Protracted Cardiovascular Impairments After Anterior Cruciate Ligament Injury: A Critically Appraised Topic

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Clinical Scenario: Anterior cruciate ligament (ACL) tear is a devastating knee injury with negative long-term consequences, such as early-onset knee osteoarthritis, biomechanical compensations, and reduced physical activity. Significant reduction in physical activity is a powerful indicator of cardiovascular (CV) disease; therefore, those with a history of ACL injury may be at increased risk for CV disease compared with noninjured individuals. **Focused Clinical Question:** Do individuals with a history of ACL injury demonstrate negative CV changes compared with those without a history of ACL injury? **Summary of Key Findings:** Three articles met the inclusion criteria and investigated CV changes after ACL injury. Both cross-sectional studies compared participants with ACL injury with matched controls. Bell et al compared time spent in moderate to vigorous physical activity and step count, whereas Almeida et al compared maximum rate of oxygen consumption, ventilatory thresholds, isokinetic quadriceps strength, and body composition. Collectively, both quantitative studies found that individuals with a history of ACL injury had less efficient CV systems compared with matched controls and/or preoperative data. Finally, a qualitative study of 3506 retired National Football League athletes showed an increased rate of arthritis and knee replacement surgery after an ACL injury when compared with other retired National Football League members, in addition to a >50% increased rate of myocardial infarction. **Clinical Bottom Line:** A history of ACL injury is a source of impaired physical activity. Preliminary data indicate that these physical activity limitations negatively impair the CV system, and individuals with a history of ACL injury demonstrate lower maximum oxygen consumption, self-reported disability, and daily step count compared with noninjured peers. These complications support the need for greater emphasis on CV wellness. **Strength of Recommendation:** Consistent findings from 2 cross-sectional studies and 1 survey study suggest level IIB evidence to support that ACL injury is associated with negative CV health.

Keywords: cardiovascular diseases, coronary artery heart disease, exercise, rehabilitation and therapy, rehabilitation

Clinical Scenario

Traumatic knee injuries lead to a multitude of negative effects on the body, including altered physical activity, biomechanical compensations, and early onset knee osteoarthritis.¹⁻⁵ Individuals recovering from anterior cruciate ligament (ACL) injury spend less time in moderate to vigorous physical activity and take fewer steps per day, compared with healthy individuals.¹ Significant reductions in physical activity are a powerful indicator of cardiovascular disease. Accordingly, those with a history of ACL injury may be at an increased risk of cardiovascular disease compared with their nonsurgical peers.

Focused Clinical Question

Do individuals with a history of an ACL injury demonstrate negative cardiovascular changes compared with those who have not experienced an ACL injury?

Summary of Search, “Best Evidence” Appraised, and Key Findings

- A literature search was performed to investigate cardiovascular changes after ACL injury.

- All studies must have investigated the protracted cardiovascular changes (such as heart rate, blood pressure, and oxygen consumption) following ACL injury.
- Of the initial 106 articles retrieved, 3 met the inclusion criteria, 2 cross-sectional studies, and 1 qualitative survey.
- Cardiovascular testing ranged from presurgery to 6 months postsurgery,² as well as multiple years postsurgery.¹
- Both cross-sectional studies^{1,2} compared ACL reconstruction (ACLR) participants with matched healthy controls. One study used accelerometers and measured time spent in moderate to vigorous physical activity and step count between groups (ACLR vs controls) for 7 days. The other cross-sectional investigation compared maximum rate of oxygen consumption ($\text{VO}_{2\text{max}}$), ventilatory thresholds, isokinetic strength, and body composition between groups. It examined participants with ACL injury at presurgery and 6 months postoperation. Results were also compared with healthy controls.
- The qualitative survey study³ showed an increased rate of arthritis and knee replacement surgery after an ACL injury. In addition, although statistical significance was not reached, there was a >50% increased rate of myocardial infarction in players with a history of ACL tear.
- Although 1 study found that participants with a history of ACL injury had better cardiovascular outcomes compared with presurgical data,² collectively, both cross-sectional studies found that individuals with a history of ACL injury had less efficient cardiovascular systems compared with healthy controls.

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- Deficits in oxygen consumption, heart rate, and self-reported function associated with cardiac events were observed in the ACL-injured groups.

Clinical Bottom Line

A history of an ACL injury and reconstruction significantly influences physical activity. For instance, those with a history of ACL injury reportedly have a lower daily step count and decreased aerobic fitness.¹ These significant declines in physical activity may negatively impair the cardiovascular system. Strikingly, a recent qualitative report concluded that those with a history of ACLR reportedly have a >50% increased risk of myocardial infarction.³ This risk of cardiovascular disease, taking into account the well-established risk of early onset osteoarthritis complications that plague this population, may indicate that individuals with a history of ACL injury that develop early onset osteoarthritis are at an increased risk of cardiovascular disease.³ Though these are early data, this link between osteoarthritis and cardiovascular disease has been found in idiopathic osteoarthritis development.^{6,7} Altogether, this clinical scenario suggests that there is a risk of cardiovascular complications after ACL injury, and there is a need to consider incorporating cardiovascular-focused rehabilitation strategies.

Strength of Recommendation

Consistent preliminary findings from 2 cross-sectional studies and 1 survey study suggest that level IIB evidence to support that ACL injury is associated with negative cardiovascular health.

Search Strategy

Terms Used to Guide Search Strategy

- Participant/Client group: individuals who have undergone knee surgery
- Intervention/Assessment: cardiovascular function (VO₂max, blood pressure [BP], heart rate [HR], heart rate variability [HRV], and cardiovascular disease)
- Comparison: nonsurgical
- Outcome: aerobic fitness or cardiovascular function/disease

Sources of Evidence Searched (Databases)

- PubMed
- SPORTDiscus

Inclusion and Exclusion Criteria

Inclusion

- Human participants only
- Articles available in the English language
- Group of postknee orthopedic surgical participants
- Measure of cardiovascular health (VO₂max, BP, HR, HRV, and cardiovascular disease)

Exclusion

- Animal participants
- Languages other than English
- Participants with other major lower-extremity injury

Results of Search

Three relevant studies were located and categorized and are presented in Table 1.

The following studies were identified as the “best” evidence and selected for inclusion in the critically appraised topic. Reasons for selecting these studies were as follows:

- All studies matched the inclusion/exclusion criteria.
- All studies contain groups with a knee-specific orthopedic surgery.
- All studies utilized cardiovascular-based outcomes.

Implications for Practice, Education, and Future Research

The 2 cross-sectional studies included in this critically appraised topic found a significant decrease in cardiovascular measures when compared with healthy controls.^{1,2} Both studies compared the results of athletes (aged 20–22 y) who had torn their ACL and underwent reconstructive surgery versus a healthy matched control. Bell et al¹ found that individuals with a history of ACL injury spent less time in moderate to vigorous physical activity and had lower daily step counts, which are variables that have a direct effect on cardiovascular health. Almeida et al² evaluated the cardiovascular system via VO₂max and ventilatory thresholds, as well as a knee function questionnaire, isokinetic strength test, and body composition measurement. This study found that participants with a history of ACL injury scored significantly lower in all categories. Cumulatively, these results indicate that those with a history of ACL injury may be at risk for a compromised cardiovascular system compared with their nonsurgical peers.^{1,2} Finally, the qualitative study showed that out of 3506 former National Football League athletes, those who had torn their ACL had a higher incidence of myocardial infarction compared with other retired National Football League members.³ In brief, there is a short-term, immediate problem demonstrated by the 2 cross-sectional studies reporting significant reductions in physical activity; and, long-term, there is a troubling qualitative study that points to a high incidence of cardiac events. See Table 2 for article characteristics.

On a global scale, ACL ruptures occur in 300,000 Americans every year,⁸ with a reported reinjury rate as high as 23%,⁹ which may also influence declines in physical activity rates. These statistics, in conjunction with the findings of this critically appraised topic, and the link between osteoarthritis and cardiovascular disease in idiopathic populations,^{6,7} demonstrate the necessity of further studies to better determine the long-term impairments of ACL injury.

Although there is extensive literature studying the long-term changes of ACL injury on the knee joint,¹⁰ the evidence regarding the long-term cardiovascular changes after knee surgery is limited,

Table 1 Summary of Study Design of Articles Retrieved

Level of evidence ^a	Study design	Reference
3	Cross-sectional study	Bell et al ¹
3	Cross-sectional study	Almeida et al ²
6	Survey study	Meehan et al ³

^aOxford Centre for Evidence-Based Medicine Best Evidence.

Table 2 Characteristics of Included Studies

	Bell et al¹	Almeida et al²	Meehan et al³
Study design	Cross-sectional study	Cross-sectional study	Survey study
Participants	33 participants with a history of primary unilateral or bilateral ACLR matched with 33 healthy participants with no history of ACLR. Participants with an ACLR had a postsurgical timeline with an average of 27.8 (17.5) mo.	Professional male soccer players with ACLR (n = 20) compared with a control group of healthy, non-ACLR male professional soccer players (n = 20). Median time between injury and surgery was 3 mo (range: 1–12 mo). Exclusion criteria were associated ligament lesions requiring surgical repair/reconstruction, knee effusion, impossibility to perform the running test, previous knee surgeries, postoperative infection, arthrofibrosis, ACL reconstruction failure, and inadequate follow-up.	Former NFL players (n = 3056; mean age 53 [14] y), who played since 1960.
Intervention investigated	Participants were fitted with an accelerometer with instructions to wear it for 7 d. Accelerometer measured time spent in MVPA and step count.	Aerobic fitness was assessed with VO ₂ max and ventilatory thresholds using a treadmill protocol. Isokinetic strength and body composition were also performed. Testing was performed presurgery and 6 mo after ACLR.	History of ACL tear during active playing years
Outcome measure(s)	Time spent in MVPA, step count, International Knee Documentation Committee Questionnaire, Tegner, and Marx	VO ₂ max, ventilatory thresholds, knee function questionnaire, isokinetic strength test, and body composition	Self-administered questionnaire and physician-diagnosed health condition reporting
Main findings	Patients with a history of ACLR spent less time in MVPA (ACLR: 79.37 (23.95) min/d; control: 93.12 (23.94) min/d; $P = .02$) and exhibited a lower daily step count (ACLR: 8158 (2780) steps/d; control: 9769 (2785) steps/d; $P = .02$). The outcome scores on the Marx and Tegner did not differ between groups.	For the ACLR group, preoperative VO ₂ max was 45.2 (4.3) mL/kg/min, postoperative was 48.9 (3.8) mL/kg/min, and the control group was 56.9 (4.2) mL/kg/min ($P < .001$ in presurgery vs postsurgery, presurgery vs control, and postsurgery vs control). Body composition was similar for all 3 situations. Knee function questionnaires and decreased quadriceps peak torque improved after surgery, but were significantly lower compared with the controls ($P < .001$).	Former NFL players who tore their ACL had roughly a 2-fold increase in musculoskeletal comorbidities (including knee joint replacement and arthritis) compared with players without ACL tears. Also, those who tore their ACL had a >50% increased risk of myocardial infarction.
Level of evidence	III	III	VI
Conclusion	Patients with a history of ACLR spent less time in MVPA and had lower daily step counts compared with matched healthy controls. In patient-related outcome measures, both groups had similar results. This explains that although patients with ACLR subjectively believe that they are similar to healthy controls, there are still objective statistically significant differences between groups.	Regarding ACLR, aerobic fitness is significantly less in professional male soccer players' presurgery; although aerobic fitness improved 6 mo postoperation, it did not return to baseline levels, nor to the levels of the control group.	Similar to previous research, there was an increased rate of arthritis and knee replacement surgery after an ACL injury. In addition, although statistical significance was not reached, there was a >50% increased rate of myocardial infarction in players with ACL tear. As this is the first study to demonstrate these findings, further research should be conducted to evaluate this potential public health concern.
Validity score	6	4	4

Abbreviations: ACL, anterior cruciate ligament; MVPA, moderate to vigorous physical activity; NFL, National Football League; VO₂max, maximum oxygen uptake.

and, as such, future research is needed to better understand the early signs of cardiovascular distress and how it evolves over time. A refined understanding of the timeline of cardiovascular changes would help both the researcher and clinician better understand how to treat these impairments transcribed from ACL injury. It is important to note that of the 3 appraised articles, only one article assessed cardiovascular fitness presurgery.¹ Future research should focus on the effects of ACL injury compared with ACL reconstruction.

Current trends of ACL rehabilitation focus on regaining strength and functional movements for return to play goals. Clinicians tend to tailor therapy to patient-centered goals, such as being able to run, play a particular sport, or successfully perform activities of daily living. Unfortunately, 88% of patients expect to return to sport¹¹ despite alarmingly high reinjury rates.⁹ Plausibly, this decline in preinjury level of sport could be an important link to cardiovascular disease later in life. Future research will need to evaluate this relationship. The results from this topic indicate a need for greater focus on cardiovascular-based therapy during rehabilitation and encouragement to return to endurance-based physical activity post-rehabilitation. The evidence presented should also encourage clinicians to modify current trends of ACL rehabilitation strategies to also focus on cardiovascular health after ACL injury.

As the data to observe progressive cardiovascular changes are not yet available, longitudinal studies will be beneficial to understand the relationship between ACL injury and long-term cardiovascular health. The emerging picture, at the very least, suggests that cardiovascular fitness should be an important component of rehabilitation, which should be on a clinician's radar.

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