The Need for Neurocognitive Tasks in ACL Rehabilitation Protocols: A Critically Appraised Topic

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ABSTRACT

Brochin, G, Stewart, A. The Need for Neurocognitive Tasks in ACL Rehabilitation Protocols: A Critically Appraised Topic. JEPonline 2023;26(2):79-86. ACL injuries are the most common injury of the knee with an estimated reported rate of around 1 in 3,500 people with up to 200,000 injuries occurring in the United States each year. Biomechanical factors have historically been believed to be the primary contributors to these injuries. However, newer research has identified the importance of neurocognitive processes as one of the contributing factors to injury of the knee. This article will critically appraise the current research to examine the neurocognitive differences and apply it to patients with ACL reconstructions. Using MEDLINE, SPORTdiscus, and ProQuest, search was performed to identify articles that met the inclusion criteria. The application of the exclusion criteria resulted in 3 articles being found. The evidence indicates that differences in cortical activity, gaze acuity, and muscle activation patterns exist in subjects with ACL reconstruction. This may indicate that neurocognitive training should be included in rehabilitation programs for those with a history of ACL reconstruction to help decrease further odds of injury by increasing proprioceptive activity. This concept should be explored in future research to a greater degree and applied to other categories of musculoskeletal injury.

Key Words: ACL, Neurocognition, Proprioception, Rehabilitation
INTRODUCTION

Anterior cruciate ligament (ACL) injuries are the most common injury of the knee with an estimated reported incidence of 1 in 3,500 people with about 200,000 injuries occurring in the United States each year (4). Currently, the accepted method of treatment is surgical reconstruction. Despite this being the best currently accepted treatment, it has been shown to have a 30% reinjury rate (12). With this high rate of injury and reinjury, it is not uncommon to regularly see ACL injuries in the rehabilitation setting.

Biomechanics and muscular factors have often been acknowledged as the primary reason for ACL injuries with excessive knee valgus during extension being one of the most common reported causes (6). In contrast to this, newer research has identified the importance of considering neurocognitive processes as one of the contributing factors that contribute to the ACL injury (2). With most ACL injuries being found to occur within about 40 ms of contact, it is very likely that delays or distractions in neuro- and neurocognitive processing can result in an increase in the likelihood of an injury (2,8,14,15). Walden, for example, has established that in the sport of soccer, the most common mechanism of a non-contact ACL injury involves a player interpreting the action of another and needing to adjust to the changes in actions (6,15). This leads to the theory that a patient’s attention, and therefore overall neurocognitive processing is directly related to the likelihood of an ACL injury (6). In respect to the high incidence of ACL reinjury, many of the return to activity protocols have relied on measures of physical performance, such as strength and flexibility (10). While these factors are important, the lack of a commonly agreed upon return-to-play (RTP) decision-making process is clearly problematic since ACL reconstruction (ACLR) has a reinjury rate of nearly 30% (10,12). With these observations, many researchers have recently started pushing for the integration of neurocognitive tasks into the rehabilitation of ACL injuries. Thus, the purpose of this critically appraised topic will be to examine if the evidence supports the need for integration of neurocognitive tasks in ACL injury rehabilitation and if its inclusion in rehabilitation protocols is appropriate.

METHODS

Focused Clinical Question
Using a modified PICO format, a clinical question was formatted: (P) In patients with a history of ACL injury, (I) is neurocognitive intervention/necessary, (C) for a return to pre-injury physical activity, (O) with a decrease in injury risk?

Procedure – Literature Search
A search for experimental trials related to ACL rehabilitation and neurocognition was performed with the National Library of Medicine MEDLINE database, SPORTdiscus, and ProQuest Central. Dates of publication were limited to those published after January 1st, 2012 and June 30th, 2022. Search terms used were “ACL AND neurocog* AND task” along with “ACL AND neurocog* AND rehab”, produced a total of 66 results that included duplicates. Studies not relevant or not utilizing a healthy population control group were excluded based on the abstract. Each study was evaluated using the PEDro scale with scores of below 5 being excluded. This left 3 studies for use in this CAT. A summary of the articles is presented in Table 1. The articles selected examined various neurocognitive functions when performing various tasks (3,5,13).
All the articles scored 5/10 on the Pedro scale indicating moderate levels of validity. Blinding and allocation were two of the major weaknesses as it is impossible to blind the ACLR groups and no study indicated if the accessors were blinded (3,5,13). It can be assumed that blinding and allocations of the participants may not be a limitation as the patients know of their condition and the studies are comparing the condition to healthy controls. Strengths of the articles include the use of control groups, similarities between groups at the start, and comparisons within and between groups (3,5,13).

Table 1. The Accepted Literature Search in Accordance with the PEDro Scale.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Giesche et al. (2018)</th>
<th>Smeets et al. (2020)</th>
<th>Bodkin et al. (2021)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Title</td>
<td>Cortical Motor Planning and Biomechanical Stability During Unplanned Jump-Landings in Males With ACL-Reconstruction</td>
<td>Athletes with an ACL Reconstruction Show a Different Neuromuscular Response to Environmental Challenges Compared to Uninjured Athletes</td>
<td>Gaze Accuracy Differences During Single-Leg Balance Following Anterior Cruciate Ligament Reconstruction</td>
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<tr>
<td>Participants</td>
<td>ACLR Group: n = 10, age 28 ± 4 years, time since surgery 63 ± 35 months, limb symmetry 96 ± 4, flight time planned vs. unplanned 457 ± 28 ms vs. 469 ± 29 ms Control Group: n=17, age 28 ± 4 years, limb symmetry 96 ± 3, flight time planned vs. unplanned 472 ± 23 vs. 483 ± 27</td>
<td>ACLR Group: n = 20, 14M 6 Fe, age 23.7 ± 4.3 years, time postsurgery 258.6 ± 54 days Healthy Group: n=20, 14M 6Fe, age 21.4 ± 1.5 years</td>
<td>ACLR Group: n = 10, 6M 4Fe, age 19.9 ± 1.66 years, time since surgery 22.3 ± 15.4 months. Healthy Group: n = 10, 6M 4Fe, age 21.1 ± 1.37 years</td>
</tr>
<tr>
<td>Inclusion and Exclusion</td>
<td>ACLR: Inclusion criteria included males between 20 and 40 years of age with at least 2 occurrences of sporting activity per week alongside a counter movement jump height of at least 30 cm. ACLR participants needed to have history of unilateral and non-contact ACL injury at least 1 year with a limb-symmetry index of at least 85% and cleared for return to sports participation. Exclusion criteria of this group included somatic or psychological disease, acute or chronic joint</td>
<td>Inclusion criteria: All participants required participation in sports prior to injury with a minimum of 2 training days per week. The ACLR Group required semitendinosus autograft, completed rehabilitation with a physical therapist, and be cleared for participation in full training sessions. The Control athletes were required to be free of lower extremity or back injury in the previous 6 months and they could not have a history of an ACL injury.</td>
<td>ACLR inclusion required the participants to have a single and isolated unilateral ACLR and clearance for unrestricted activity by treating practitioner. Healthy inclusion required no history of lower extremity injury or surgery. All inclusion - recreationally active at least 3 times per week for 30 minutes. No history of lower extremity injury, neurological or visual abnormalities in the previous 6 months,</td>
</tr>
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inflammation, use of drugs to modify pain perception, muscle soreness, a history of brain/head injury in the previous year, or previous ACLR on either limb. Also, for healthy participants:

**Inclusion:** No history of severe musculoskeletal injury of the lower limb or lower limb surgery.

**Outcome Measure(s)**
- Movement-related cortical potentials, frontal theta frequency power, and landing stability.
- Muscle activation via EMG under 4 different tasks: step down without challenge, step down with cognitive dual-task, step down with unpredictable surface changes, and step down with combined cognitive dual-task and unpredictable surface changes.
- Stationary gaze error and velocity, moving target gaze error and velocity, center of pressure for both stationary and moving target tasks.

**Results**
- Both groups had decreased flight time with unplanned tasks but no statistical difference between groups for flight time ($P > 0.05$). The ACL Group evoked higher MCRP in a non-statistically significant manner but with moderate to high effect sizes ($P > 0.05$, RP-1 $d = 0.48$, RP-2 $d = 0.50$, NS $d = 0.42$) in unplanned activity. The ACL Group had higher theta power with a small-to-moderate effect size in planned and unplanned ($d = 0.5$, $d = 0.3$). ACLR males may rely on cortical motor planning to a higher degree than their non-injured counterparts.
- The ACLR Group showed higher total hamstring activation ($P = 0.035$, 6.5%, ES = 0.72) and lower VM activation ($P = 0.042$, 7.5%, ES = 0.45). The ACLR Group had significantly smaller activation of VM ($P = 0.023$), VL ($P = 0.037$), and GL activation ($P = 0.025$) during the perturbed tasks. With cognitive tasks, ACLR had higher degrees of medial hamstring activation ($P = 0.006$, ES = 0.75) and co-contraction.
- The ACLR Group exhibited greater gaze error ($P = 0.046$, $d = 0.96$) and higher gaze velocity ($P = 0.056$, $d = 0.92$) with moving target tasks. Targets superior or inferior demonstrated error. Significant gaze error was demonstrated for involved and uninvolved side target locations for superior and inferior targets in comparison to middle targets ($d = 0.83$, $d = 1.67$). ACLR had moderate correlation of visual gaze error to center of pressure ($r = .67$, $P = 0.05$).

**PEDro Score**

| 5 | 5 | 5 |

**Abbreviations:** M = Male, Fe = Female, ACLR = Anterior Cruciate Ligament Reconstruction
RESULTS

Across the board, the evidence indicates an important difference between healthy controls and those with ACLR when performing neurocognitive tasks during physical activity (3,5,13). For those with ACLR, there are alterations in cortical activity of low to moderate effect sizes (5). This finding has important implications in the other results that indicate errors in gaze and differences in muscle activation (3,13). In the Giesche study that did not show significant differences between the ACLR subjects and the healthy subjects, they did find moderate effect sizes of 0.5 and 0.3 for planned and unplanned actions for theta power in the ACLR group (5).

In addition, muscle activation and co-contractions were found to be different in the ACLR patients. Higher total hamstring activation was increased by 6.5% while vastus medialis was decreased by 7.5%. With unstable surfaces, the ACLR Group also had significantly reduced vastus medialis, lateral gastrocnemius, and vastus lateralis activations. Once cognitive tasks were introduced, the co-contraction between hamstring and measured quadriceps was significantly increased with the medial hamstrings also being individually significantly increased (13).

Gaze accuracy also appears to be impacted by the ACL reconstruction. Errors in gaze response were higher in the ACL Group when the visual target was above or below the straight-ahead vision. Also, in moving target tasks, the ACL Group had overall lower accuracy as well.

DISCUSSION

The evidence provides several different outcomes to examine neurocognition differences that occur after the ACLR. The studies show statistically significant information that indicates the introduction of neurocognitive tasks is crucial to avoid poor outcomes for those with an ACLR. Theta power is associated with brain activities such as attention, orientation, and perceptual performance, and the results from Giesche and other studies indicate that this may be a part of the differences in the ACLR patients (5,7). The results can be interpreted as indicating that ACLR patients require greater brain activity in the theta range to keep the same level of physical performance as non-ACLR patients, and this could explain the non-statistically significant results seen in the study by Giesche and colleagues and therefore warrants further evaluation (5). This also falls in line with the theorized mismatch of feedback, feedforward, and overall motor control proposed by several other authors (6,9).

Smeets and colleagues believe the difference in muscular responses seen in their study are that of an atherogenic response, which is hypothesized to occur when an injured joint increases sensory receptor discharge to protect from further injury (11,13). This potentially provides further evidence for the theorized mismatched proprioceptive origin of high ACL reinjury rates and may tie into the cortical differences observed above.

Another interesting aspect of the studies presented here is the evaluation of gaze accuracy. As established in previous studies, visual attention seems to play a role in ACL injury in sport with athletes more likely to have non-contact type injuries while their attention is not on their own actions (6,9). The study examining gaze accuracy determined a statistically significant
difference in moving visual accuracy in those with ACLR when the target required a superior or inferior gaze (3). Gaze that is above and below an active individual’s straight-ahead vision is very common and this inaccuracy could contribute to further injury if the gaze location has influence on risk of ACL injury.

Overall, the studies presented here provide additional insight into the needs of the ACLR patient during rehabilitation. It can be clearly seen from the results of these studies that there is most likely to be a mismatch in both feedforward and feedback systems within the nervous system. A wide range of neurological pathways exist with input from various receptor types that most likely influence this thinking. Smeets and colleagues believe their results match previously researched arthrogenic responses that influence proprioceptive signaling via neurological tracts like the spinocerebellar and dorsal-column medial-lemniscus (DCML) pathways (13). We also see the potential mismatch of the visual to sensory and motor loops with dysfunctional cerebellar integration as gaze accuracy is impacted in those with ACLR (3). If this gaze inaccuracy is due to specific sensory or motor deficits is yet to be established. We also know that EEG measured brain activity increases showing moderate effect sizes for theta waves in those with ACLR (5). These results indicate that neurocognitive deficits most likely do exist in those with ACLR.

Many of the above studies contained several limitations. Two studies only included male participants to reduce biomechanical influence (1,5). Overall, the studies included relatively a small number of participants with the largest group being 25 participants (1,3,5,13). None of the studies included blinding of the investigators or long-term follow up. Also, the studies used physically active patients that do not represent all ACLR patients.

Future research into this topic is necessary. There are currently very few studies directly comparing neurological differences in those with ACLR to healthy subjects. The number of different outcomes measured in these studies are also widely ranging and more research on these outcomes are necessary. To examine cortical activity differences, it may be beneficial for future examiners to also combine the measures employed by Giesche and those used by Smeets (5,13).

For evaluating the deficits discussed in this paper, Ahkbari and colleagues examined the reliability of the auditory stroop task in those with ACLR and ACLD. The stroop task is a general executive function evaluation that involves recognizing a pitch in sound and telling the test administrator if the pitch is high or low. This was performed during both sitting and balance tasks and during medium and large surface perturbations (1). This study indicates that the stroop test is valuable in detecting neurocognitive deficits in ACLR patients and could be a lower cost option with real world implication in comparison to the methods used in the 3 appraised studies.

Beyond this, we also wanted to evaluate the success of the use of neurocognitive tasks during rehabilitation post-ACLR. With nearly 30% of ACLRs experiencing reinjury, it is pertinent to find ways to reduce this rate of incidence. Randomized control trials will need to be performed to compare incorporating these tasks into their rehabilitation to those that do not. These RCTs should have long term follow up to determine if the integration of these tasks in ACL rehabilitation decreases the rate of reinjury over the long term.
CONCLUSIONS

Neurocognitive tasks may be necessary to incorporate in rehabilitation protocols for ACL patients. Further research is needed to examine specific tasks and long-term outcomes.

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REFERENCES


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