The potential role of cross-education in early-stage rehabilitation after anterior cruciate ligament reconstruction

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Cross-education, which refers to the interlimb transfer of strength or motor skill following unilateral motor training, has demonstrated promise as a rehabilitation strategy for orthopaedic and neurological injuries, despite the limited number of clinical trials conducted. However, its application in anterior cruciate ligament reconstruction (ACLR) rehabilitation has recently been contested, primarily due to the perceived risk of increasing limb asymmetry [1]. During ACLR rehabilitation, improved physical function is associated with the ability to restore compromised quadriceps strength and activation [2]. Protocols that mitigate and restore quadriceps weakness and strength post-ACLR are a critical component of rehabilitation. Cross-education may attenuate the loss in neuromuscular function during disuse [supplement], serve as an adjunct intervention for increasing quadriceps strength [3], and enhance neuroplasticity in pathways known to be attenuated with ACLR [supplement]. This commentary reviews the potential role of cross-education in rehabilitation following ACLR and offers a summary of the physiological rationale for considering this intervention during early-stage ACLR rehabilitation.

Facilitating early strength

Current clinical recommendations after ACLR delay externally-loaded open kinetic chain exercises until the fourth week after surgery [1]. Although this is advocated to reduce swelling and facilitate the early stages of healing, this process causes a decline in neuromuscular function and strength. When implemented effectively [supplement] cross-education may be an adjunct intervention to mitigate a decline in neuromuscular function and help restore quadriceps strength in the first three weeks post-surgery.

Training specificity

Cross-education follows the principle of training and muscle specificity in adults, with the largest effect occurring in the contralateral homologous muscle [supplement]. Many of the studies of cross-education during ACLR rehabilitation have investigated strength outcomes that differ from the exercise training intervention. These misalignments contribute to the mixed findings in the literature, including recent interpretations to avoid cross-education in ACLR clinical practice [1]. To this point, Kotsifaki, et al. [1] stated that cross-education has no effect on hamstrings strength, single-leg hop performance for distance, balance, or proprioception. Yet, all of the included studies, except Minshull, et al. [4], prescribed a knee extensors-focused exercise protocol. Assessing the efficacy of cross-education for ACLR should rely primarily on the evaluation of specific outcome measures matched to the nature of the cross-education intervention.

The mode of exercise is important

Eccentric strength is an important factor in ACLR recovery, and greater corticospinal excitability has been observed during eccentric contractions compared to forceful concentric contractions [5] After eccentric training, robust gains are made across different modes of muscle contractions (i.e., eccentric, concentric, isometric), especially when the training is performed at a high-intensity [supplement]. Therefore, eccentric-focused cross-education during ACLR

rehabilitation may provide a robust treatment effect. Presently, only four of the published studies investigating cross-education for ACLR recovery have used eccentric contractions, and compared to other studies, strength gains were superior relative to standard rehabilitation alone. Importantly, only one study implemented a 'best-practice' high-intensity eccentric cross-education intervention for two groups that trained either three (-16.25%) or five days (-6.30%) per week and found favourable results (i.e., attenuated quadriceps strength loss in the injured limb) compared to a standard rehabilitation group (-37.83%) [6].

Symmetrical versus sufficient strength

One area causing clinical scepticism of cross-education is apprehension about an increase in limb asymmetry, but this concern is misplaced in early-stage ACLR. First, cross-education serves as an adjunct intervention that does not replace progressive rehabilitation strength training of the ACLR limb. When it is appropriate to commence externally-loaded strength training for the ACLR limb, the volume of cross-education via the un-injured limb can be reduced so that the ACLR limb can 'catch up' (figure 1C). Second, limb symmetry alone does not represent 'recovery' [7] and focusing on it without considering absolute muscle strength neglects the value of strength preservation in the ACLR limb during rehabilitation [supplement].

A focus on mitigating quadriceps weakness via cross-education in early-stage ACLR rehabilitation could result in greater functional capacity of both limbs given a decline in strength is often experienced bilaterally (i.e., the ACLR and un-injured limb). Restoration of symmetry can be addressed when the ACLR limb is at an appropriate functional level and it is safe to do so [supplement; figure 1C].

Conclusions

Many features of cross-education interventions for ACLR have not been adequately researched [8]. There is considerable variability in how cross-education has been implemented with respect to exercise type, intensity, muscle group, contraction type, and training volume. Despite the limited literature, by emphasising targeted and effective cross-education [8], we contend that cross-education provides a promising low-risk adjunct approach to facilitate early-stage ACLR rehabilitation. Randomised clinical trials carefully investigating the efficacy of cross-education for ACLR rehabilitation are needed.

Competing interests

None

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