry.
Broad jump and stick / plyometric	Months 4-6	Horizontal force and landing control.	Repeated broad jumps.
Lateral bound and stick / plyometric	Months 4-6	Frontal-plane force acceptance.	Increase distance, then continuous bounds.
Drop landing - low box / landing	Months 4-6	Deceleration mechanics; quiet landing and stable trunk.	Increase box height modestly.
Single-leg hop and stick / plyometric	Months 4-6	Unilateral landing control.	Increase distance or add direction.
Split squat jump / plyometric	Months 4-6	Unilateral power and scissoring control.	Repeated contacts or added arm action.
Medicine-ball throw with squat / kinetic chain	Months 4-6	Whole-body power while preserving lower-limb alignment.	Increase ball speed/load.
Forward deceleration 3-to-2 step / agility	Months 4-6	Braking strategy and trunk control.	Shorter stopping distance.
Lateral shuffle to stick / agility	Months 4-6	Frontal-plane braking and stance control.	Increase entry speed.
Figure-8 run / agility	Months 4-6	Curved running and gradual directional loading.	Tighter radius or faster speed.
Resisted sled push / CKC	Months 4-6	Horizontal force and conditioning.	Increase load or speed.
Heavy single-leg press / CKC	Months 4-6	Unilateral strength reserve.	Progress toward 3-6RM sets when appropriate.

8. Phase 6 library - agility and sport preparation

Typical window: months 6 to 9. Requires strong running tolerance, adequate strength, quality hopping, and no reactive effusion.

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Repeated single-leg hops / plyometric	Months 6-9	Elastic unilateral capacity and stiffness.	Increase distance, speed, or contacts.
Triple hop progression / plyometric	Months 6-9	Horizontal power/endurance; control final landing.	Add timed or crossover variation.
Crossover hop progression / plyometric	Months 6-9	Frontal/transverse plane control.	Increase distance without knee collapse.
Depth jump / plyometric	Months 6-9	Rapid stretch-shortening cycle; requires advanced readiness.	Increase intent before height.
45-degree cut - planned / agility	Months 6-9	Controlled change of direction; lower center of mass.	Increase approach speed.
90-degree cut - planned / agility	Months 6-9	Higher braking and redirection demand.	Add reactive cue only after planned control.
Reactive shuffle / agility	Months 6-9	Perception-action coupling and lateral response.	Increase cue complexity.
Mirror drill / agility	Months 6-9	Reactive movement and whole-body control.	Increase duration or area.
Acceleration-deceleration intervals / conditioning	Months 6-9	Sport-relevant speed changes.	Increase peak speed or reduce recovery.
Lateral hurdle series / plyometric	Months 6-9	Repeated frontal-plane contacts.	Single-leg or reactive sequence.
Single-leg landing with perturbation / valgus	Months 6-9	Maintain alignment under external challenge.	Increase perturbation timing/force.
Fatigue-state landing retraining / motor control	Months 6-9	Preserve mechanics after conditioning.	Add only after pristine nonfatigued control.

Valgus correction under speed

Do not chase the knee alone. Manipulate approach speed, stopping distance, trunk position, hip strategy, foot placement, visual target, task predictability, and fatigue. Use video replay and external targets.

9. Phase 7 library - return to sport and maintenance

Typical window: months 9 to 12+ after objective clearance. Allograft and complex pathways often require longer.

Exercise / classification	Earliest typical window	Purpose and key cues	Advance / modify when
Noncontact practice progression / exposure	Months 9-12+	Restore sport-specific volume without contact.	Increase duration, intensity, and drill density.
Small-sided practice / exposure	Months 9-12+	High decision density with controlled area/player count.	Increase space, speed, or contact.
Full practice - restricted volume / exposure	Months 9-12+	Integrate team demands while controlling workload.	Increase weekly participation gradually.
Competition - restricted workload / exposure	Months 9-12+	Initial competition exposure with planned minutes/ reps.	Advance only without symptoms or compensation.
Competition - unrestricted / exposure	Months 9-12+	Full role after successful graded exposure.	Maintain strength and prevention program.
Heavy knee extension / OKC	Months 9-12+	Maintain isolated quadriceps strength.	Periodic testing and progressive overload.
Heavy squat / CKC	Months 9-12+	Bilateral maximum strength and whole-body capacity.	Cycle strength and power blocks.
Heavy unilateral strength / CKC	Months 9-12+	Maintain side-to-side capacity and control.	Split squat, step-up, single-leg press variations.
Nordic hamstring / OKC	Months 9-12+	Eccentric hamstring capacity for sprinting.	Progress assistance, range, and volume.
Copenhagen plank / kinetic chain	Months 9-12+	Adductor/trunk capacity for field and court sport.	Long lever and dynamic variations.
FIFA 11+ style prevention / secondary prevention	Months 9-12+	Neuromuscular warm-up and reinjury reduction behaviors.	At least twice weekly in season.
Periodic hop / strength reassessment	Months 9-12+	Detect loss of capacity and guide maintenance.	Test pre-season and during workload transitions.

Return is an exposure continuum

Clearance is not the end of rehabilitation. Continue progressive strength training and a secondary prevention program at least twice weekly throughout the athletic career.

10. Dedicated open-chain exercise library

Open-chain exercises isolate or emphasize a segment with the distal end relatively free. They are essential for directly restoring quadriceps, hamstring, hip, and ankle capacity.

Exercise	Earliest typical window	Primary target	Key modification
Quad set	Day 0	Quadriceps activation	NMES/biofeedback as needed.
Straight-leg raise	Lag-free, usually week 0-2	Quadriceps/hip flexor	Do not add weight with lag.
Short-arc knee extension	Week 0-2	Quadriceps	Control terminal range.
Long-arc knee extension	Week 0-2 low load	Quadriceps	Protected 90-45 or full ROM per pathway.
Knee extension machine	Weeks 2-6	Quadriceps strength	Progress range, then load.
Isometric knee extension	Weeks 2-6	Angle-specific quadriceps force	Use multiple angles.
Eccentric knee extension	Weeks 6-12	Quadriceps eccentric force	Assist concentric phase if needed.
Seated hamstring curl	Weeks 2-6 if cleared	Hamstrings	Delay/heavily modify after hamstring graft.
Prone hamstring curl	Weeks 6-12 if cleared	Hamstrings	Monitor harvest site.
Nordic hamstring assisted	Weeks 8-12 if cleared	Eccentric hamstrings	Reduce assistance gradually.
Hip abduction/adduction machine	Weeks 2-6	Frontal-plane hip strength	Avoid pelvic compensation.
Cable hip flexion/extension	Weeks 2-6	Hip force production	Control trunk.
Seated soleus raise	Weeks 2-6	Soleus	Progress heavy for running.
Tibialis raise	Weeks 2-6	Dorsiflexors	Progress lever/load.

OKC principle

The question is not “Is knee extension safe?” The clinical questions are: which range, what load, which graft/donor site, what dosage, and how did the knee respond over 24 hours?

11. Dedicated closed-chain exercise library

Closed-chain exercises integrate multiple joints and are highly scalable. They should complement, not replace, isolated quadriceps testing and loading.

Exercise	Earliest typical window	Primary target	Progression
Weight shift	Day 0	Weight acceptance	Reduce hand support.
Supported mini-squat	Days 3-14	Co-contraction/squat pattern	Increase depth.
Sit-to-stand	Days 3-14	Functional strength	Lower seat/add load.
Leg press	Weeks 2-6	Quadriceps/hip strength	Range then load.
Goblet box squat	Weeks 2-6	Squat mechanics	Lower box/add load.
Step-up	Weeks 2-6	Concentric unilateral strength	Height then load.
Supported split squat	Weeks 3-6	Unilateral control	Reduce support/deepen.
Step-down	Weeks 6-12	Eccentric quadriceps	Height/load.
Reverse lunge	Weeks 6-12	Unilateral control	Deficit/load.
Rear-foot elevated split squat	Weeks 8-12	Unilateral maximum strength	Load/range.
Single-leg leg press	Weeks 6-12	Unilateral strength	Load and deeper ROM.
Sled drag backward	Weeks 8-12	Quadriceps work capacity	Load/distance.
Sled push	Months 4-6	Horizontal force	Load/speed.
Heavy squat	Months 4-6	Maximum strength	Periodized strength.

Closed-chain depth modifiers

- Respect loaded-flexion restrictions after meniscal or cartilage procedures.
- Increase depth only while the knee response remains green and the movement strategy remains controlled.
- Select heel elevation, box height, stance, or external load placement to match the goal and available mobility.

12. Dedicated proprioception and dynamic valgus library

Proprioception progression

Exercise	Earliest typical window	Progression sequence
Staggered stance balance	Days 3-14	Hand support -> no support -> head turn.
Single-leg stance	Weeks 2-6	Firm -> foam -> eyes closed.
Star reach / Y-Balance pattern	Weeks 6-12	Reach distance -> load -> speed.
Ball toss in single-leg stance	Weeks 6-12	Predictable -> unpredictable direction.
Perturbation balance	Weeks 6-12	Trunk/limb perturbation -> reactive step.
Landing perturbation	Months 6-9	Predictable -> unpredictable external challenge.

Dynamic valgus correction progression

Exercise	Earliest typical window	Primary correction target
Band-resisted squat	Weeks 2-6	Knee-over-foot awareness and hip engagement.
Lateral band walk	Weeks 2-6	Hip abductor endurance and pelvis control.
Lateral step-down	Weeks 6-12	Pelvic drop, foot collapse, knee drift.
Single-leg RDL	Weeks 6-12	Hip rotation, trunk and stance-foot control.
Hip airplane	Weeks 8-12	Rotational pelvis control.
Single-leg hop and stick	Months 4-6	Frontal-plane landing control.
Lateral bound and stick	Months 4-6	Lateral force acceptance.
Planned cut with targets	Months 6-9	Foot placement, trunk angle and braking strategy.
Reactive cut	Months 6-9	Perception-action control under uncertainty.
Fatigue-state landing	Months 6-9	Retention of strategy under workload.

Coaching hierarchy

1) Reduce task difficulty. 2) Use an external target or video. 3) Adjust foot placement and trunk strategy. 4) Add hip/trunk strength where a capacity deficit exists. 5) Rebuild speed and fatigue only after control improves.

13. Dedicated whole-kinetic-chain and conditioning library

Region / goal	Exercise options	Earliest typical window
Trunk anti-extension	Dead bug, plank, body saw progression	Days 3-14 for basic variations
Trunk anti-rotation	Pallof press, cable hold, suitcase carry	Weeks 2-6
Lateral trunk	Side plank, side plank with hip abduction	Weeks 2-6
Hip extension	Bridge, hip thrust, RDL, single-leg RDL	Day 3 to week 12 progression
Hip abduction/adduction	Sidelying abduction, lateral walk, machine work, Copenhagen plank	Day 0 to week 12 progression
Calf / soleus	Double/single-leg calf raise, seated soleus, pogo progression	Day 3 to week 12 progression
Foot / ankle control	Short-foot drill, tibialis raise, ankle inversion/eversion	Weeks 2-6
Carry / gait integration	Farmer carry, suitcase carry, rack carry	Weeks 6-12
Aerobic base	Walking, bike, pool after wound clearance, elliptical	Day 0 to week 12 progression
Running / sprint base	Walk-jog, tempo run, acceleration intervals	Weeks 12-16 to month 6 progression

Conditioning progression

- Weeks 0-2: frequent short walks within gait and weight-bearing limits.
- Weeks 2-6: stationary cycling when ROM and wound status allow; upper-body ergometry if safe.
- Weeks 6-12: longer bike intervals, elliptical, pool after wound clearance, and progressive walking.
- Weeks 12-16: criterion-based walk-jog progression.
- Months 4-6: tempo running, acceleration/deceleration intervals, and sport-relevant aerobic work.
- Months 6-12+: repeated-sprint ability, practice conditioning, and workload exposure.

Entire-chain principle

The knee is the local tissue under rehabilitation, but performance depends on trunk control, pelvic strategy, hip force, ankle stiffness, foot control, aerobic capacity, confidence, and sport-specific decision making.

14. Phase-matched programming examples

These are examples, not mandatory templates. Choose the smallest effective set of exercises that addresses the examination findings.

Phase	Example session menu
0-2 weeks	Heel prop; heel slide; quad set + NMES; lag-free SLR; weight shift; supported mini-squat; bridge; calf raise; gait practice.
2-6 weeks	Bike; knee extension; leg press; goblet box squat; low step-up; supported split squat; lateral band walk; single-leg stance; Pallof press.
6-12 weeks	Knee extension machine; single-leg leg press; split squat; step-down; RDL; hamstring curl; soleus raise; Y-Balance reach; side plank.
12-16 weeks	Heavy knee extension; heavy split squat; single-leg RDL; calf/soleus; pogos; snap-down; A-skip; walk-jog intervals.
4-6 months	Heavy strength; broad jump; lateral bound; single-leg hop and stick; low drop landing; planned deceleration; figure-8 run.
6-9 months	Strength maintenance; repeated hops; crossover hops; planned then reactive cuts; mirror drill; acceleration/deceleration; fatigue-state landing.
9-12+ months	Heavy quadriceps and whole-chain strength; secondary prevention; graded practice; restricted competition; periodic testing.

Weekly loading architecture

- Early phases: short daily ROM/activation with 2-3 supervised strength exposures weekly.
- Middle phases: 2-4 strength sessions weekly, alternating high and moderate loads.
- Impact phases: separate high-intensity jump/cut days with adequate recovery.
- Return phases: coordinate rehabilitation, gym, practice, conditioning, and competition so total workload rises gradually.

What to retain long term

- Isolated knee extension and objective quadriceps testing.
- Heavy bilateral and unilateral strength.
- Hamstring, calf/soleus, hip, adductor, and trunk training.
- Landing, deceleration, and change-of-direction skill.
- A secondary prevention warm-up at least twice weekly.

Progress one variable

Change load, range, speed, volume, complexity, or fatigue exposure one at a time whenever possible. This makes the knee response interpretable.

15. Evidence and protocol synthesis

This original exercise library is designed as a companion to The Physical Root ACL Reconstruction Rehabilitation Protocol. It synthesizes recurring exercise categories and progression principles from major academic protocols and contemporary ACL rehabilitation literature.

Primary source families

Source family	Contributions reflected
University of Delaware / Delaware Physical Therapy Clinic and Brinlee et al.	Immediate quadriceps loading, objective strength testing, effusion/soreness rules, criterion-based running and delayed return to sport.
Perriman et al. 2018 systematic review	Evidence comparing early/late open- and closed-chain exercise, including graft- and range-specific caution.
Massachusetts General Hospital ACL reconstruction protocol	Phase structure, exercise progression, graft/concomitant procedure precautions, running and return criteria.
The Ohio State University Wexner Medical Center ACLR guideline	Clinical decision rules, progressive loading, proprioception, running, agility and testing.
JOSPT/APTA knee ligament and injury-prevention guidance	Objective outcomes, neuromuscular training, movement quality, psychological readiness and secondary prevention.
Contemporary strength and conditioning principles	RPE/RIR dosing, progressive overload, kinetic-chain development, plyometrics, agility and workload management.

Important interpretation note

Institutional protocols differ in open-chain initiation, knee-extension range, weight bearing, brace use, loaded knee flexion, hamstring loading, running, plyometrics, and return-to-sport timing. Graft type and concomitant meniscal, cartilage, ligament, or osteotomy procedures can materially change exercise eligibility. The operative report and direct surgeon instructions take precedence.

MEDICAL AND LEGAL DISCLAIMER

For Educational and Informational Purposes Only	This exercise library is provided by The Physical Root for general educational and professional informational purposes only. It is not medical advice, diagnosis, treatment, a prescription, a guarantee of outcome, or a substitute for evaluation by a qualified healthcare professional.
No Professional Relationship	Accessing or using this document does not create a clinician-patient, therapist-patient, or other professional relationship with The Physical Root.
Notice to Clinicians	Procedures, grafts, fixation, associated procedures, patient status, surgeon preferences, precautions, and recovery vary. The treating clinician must independently evaluate the patient, use professional judgment, practice within applicable laws and standards, and follow the operative report, surgeon instructions, facility policy, and current evidence.
Notice to Patients	Do not begin, stop, or modify exercise, medication, wound care, brace or device use, or restrictions based solely on this document. Consult your treating physician or physical therapist.
Medical Emergencies	Seek urgent or emergency care for concerning symptoms, including chest pain, difficulty breathing, fainting, suspected blood clot, fever with wound changes, rapidly increasing swelling, new neurological symptoms, acute deformity or loss of function, or severe/unremitting pain.
Limitation of Liability & Non-Endorsement	To the fullest extent permitted by law, The Physical Root and contributors disclaim liability for loss, injury, or damages arising from use or misuse. No exercise library eliminates all risk. Named external institutions have not reviewed, endorsed, sponsored, or approved this derivative document; names identify educational source frameworks only.