Effects of Cross-education on Quadriceps Strength in Patients After ACL Reconstruction Surgery: A Critically Appraised Topic

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Abstract and Focused Research Question

Abstract: Anterior cruciate ligament reconstruction (ACLR) surgery is often an integral part of an athlete's return to play following an ACL tear. While standard ACL rehabilitation is used post-surgery, many athletes experience, and will continue to experience years after, quadriceps weakness and strength deficits. Research has recently investigated the addition of cross-education for the contralateral limb to produce quadriceps strength gains or attenuation of deficits in the injured leg.

Focused Clinical Question: What is the effect of cross-education on quadriceps strength recovery as an adjunct to standard rehabilitation after ACL reconstruction surgery? ***Summary of Key Findings***: Two studies showed a significant difference between cross-education along with ACLR rehabilitation, and one found no effect on strength in the early stages of rehabilitation. ***Clinical Bottom Line***: Evidence shows adding cross-education to the standard ACLR rehabilitation can be beneficial in attenuating quadriceps weakness, according to two out of the three studies. This idea should be investigated further to fully understand the benefits of the different phases of rehabilitation. ***Strength of Recommendation***: Grade B

Keywords: Cross-education, quadriceps strength, quadriceps weakness, ACL reconstruction

Clinical Scenario Background

Anterior cruciate ligament (ACL) injuries are a common injury among the athletic population, especially in sports that require cutting and pivoting.[1] It is estimated there are over 250,000 ACL reconstruction surgeries performed a year in the United States—many of those often are athletes. Athletes who wish to continue participating in their sport at their pre-injury level of performance are often recommended to undergo reconstruction surgery. Although the surgery is thought to be generally successful, only around 60% of athletes will make a full recovery after surgery.[1]

Quadriceps weakness is a common deficit following an ACL injury and is a factor in many athletes not reaching their pre-injury performance.[2] Evidence has shown that quadriceps strength can be reduced for years following reconstruction, and athletes often still return to play with significant quadriceps weakness.[1] Chronic quadriceps weakness can lead to knee instability and increase the risk of reinjury, therefore, it is imperative to study new ACLR rehabilitation techniques to combat the long-term consequences of an ACL tear. [2] Though rehabilitation is started immediately post-operatively, muscular strengthening and atrophy is sometimes not addressed until after 3-4 months.[3] Also, quadriceps strengthening in the early phases of rehabilitation is difficult because of effusion and knee pain.[3] Standard ACLR rehabilitation often starts the first week post-surgery, with rehabilitation done 3 days a week. Early mobilization is done in the first phase of rehabilitation (weeks 1-4), followed by basic strength (weeks 4-12), and maximal strength (weeks 12-24).[7,8]

Some research has investigated the phenomenon of cross education to improve quadriceps strength for injured athletes. This concept explains that strength training the contralateral limb will produce an increase of strength of the opposite, injured limb.[4] The theory of cross education is unilateral contractions of a limb will result in a bilateral increase of corticospinal excitability and increase in motor output.[4] Cross-education was originally introduced by Scripture et al, and since this study, many studies have made an effort to show the effects in both patient and healthy population, though the exact physiological mechanisms are unknown.[5] Since there is already an established and traditionally used rehabilitation technique for post-operative ACLR patients, cross education is researched as an addition to the current rehabilitative research. Therefore, the purpose of this critically appraised topic (CAT) was to assess the effect of cross education on quadriceps weakness in addition to standard ACLR rehabilitation.

	Harput et al.[7]	Zult et al.[8]	Minshull et al.[9]
Title	Cross-education improves quadriceps strength recovery after ACL reconstruction: a randomized controlled trial	Cross-education does not improve early and late-phase rehabilitation outcomes after ACL reconstruction: a randomized controlled clinical trial	Contralateral strength training attenuates muscle performance loss following anterior cruciate ligament (ACL) reconstruction: a randomized-controlled trial
Study Design	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial
Participants	48 physically active patients (mean age: 29.5 ± 6.8 years; mean body mass index: 26.1 ± 3.2 kg/m^2) who have undergone ACL reconstruction surgery (with hamstring tendon autograft)	43 participants (24 males, 19 females; mean age: 28 + 9.5 years; mean body mass index: 24.5 + 3 kg/m^2) who had undergone ACLR surgery	44 male participants (mean age: 31.6 + 9.4) post-ACL reconstruction
Inclusion and exclusion criteria	Inclusion: Unilateral arthroscopic ACLR with hamstring tenson autograft, age 17-45 years, non-contact mechanism, Pre-injury Tegner score >5, regular participation in physical therapy program Exclusion: ACLR with patellar tendon, revised ACLR, ACLR + meniscus repair, systematic or neurological issues, lower extremity injury of contralateral limb within the last 12 months	Inclusion: age 18-60 years, unilateral ACL tear (with or without meniscus resection), time between injury and testing < 2 years, auto or allograft used, minimal one supervised rehab session a week. Exclusion: previous ACL reconstruction, history of lower extremity injury the required surgery, pregnancy, prior or current neurological issues.	Exclusion: not within the range of 15-60 years old, comorbidities, diagnosis of a systemic disease, symptoms within the non-surgical knee, reasons that would limit compliance.
Interventions Investigated	1. *Concentric CE:* Concentric isokinetic contralateral limb training 3x12 at 60 degrees/s 3 times a week for 8 weeks + ACLR rehabilitation. *2.Eccentric CE:* Eccentric isokinetic contralateral limb training at 60 degrees/s 3 times a week for 8 weeks + ACLR rehabilitation 3. *Control*: Standard ACLR rehabilitation staring week 1 post-surgery 3 days per week, until week 12.	1. *Cross-education intervention:* Quadriceps strengthening of uninjured limb: leg press and leg extension machine; 3 sets of 8-12 RM with 1-2 min rest period performed weeks 1-12. *2.Control*: standard ACLR rehabilitation	1. *Cross-education:* strength training contralateral limb starting 2 weeks post-surgery – performed 3 times a week for 8 weeks. 3 sets of 3-5 RM of knee extensions, hamstring curls, and leg press on resistance machine + ACLR rehabilitation. 2. *Control:* Sham exercise upper extremity flexibility training; 3x20 bilateral static stretching + ACLR rehabilitation
Outcome Measures	*Quadriceps maximum voluntary isometric contractions (MVIC):* assessed by an isokinetic dynamometer at week 4 (baseline), and week 12 after 8-week intervention. 3 MVICs performed for 5 second duration, with the average taken. *Single leg hop distance:* OLHFDT assessed 24 weeks post-surgery. *IKDC scores:* Includes 10 items related to knee symptoms in sport or daily activity. knee symptoms scored from 0-100 (higher score = less disability) 24 weeks post-surgery.	*Self-reported Knee Function*: HCK questionnaire; rates subjective knee symptoms/complaints 0-10 on visual analogue scale. *Maximal Quadriceps Torque*: isometric and dynamic MVCs measured on Biodex isokinetic dynamometer *Maximal Hamstrings Torque*: isometric and dynamic MVCs measured on Biodex isokinetic dynamometer *Single Leg Hop Distance*: maximal hop distance	*QPF and HPF*: 5-10 maximal contractions of knee flexion and extension. Peak force recorded at the highest force achieved on the contractions. Measured 6 weeks post-surgery for baseline, 10 weeks, and 24 weeks. *RFD*: measured across three 50 ms epochs *IKDC score*: assess symptoms and knee function on a scale of 1-100. *HOP distance*: hop forward as far as possible to assess knee function
Main Findings	Interaction of time-by-group for quad MVICs for strength recovery was significant for both limbs (p=0.01). Quad strength for both limbs was greater at 12 and 24 weeks (concentric CE and Eccentric CE vs control) p<0.001 and p=0.01. There was no statistical difference found between eccentric and concentric CE. Strength gains were 28% for concentric and 31% for eccentric compared to the control. IKDC and single leg hop scores were not statistically significant.	No cross-education effect was found between the experimental and control groups.	CE attenuated decline of quadriceps weakness and PF of reconstructed leg (16.6% decrease vs 32%) at 10 weeks compared to the control, but not at 24 weeks. No significant difference in IKDC, HOP, HPF, or RFD.
Level of Evidence	1b	1b	1b
Validity Score	PEDro 10/10	PEDro 8/10	PEDro 7/10
Conclusion	Concentric and eccentric quadriceps strengthening of the contralateral leg improved quadriceps strength recovery in the injured leg in the early phases of ACL rehabilitation.	The 26 weeks of standard ACLR rehabilitation improved knee function and maximal strength but adding cross-education did not accelerate or benefit ACL recovery.	Cross-education strength training decreased the decline of QPF and should be considered for the early phases of ACL rehabilitation.

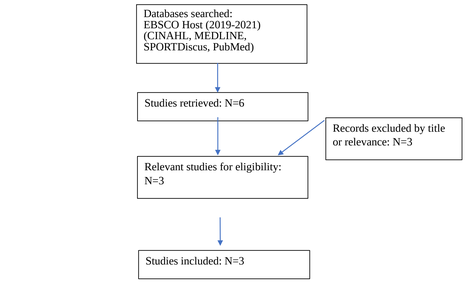

Figure 1 – Search strategy

	Harput et al.[7]	Zult et al.[8]	Minshull et al.[9]
1.Eligibility criteria was specified (yes/no)	yes	yes	yes
2. Subjects were randomly allocated to groups (yes/no)	yes	yes	yes
3. Allocation was concealed (yes/no)	yes	yes	no
4. Groups were similar at baseline (yes/no)	yes	yes	yes
5. Subjects were blinded to group (yes/no)	yes	yes	no
6. Therapists who administered therapy were blinded (yes/no)	yes	no	no
7. Assessors were blinded (yes/no)	yes	yes	no
8. Minimum 85% follow-up (yes/no)	yes	yes	yes
9. Intent to treat analysis for at least one key outcome (yes/no)	yes	yes	yes
10. Results of statistical analysis between groups were reported (yes/no)	yes	yes	yes
11. Point measurements and variability reported (yes/no)	yes	yes	yes
Overall Score (out of 10)	10/10	9/10	6/10

Results and Discussion

Results of Search

As described in Table 2 below, the studies selected were selected for the best evidence. The literature search identified 6 studies. One study was excluded as a systematic review, one was excluded based on the title, and one was excluded for lack of relevance to the research question. Three studies were retrieved that were randomized control trials (Table 1) and using the search strategies listed above (Figure 1). Validity of the studies retrieved were assessed using the PEDro scale (Tables 2 and 3). As shown in Table 2, the studies selected for this article compared cross-education plus ACLR rehabilitation to solely the standard ACLR rehabilitation, and each study used cross-education on the uninjured leg to produce an attenuation of quadriceps weakness in the injured leg

Clinical Bottom Line

Based upon the results of the studies done by Harput et al and Minsull et al, cross-education proved to be statistically significant and showed a positive effect on quadriceps strength. In Harput et al, isokinetic quadriceps strengthening was done concentrically and eccentrically, and although there was not a statistical difference between the two, there was a positive effect on isometric quadriceps strength of the untrained/reconstructed limb in the early phases of rehabilitation. The greater strength gained in the reconstructed limb as opposed to the control group suggest the mechanism of cross-education could be a positive addition to rehabilitation, especially the early phases, to maximize quadriceps strength. The study done by Minshull et al resulted in cross-education attenuating the decline of quadriceps weakening at 10 weeks, as opposed to the control group. Although, there was no significant difference or advantage retained at 24 weeks. The study done by Zult et al showed that cross-education did not aid standard ACLR rehabilitation at all three intervention marks of 5, 12, and 26-weeks post-surgery.

Based upon the results of the studies, cross-education may be beneficial in attenuating the rapid decline of quadriceps weakness in the early phases of rehabilitation. Research suggests that this mechanism may not be beneficial with long-term effects.

Future Research

1. Research the effects of Cross education as adjunct to standard ACL reconstruction rehabilitation
2. Research the short term and long-term cross education benefits
3. Research the use of cross education in both athletic and nonathletic populations

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