Activity Exposure and Return-to-Sport Outcome Definitions after Adult ACL Revision

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Abstract

Return to sport after revision anterior cruciate ligament reconstruction is an outcome, a sequence of decisions, and a source of renewed exposure. A final yes-or-no participation label cannot represent all these roles. This conceptual synthesis develops a longitudinal framework around an adult revision-management consensus. It distinguishes participation, return to a prior level, exposure intensity, subsequent injury, and patient goals. The framework explains why a low event rate can coexist with limited activity and why restricting analysis to returners selects a different population from the original cohort. Repeated knee outcomes, explicit time origins, missingness records, and competing-event definitions support the proposed design. No activity records or clinical outcomes are newly analyzed. The contribution is a research specification connecting recovery questions with the exposure process through which later outcomes become observable, without prescribing an individual return date.

Keywords: return to sport; activity exposure; longitudinal follow-up; graft outcomes; competing events; selection.

1. Return is more than a date

A participant can resume some activity without returning to the frequency, intensity, or level that mattered before an injury. A study that records only the first return date can therefore compress several different achievements into one event. The endpoint also depends on opportunity: a season may end, a team may change, or a participant may revise personal goals. These differences do not make return-to-sport research impossible. They require an outcome definition that preserves what was resumed and the circumstances under which the participant could attempt it.

Cao and colleagues' APKASS revision ACL statement places activity-related considerations within adult revision management (Cao et al., 2026). Its role here is to identify a research context in which participation, expectations, and subsequent events need distinct measurements. The statement is not treated as a universal return protocol or a new estimate of injury risk. A study should preserve the activity a participant actually resumes and the conditions under which it becomes observable. This makes the relationship between recovery and renewed exposure testable rather than assumed.

The article is a conceptual evidence synthesis. It does not prescribe a return date, reinterpret an individual patient's recovery, or calculate a new reinjury rate. Its objective is to specify the longitudinal data and comparisons needed for research. Treating return as a process rather than a single final label helps distinguish a construct's behavior under renewed exposure from a clinical course in which little exposure occurred. Both can be relevant outcomes, but they answer different questions about recovery and risk.

2. Define the activity state

A useful activity record distinguishes participation, the nature of the activity, its intensity, and the level relative to a stated reference. The reference might be preinjury activity or a goal identified before treatment. It should not be reconstructed only after the result is known. A participant who changes priorities may have a satisfactory recovery while not returning to the original sport. Conversely, participation can occur despite persistent symptoms or restricted performance. The data should allow these combinations rather than force every participant into one unqualified success category.

Patient-reported measures can complement activity records without replacing them. The KOOS represents specified knee-related domains (Roos et al., 1998). It can capture experiences that a participation indicator misses, but its scores do not directly measure hours of exposure. A study should identify the domain relevant to its hypothesis and keep the activity variables separate. Correlation between them can be investigated rather than presumed. A participant can report improvement while modifying sport intensity or goals, and those combinations should remain visible in the longitudinal record.

The ascertainment interval should also be specified. A monthly report, a retrospective annual summary, and a recorded competition appearance have different opportunities for recall error and missed transitions. Frequent measurement can reveal intermittent participation that a final visit obscures. It can also increase respondent burden and missingness. The protocol should choose a resolution appropriate to the hypothesized process and preserve the basis of each observation. A precise-looking date derived from broad retrospective recall should not be treated as equivalent to a contemporaneous event record.

3. Exposure changes the opportunity for an event

An injury rate per participant followed over calendar time and an injury rate per unit of activity exposure are different quantities. A group with less participation can have fewer observed activity-related events without a more resilient construct under comparable loading. Conversely, a group returning to more demanding activity can experience more events while achieving a higher level of participation. A study should report the relevant denominators and avoid treating either pattern as a complete verdict on graft performance. The intended comparison determines whether exposure is an outcome, a denominator, or a variable in another model.

The Delaware-Oslo ACL cohort illustrates a relationship between return-related decisions and subsequent injury observations (Grindem et al., 2016). It motivates careful longitudinal design but does not supply a universal rule for revision patients. A future comparison should identify its own eligibility, rehabilitation context, ascertainment, and event definition. It should also distinguish observed outcomes after actual return from counterfactual outcomes under another return strategy. Transferring a study-specific association to a different revision population requires a substantive argument and appropriate validation.

Return itself is selected. Participants with better early recovery, fewer symptoms, different opportunities, or stronger motivation may be more likely to resume demanding activity. Restricting analysis to returners can therefore create a population different from the original surgical cohort. The resulting comparison may be useful when explicitly framed as an outcome among those who returned, but it does not automatically estimate the effect of graft choice in all eligible patients. The selection process should be visible in the participant flow and in baseline and early follow-up descriptions.

4. Activity can be a consequence and a cause

Postoperative activity can respond to early recovery and can influence subsequent outcomes. This makes it different from a simple baseline confounder. Causal diagrams can clarify the timing of these relationships (Greenland et al., 1999). If the intended question concerns the total effect of an initial graft strategy under ordinary follow-up, adjusting for every later activity measure may remove part of the pathway the strategy affects. If the question concerns outcomes under a specified activity regime, additional longitudinal assumptions and measurements are required. The same regression adjustment does not answer both questions.

Clinician advice, symptoms, patient confidence, and participation opportunities can also evolve together. A recorded return decision may reflect information unavailable in the study dataset. A model that conditions on that decision can therefore introduce selection that is difficult to characterize. A stronger

design records the basis and timing of the decision where feasible, while recognizing that complete measurement may remain impossible. The analysis should state whether it examines an observed pathway or attempts a counterfactual comparison. Calling an association adjusted does not resolve that distinction.

The framework also separates an event from its detection. Participants who return to organized sport may have closer monitoring than those exercising informally or not participating. Their symptoms and injuries can be identified more readily. An event-ascertainment plan should therefore include contact and verification procedures that do not depend entirely on team participation. If comparable ascertainment is not possible, the limitation should remain attached to the result. Different surveillance can influence an observed event rate even when the biological process is unchanged.

5. Follow the whole cohort over time

Repeated measurements can describe changes in participation, symptoms, and performance. Mixed-effects models offer one approach to representing correlated observations within a participant (Laird and Ware, 1982). Their interpretation depends on the chosen time scale and the pattern of observation. A mean trajectory across everyone is different from a trajectory conditional on continued participation. The report should preserve the number of participants observed at each interval and the reasons measurements are missing. A smooth fitted curve should not conceal a progressively selected group of returners.

Missing-data methods require assumptions about how unobserved outcomes relate to observed information (Little and Rubin, 2002). A participant may stop reporting because of good recovery, disappointment, another injury, or changing access. These mechanisms can distort activity trajectories in different directions. The study should record contact attempts and reasons for missingness where possible. Sensitivity analyses can then examine alternatives to the primary assumption. Treating a missing final sport status as either a success or a failure without justification would replace uncertainty with an administrative convention.

Additional treatment or withdrawal from sport can change the probability of observing another event. Competing-risk frameworks help define cumulative-incidence questions in the presence of specified competing events (Fine and Gray, 1999). They do not decide whether a particular transition should count as a competing event, a censoring event, or an outcome. That decision should follow the scientific question. A participant who chooses a less demanding activity has not necessarily experienced the same endpoint as a participant undergoing another reconstruction, even if both stop contributing exposure to the original sport.

6. Compare strategies without hiding the care setting

Activity outcomes can cluster within teams, surgeons, centres, or rehabilitation services. Cluster-robust inference addresses dependence under stated conditions (Cameron and Miller, 2015). It does not remove differences in the content of care or create comparable treatment alternatives across centres. A multisite study should retain the source of return-related assessments and the pathway through which participants received guidance. If a graft is used predominantly in one setting, an observed difference can partly reflect that setting. Statistical uncertainty and the comparability of care need separate consideration.

A prespecified outcome hierarchy can reduce selective interpretation. The primary question might concern participation at a stated level by a defined time, with subsequent injury and patient-reported domains as separate secondary outcomes. Another study might legitimately make time to an adjudicated event primary. The choice should reflect the research objective rather than whichever endpoint produces the most favorable comparison. Complete reporting should preserve tradeoffs, such as greater

participation alongside more exposure-related events. A single preferred metric can otherwise conceal what the strategy actually changed.

STROBE provides a foundation for reporting the observational design and participant flow (von Elm et al., 2007). For activity research, the record should add the activity reference, exposure definition, measurement interval, return criteria, and event verification. The dates of surgery, rehabilitation milestones, return, and additional procedures should remain distinguishable. If a participant begins observation only after return, the report must state the resulting selection. These details allow readers to determine whether a reported rate concerns the original cohort, an observed returner subgroup, or accumulated activity exposure.

7. Implications for graft evidence

Participants who never return should remain in the outcome description with reasons where available. Some may be unable to return, some may no longer wish to, and some may lack the opportunity. A single nonreturn category cannot distinguish these states. Treating every nonreturn as biological failure would overstate what was measured, while excluding all nonreturners would remove a potentially important consequence of the treatment course. A structured report can preserve the observed reason, acknowledge uncertainty about attribution, and show how alternative classifications affect the descriptive results. This is particularly useful when the study's primary goal concerns participation rather than an event conditional on participation. The classification should be chosen before comparing treatment groups whenever the planned design permits it.

Research on renewed loading after ACL revision requires more than a structural measurement at one visit. It needs a record of the activity under which later function or an event is observed. The management question motivating the consensus can guide that record while leaving the empirical relationship open. A proposed study should identify whether activity is an outcome, an exposure denominator, or part of a longitudinal treatment process. Those roles cannot be exchanged after observing the most favorable result.

A prospective study could collect a compact activity diary, scheduled patient-reported measures, and consistently verified events while preserving participants who never return. That design would support several complementary descriptions without forcing them into one endpoint. Its feasibility should be assessed with attention to respondent burden and the reliability of exposure reports. A more detailed measurement is useful only if it can be collected consistently enough to answer the intended question. The proposed design remains a research agenda rather than a completed longitudinal study.

The IKDC subjective knee form can complement exposure histories with a defined report of knee-related experience (Irrgang et al., 2001). It should remain separate from a return date or accumulated activity hours. A study might ask whether reported function and actual participation recover on similar schedules, but that relationship requires observations of both. Preserving disagreements can be informative when participants change their goals or opportunities. A favorable score should not be converted automatically into a completed return event, and a missing participation record should not be inferred from the questionnaire.

Return to sport becomes interpretable when participation, exposure, selection, and subsequent events remain visible. A low event count cannot be assessed independently of the opportunity to experience and detect an event. Repeated-measure and competing-risk methods can help after the target is defined, but they cannot supply missing exposure histories. The framework connects these requirements to adult ACL revision research and preserves the distinction between a management question and an observed effect. It offers a plan for stronger follow-up evidence rather than a new claim of graft superiority.

References

Cao, Mingde, et al. "APKASS 2024 consensus statement on anterior cruciate ligament reconstruction, Part II: Management of anterior cruciate ligament revision in adults." *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology* 45 (2026): 74-81.

Grindem, Hege, et al. "Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study." *British Journal of Sports Medicine*, vol. 50, no. 13, 2016, pp. 804-808. https://doi.org/10.1136/bjsports-2016-096031.

Fine, Jason P., and Robert J. Gray. "A Proportional Hazards Model for the Subdistribution of a Competing Risk." *Journal of the American Statistical Association*, vol. 94, no. 446, 1999, pp. 496-509. https://doi.org/10.1080/01621459.1999.10474144.

Little, Roderick J. A., and Donald B. Rubin. *Statistical Analysis with Missing Data*. Wiley, 2002. https://doi.org/10.1002/9781119013563.

Laird, Nan M. and James H. Ware. “Random-Effects Models for Longitudinal Data.” *Biometrics*, vol. 38, no. 4, 1982, pp. 963. https://doi.org/10.2307/2529876.

Greenland, Sander, Judea Pearl, and James M. Robins. “Causal Diagrams for Epidemiologic Research.” *Epidemiology*, vol. 10, no. 1, 1999, pp. 37-48. https://doi.org/10.1097/00001648-199901000-00008.

Cameron, A. Colin, and Douglas L. Miller. “A Practitioner’s Guide to Cluster-Robust Inference.” *Journal of Human Resources*, vol. 50, no. 2, 2015, pp. 317-372. https://doi.org/10.3368/jhr.50.2.317.

von Elm, Erik, et al. "The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies." *PLoS Medicine*, vol. 4, no. 10, 2007, pp. e296. https://doi.org/10.1371/journal.pmed.0040296.

Roos, Ewa M., et al. "Knee Injury and Osteoarthritis Outcome Score (KOOS): Development of a Self-Administered Outcome Measure." *Journal of Orthopaedic & Sports Physical Therapy*, vol. 28, no. 2, 1998, pp. 88-96. https://doi.org/10.2519/jospt.1998.28.2.88.

Irrgang, James J., et al. "Development and Validation of the International Knee Documentation Committee Subjective Knee Form." *The American Journal of Sports Medicine*, vol. 29, no. 5, 2001, pp. 600-613. https://doi.org/10.1177/03635465010290051301.