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Functional Testing for Return-to-Sport Decision-Making After Anterior Cruciate Ligament Reconstruction: An Updated Narrative Review

Mingyang Wei[1]

[1] ANNPO Biotechnology Inc., Guangzhou 510515, China
Correspondence: Mingyang Wei, ANNPO Biotechnology Inc., Guangzhou 510515, China.

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Abstract

Return-to-sport (RTS) decision-making after anterior cruciate ligament reconstruction (ACLR) has moved away from time alone toward criterion-based models, yet the optimal composition of a functional testing battery remains debated. Functional tests are still essential because they quantify residual deficits in strength, power, neuromuscular control, balance, and confidence; however, contemporary evidence shows that no single test has adequate validity to clear an athlete independently. This updated narrative review synthesizes landmark cohort studies together with recent reviews, guidelines, and meta-analyses on functional RTS assessment after primary ACLR. The current literature indicates that hop tests remain clinically valuable, especially the single-leg hop for distance, crossover hop, 6-m timed hop, and single-leg vertical hop, but isolated pass/fail thresholds show inconsistent ability to predict second injury or successful RTS. Quadriceps strength remains indispensable, although limb symmetry index (LSI) should not be interpreted without consideration of absolute strength, time since surgery, graft type, sex, and possible deconditioning of the contralateral limb. Movement-quality assessments during landing, single-leg squat, or change-of-direction tasks may reveal high-risk patterns that distance-based tests miss. Psychological readiness, most commonly assessed with the ACL-Return to Sport after Injury scale, is another core domain because fear of reinjury and low confidence often persist despite acceptable physical scores. Importantly, recent evidence shows that RTS testing is commonly administered around 7 months post-operatively, which is earlier than timelines associated with lower reinjury risk in pivoting sports. A contemporary RTS strategy should therefore rely on a domain-based battery combining clinical status, strength testing, at least two hop or jump tasks, movement-quality assessment, patient-reported outcomes, and psychological readiness. For unrestricted return to level I pivoting sports, final clearance is best delayed until at least 9 months after surgery and only after satisfactory performance is demonstrated across domains.

Keywords: anterior cruciate ligament reconstruction, return to sport, functional testing, hop tests, quadriceps strength, psychological readiness

1. Introduction

Anterior cruciate ligament (ACL) injury is one of the most consequential injuries in sport because it affects short-term performance, long-term knee

health, and the athlete's confidence in the injured limb. Although ACL reconstruction (ACLR) restores passive restraint and often allows a return to sport, the period after surgery remains clinically challenging. Young and highly active athletes continue to face a substantial risk of secondary ACL injury after returning to pivoting sports, which makes the quality of the return-to-sport (RTS) decision at least as important as the operation itself (Wiggins AJ, Grandhi RK, Schneider DK, Stanfield D, Webster KE & Myer GD., 2016).

Earlier rehabilitation models often used time from surgery as the dominant criterion for sport clearance. That approach is now widely regarded as insufficient. In the Delaware-Oslo ACL cohort, athletes who returned to level I sport had a more than fourfold higher reinjury rate than those who did not, and the risk of reinjury fell by approximately 51% for each month RTS was delayed until 9 months after surgery (Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L & Risberg MA., 2016). These data do not mean that time is irrelevant; rather, they indicate that time should be treated as a protective boundary condition rather than a stand-alone decision rule.

Functional testing emerged as an attractive complement to time-based decisions because it is relatively inexpensive, repeatable, and clinically intuitive. Historically, hop tests became the most frequently reported field measures, and early cohort studies suggested that the crossover hop and the 6-m timed hop could help predict self-reported knee function one year after reconstruction (Logerstedt D, Grindem H, Lynch A, Eitzen I, Engebretsen L, Risberg MA, et al., 2012). More recent evidence, however, has complicated this picture by showing that the most commonly used strength and hop tests have limited and inconsistent value when they are used in isolation to predict second injury or successful return to the preinjury level of sport (Gill VS, Tummala SV, Sullivan G, Han W, Haglin JM, Marks L & Tokish JM., 2024).

The purpose of this revised manuscript is to update the original review with a contemporary interpretation of the literature. Rather than ranking tests solely by frequency or convenience, the present paper organizes the evidence by domain—strength, hop and jump performance, movement quality, balance and proprioception, patient-reported outcomes, and psychological readiness—and then proposes a pragmatic, clinically feasible battery for RTS decision-making after primary ACLR.

2. Functional Testing as Part of a Broader RTS Framework

Modern rehabilitation frameworks describe RTS as a continuum rather than a single event. Athletes first progress to running, then to controlled change of direction, then to sport-specific practice, and only later to unrestricted competition and return to performance (Brinlee AW, Dickenson SB, Hunter-Giordano A, Snyder-Mackler L., 2022; Simonsson R, Piussi R, Högberg J, Sundberg A & Hamrin Senorski E., 2024). Functional testing is therefore most useful when it is repeated across phases and interpreted within a broader clinical context that includes symptoms, swelling, range of motion, training exposure, psychological readiness, and the demands of the target sport.

Recent reviews consistently emphasize that no single test can capture the multiple constructs relevant to RTS after ACLR (Brinlee AW, Dickenson SB, Hunter-Giordano A & Snyder-Mackler L., 2022; Turk R, Shah S, Chilton M, Thomas TL, Anene C, Mousad A, et al., 2023; Golberg E, Sommerfeldt M, Pinkoski A, Dennett L & Beaupre L., 2024; Simonsson R, Piussi R, Högberg J, Sundberg A & Hamrin Senorski E., 2024; Kodama E, Tartibi S, Brophy RH, Smith MV, Matava MJ & Knapik DM., 2025; Mengis N, Höher J, Ellermann A, Eberle C, Hartner C, Keller M, et al., 2025). A useful test battery should sample at least five domains: (1) knee status and load tolerance, (2) muscle strength, (3) hop or jump performance, (4) movement quality and sensorimotor control, and (5) self-reported and psychological readiness. This domain-based perspective is more defensible than searching for one universally superior field test because athletes may compensate in one task while still displaying meaningful deficits in another.

Table 1. Contemporary domains that should be represented in RTS assessment after ACL reconstruction

Domain	Examples of common tools	Primary purpose	Important limitation
Clinical	Effusion assessment, pain	Establishes whether	An athlete may feel

Domain	Examples of common tools	Primary purpose	Important limitation
status and load tolerance	response, range of motion, tolerance of running and practice loads	the knee is currently able to tolerate progression	symptomatically well while still showing major performance deficits
Strength	Isokinetic testing, handheld dynamometry, portable dynamometry, 8-repetition maximum testing	Quantifies quadriceps and hamstring recovery and residual asymmetry	Limb symmetry can be misleading if the contralateral limb is also deconditioned
Hop and jump performance	Single hop, triple hop, crossover hop, 6-m timed hop, single-leg vertical hop	Captures explosive function, confidence, and task-specific asymmetry	Distance or time alone can hide compensatory movement strategies
Movement quality and agility	Single-leg squat, drop jump, cutting or change-of-direction tasks, Y-Balance or Star Excursion tests	Detects frontal-plane collapse, trunk compensation, landing asymmetry, and sensorimotor deficits	Observational scoring can be subjective if the task is not standardized or video recorded
Self-reported and psychological readiness	ACL-RSI, IKDC, KOOS Sport/Rec	Captures fear of reinjury, confidence, symptoms, and perceived function	Good questionnaire scores do not guarantee adequate physical capacity

3. Strength Testing

Quadriceps strength remains the anchor of postoperative performance testing. Persistent quadriceps weakness after ACLR is associated with poorer function, altered mechanics, and delayed progression through rehabilitation (Brinlee AW, Dickenson SB, Hunter-Giordano A & Snyder-Mackler L., 2022; Thomeé R, Kaplan Y, Kvist J, Myklebust G, Risberg MA, Theisen D, et al., 2011). In the Delaware-Oslo cohort, more symmetrical quadriceps strength before RTS was associated with a lower reinjury rate (Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L & Risberg MA., 2016). For that reason, recent reviews still place quadriceps and hamstring testing at the center of RTS evaluation (Turk R, Shah S, Chilton M, Thomas TL, Anene C, Mousad A, et al., 2023; Simonsson R, Piussi R, Högberg J, Sundberg A & Hamrin Senorski E., 2024; Kodama E, Tartibi S, Brophy RH, Smith MV, Matava MJ & Knapik DM., 2025; Mengis N, Höher J, Ellermann A, Eberle C, Hartner C, Keller M, et al., 2025).

At the same time, contemporary evidence warns against simplistic interpretation of limb symmetry index (LSI) thresholds. An LSI of 90% or greater is the most commonly reported criterion in the literature (Kodama E, Tartibi S, Brophy RH, Smith MV, Matava MJ & Knapik DM., 2025), yet a 2025 critical analysis concluded that LSI from muscle-function tests could not distinguish athletes who returned safely from those who sustained a second ACL injury within two years (Simonsson R, Sundberg A, Piussi R, Högberg J, Senorski C, Thomeé R, et al., 2025). The fundamental issue is that symmetry alone is not sufficient to indicate adequacy. An athlete can reach an apparently acceptable LSI because the uninvolved limb is also weak, because the test favors compensation, or because the strength deficit is small in percentage terms but still meaningful in sport-specific contexts.

The practical consequence is that clinicians should interpret symmetry together with absolute performance and the context of recovery. Hazzard and colleagues showed that quadriceps symmetry follows a time-dependent trajectory after surgery and varies by sex, age, and graft type; many athletes are only reaching approximately 80% symmetry around the time they begin running (Hazzard S, Connolly S, Wiater A, Sprague I, Doolan-Roy E, Lampros R & Asnis PD., 2024). Thus, an athlete assessed at 5 to 7 months may appear to be progressing appropriately, while still not meeting the physical demands of competitive pivoting sports. When laboratory isokinetic dynamometry is unavailable, practical alternatives such as portable dynamometry or 8-repetition maximum testing appear reasonable for everyday use

(Mengis N, Höher J, Ellermann A, Eberle C, Hartner C, Keller M, et al., 2025).

4. Hop and Jump Performance Testing

Hop testing remains widely used owing to its practicality and clinical relevance. Single-leg hop tasks are inexpensive, straightforward to administer, and familiar to both clinicians and athletes. The traditional battery typically includes the single hop for distance, triple hop, crossover hop, and 6-m timed hop. In an influential cohort study, the crossover hop and 6-m timed hop measured six months after ACLR were the strongest individual predictors of self-reported knee function at one year (Logerstedt D, Grindem H, Lynch A, Eitzen I, Engebretsen L, Risberg MA, et al., 2012). These tasks therefore still deserve a place in rehabilitation and late-stage progression.

However, the current literature no longer supports the view that horizontal hop tests alone can serve as a dependable surrogate for safe RTS. In a 2024 systematic review, Gill and colleagues found that single-leg hop for distance had no association with retear risk in any included study and no relationship with RTS rates in most studies; quadriceps strength also showed conflicting associations with reinjury, and combined hop-plus-strength batteries demonstrated low sensitivity and negative predictive value (Gill VS, Tummala SV, Sullivan G, Han W, Haglin JM, Marks L & Tokish JM., 2024). In other words, passing a conventional battery does not guarantee safe RTS, and failing a battery does not always identify the athlete who will later experience reinjury.

Recent work suggests that vertical tasks may expose residual deficits more effectively than hop-for-distance alone. In a systematic review and meta-analysis, Wang and colleagues reported that the single-leg vertical jump produced lower LSI values than the single-leg hop for distance between 7 and 18 months after ACLR, indicating that the vertical task may be more sensitive during the period when many athletes are preparing for sport clearance (Wang L, Xia Q, Li T, Wang Z & Li J., 2024). The key implication is not that vertical hopping should replace traditional hop tests, but that horizontal distance, timed hopping, and vertical jumping should be treated as complementary, not interchangeable, measures.

For clinical practice, hop and jump tests are most useful when clinicians record more than one outcome: the score itself, the quality of landing, the consistency across trials, and the athlete's confidence in the task. A horizontal hop performed with a stiff landing, trunk shift, contralateral arm overuse, or obvious valgus collapse should not be treated as a clean pass merely because the distance was acceptable.

5. Movement Quality, Agility, and Sensorimotor Control

One of the clearest developments in the recent literature is the growing emphasis on movement quality. Athletes can often achieve acceptable hop distance by using compensatory strategies that increase joint loading or conceal deficits in eccentric control. In a prospective cohort, Paterno and colleagues showed that landing biomechanics and postural stability deficits predicted second ACL injury after return to sport Paterno MV, Schmitt LC, Ford KR, Rauh MJ, Myer GD, Huang B & Hewett TE., 2010). More recently, Gill et al. reported that asymmetrical knee extension and hip moments, together with increased knee valgus and altered knee flexion patterns, were among the variables associated with retear risk (Gill VS, Tummala SV, Sullivan G, Han W, Haglin JM, Marks L & Tokish JM., 2024). These observations help explain why distance-based tests frequently underperform as standalone predictors.

The single-leg squat remains one of the most useful office-based movement-quality assessments because it is accessible and reveals deficits in trunk control, pelvic control, hip strategy, and dynamic knee valgus. Hall et al. found that 45% of patients still demonstrated poor single-leg squat performance at approximately six months after ACLR, and poor performers also had weaker hip abductors, shorter hop distance, and lower IKDC scores (Hall MP, Paik RS, Ware AJ, Mohr KJ & Limpisvasti O., 2015). Although the single-leg squat is not a complete RTS test by itself, it is a valuable adjunct because it highlights how the athlete produces movement rather than only how far or how fast the athlete can move.

Balance and proprioceptive tests are best viewed as secondary contributors to a broader battery. The Star Excursion Balance Test and related reach tests can detect persistent postural-control deficits, particularly when the involved limb is challenged dynamically (Herrington L, Hatcher J, Hatcher A & McNicholas M., 2009). Nevertheless, contemporary evidence does not support

clearing an athlete for RTS on the basis of balance testing alone. The strongest clinical role of these tests is to complement strength and hop testing and to help guide targeted neuromuscular retraining.

In high-resource settings, three-dimensional motion analysis and force-plate metrics may improve sensitivity, but the absence of laboratory equipment should not prevent clinicians from addressing movement quality. Video-assisted observation of single-leg squats, drop jumps, and change-of-direction tasks can meaningfully strengthen RTS decision-making when the task is standardized and the scoring criteria are explicit.

6. Psychological Readiness and Patient-Reported Outcomes

Functional recovery after ACLR is never purely physical. Fear of reinjury, hesitancy during cutting and landing, and loss of trust in the knee frequently persist even when strength and hop scores improve. For that reason, recent reviews consistently include patient-reported outcome measures (PROMs) and psychological readiness as core components of RTS evaluation (Turk R, Shah S, Chilton M, Thomas TL, Anene C, Mousad A, et al., 2023; Simonsson R, Piussi R, Högberg J, Sundberg A & Hamrin Senorski E., 2024; Kodama E, Tartibi S, Brophy RH, Smith MV, Matava MJ & Knapik DM., 2025; Mengis N, Höher J, Ellermann A, Eberle C, Hartner C, Keller M, et al., 2025).

The ACL-Return to Sport after Injury scale (ACL-RSI) is the most commonly used measure of psychological readiness. In a 2024 systematic review and meta-analysis, Sell and colleagues found that ACL-RSI scores improved early after injury and reconstruction but then remained relatively stable during much of the conventional rehabilitation window, suggesting that fear and confidence deficits may persist despite ongoing physical recovery (Sell TC, Zerega R, King V, Reiter CR, Wrona H, Bullock GS, et al., 2024). The review also noted that the overall certainty of evidence was weak, which further supports repeated monitoring rather than one-time interpretation.

PROMs such as the IKDC or the KOOS Sport and Recreation subscale provide another clinically important perspective. They capture symptoms, perceived function, and sport-related limitations that objective tests may miss. A practical RTS decision is therefore strengthened when PROMs and psychological measures move in the same direction as physical performance. By contrast, low ACL-RSI or IKDC scores despite satisfactory physical performance may indicate the need for continued rehabilitation before return to sport.

7. Timing of RTS Testing and Repeated Interpretation

A central weakness of many existing RTS protocols is not merely what they test, but when they test it. A 2025 systematic review found that RTS testing is administered, on average, at 7.30 months after ACLR, with 6 and 12 months being the most common testing points (Pales Taylor ML, Ihn H, Cushman DM & Bodkin SG., 2025). This timing is problematic because it places much of the literature's RTS assessment earlier than the time frame associated with lower reinjury risk in pivoting sports (Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L &, Risberg MA., 2016; Pales Taylor ML, Ihn H, Cushman DM & Bodkin SG., 2025).

The solution is not to avoid early testing, but to reinterpret its purpose. Testing at 4 to 6 months is useful for progression decisions such as return to running, more advanced strength work, and early plyometrics. Testing at 7 to 9 months can support late-stage reconditioning and identify residual barriers. Final unrestricted RTS for level I pivoting sports, however, is better conceptualized as a later decision that integrates repeated testing, sport-specific exposure, and an adequate postoperative timeline, ideally 9 months or later (Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L &, Risberg MA., 2016; Simonsson R, Piussi R, Högberg J, Sundberg A & Hamrin Senorski E., 2024; Pales Taylor ML, Ihn H, Cushman DM &, Bodkin SG., 2025).

This staged approach also helps explain an important clinical tension. Athletes may achieve acceptable results on simplified field-based tests even when graft healing, the physical demands of sport, and the risk of reinjury still suggest that caution is needed. Repeated assessment across recovery phases is therefore more informative than relying on a single pass-or-fail decision near the anticipated return-to-sport date.

8. Proposed Clinically Feasible Battery

Based on the current evidence, an appropriate RTS battery after primary ACLR should prioritize breadth across domains, repeated assessment, and feasibility in real-world practice. The proposed battery in Table 2 is not intended as a universal law or a substitute for clinical judgment. Instead, it offers a pragmatic framework for outpatient clinics, sports medicine

practices, and rehabilitation settings that do not have access to full laboratory biomechanics.

Table 2. Pragmatic domain-based RTS battery for everyday clinical practice

Domain	Suggested assessment	How to interpret it	Minimum progression consideration
Clinical knee status	Pain, effusion, full extension, near-full flexion, tolerance of current training load	Screen for irritability before performance testing	No significant swelling or pain flare after training or testing
Time and exposure	Document months since surgery and recent progression through running, plyometrics, change of direction, and practice	Time is not sufficient alone, but it sets the context for risk	Avoid final clearance for unrestricted pivoting sport before ~9 months after surgery
Strength	Quadriceps and hamstring testing using isokinetic dynamometry, portable dynamometer, or validated field alternative	Interpret LSI together with absolute performance, limb dominance, and contralateral deconditioning	Prefer symmetry of at least 90% plus acceptable sport-relevant strength capacity
Hop and jump performance	At least two tasks, ideally one horizontal (single or crossover hop / 6-m timed hop) and one vertical (single-leg vertical hop)	Record both the score and landing strategy	Do not rely on a single hop task as the decisive clearance criterion
Movement quality	Video-assisted single-leg squat, drop jump, and/or change-of-direction task	Look for valgus collapse, trunk shift, poor eccentric control, asymmetrical loading, and loss of balance	No obvious high-risk compensations on repeated trials
Patient-reported and psychological readiness	ACL-RSI plus IKDC or KOOS Sport/Rec	Use trends and discordance across domains to guide counseling and further intervention	Scores should support—not contradict—the physical testing profile
Sport-specific progression	Controlled practice, reactive drills, fatigue exposure, and gradual return to team training	Final decision should reflect real sporting demands, not only laboratory or clinic tasks	Progress from participation to performance in stages rather than immediate unrestricted competition

Two principles deserve emphasis. First, thresholds should be treated as decision aids rather than guarantees of safety. An athlete may meet every visible criterion and still remain at risk if exposure is advanced too quickly, if task quality deteriorates under fatigue, or if the athlete lacks confidence when competition becomes chaotic. Second, failing one domain should not automatically delay all progress, but it should direct treatment toward the residual problem. For example, an athlete with adequate strength but poor ACL-RSI may need targeted psychological and graded exposure work, whereas an athlete with reassuring questionnaires but marked movement asymmetry requires further neuromuscular

retraining.

9. Limitations of the Current Evidence

The evidence base for RTS testing after ACLR remains heterogeneous. Reviews differ in inclusion criteria, athlete level, surgical techniques, graft types, rehabilitation models, test protocols, and outcome definitions (Golberg E, Sommerfeldt M, Pinkoski A, Dennett L & Beaupre L., 2024; Gill VS, Tummala SV, Sullivan G, Han W, Haglin JM, Marks L & Tokish JM., 2024; Kodama E, Tartibi S, Brophy RH, Smith MV, Matava MJ & Knapik DM., 2025; Pales Taylor ML, Ihn H, Cushman DM & Bodkin SG., 2025). Some studies define success as return to participation, others as return to the same competitive level, and others as absence of reinjury. This heterogeneity makes it difficult to validate one universal battery.

Another limitation is the continued overreliance on LSI. Symmetry is easy to understand and simple to communicate, but it is not equivalent to full recovery (Wang L, Xia Q, Li T, Wang Z & Li J., 2024; Simonsson R, Sundberg A, Piussi R, Högberg J, Senorski C, Thomeé R, et al., 2025). The contralateral limb may also weaken during rehabilitation, and many functional tasks permit compensation patterns that inflate symmetry scores. In addition, much of the literature focuses on young athletes in pivoting sports, so the applicability of the same criteria to older recreational populations is uncertain.

Finally, many promising biomechanics variables are derived from laboratory studies and are not yet standardized for everyday practice. The field therefore needs more validation of portable, low-cost alternatives that preserve as much clinical meaning as possible without demanding specialized motion-analysis infrastructure.

10. Future Directions

Future research should move beyond one-time clearance models and evaluate repeated, phase-specific testing strategies. Portable technology offers a promising route. Recent focused guidance suggests that smartphone-based or sensor-based jump testing, portable dynamometry, and other lower-cost alternatives may allow more clinics to monitor meaningful RTS domains with acceptable validity and feasibility (Mengis N, Höher J, Ellermann A, Eberle C, Hartner C, Keller M, et al., 2025).

Research also needs to determine which combinations of domains—not merely which single tests—best predict safe return to sport. The most clinically relevant outcome is not whether the athlete can pass one battery on one day, but whether the athlete can tolerate progressive exposure to sport without recurrent instability, marked fear, or a second ACL injury. Longitudinal studies that combine strength, movement quality, psychological readiness, and sport-exposure data are likely to be more informative than studies focused on isolated test cutoffs.

11. Conclusion

Functional testing remains indispensable for RTS decision-making after ACLR, but the role of testing has matured. The most useful question is no longer which single test is best, but how a clinician can assemble a battery that samples the domains most relevant to safe and effective return. Contemporary evidence indicates that quadriceps strength, multiple hop or jump tasks, movement-quality assessment, PROMs, and psychological readiness should all contribute to the final decision (Turk R, Shah S, Chilton M, Thomas TL, Anene C, Mousad A, et al., 2023; Gill VS, Tummala SV, Sullivan G, Han W, Haglin JM, Marks L & Tokish JM., 2024; Simonsson R, Piussi R, Högberg J, Sundberg A & Hamrin Senorski E., 2024; Kodama E, Tartibi S, Brophy RH, Smith MV, Matava MJ & Knapik DM., 2025; Mengis N, Höher J, Ellermann A, Eberle C, Hartner C, Keller M, et al., 2025).

Traditional tasks such as the single-leg hop for distance, crossover hop, 6-m timed hop, single-leg squat, and dynamic balance tests remain clinically useful, yet they should be treated as components of a domain-based algorithm rather than as individually decisive clearance tools. For athletes planning to return to pivoting sports, a more cautious return-to-sport timeline, usually no earlier than 9 months after surgery, is better aligned with the documented risk of reinjury. (Grindem H, Snyder-Mackler L, Moksnes H, Engebretsen L & Risberg MA., 2016; Pales Taylor ML, Ihn H, Cushman DM, Bodkin SG., 2025). In practical terms, the strongest RTS decision is the one supported by converging evidence across time, function, movement quality, symptoms, and confidence.

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