The Impact of Functional Outcomes Following Anterior Cruciate Ligament Reconstruction on Return to Sport in Basketball Players: A Systematic Review

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ABSTRACT

Anterior cruciate ligament (ACL) injuries are common among basketball players and have a significant impact on athletic performance; consequently, the extent to which athletes can return to competitive level following reconstruction surgery has become a key focus of sports rehabilitation research. Basketball involves frequent jumping, rapid changes of direction and physical contact, placing high demands on lower limb strength and dynamic stability. The degree of functional recovery following surgery directly influences an athlete's ability to participate in training and competition, and is closely linked to the risk of re-injury. Previous studies have shown that determining the timing of return to sport based solely on postoperative time does not accurately reflect actual functional status. Functional performance has gradually become the core basis for assessment, primarily encompassing muscle strength, jumping ability, dynamic balance, neuromuscular control and sport-specific performance, whilst also involving functional symmetry and subjective perceptions of recovery. These indicators influence one another and collectively determine athletic performance. Current evidence suggests that multidimensional functional assessments hold greater value than single-parameter measures, and sport-specific functional testing is increasingly being prioritised. However, issues such as discrepancies in assessment criteria and a lack of sport-specific tests persist in the research literature. The development of a comprehensive assessment system that integrates basic functional abilities with sport-specific skills will help enhance the safety and effectiveness of postoperative return to sport for basketball players.

Keywords: Basketball players; anterior cruciate ligament reconstruction; functional performance; return to sport; quadriceps

INTRODUCTION

The anterior cruciate ligament (ACL) plays a crucial role in maintaining knee stability, and injuries to this ligament are relatively common in basketball. Activities such as jumping and landing, sudden stops and changes of direction, and contact play place increasing strain on the knee joint, significantly raising the risk of ACL injury. Following an injury, athletes typically require reconstructive surgery and undergo a lengthy rehabilitation process, with considerable variation in recovery outcomes between individuals. Traditional criteria for return to sport are often based on postoperative time, but time-based indicators fail to reflect the actual level of recovery in muscle function and motor control.[18] Some athletes still exhibit insufficient strength and abnormal motor control even after meeting time-based criteria[19], placing them at higher risk during high-intensity activities. The academic community has gradually shifted towards using functional performance as the core basis for assessing readiness to return to sport. Functional performance encompasses multiple dimensions, including muscle strength, neuromuscular control and sport-specific abilities. As basketball places high demands on lower-limb functional integration, a single test is unlikely to fully reflect an athlete's actual condition. Integrating research evidence across these dimensions helps clarify the specific role of functional outcomes in return-to-sport

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decision-making and provides a basis for clinical rehabilitation assessment. This review aims to address the following central question: Which functional outcomes have the most significant impact on basketball players' readiness to return to sport following anterior cruciate ligament reconstruction? Centred on this central question, this paper explores five sub-questions:

Sub-question 1: How does the level of muscle strength recovery influence basketball players' readiness to return to sport?

Sub-question 2: What role does jumping ability play in determining whether an athlete meets the functional criteria for return to sport?

Sub-question 3: How do the degree of recovery in dynamic balance and neuromuscular control influence the risk of injury and performance levels following a return to sport?

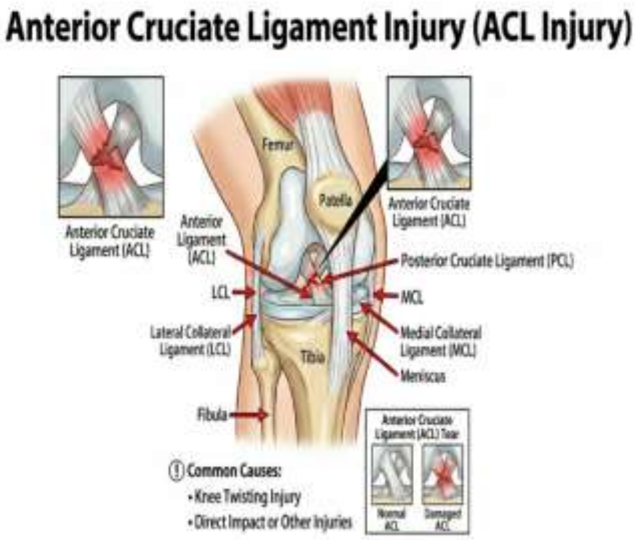
Sub-question 4: To what extent can sport-specific functional tests reflect the actual match readiness of basketball players?

Sub-question 5: What limitations do current functional symmetry indicators have in guiding decisions regarding return to sport?

Key Dimensions of Functional Outcome Following Anterior Cruciate Ligament Reconstruction

Muscle Strength Recovery

The recovery of muscle strength forms the basis of postoperative functional assessment, and quadriceps weakness is considered one of the key factors affecting recovery. Joint-induced muscle inhibition frequently occurs in the early postoperative period, leading to reduced muscle activation capacity; this phenomenon can sometimes persist for an extended period. In basketball, the relevant muscle groups are involved in deceleration and landing control; insufficient strength can compromise joint stability. Research indicates that quadriceps strength deficits are associated with reduced athletic performance and an increased risk of re-injury. Isokinetic strength testing is a commonly used method for assessing the level of recovery, typically analysed in conjunction with limb symmetry indices. Symmetry indices have some reference value, but may be subject to bias due to reduced function in the unaffected side. Some studies suggest that absolute muscle strength values are more predictive of athletic performance; therefore, strength assessments must be evaluated comprehensively in relation to the specific demands of the sport. The degree of muscle strength recovery directly determines the foundation of joint stability for athletes during high-load basketball movements; when quadriceps strength has not fully recovered, readiness for return to sport is insufficient, and the risk of re-injury is significantly higher. Relying solely on symmetry indices may overestimate the level of recovery; the degree to which absolute strength values align with sport-specific requirements is a more reliable basis for assessment.



Jumping ability

Jumping ability reflects lower-limb explosive power and motor coordination; in basketball, this is primarily manifested in take-off height, landing stability and the ability to execute consecutive movements. The single-leg jump test is commonly used in post-operative functional assessment, as it reflects the affected limb's ability to generate and control force under high-load conditions; jumping performance is closely related to muscle strength levels and the degree of neuromuscular control. Some athletes continue to exhibit insufficient jumping ability even after resuming daily activities, indicating that their explosive power and motor control have not yet met the requirements of their sport.

Jumping movements involve both eccentric control and concentric contraction, placing high demands on muscle mechanical properties and neuromuscular regulation; changes in muscle stiffness and force-generating capacity directly affect the quality of movement execution. The single-leg jump test can simultaneously reflect both strength and stability characteristics, making it highly valuable in functional assessment.

Jumping ability is a key functional indicator for assessing readiness to return to sport; any deficiency in this area directly reflects shortcomings in explosive power and landing control. The single-leg jump test is highly representative in both clinical and competitive assessments; failure to meet the required standards in jumping performance indicates that the athlete does not yet possess the ability to cope with the high-intensity demands of jumping and landing in basketball matches.[22] Farmer et al. found that athletes with injuries to their non-dominant jumping leg had a significantly lower LSI score in the single-leg hop test than those with injuries to their dominant jumping leg (81.1% vs 94.1%), suggesting that Hop Test results may be influenced by task preferences and limb function characteristics, rather than merely reflecting the true level of recovery.

Table 2.

Study results based on preferred limb to kick a ball or preferred limb for jumping.

	Injured Limb Based on Preference to Kick Ball				Injured Limb Based on Preference to Jump			
	Dominant	Non-Dominant	P	d	Dominant	Non-Dominant	P	d
IKDC	78.1 ± 13.8%	78.1 ± 15.2%	0.99	0.01	80.4 ± 14.0%	75.7 ± 14.7%	0.31	0.33
Quadriceps LSI	78.3 ± 17.4%	80.8 ± 21.8%	0.69	−0.13	82.6 ± 21.2%	76.3 ± 17.6%	0.31	0.32
Single Leg Forward Hop LSI	87.0 ± 18.4%	89.6 ± 16.2	0.70	−0.15	94.1% ± 12.6%	81.1 ± 19.5%	0.05	0.77

Table 3.

Correlations between patient-reported and performance outcome measures.

	IKDC	Quadriceps LSI
IKDC	--	
Quadriceps LSI	.790 *	--
Single Leg Forward Hop LSI	.778 *	.685 *

* indicates significant correlation ($p < 0.05$)

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Table 4.

Regression models to predict IKDC Scores at intermediate stages of ACL rehabilitation (3–6 months post-surgery).

Model	Variable	Standardized ß	P	R	R^2	R^2 Change	SE
1	Constant		< .001	.790	.624	.624	.086
	Quadriceps LSI	.790					
2	Constant		< .001	.854	.729	.105	.074
	Quadriceps LSI	.485					
	Single leg forward hop LSI	.445					

Dynamic Balance and Neuromuscular Control

Following an anterior cruciate ligament injury, proprioceptive input to the joint decreases and positional awareness declines, thereby affecting the level of neuromuscular control. Dynamic balance reflects the body's ability to maintain postural stability during movement and is crucial for the changes of direction, sudden stops and landing movements involved in basketball. The Y-balance test and the Single-Leg Balance Test (SEBT) are commonly used tools for assessing dynamic stability.[5] Inadequate recovery of neuromuscular control leads to reduced motor coordination, which is particularly evident during high-intensity exercise. When balance is impaired, stability during single-leg support phases is reduced and joint control is weakened, thereby increasing the risk of injury. Under conditions of fatigue, eccentric control capacity declines further, and issues such as abnormal movement trajectories and reduced force transmission efficiency become more pronounced[16]. The degree of recovery in dynamic balance and neuromuscular control is directly correlated with the risk of injury following a return to sport. Athletes with inadequate control exhibit reduced joint protection during changes of direction and landing movements, a phenomenon that is particularly pronounced under conditions of fatigue. Assessment in this area should not rely solely on static stability tests; dynamic measurements must be conducted under simulated sports load conditions. [23]Kotsifaki et al. found that, although athletes met the RTS criteria (LSI > 90%), there remained significant asymmetry in ACL loading and tibiofemoral contact forces during cutting and running manoeuvres, suggesting that traditional RTS criteria may not adequately reflect the true state of biomechanical recovery.

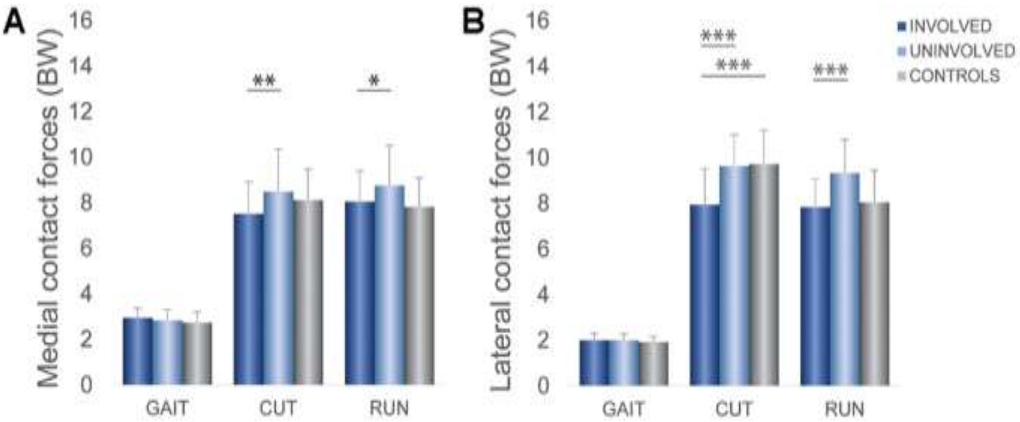

Figure 4. Maximum (A) medial and (B) lateral tibiofemoral contact forces for the involved leg, uninvolved leg, and controls. *P < .05. **P < .01. ***P < .001. BW, body weight; CUT, side cutting 45°; GAIT, walking at self-selected speed; RUN, running maximum speed.

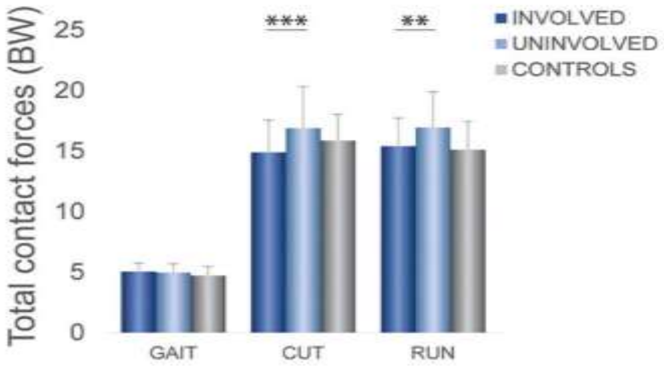

Figure 3. Maximum total tibiofemoral contact forces for the involved leg, uninvolved leg, and controls. **P < .01. ***P < .001. BW, body weight; CUT, side cutting 45°; GAIT, walking at self-selected speed; RUN, running maximum speed.

ACL forces than the uninvolved leg during cutting (P ¼ .025) and running (P ¼ .004) (Figure 5 and Appendix Table A1)

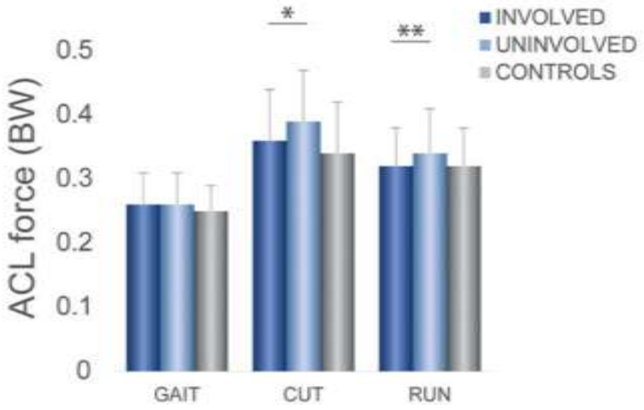

Figure 5. Anterior cruciate ligament (ACL) forces for the involved leg, uninvolved leg, and controls. *P < .05. **P < .01. BW, body weight; CUT, side cutting 45°; GAIT, walking at self-selected speed; RUN, running maximum speed.

Sport-Specific Functionality in Basketball

Sport-specific ability reflects an athlete’s actual performance in competitive situations, with key elements including multi-directional mobility, the ability to vary speed, and the quality of movement under competitive conditions. Basketball frequently involves acceleration, deceleration and changes of direction, placing high demands on muscular strength and neuromuscular control; the individual metrics provided by basic functional tests are insufficient to reflect complex sporting scenarios.

Sport-specific testing simulates movement patterns found in competition and is therefore closer to actual sporting demands. Athletes who have recovered their sport-specific abilities more effectively demonstrate greater adaptability and more consistent movement quality upon returning to competition, whereas deficiencies in sport-specific function can impair the execution of technical movements and reduce competitive performance.

Sport-specific functional testing reflects an athlete’s functional status under conditions approximating real-match scenarios and serves as a vital supplement to traditional basic testing. However, existing literature on the design of sport-specific tests for basketball players remains limited, and the extent to which current assessment systems cover basketball-specific movement patterns is insufficient, representing a major gap in current research.

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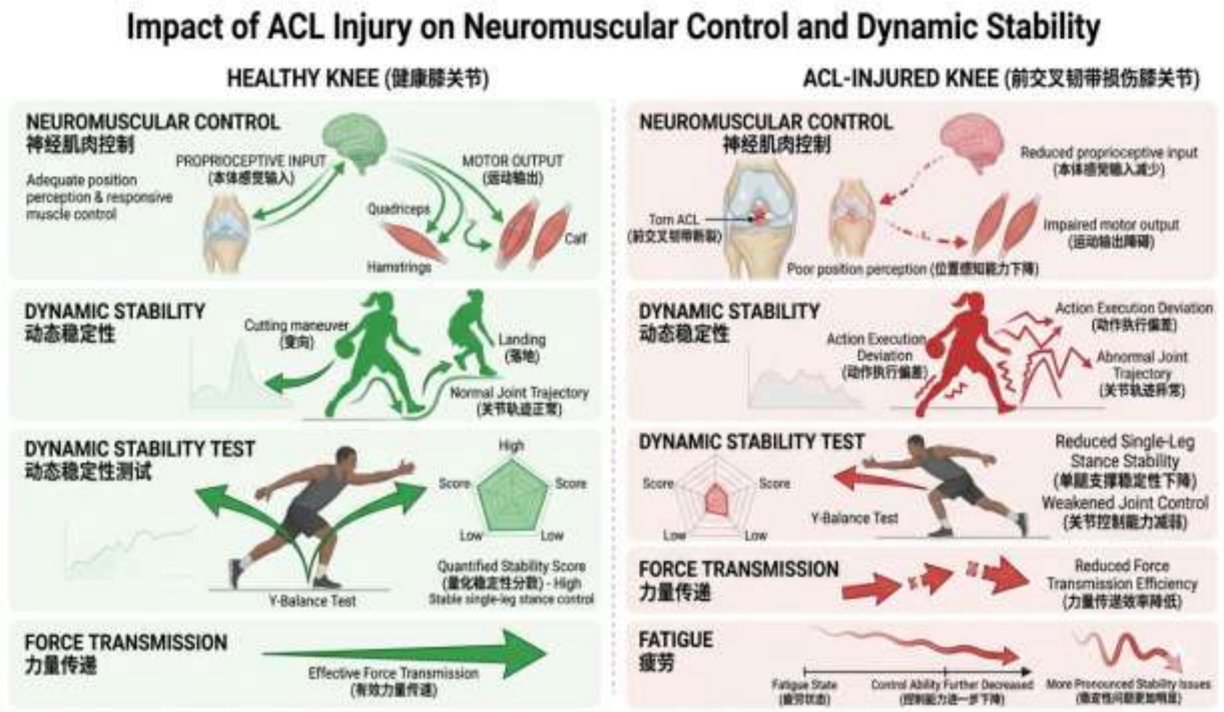
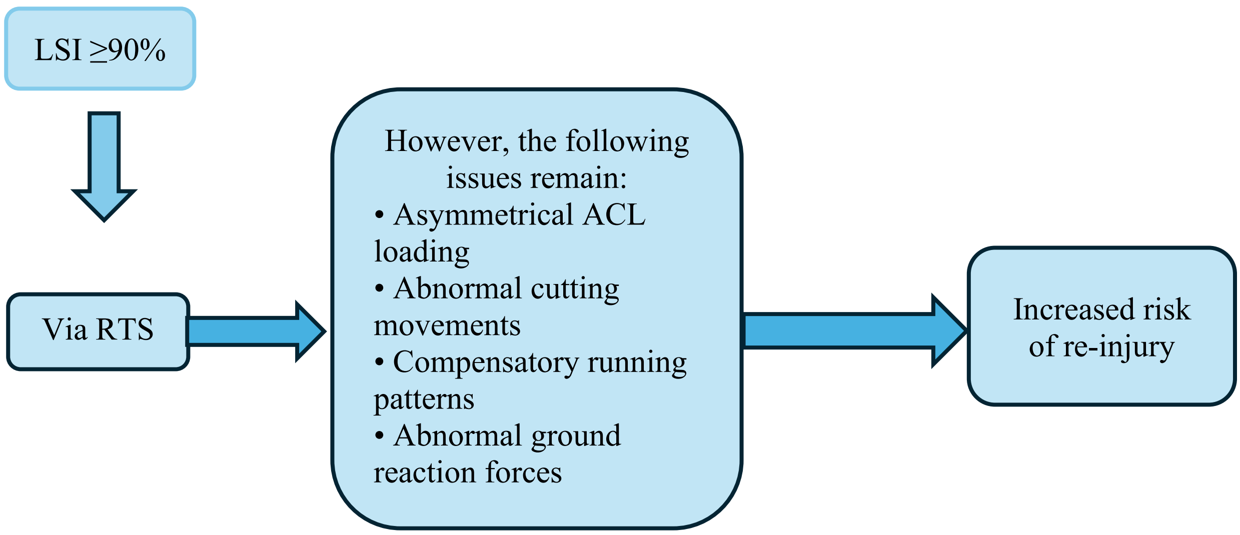


Functional Symmetry and Comprehensive Assessment

Functional symmetry is commonly used to assess the extent of recovery, with a Limb Symmetry Index (LSI) of ≥90% typically regarded as the benchmark. This metric compares the function of the affected side with that of the unaffected side; however, during the rehabilitation process, function on the unaffected side may decline, leading to an overestimation of the actual level of recovery in the symmetry results. Multidimensional assessment methods are increasingly gaining prominence. Integrating indicators such as muscle strength, jumping ability and balance into a comprehensive analytical framework can provide a more holistic reflection of motor function status and reduce the bias associated with single-parameter measurements. As the functional recovery process involves changes in muscle structure and adaptations in neural regulation, multidimensional comprehensive assessment methods are better suited to the diverse skill requirements of basketball[12]. In practice, the functional symmetry index carries a risk of systematically overestimating the level of recovery and should not be used alone as a clearance criterion for return to sport. This limitation highlights the need to introduce a multidimensional comprehensive assessment framework, incorporating absolute functional levels, dynamic stability and sport-specific performance into a unified decision-making basis to enhance the accuracy of assessment conclusions.



The Impact of Functional Performance on Return to Sport

The functional performance across these five dimensions does not influence the outcome of a return-to-sport process in isolation; rather, through mutual interdependence and synergistic reinforcement, they collectively determine athletes' actual performance across the three domains of training, competition and injury risk.

Impact on Return to Training

The level of functional recovery determines the extent to which athletes can participate in training. The deficiencies in muscle strength and jumping ability revealed by Sub-questions 1 and 2 directly limit the choice of training intensity and exercise types. Athletes with a higher degree of functional recovery are able to commence sport-specific training at an earlier stage [18]and demonstrate better training adaptability.

Impact on Return to Competition

Competitive ability depends on the extent of overall functional recovery. The neuromuscular control and sport-specific functions addressed in Sub-questions 3 and 4 determine whether athletes can maintain movement quality and joint control under the intensity of competitive play. There is a clear correlation between the degree of functional recovery and the rate of return to competition[21]; athletes whose motor control is closer to their pre-injury state demonstrate greater stability following their return to competition.

Impact on the Risk of Secondary Injury

The limitations of assessment highlighted in Sub-question 5 have direct clinical implications here: allowing athletes to return to sport based solely on symmetry indices may mask the fact that their neuromuscular control and sport-specific function have not yet reached the required standards. Participation in high-intensity activities before meeting multidimensional functional criteria significantly increases the risk of imbalanced joint load distribution and leads to a higher incidence of re-injury[10].

DISCUSSION

With regard to the core issue, the existing literature consistently indicates that functional outcomes have a multidimensional and decisive influence on readiness to return to sport; however, the relative weighting of these dimensions and the assessment criteria remain inconsistent across different studies.

As for Sub-questions 1 and 2, muscle strength and jumping ability are the two dimensions most extensively studied in the literature, and relatively well-established reference value systems have been developed for isokinetic muscle strength testing and single-leg jump testing. However, most existing thresholds are derived from general sports populations, and standards established specifically for the load characteristics of basketball players are still lacking; this gap undermines the reliability of translating assessment conclusions into clinical practice.

Regarding Sub-question 3, dynamic balance and neuromuscular control have received relatively little attention in the literature; existing testing tools are predominantly used under laboratory conditions, making it difficult to simulate the fatigue and competitive scenarios encountered in basketball matches. In highly dynamic sporting environments, the predictive validity of static or low-intensity balance tests is questionable.

Regarding Sub-question 4, the research gap in sport-specific functional testing is most pronounced. Very few studies in the existing literature have designed and validated sport-specific functional test batteries for basketball; most assessment protocols still rely primarily on general lower-limb functional tests. The applicability of psychological assessment tools such as the TSK scale and ACL-RSI also needs to be re-evaluated in light of the characteristics of the sport.

Regarding Sub-question 5, the limitations of functional symmetry indices have been highlighted in numerous studies; however, in practice, this metric continues to be widely used as a clearance criterion. This phenomenon reveals a gap between clinical decision-making and research evidence; the establishment and promotion of a multidimensional comprehensive assessment framework is a necessary pathway to bridging this gap.

Future research should establish a comprehensive testing system based on the specific demands of basketball, integrating strength, jumping, balance and sport-specific movements, and validate the predictive validity of indicators across these dimensions for the risk of re-injury through long-term follow-up studies.

CONCLUSION

This review draws the following conclusions regarding the core research question: following anterior cruciate ligament reconstruction, five dimensions—muscle strength, jumping ability, dynamic balance and neuromuscular control, sport-specific function, and functional symmetry—collectively constitute the functional outcome system influencing basketball players' return to sport, and each dimension is indispensable.

Sub-questions 1 and 2 indicate that the recovery of strength and power forms the foundation for joint stability and the ability to perform high-intensity movements, with absolute levels demonstrating greater predictive value than symmetry ratios. Sub-question 3 reveals that deficits in neuromuscular control pose the highest risk during fatigue and competitive scenarios, and that static testing cannot adequately capture the actual status of this dimension. Sub-question 4 indicates that sport-specific functional testing is the weakest link in the current assessment system, and that the development of sport-specific tools for basketball is the most urgent research need at present. Sub-question 5 suggests that there is a risk of systematic overestimation of functional symmetry indices in clinical practice; these must be used in conjunction with multidimensional indicators to form a reliable basis for clearance.

Establishing a comprehensive assessment system that integrates the above five dimensions and aligns with the specific requirements of basketball is the key pathway to enhancing the scientific rigour of return-to-sport decisions and reducing the risk of re-injury.

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