Abstract

Introduction

Positive outcomes from anterior cruciate ligament reconstruction (ACLR) surgery are frequently reported within the published literature. These papers often measure the patients’ outcome against a baseline of their pre-operative post-injury status, often reporting considerable improvements. This review attempts to examine the outcome of patients, who have undergone ACLR, from a different perspective, by comparing their outcome to population norms across a variety of tests.

Conclusion

Undertaking a comparison in this manner shows that the majority of ACLR patients do not make a full functional recovery when comparing their performance to that of their uninjured peers. It would appear that ACLR surgery provides positive benefits for the patient, but the challenge still remains for clinicians to return these patients to a full functional status.

Discussion

In this review, the author has referenced some of his own studies. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964) and the protocols of these studies have been approved by the relevant ethics committees associated to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in the studies.

Patien-derived outcome measures

Patient-derived subjective assessments of symptoms and function are often more robust when evaluating the outcome of ACLR than clinical measurements such as arthrometers. Renström suggested that the patient’s perspective of the ACLR outcome should be the primary outcome measure used by surgeons. If the patient is going to have a good subjective functional outcome, then the post-operative score from the functional questionnaire for the ACLR patient would need to be equal to or greater than that of the normal asymptomatic population score. Table 1 shows studies reporting the outcome using International Knee Documentation Committee (IKDC) subjective score and Table 2 shows studies reporting outcome using Knee injury and Osteoarthritis Outcome Score (KOOS) score.

Table 1 illustrates that a normal value for IKDC subjective would be in the range of 86%–89.4%9,19, though both these population samples also included individuals with a history of knee injury. The absolute best score would be 100%, which would indicate problem free in all categories of the questionnaire, a score which was found in the uninjured control group of Xergia et al.11. As can be seen from Table 1, the majority of studies failed to report scores above these average normal scores. There are exceptions to the studies of Hussein et al.12, Lentz et al.13, McCullogh et al.14 and Reinke et al.15, in which patients reported scores greater than the normal average scores at various intervals, post-operatively. The majority of those patients successfully returned to sport (in the short term), though the patients who had returned to sport (same level) in the study of Devgan et al.16 scored only 87.6%. It is noticeable that patients reporting a score of greater than 95% (virtually problem free) are very much the minority.

KOOS questionnaire scores are presented in Table 2; again here, the majority of studies failed to report outcomes greater than the normative data of Cameron et al.17 and...
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All authors contributed to the conception, design, preparation of the manuscript, as well as read and approved the final manuscript.

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operative was 81.7%, which was similar to Xergia et al. (2013) finding of an index of 76.9% at seven months post-operative. Mattcola et al. found that the deficit in knee extensor strength continued to persist even at 18 months post-operative and the uninjured knee extensors were also significantly weaker than matched controls. However, Xergia et al. found no difference between knee extensor strength in the uninjured limb and controls. Those individuals with lower knee extensor LSI (less than 85%) appear to perform worse at hop tests and score significantly lower on IKDC subjective questionnaire. Similarly, at the time of return to sport, those ACLR patients, who had weaker knee extensors (LSI less than 85%) demonstrated decreased function, whilst those with LSI greater than 90%, had functional performances similar to uninjured individuals.

When ACLR patients have been reported to have symmetrical knee extensor strength at six months post-operative, this occurs when they have undertaken specific rehabilitation programmes. Even then, despite having symmetrical strength, the ACLR patients often lack the ability to generate force rapidly, with their injured limb. Angelozzi et al. found that the rate of force development was significantly reduced (greater than 20% difference) in the ACLR limb at six months post-operative, despite having symmetrical knee extensor strength. Similarly, Myer et al. found that LSI in vertical jump height was 89% in the ACLR group compared to 101% in the matched-control group. The LSI for the vertical ground reaction force when normalised to potential energy, achieved during flight of the vertical hop, was increased in ACLR group at 112% relative to the control group at 102%. This would indicate the ACLR group are less able to dissipate landing loads, with the potential to increase joint stress and damage.

### Table 2 KOOS scores.

<table>
<thead>
<tr>
<th>Paper</th>
<th>KOOS domain</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pain</td>
<td>Symptoms</td>
</tr>
<tr>
<td>Paradowski et al., 2006</td>
<td>90–95</td>
<td>84–91</td>
</tr>
<tr>
<td>Cameron et al., 2013</td>
<td>100</td>
<td>96.4</td>
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<tr>
<td>Hill et al., 2012</td>
<td>92.7</td>
<td>88.9</td>
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<td>Ahlden et al., 2012</td>
<td>85</td>
<td>78</td>
</tr>
<tr>
<td>Ahlden et al., 2012</td>
<td>84</td>
<td>77</td>
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<td>Reinke et al., 2011</td>
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<tr>
<td>Frobell et al., 2013</td>
<td>91</td>
<td>83</td>
</tr>
</tbody>
</table>

ACLR, anterior cruciate ligament reconstruction; ADL, activities in daily living; KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, quality of life.

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through these increased loads. The ACLR patients in this study, who were 12 months post-operative, had all returned to sport and had symmetrical knee extensor strength.

The use of hop tests provides an indirect means to assess a number of factors, such as the extent pain inhibits performance, muscle strength and power, ability of a limb to absorb force and dynamically control tibial translation during application of shearing and rotational forces. The ability of the application of shearing and rotational forces to absorb force and dynamically strength and power, ability of a limb in inhibits performance, muscle factors, such as the extent pain inhibits performance, muscle.

The importance, when judging functional performance. With regards to LSI, Munro and Herrington found asymptomatic individuals to have less than 5% deficit in LSI across all the commonly used hop tests. The most reliable and valid of the multitude of hop tests in relation to the ACLR patient would appear to be the single hop for distance and the crossover hop tests, this review will concentrate on the performance of those tests.

At 12 months post-operative, Grindem et al. found single hop LSI to be 90% and crossover hop to be 91%, Hopper et al. reported that an average of 39 weeks post-operative was required to achieve an LSI of 85% on crossover hop, which was similar to findings by Grindem et al., who reported that it took 12 months to achieve LSI of 91.9%. Moussa et al. reported that symmetry in performance of these tests did not occur until two years post-operative. Mattcola et al. reported that in fact 43% patients still had a single hop LSI, less than 85% at 18 months post-operative, with Reinke et al. finding that less than 40% of patients had an LSI greater than 95% for crossover and single hop tests at 2–3 years post-operative. Xergia et al. found that at seven months, single-hop LSI was 81%. But perhaps more significant was that when compared to controls, the ACLR limb hopped 32% less and the non-injured leg was 16% less. During crossover hop, LSI was 83%, but when compared to controls, ACLR leg was 25% less and non-injured leg was 11% less. Furthermore, during the hops, ACLR leg demonstrated significantly less knee flexion and ankle dorsiflexion than non-injured leg; these altered kinematic variables are likely to reflect the alter forces found by Myer et al. and are likely to increase stress loading onto the articular surfaces.

The significance of the poor performance in the hop tests lies in their relationship to patient-derived outcome scores. Grindem et al. found an LSI less than 88% to significantly predict poor function outcome (IKDC subjective score). Whilst Logerstätt et al. found that a crossover hop LSI greater than 94.9% predicted normal functional score (IKDC subjective score). Deficits in knee extensor strength also predicted hop test performance showing the link between strength and functional performance.

Knee symptoms and secondary anterior cruciate ligament injury

Lentz et al. found 40% of patients, who did not return to the same level of sport, reported that it was because of ongoing knee symptoms, principally pain and swelling. These might be related to patellofemoral joint issues as by 7–11 years after ACL injury, irrespective of conservative or surgical management, individuals have been shown to be 30 times more likely to have patellar cartilage loss on magnetic resonance imaging compared with baseline, time of ACL injury. Furthermore, current evidence indicates that patellofemoral joint OA (PFJ OA) is prevalent after ACLR, with global frequency averaged around 38%. Although most radiographic changes are mild, PFJ OA has the potential to adversely affect pain and function after ACLR. Ho et al. found bone marrow water content to significantly increase in patellofemoral pain patients following running. This disproportionate increase in hydrostatic pressure is likely to relate to pain and provide a link between increased loading of ACLR patients and onset of knee symptoms.

The ongoing symptoms also might be related to tibiofemoral joint articular stress due to increased loading following meniscal damage. Fifty one percent of ACLR patients required meniscal surgery within five years, with the strong link between meniscal loss and degenerate change in the knee. Similarly, increased articular stress might be associated to high frequency of radiological changes, within the tibial and femoral condyles following ACL injury, with 80% of ACL cases being associated with bone bruising. There appears to be a strong association between these bony bruising, osteochondral lesions and degenerate changes within the joint. Van Ginckel et al. reported that at six months post-ACLR and having returned to sport, that no differences in cartilage volume or thickness, or deformation during standard loading (running based) test occurred. Although, the ACLR group showed significantly slower recovery of morphological characteristics and deformation of cartilage following loading; therefore, tissue is more likely to become stressed with repetitive loading, resulting in a highly vulnerable joint-to-degenerate change in the short term. This may be associated to long-term problems.

It would appear that the ACLR patient is at a significantly elevated risk of either rupturing the graft or injuring the contralateral ACL, as Hui et al. found that 31% of ACLR patients had subsequent ACL injury (within 15 years). More specifically, Hettrich et al. following up 900 ACLR patients found that 18.9% patients had subsequent surgery, 7.7% patients had ACL revision, 9.4% patients had meniscal surgery, 6.9% patients had contralateral ACLR and 8.8% patients had articular cartilage or meniscal surgery on contralateral knee. Wright et al. in their...
Finally, Ardern et al. found that only poor functional outcomes assessed re-injury was significantly associated for undertaking ACLR is to allow the primary reported reasons for undertaking ACLR is to allow the patient to return to sporting activities. Beasley et al. reviewed 37 studies and found the average return to sport across these studies to be 70.7%, whilst Ardern et al., in their review of 48 studies found that the return rate was 44%. Apart from knee symptoms mentioned above, the second most common reason for failing to return to sport at the same level or at all is fear of re-injury. In fact Devgan et al. found that at five years post-operative, in the group which had not returned to sport (25% cohort), reported fear of re-injury being the biggest single factor in not returning to sport. Lentz et al. found that 45% of patients, who had not returned to sport reported fear of re-injury/lack of confidence as a reason; this group also had significantly lower IKDC subjective scores of 78 versus 93.8% (in the return to sport group), and significantly greater fear of movement (kinesiophobia). Similarly, Chmielewski et al. found that fear of movement/re-injury was significantly associated to poor functional outcomes assessed by IKDC subjective questionnaire. Finally, Ardern et al. found that only 31% of their cohort had returned to sport at 1 year post-operative, with a significant relationship between perceived psychological readiness to return to sport and fear of re-injury and date of return.

Conclusion
The majority of the published literature on the outcome from ACLR surgery would appear to report that the surgery brings about significant improvements in function. But, this is only often when the outcome is compared to the patient’s pre-operative status. The purpose of this review was to compare the outcome from ACLR surgery to that of asymptomatic individuals, the patients’ peer group. When considering the question does an ACLR patient achieve normal function following surgery? The answer from the work presented in this review would be they do not; that is not to say the operation was not successful, but just that the majority of the patient’s do not return to full unrestricted function. The question as to why this is the case is difficult to answer and in some respects beyond the scope of this review. This issue might in part be associated to the way these patients are rehabilitated after surgery. The rehabilitation process needs to be constructed around aims and goals that aid appropriate progression from both injury and performance perspectives. This can be done by achieving certain criteria before progressing further to the next rehabilitation phase.

The majority of the factors creating these restrictions in function could possibly be addressed with appropriate rehabilitation. The reduced muscular strength and rate of force development capabilities could be resolved with appropriate exercises and progressive strengthening programmes, moving from high-load strengthening activities that stimulate force development that can be applied into load acceptance and plyometric drills. The resolution of strength issues are likely to resolve the asymmetry and performance issues associated to hopping. Improving strength is also likely to improve the ability of the knee to absorb load, which could reduce articular stress and some of the issues associated to degenerative changes within the knee and patellofemoral joints. Having a knee, which feels stronger and more stable, is likely to improve the patient’s kinesiophobia and lack of confidence in the knee. The author has presented elsewhere a sequential task-orientated rehabilitation programme for the ACLR patients.

The outcome from ACLR surgery would appear to be good overall; the status of the patient improves significantly when compared to their pre-operative abilities. This by no means implies though that the patient has normal knee function, the data presented in this paper would indicate that in maximum percentage of cases, the ACLR patient fails to be capable of normal unrestricted function following their surgery.

Abbreviations list
ACLR, anterior cruciate ligament; ACLR, ACL reconstruction; IKDC, International Knee Documentation Committee; LSI, limb symmetry index; OA, osteoarthritis; PFJ OA, patellofemoral joint OA.

References
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