LOTHIAN PHYSIOTHERAPY ORTHOPAEDIC GUIDELINES
Anterior Cruciate Ligament Reconstruction (ACLR)

Introduction
Surgery: Medial para-patella incision in proximal tibia for graft harvest, usually four strand medial hamstrings, central bone-patella-bone (B-PT-B) or quadriceps tendon (QT) graft.
Indications for surgery: Unstable knee, return to pivoting sport.
Expected length of stay: Day case
Surgeons: Mr J. Keating, Mr G. Lawson, Mr T. White, Mr I. Murray, Mr C. Arthur

Scope of practice
These updated guidelines were produced by a process of systematic review of the current research literature and expert opinion. They are designed to provide an evidenced based framework to guide physiotherapists when treating patients following this surgical procedure. The guidelines should be used in conjunction with the clinical reasoning skills of the physiotherapist and be based on the patient's goals.

Aim
The aim of these guidelines is to provide physiotherapy staff with a series of recommendations from the current evidence base to assist them in the management of patients who have undergone Anterior Cruciate Ligament Reconstruction (ACLR) surgery.

Literature review question
What is a safe and effective rehabilitation programme following ACL reconstruction from day of surgery to return to function and sport?

Search Process
Dates to be searched: Sept 2013 – November 2022.
Library search: The Knowledge network
Databases: MEDLINE, Cochrane, Embase, Google Scholar, AMED, Sport Discus, CINAHL, Pedro, Pubmed.
Hand search: British Journal of Sports medicine
Limitations: English language

Literature search:

Patient / population MeSH heading	**AND**	**Intervention keywords**	**AND**	**Outcome keywords**
Anterior Cruciate Ligament Reconstruction		Rehabilitation OR		Functional outcome OR
		Physical therap* OR		Return to sport* OR
		Exercise program* OR		Graft failure OR
		Strength train* OR		Reinjury OR

		Neuromuscular train* OR		Running
		Proprioception train* OR		
		Plyometric train*		

Title and abstract reviewed to assess relevance to research question.

Appraisal process:
CASP RCT and SR appraisal tools used: 37
Total number of articles used: 38

Results:

Three high quality systematic reviews (SR's) broadly answered our review question and form the basis of these guidelines. One is a systematic review of systematic reviews of rehabilitation post ACLR (Culvenor et al., 2022). Two appraised all randomised controlled trials (RCTs) and practice guidelines (Van Melick et al., 2015. Andrade et al., 2020).
Many of the findings are based on low, to moderate quality evidence. This means the recommendations are often of low certainty and occasionally draw different conclusions from the same RCTs. More specific evidence included in this guideline was synthesised either from systematic reviews or RCTs looking at single treatment approaches, like strength training, or single outcomes such as risk of re-injury. There has been minimal high quality original research since the last guideline to dramatically change the specific components of ACLR rehabilitation.
To answer the research question, it is not clear what the optimal components of rehabilitation are post ACLR and some recommendations may be challenging to apply into certain clinical settings. There is also no conclusive evidence on what measurements and assessments should be used to guide return to running and training, or the criteria used to determine when to safely return to sport (Van Melick et al., 2015, Kotisfaki et al., 2022).
Where original research is lacking recommendations are drawn from expert consensus locally and in new clinical guidelines (Brinlee et al., 2019, Kotisfaki et al., 2022).

<u>Updates from the articles reviewed:</u>

- New moderate certainty research on pre surgical rehabilitation (prehab) and neuromuscular electrical stimulation (NMES) has been included in the guideline.
- Developments in the guideline on predictors of outcome, assessment, return to play, and risk of re-injury.
- Minor changes to recommendations on early quadricep and hamstring loading are not based on any new high quality RCT's but differing interpretation of existing data in recent systematic reviews.
- Ongoing lack of research on females. They have poorer outcomes and are less likely to return to sport after ACLR.
- There is very little evidence on optimal loading, volume, intensity and dose-response relationship of exercise and outcomes.
- Very low certainty or contradictory evidence from multiple trials of new treatment approaches such as blood flow restriction training or cross

education training after ACLR were not included in this updated guidance but could be used in addition (Curran et al., 2020. Charles et al., 2020).
- There is low certainty evidence and therefore no recommendation on rehabilitation setting. National practice guidelines recommend a home-based setting *only* in specific groups of highly motivated patients (Andrade et al., 2019)

Key points

Preoperative**:**

- Pre op knee extension deficit and or quadriceps strength deficit greater than 20% predicts poor functional outcome 2 years after ACLR (Mansson, Krauss and Sernert 2013. Van Melick et al., 2015. Grindem et al., 2015).
- Prehabilitation aims to reduce the risk of postoperative complications (Culvenor et al., 2022).
- Prehabilitation leads to better self-reported knee function at 2 years post ACLR (Giesche et al., 2020).

Post operative:

- Knee extension range of motion deficit at 4 weeks predicts knee extension range deficit at 1 year (Van Melick et al., 2015).
- Strength training alone does not reduce risk of re-injury. Rehabilitation needs to include neuromuscular control exercises (Brinlee et al., 2021)
- Both Closed Kinetic Chain (CKC) and Open Kinetic Chain (OKC) are equally effective and should be included for regaining quadriceps strength (Gokeler et al., 2013. Jewiss, Osteman and Smart., 2017).
- Safe return to activity depends on a dedicated, sequentially phased rehabilitation routine for at least 9-12 months (Van Melick et al., 2015, Brinlee et al., 2021, Grindem et al., 2016, Kotsifaki et al., 2022).
- Rehabilitation should be appropriate to the individual and progression, readiness to return to sport and risk for reinjury measured by strength tests, hop tests, quality of movement and psychological tests (Czuppon et al 2012., Van Melick et al., 2015. Andrade et al., 2019. Brinlee et al., 2021)
- Objective measures of the knee are not associated with return to sport - 90% achieve normal knee function, 81% return to some form of sport, 65% to previous level of sport and 55% to competitive sport (Arden et al., 2016).
- Contextual factors of younger age, male gender, playing elite sport and positive psychological response favoured returning to preinjury sport (Arden et al., 2016)

Recommendations

Pre-operative rehabilitation:

Preoperative knee extension deficit and / or quadriceps strength deficit >20% predicts poor functional outcome 2 years after ACLR (Grindem et al., 2014).

Early to mid-stage: Resolve impairments.

Goals	Recommendations	Level of Evidence
Resolve joint effusion.	Sweep/stroke test	C
	P.O.L.I.C.E or PRICE principle	C
Restore range of motion.	Measure passive range of motion	A3
	Mobilisation or stretching techniques	A3

Mid to late stage: Return to activities and participation.

Proceed when the knee is 'quiet' and not swollen.

Precaution: If the patient has unchanging range of motion deficits or has accompanying symptomatic meniscus injuries during plyometric exercises (Grindem et al., 2014)

Goals	Recommendations	Level of Evidence
Regain strength >90% quadriceps and hamstrings	Progressive heavy resistance strength exercises	A3
	Including hamstrings quadriceps and hamstring strength measurement	A3
Regain neuromuscular function	Balance/stability/proprioceptive/ perturbation exercise.	A3
>90% hop performance	Muscle control and co-contraction exercise	A3
	Plyometric training e.g single leg hops	A3
	Hop testing.	A3
Regain self-efficacy.	Consider testing eg Knee self-efficacy scale (level 2)	A3
	Education on post operative rehabilitation process	C

Post operative rehabilitation:

Early-stage rehabilitation – surgical recovery

Immediate post-op period

Precautions: timescales are approximate and rehabilitation at this stage, is guided by reducing swelling, reducing pain, restoring range of motion and minimising muscle atrophy.

Outpatient physiotherapy to commence between 7-10 days post-surgery.

Goals	Recommendations	Level of Evidence
Decrease pain / swelling.	Use ICE to decrease pain in the 1st week.	A3
	Compress when active.	C
	Elevate when resting.	C
Increase ROM / avoid extension deficit.	Begin active ROM exercises.	A3
	Extension exercises,	A3
	avoiding forceful hyperextension.	C
Mobility	Immediate weight bearing as tolerated.	A3
	Correct gait pattern with crutches if necessary.	A3
	Monitor no increase pain/swelling/temperature during or after walking.	C
Improve muscle recruitment.	Commence static/isometric exercises	A3

Early to mid-stage rehabilitation – Impairment resolution

10 days to 12 weeks approximately.

Precautions: Rehabilitation at this stage is aimed at regaining basic knee function. Regaining range of motion, normal walking pattern, resolution of pain and minimal swelling. Consideration needs to be given to the graft type used and any increase in pain or swelling (Andrade et al., 2019. Van Melick et al., 2015).

Goals	Recommendations	Level of Evidence
Resolution or minimal pain / swelling	Numerical Rating Scale of pain	C
	Stroke / sweep test.	A3

Increase ROM / avoid extension deficit.	Mobilisation / range of motion techniques.	A3
	Strive to achieve full hyper extension.	A3
	Measure ROM e.g. goniometer or prone hang test.	A3
Improve quadriceps muscle recruitment, progressing to strength training.	Initial lower intensity loads while the knee is loading intolerant, swollen, painful or has muscle inhibition.	A3
	Consider adding Neuromuscular Electrical Stimulation (NMES) 2-6 sessions a week for up to two months if struggling to regain voluntary contraction.	A3
	CKC maybe preferable in 1st 4 weeks – reduced risk of patellofemoral pain.	A3
	CKC eccentric quads training from 3 weeks > improvement in strength than concentric e.g. step down.	A3
	OKC exercises may be started guided by pain and swelling. Gradually progress weight and / or range as tolerated.	C
Improve hamstring recruitment progressing to strength training principles.	<u>ACLR with hamstring graft:</u> Lower load and shorter muscle lengths may be preferable in the first 6 weeks to allow harvested graft recovery. e.g prone or standing leg curl, and bridges.	C
	From 6-8 weeks gradually progress load and range	C
	<u>ACLR with B-PT-B or QT graft:</u> Isokinetic hamstring training can be started gently from 3 weeks.	A3
Increase neuromuscular control and stability.	Begin stability and balance exercises to improve dynamic joint control.	A3
Progress strength of other lower limb muscle groups.	Both isolated and combined exercises.	A3
	Consider using NHS Lothian Lower Limb motor control screening – appendix A.	C

Include cardiovascular exercise.	E.g static bike.	C

<u>Mid to late-stage rehabilitation-</u> From basic knee function to high level function

Precautions: timescales are approximate and rehabilitation progress is guided by minimal swelling, resolution of pain, good muscle recruitment and no changes in ligament laxity on testing.

Encourage independence with a training program of the unaffected lower limb (Van Melick et al., 2015)**.**

Goals	**Recommendations**	**Level of Evidence**
Restore strength	Progressive isotonic, isokinetic, eccentric, and concentric strengthening all muscle groups.	A3
	Strength rehabilitation with training frequency 2-3 times a week	A1
	Test quadriceps and hamstring strength objectively, Ideally isokinetically.	A3
	Consider using Lothian lower limb motor control screening - appendix A.	C
Restore neuromuscular control.	Increase difficulty of neuromuscular training e.g. Single leg static to dynamic movements Forward, backward, and sideways movement Double leg jumping to single leg hopping.	A3
	Test movement quality and quantity	A3
Regain endurance and cardiovascular fitness.	Begin straight line running when knee non irritable, has adequate motion, functional stability, and strength.	A3

<u>Late stage to return to sport</u> - **Pivoting, change of direction, or contact sports.**

Precautions: Return to cutting, pivoting and contact sport should be delayed until a minimum of 9 months post operatively and once the patient can meet criteria outlined below (Grindem et al., 2016).

Goals	Recommendations	Level of Evidence
Begin functional or sports specific rehabilitation.	Progress to different intensities and speeds e.g acceleration/deceleration, change of direction and pivoting drills.	A3
	Increase difficulty of neuromuscular and perturbation training with emphasis on sports specific movements and tasks	A3
Confidence, self-efficacy, and fear of re-injury	Evaluate psychological changes with an objective measurement. e.g. Knee Self-efficacy Scale (K-SES level 2)	A3
Meet return to play criteria.	Perform extensive assessments of quantity and quality of movement, Including:	A3
	A strength test battery e.g. Isokinetic 3 speed test	A3
	Aiming >90% or ideally _>100% of unaffected limb for pivoting/contact sports	A3
	A hop test battery e.g. single, vertical, triple or quadruple cross over hop	A3
	Aiming >90% or ideally _>100% of unaffected limb for pivoting/contact sports	A3
	Consider using Lothian lower limb screening profile – appendix A.	C
	A measurement of movement quality e.g. drop jump test	A3
	Graded return to own sporting environment.	C

Criteria for return to functional and sporting activities.

Subjective measures of no knee irritability or instability on sport specific activities	C
Clinical measures: ROM, knee laxity, strength, hops and movement quality	A3
Patient reported outcome measures of knee function (IKDC and / or KOOS) and psychological readiness (TSK-11, ACL-RSI, K-SES)	A3

NHS Lothian

Lower Limb Motor Control Screening Profile

NAME: Diagnosis/Surgery & Date: Physio:

CHI: Body weight (kg): Height (m):

	Goal	Date:		Date:		Date:		Date:	
		Right	Left	Right	Left	Right	Left	Right	Left
1	Effusion								
2	Knee hyper-extension								
3	Weight-bearing dorsiflexion								
4	Single leg calf raise								
5	Single leg stance								
6	Side bridge								
7	Gluteus maximus								
8	Gluteus medius								
9	1RM OKC quads: Relative Strength (to BW) Index (RSI) Uninjured Limb Symmetry Index (ULSI)	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %
10	1RM leg press: Relative Strength (to BW) Index (RSI) Uninjured Limb Symmetry Index (ULSI)	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %	kg: % of BW: %
11	Hamstring-Quadriceps ratio								
12	Dynamic single leg ½ squat								
13	Functional hop tests: • single hop for distance • single vertical hop • triple hop for distance • quadruple cross over hop								

(Adapted from Nicholas Clark, Ultimate Knee Rehabilitation Course, December, 2008) – version 3 April 2011

Appendix A

ACLR guidelines July 2024 V5
Date for review: December 2029
Authors: Chris Walsh, Cormac Gallen and Andrew Baxter

LLMCSP Instructions and Reference Ranges

	Expected Value	
1 swelling	No effusion	Check sweep test – swelling inhibits quads function
2 hyper ext	Full pain free hyper-extension	Compare to other leg – optimises lower limb and quads function
3 WB DF	10-13cm toe to wall	Foot flat on ground, flex knee to touch wall. If insufficient range – knee will drift into valgus on running/jumping. Optimises shock absorption. Compare with normal side.
4 calf raise	25-33 reps	Test using fingertips on plinth (use scales to avoid too much weight bearing through hands). Rhythmical – use clock/metronome. Calf absorbs 30% of lower limb shock on impact. Consider what is normal for patient.
5 balance	≥ 45secs eyes open & closed	Balance – make note of quality if appropriate
6 side bridge	90 second hold	Elbow under shoulder for test (start with elbow slightly closer to body). Hips and thighs in line with body. Knees bent. Consider knees straight if patient high level. Make note
7 glut max	Prone lying grade 5	Manual muscle test hip extension in prone with knee flexion to 90°
8 glut med	90 second hold	Side lying, back to wall, hips at 45° and knees at 90°. Keep feet together. 'Clam shell', lift upper knee to maximum passive range.
9 OKC quads	10% of BW: kg 25% of BW: kg 30% of BW: kg **50% of BW: kg (normal)** ≥90%	Work out normal value first from pts body weight. Warm up x 10 reps at 25% of body weight. First trial at 30% of BW. Rest 120 secs in between trials. Increase by 10% BW each time. Repeat until failure ULSI = affected leg/unaffected leg x100 RSI = amount lifted/body weight x 100
10 leg press	25% of BW: kg 30% of BW: kg 50% of BW: kg 100% of BW: kg **>150% of BW: kg** (normal) ≥90%	Work out normal value first from pts body weight. Warm up x 10 reps at 50% of body weight. First trial at 100% BW. Rest 120 secs in between trials. Increase by 25% (females), 30% (males) each time. Repeat until failure. NB – Put other foot on wobble cushion on floor. ULSI = affected leg/unaffected leg x100 RSI = amount lifted/body weight x 100
11 H-Q ratio	60-70% (from Biodex)	Obtain from Biodex machine test results
12 dips	Aim 3x15 (good control)	Look for good quality movement – no valgus, no fatigue, good core stability etc Compare subjectively with unaffected leg
13 hop tests	116% of pts height : 10% of pts height : Limb symmetry 456% of pts height :	Uninjured limb symmetry index = injured/uninjured x 100 Relative Distance (to height) index (RDI)% = mean *vertical* or *horizontal* distance hopped/patients height x100 Risberg, MA, Ekeland, A (1994) Correlates to strength, stability & function. Often called triple jump test Must include vertical (more quads bias) and a horizontal hop (more gluts and calf bias, with functional ability esp cross over hop) Tests force production. Best of 3 tests

(Adapted from Nicholas Clark, Ultimate Knee Rehabilitation Course, December, 2008) – version 3 April 2011

ACLR guidelines July 2024 V5
Date for review: December 2029
Authors: Chris Walsh, Cormac Gallen and Andrew Baxter

References

Andrade, R., Pereira, R., van Cingel, R., Staal, J.B. and Espregueira-Mendes, J. (2019). How should clinicians rehabilitate patients after ACL reconstruction? A systematic review of clinical practice guidelines (CPGs) with a focus on quality appraisal (AGREE II). *British Journal of Sports Medicine*, 54(9), pp.512–519. doi:https://doi.org/10.1136/bjsports-2018-100310.

Ardern, C.L., Taylor, N.F., Feller, J.A. and Webster, K.E. (2014). Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *British Journal of Sports Medicine*, [online] 48(21), pp.1543–1552. doi:https://doi.org/10.1136/bjsports-2013-093398.

Brinlee, A.W., Dickenson, S.B., Hunter-Giordano, A. and Snyder-Mackler, L. (2021). ACL Reconstruction Rehabilitation: Clinical Data, Biologic Healing, and Criterion-Based Milestones to Inform a Return-to-Sport Guideline. *Sports Health: A Multidisciplinary Approach*, 14(5), p.194173812110568. doi:https://doi.org/10.1177/19417381211056873.

Buckthorpe, M., Danelon, F., La Rosa, G., Nanni, G., Stride, M. and Della Villa, F. (2020). Recommendations for Hamstring Function Recovery After ACL Reconstruction. *Sports Medicine*. doi:https://doi.org/10.1007/s40279-020-01400-x.

Charles, D., White, R., Reyes, C. and Palmer, D. (2020). A SYSTEMATIC REVIEW OF THE EFFECTS OF BLOOD FLOW RESTRICTION TRAINING ON QUADRICEPS MUSCLE ATROPHY AND CIRCUMFERENCE POST ACL RECONSTRUCTION. *International Journal of Sports Physical Therapy*, 15(6), pp.882–891. doi:https://doi.org/10.26603/ijspt20200882.

Culvenor, A.G., Girdwood, M.A., Juhl, C.B., Patterson, B.E., Haberfield, M.J., Holm, P.M., Bricca, A., Whittaker, J.L., Roos, E.M. and Crossley, K.M. (2022). Rehabilitation after anterior cruciate ligament and meniscal injuries: a best-evidence synthesis of systematic reviews for the OPTIKNEE consensus. *British Journal of Sports Medicine*. [online] doi:https://doi.org/10.1136/bjsports-2022-105495.

Curran, M.T., Bedi, A., Mendias, C.L., Wojtys, E.M., Kujawa, M.V. and Palmieri-Smith, R.M. (2020). Blood Flow Restriction Training Applied With High-Intensity Exercise Does Not Improve Quadriceps Muscle Function After Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial. *The American Journal of Sports Medicine*, 48(4), pp.825–837. doi:https://doi.org/10.1177/0363546520904008.

Czuppon, S., Racette, B.A., Klein, S.E. and Harris-Hayes, M. (2014). Variables associated with return to sport following anterior cruciate ligament reconstruction: a systematic review. *British Journal of Sports Medicine*, [online] 48(5), pp.356–364. doi:https://doi.org/10.1136/bjsports-2012-091786.

Everhart, J.S., Best, T.M. and Flanigan, D.C. (2015). Psychological predictors of anterior cruciate ligament reconstruction outcomes: a systematic review. *Knee Surgery, Sports Traumatology, Arthroscopy*, [online] 23(3), pp.752–762. doi:https://doi.org/10.1007/s00167-013-2699-1.

Fukuda, T.Y., Fingerhut, D., Moreira, V.C., Camarini, P.M.F., Scodeller, N.F., Duarte, A., Martinelli, M. and Bryk, F.F. (2013). Open Kinetic Chain Exercises in a Restricted Range of Motion After Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine*, 41(4), pp.788–794. doi:https://doi.org/10.1177/0363546513476482.

Giesche, F., Niederer, D., Banzer, W. and Vogt, L. (2020). Evidence for the effects of prehabilitation before ACL-reconstruction on return to sport-related and self-reported knee function: A systematic review. *PLOS ONE*, 15(10), p.e0240192. doi:https://doi.org/10.1371/journal.pone.0240192.

Gokeler, A., Benjaminse, A., van Eck, C.F., Webster, K.E., Schot, L. and Otten, E. (2013). Return of normal gait as an outcome measurement in acl reconstructed patients. A systematic review. *International Journal of Sports Physical Therapy*, [online] 8(4), pp.441–451. Available at: https://pubmed.ncbi.nlm.nih.gov/24175130/ [Accessed 13 March 2023].

Gokeler, A., Bisschop, M., Benjaminse, A., Myer, G.D., Eppinga, P. and Otten, E. (2013). Quadriceps function following ACL reconstruction and rehabilitation: implications for optimisation of current practices. *Knee Surgery, Sports Traumatology, Arthroscopy*, [online] 22(5), pp.1163–1174. doi:https://doi.org/10.1007/s00167-013-2577-x.

Grindem, H., Granan, L.P., Risberg, M.A., Engebretsen, L., Snyder-Mackler, L. and Eitzen, I. (2014). How does a combined preoperative and postoperative rehabilitation programme influence the outcome of ACL reconstruction 2 years after surgery? A comparison between patients in the Delaware-Oslo ACL Cohort and the Norwegian National Knee Ligament Registry. *British Journal of Sports Medicine*, 49(6), pp.385–389. doi:https://doi.org/10.1136/bjsports-2014-093891.

Grindem, H., Snyder-Mackler, L., Moksnes, H., Engebretsen, L. and Risberg, M.A. (2016). Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *British Journal of Sports Medicine*, 50(13), pp.804–808. doi:https://doi.org/10.1136/bjsports-2016-096031.

Hart, J.M., Kuenze, C.M., Diduch, D.R. and Ingersoll, C.D. (2014). Quadriceps Muscle Function After Rehabilitation With Cryotherapy in Patients With Anterior Cruciate Ligament Reconstruction. *Journal of Athletic Training*, [online] 49(6), pp.733–739. doi:https://doi.org/10.4085/1062-6050-49.3.39.

Hauger, A.V., Reiman, M.P., Bjordal, J.M., Sheets, C., Ledbetter, L. and Goode, A.P. (2017). Neuromuscular electrical stimulation is effective in strengthening the quadriceps muscle after anterior cruciate ligament surgery. *Knee Surgery, Sports Traumatology, Arthroscopy*, [online] 26(2), pp.399–410. doi:https://doi.org/10.1007/s00167-017-4669-5.

Jewiss, D., Ostman, C. and Smart, N. (2017). Open versus Closed Kinetic Chain Exercises following an Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-Analysis. *Journal of Sports Medicine*, [online] 2017, pp.1–10. doi:https://doi.org/10.1155/2017/4721548.

Kijkunasathian, C., Limitlaohaphan, C., Saengpetch, N., Chanasit, P., Sundarathiti, P. and Waratanarat, P. (2017). A Comparison between Modified Robert Jones Bandage and Intermittent Cold Pack in Arthroscopic Anterior Cruciate Ligament Reconstruction: A Prospective Randomized Controlled Trial. *Journal of the Medical Association of Thailand = Chotmaihet Thangphaet*, [online] 100(3), pp.287–294. Available at: https://pubmed.ncbi.nlm.nih.gov/29911785/ [Accessed 13 March 2023].

Kotsifaki R, Korakakis V, King E, et al. Aspetar clinical practice guideline on rehabilitation after anterior cruciate ligament reconstruction. Br J Sports Med. 2023;57(9):500-514. http://dx.doi.org/10.1136/bjsports-2022-106158. doi: 10.1136/bjsports-2022-106158

Labanca, L., Rocchi, J.E., Giannini, S., Faloni, E.R., Montanari, G., Mariani, P.P. and Macaluso, A. (2022). Early Superimposed NMES Training is Effective to Improve Strength and Function Following ACL Reconstruction with Hamstring Graft regardless of Tendon Regeneration. *Journal of Sports Science and Medicine*, pp.91–103. doi:https://doi.org/10.52082/jssm.2022.91.

Lepley, L.K. and Palmieri-Smith, R.M. (2017). Pre-operative quadriceps activation is related to post-operative activation, not strength, in patients post-ACL reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy*, 24(1), pp.236–246. doi:https://doi.org/10.1007/s00167-014-3371-0.

Ma, J., Zhang, D., Zhao, T., Liu, X., Wang, J., Zheng, H. and Jin, S. (2021). The effects of proprioceptive training on anterior cruciate ligament reconstruction rehabilitation: A systematic review and meta-analysis. *Clinical Rehabilitation*, [online] 35(4), pp.506–521. doi:https://doi.org/10.1177/0269215520970737.

Månsson, O., Kartus, J. and Sernert, N. (2013). Pre-operative factors predicting good outcome in terms of health-related quality of life after ACL reconstruction. *Scandinavian Journal of Medicine & Science in Sports*, 23(1), pp.15–22. doi:https://doi.org/10.1111/j.1600-0838.2011.01426.x.

Moran, U., Gottlieb, U., Gam, A. and Springer, S. (2019). Functional electrical stimulation following anterior cruciate ligament reconstruction: a randomized controlled pilot study. *Journal of NeuroEngineering and Rehabilitation*, [online] 16. doi:https://doi.org/10.1186/s12984-019-0566-0.

Nichols, Z.W., O'Brien, D. and White, S.G. (2021). Is resistance training intensity adequately prescribed to meet the demands of returning to sport following anterior cruciate ligament repair? A systematic review. *BMJ Open Sport & Exercise Medicine*, 7(3), p.e001144. doi:https://doi.org/10.1136/bmjsem-2021-001144.

Noll, S., Garrison, J.C., Bothwell, J. and Conway, J.E. (2015). Knee Extension Range of Motion at 4 Weeks Is Related to Knee Extension Loss at 12 Weeks After

Anterior Cruciate Ligament Reconstruction. *Orthopaedic Journal of Sports Medicine*, 3(5), p.232596711558363. doi:https://doi.org/10.1177/2325967115583632.

Perriman, A., Leahy, E. and Semciw, A.I. (2018). The Effect of Open- Versus Closed-Kinetic-Chain Exercises on Anterior Tibial Laxity, Strength, and Function Following Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy*, 48(7), pp.552–566. doi:https://doi.org/10.2519/jospt.2018.7656.

Roe, C., Jacobs, C., Hoch, J., Johnson, D.L. and Noehren, B. (2021). Test Batteries After Primary Anterior Cruciate Ligament Reconstruction: A Systematic Review. *Sports Health: A Multidisciplinary Approach*, p.194173812110094. doi:https://doi.org/10.1177/19417381211009473.

Ross, C.A., Clifford, A. and Louw, Q.A. (2015). Intrinsic factors associated with return to sport after anterior cruciate ligament reconstruction: A systematic review. *South African Journal of Physiotherapy*, 71(1). doi:https://doi.org/10.4102/sajp.v71i1.230.

Ruffilli, A., Buda, R., Castagnini, F., Di Nicolantonio, D., Evangelisti, G., Giannini, S. and Faldini, C. (2015). Temperature-controlled continuous cold flow device versus traditional icing regimen following anterior cruciate ligament reconstruction: a prospective randomized comparative trial. *Archives of Orthopaedic and Trauma Surgery*, 135(10), pp.1405–1410. doi:https://doi.org/10.1007/s00402-015-2273-z.

Shaarani, S.R., O'Hare, C., Quinn, A., Moyna, N., Moran, R. and O'Byrne, J.M. (2013). Effect of Prehabilitation on the Outcome of Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine*, 41(9), pp.2117–2127. doi:https://doi.org/10.1177/0363546513493594.

Slater, L.V., Hart, J.M., Kelly, A.R. and Kuenze, C.M. (2017). Progressive Changes in Walking Kinematics and Kinetics After Anterior Cruciate Ligament Injury and Reconstruction: A Review and Meta-Analysis. *Journal of Athletic Training*, [online] 52(9), pp.847–860. doi:https://doi.org/10.4085/1062-6050-52.6.06.

Te Wierike, S.C.M., van der Sluis, A., van den Akker-Scheek, I., Elferink-Gemser, M.T. and Visscher, C. (2013). Psychosocial factors influencing the recovery of athletes with anterior cruciate ligament injury: A systematic review. *Scandinavian Journal of Medicine & Science in Sports*, 23(5), p.n/a-n/a. doi:https://doi.org/10.1111/sms.12010.

Toth, M.J., Tourville, T.W., Voigt, T.B., Choquette, R.H., Anair, B.M., Falcone, M.J., Failla, M.J., Stevens-Lapslaey, J.E., Endres, N.K., Slauterbeck, J.R. and Beynnon, B.D. (2020). Utility of Neuromuscular Electrical Stimulation to Preserve Quadriceps Muscle Fiber Size and Contractility After Anterior Cruciate Ligament Injuries and Reconstruction: A Randomized, Sham-Controlled, Blinded Trial. *The American Journal of Sports Medicine*, 48(10), pp.2429–2437. doi:https://doi.org/10.1177/0363546520933622.

Uçar, M., Koca, I., Eroglu, M., Eroglu, S., Sarp, U., Arik, H.O. and Yetisgin, A. (2014). Evaluation of Open and Closed Kinetic Chain Exercises in Rehabilitation Following Anterior Cruciate Ligament Reconstruction. *Journal of Physical Therapy Science*, [online] 26(12), pp.1875–1878. doi:https://doi.org/10.1589/jpts.26.1875.

van Melick, N., van Cingel, R.E.H., Brooijmans, F., Neeter, C., van Tienen, T., Hullegie, W. and Nijhuis-van der Sanden, M.W.G. (2016). Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. *British journal of sports medicine*, [online] 50(24), pp.1506–1515. doi:https://doi.org/10.1136/bjsports-2015-095898.

White, K., Di Stasi, S.L., Smith, A.H. and Snyder-Mackler, L. (2013). Anterior cruciate ligament- specialized post-operative return-to-sports (ACL-SPORTS) training: a randomized control trial. *BMC Musculoskeletal Disorders*, [online] 14(1). doi:https://doi.org/10.1186/1471-2474-14-108.

Yang, X., Feng, J., He, X., Wang, F. and Hu, Y. (2019). The effect of knee bracing on the knee function and stability following anterior cruciate ligament reconstruction: A systematic review and meta-analysis of randomized controlled trials. *Orthopaedics & Traumatology: Surgery & Research*, 105(6), pp.1107–1114. doi:https://doi.org/10.1016/j.otsr.2019.04.015.