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A Return to Performance Continuum for Football (Soccer) Players After ACL Reconstruction: Bridging Rehabilitation, Return to Play and Sustained Performance

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Abstract

Anterior cruciate ligament reconstruction (ACLR) in football (soccer) players is associated with high return-to-competition rates but persistent deficits in performance and elevated risk of secondary injury. Whilst rehabilitation frameworks have evolved to optimise early, mid-, and late-stage recovery, limited guidance exists regarding the structured transition from typical return-to-sport clearance to sustained return-to-performance (RTP_{eff}). Failure to adequately bridge this gap may contribute to early re-injury, suppressed match performance and compromised career longevity. This paper outlines a staged RTP_{eff} continuum comprising: (1) structured on-field rehabilitation, (2) return to team training, (3) return to competitive match play and (4) early and sustained RTP_{eff}. Four interdependent pillars underpin this process: (i) the restoration of movement quality under realistic football specific situations; (ii) progressive football-specific technical and tactical re-training; (iii) football-specific physical reconditioning including speed, acceleration, deceleration and change of direction ability, endurance and chronic workload development and (iv) maximal strength and explosive neuromuscular performance restoration.

1 Introduction

An anterior cruciate ligament (ACL) rupture is one of the most severe injuries a football (soccer) player can sustain and is associated with prolonged absence from play. ACL reconstruction (ACLR) remains the recommended treatment approach [1]. Lay-off times typically exceed 12 months

in recreational sporting athletes [2] and range between 6 and 12 months in professional football players, with ~80% returning within 8 months [3–5]. However, only 55–65% of recreational athletes return to their pre-injury competitive sporting level [6] and those who return to sport (RTS) do so at elevated risk of secondary ACL injury (~20 to 30%) [7–11]. Professional football players have high return-to-football rates (83–100%) [3–5, 12, 13], yet an ACL injury remains career-threatening for a proportion of players [13]. Many elite players return at reduced performance levels [14–16], with high risk for re-injury (18%) [3, 17]. Professionals also report substantially reduced career length [3, 5], with only 65% of elite male footballers still playing at the same level 3 years after ACLR [5]. In female football players, only 62% are still playing competitively 2 years after RTS, with recurrent knee injury being the leading cause for retirement [18]. Collectively, these findings highlight the substantial functional, performance and career-related consequences of ACL injury in football players and emphasise the need to improve rehabilitation and RTS processes. A greater focus is needed on return to performance (RTP_{eff}), re-injury risk reduction and career sustainability.

Recent approaches to improve the functional recovery process after ACLR have addressed pre-operative, early

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Key Points

Completion of rehabilitation and return-to-sport clearance do not ensure readiness for competitive football.

The return-to-performance (RTP_{erf}) continuum provides a structured framework that bridges late-stage rehabilitation, return to train and sustained competitive performance by progressively restoring football-specific movement quality, technical–tactical function, physical fitness and training and match workload tolerance and maximal strength and explosive neuromuscular performance restoration and development

On-field rehabilitation (OFR) represents the first component of the RTP_{erf} continuum, progressing through staged exposure to increasing movement intensity and volume, reactive actions and football-specific technical demands to prepare players for reintegration into team training.

Following completion of OFR, a structured return-to-train and readiness for return-to-competition phase is required to progressively restore exposure to match-relevant intensities, workloads, contact demands and neuro-cognitive constraints before competitive match play.

Implementing a progressive return-to-performance framework may reduce the mismatch between rehabilitation readiness and match demands, potentially lowering injury risk and improving the likelihood of sustained performance following ACL reconstruction.

[19], mid- [20] and late-stage rehabilitation, as well as RTS training preparation [21–24]. This has included the formalisation of on-field rehabilitation (OFR) frameworks [22, 23, 25–28], considered a critical transitional phase bridging gym based in-clinic rehabilitation and resumption with the team for training [22, 23, 29, 30]. One area which has received limited research attention, despite being an essential element of the functional recovery period, is the RTS continuum [30, 31]. The RTS continuum, originally proposed by the Bern consensus group, includes return to participation, RTS, and finally, RTP_{erf} [31]. This continuum was updated by Buckthorpe et al. [30], who included OFR, followed by return to team training (RTT), prior to return to competitive match play (RTC) and gradual RTP_{erf}, from here referred to as the RTP_{erf} continuum (Fig. 1). These additions reflect the processes and practices of many elite level football teams, but guidance on how to apply this process effectively is sparse.

A big issue in clinical practice is the large disconnect between research and practice, thought to be due to ineffective implementation of evidence-based findings [32, 33]: ‘the research-to-practice gap’. However, most practitioners

working with injured athletes are often generalists (treating a range of musculoskeletal injuries), and thus cannot develop sufficient expertise [34]. As well as the research-to-practice gap, it is also important to acknowledge an ‘elite practice-to-research gap’ in which many elite practitioners are often using processes and practices which are ahead of the research. If we are to truly impact individual patients across the globe, a stronger focus on research implementation, as well as addressing barriers and facilitators to research implementation (e.g. a 9- to 12-month rehabilitation and a sufficient number of supervised treatments are not always implemented because of insurance coverage) [34], is needed from researchers (and research practitioners, who treat or have treated a large volume of patients) to translate efficacious rehabilitative and preventive methods into practice on behalf of the practitioners [35–38]. This review and clinical commentary forms part of a series of papers aimed at optimising the functional recovery process after ACLR [19–21]. The paper specifically focuses on the RTP_{erf} continuum, the process from completion of late-stage rehabilitation and meeting typical RTS criteria and being ready to perform at previous competitive level and beyond. In this paper we discuss the pillars of the RTP_{erf} continuum and why these factors should be addressed. We also demonstrate how to apply this with a focus on return to professional football after ACLR. It is important to acknowledge that whilst much research has been consulted in the formulation of these processes (which have been refined over the last 15 years), many recommendations are still based on expert opinion. Whilst this content has generalisability beyond elite

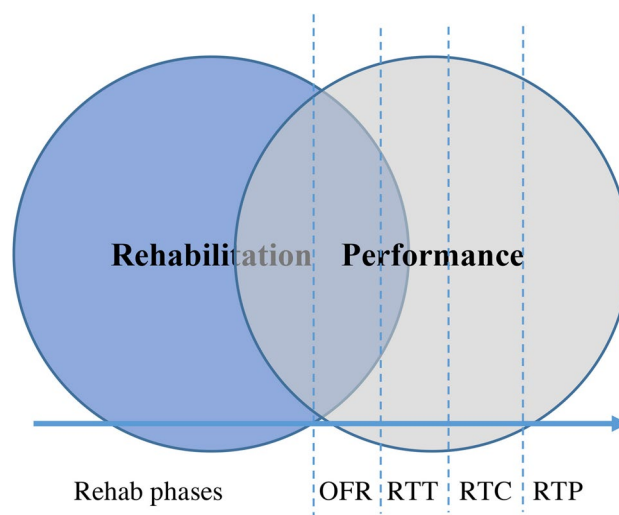


Fig. 1 The redefined return-to-sport continuum involves a progressive transition from rehabilitation to performance re-training, incorporating a continuum of return-to-sport activity, progressing from on-field rehabilitation (OFR), return to team training (RTT), return to competitive match-play (RTC) and return to performance (RTP). Modified from Buckthorpe et al. [30]

male football, to provide stronger context, in a population where there is greater available research as well as the author group having substantial anecdotal experience, this participation group was selected throughout. Where possibilities to provide examples beyond this context is possible, we have done so considering formatting restrictions. For clarity, key terminology used throughout the paper is defined in Table 1.

2 Bridging the Gap Between Rehabilitation and Return to Performance—Key Factors in the RTP_{erf} Continuum: A Brief Overview

2.1 Pillar 1: Restoring Movement Quality

Restoring movement quality after ACLR is recognised as a key component of the functional recovery process [19–21] and central pillar of OFR and RTS training [22]. Movement quality, defined as ‘the ability to control the limbs and achieve sufficient balance, neuromuscular control and kinematic alignment during functional activities, not displaying movement asymmetries or risk factors linked to ACL injury’ [21], is considered important in the aetiology of ACL injury and re-injury [39–42].

Understanding the situations, mechanisms and biomechanics associated with ACL injury is important when designing exercise programmes aimed at reducing injury risk [43, 44]. Injury-mechanism research does not imply that all postoperative movement deficits replicate the mechanics observed at the moment of injury. Rather, it helps identify the high-risk loading situations, movement demands and environmental constraints for which the player must ultimately be prepared. Most (> 85%) ACL injuries in football are either non-contact or indirect-contact injuries [45–47], suggesting that at least some may be amenable to prevention strategies. Understanding the biomechanical context of an ACL injury provides a foundation for effective (re-)injury prevention strategies, including targeted movement retraining and screening processes [43, 48]. The tensile capacity of the ACL (~2000 N in male and ~1200 N in female athletes) [49–51] is substantially lower than the forces experienced during common football actions. Peak vertical ground reaction forces during running, sprinting, deceleration and change-of-direction (COD) tasks may reach 3–6 × body mass (up to ~4500 to 5000 N) [52–55]. Many ACL injuries occur during high intense horizontal deceleration actions as opposed to vertically orientated landing actions [45–47]. These horizontal deceleration/stopping tasks involve preferential knee load distribution across the sagittal plane [56]. Effective distribution of these loads across the ankle, knee and hip joints, alongside appropriate frontal and transverse plane control and timely hamstring recruitment, may contribute to reducing ACL loading. However, aberrant

movement patterns immediately preceding injury increases knee and ACL loading [45, 57, 58], including knee-dominant sagittal plane strategies (e.g. upright trunk, > knee to hip and ankle flexion), wide foot placement, hip adduction, contralateral pelvic drop and lateral trunk lean, resulting in elevated knee abduction moments and dynamic valgus loading [45, 46, 59, 60]. Importantly, ACL injuries occur within 50–70 ms of initial ground contact [45, 60, 61], substantially shorter than the ACL-hamstring reflex latency (~110 ms) [62]. Consequently, there is insufficient time for feedback-driven neuromuscular responses to dynamically stabilise the knee. ACL injury avoidance therefore relies predominantly on feedforward motor control mechanisms, including anticipatory muscle pre-activation prior to ground contact [48, 63], and non-contact ACL injuries could be considered a sensorimotor error [64, 65].

ACL injuries in football commonly arise during complex, reactive situations, particularly whilst pressing, tackling or being tackled [45–47, 66–69]. The athlete’s neurocognitive system, including situational awareness, sensory integration, motor planning and coordination, operate as an integrated unit interacting continuously with a dynamic environment [70]. Players must process unpredictable visual-spatial information (e.g. other players’ movement, ball trajectory, spatial constraints) and rapidly select appropriate movement strategies. Failure to anticipate or adapt to these demands, whether due to an attentional error, delayed information processing or the need to rapidly modify a planned motor action within a short time window (~250 ms) [65, 71], may result in reduced or poorly timed muscle pre-activation prior to foot-ground contact, leaving the knee and ACL vulnerable. Giesche et al. [71] reported that these unplanned actions may result in at-risk knee biomechanics. In terms of playing context, most injuries involve either contact at or prior to injury (predominantly to the upper body) or a neurocognitive error occurring shortly before (~250 ms), with the latter accounting for approximately three quarters of non-contact ACL injuries [64, 65, 68].

An understanding of how ACL injuries occur is important to plan RTS training activity [44]. However, this does not tell us why a particular player gets injured and another does not. Understanding the association between an individual’s habitual movement quality and ACL injury risk is a further important factor to consider alongside injury mechanism research. Movement quality is considered important in the aetiology of ACL primary and secondary ACL injuries [39–42]. Evidence suggests that alterations in movement quality, including postural control and unilateral balance/stability, as well as jump-land kinematics, contribute to increased ACL re-injury risk [39–42, 72]. Neuromuscular training that incorporates jumping, landing and plyometric tasks has been reported to reduce primary ACL injury rates by ~50% [73], with plyometric training

Table 1 Key definitions and terminology used within the return-to-performance (RTP_{eff}) continuum

Term	Definition/description
Return-to-sport (RTS) continuum	A conceptual framework describing the graded progression from injury to full sporting performance. Originally proposed by the Bern consensus group [31], the RTS continuum includes return to participation, return to sport and return to performance (RTP _{eff})
Return to participation	The stage at which an athlete resumes modified or restricted sport-related activities (e.g. training, drills, conditioning, other less demanding sports) but is not yet able to perform at their pre-injury competitive level
Return to sport (RTS)	The point at which an athlete is medically cleared to resume unrestricted sport participation, typically based on clinical assessment and RTS testing. RTS does not imply readiness for competition or sustained performance
Return to performance (RTP _{eff})	The stage at which an athlete has restored or surpassed pre-injury performance capacity, including physical output, technical–tactical effectiveness, match availability and training and match workload tolerance. RTP _{eff} typically occurs weeks to months after RTS or return to competition
RTP _{eff} continuum	An applied extension of the RTS continuum incorporating football-specific transitional phases between rehabilitation and sustained performance. Within this paper, the RTP _{eff} continuum comprises OFR, RTT, return to competitive match play (RTC) and RTP _{eff}
On-field rehabilitation (OFR)	A structured, sport-specific rehabilitation phase bridging late-stage gym-based rehabilitation and return to team training. OFR integrates movement quality restoration, sport-specific skills, physical reconditioning, and progressive workload exposure, and culminates in training simulation to prepare players for RTT
Return to team training (RTT)	The stage at which a player resumes modified and subsequently unrestricted team training following completion of OFR. RTT represents a controlled re-exposure phase during which neurocognitive, contact, and workload demands of football training are progressively reinstated
Return to competitive match play (RTC)	The point at which a player is <i>available for competitive match selection</i> , commonly initiated via controlled exposure (e.g. substitute appearances or reduced minutes). RTC represents a high-risk transition due to the substantially greater physical and injury demands of competition compared with training
Early RTP _{eff} phase	The initial period (considered as 3 months but requires further research and consensus) following RTC during which players are typically load-compromised, often unable to tolerate full training density or repeated match exposures. They are typically at lower performance levels, unable to achieve previous in-game performance metrics. This phase requires targeted workload management and progressive performance redevelopment
Multi-disciplinary team (MDT)	The integrated group of practitioners responsible for decision-making across the RTP _{eff} continuum, typically including medical, rehabilitation, performance and coaching staff

ACL anterior cruciate ligament, *ACLR* anterior cruciate ligament reconstruction, *MDT* multi-disciplinary team, *OFR* on-field rehabilitation, *RTC* return to competitive match play, *RTT* return to team training, *RTS* return to sport, *RTP_{eff}* return to performance

specifically shown to enhance feedforward motor patterning and hamstring muscle pre-activation and dynamic knee joint stability [74, 75]. Optimising feed-forward motor control may also be an essential re-injury prevention strategy.

An ACL rupture leads to loss of mechanical stability of the knee and alters neuromuscular control due to disruption of ligamentous mechanoreceptors [76], which can result in impaired somatosensory input and joint proprioception. Whilst ACLR may restore mechanical knee joint stability, it does not necessarily restore sensory motor control. Reductions in joint position sense and kinaesthesia, alongside nociceptor input associated with pain and swelling, may impair movement quality bilaterally [77, 78]. Furthermore, residual deficits in neuromuscular function, including muscle-specific weakness [79, 80], particularly knee extensor [81–84], flexors [63, 85–87] and hip abduction, and extension and external rotation [88–90] strength, in addition to

compound strength and power asymmetries [91–94], may further contribute to alterations in movement quality, which may contribute to increased ACL (re-) injury risk. Emerging evidence suggests that movement quality deficits after ACL injury and reconstruction, including altered joint loading and asymmetrical movement strategies, as well as compensatory muscle activation strategies, can persist for months or even years after RTS [40, 41, 95–97]. These residual impairments are evidenced across a range of functional tasks [98–103] and have been prospectively linked with increased risk of graft re-rupture and contralateral ACL injury [39–41]. Reduced movement quality is also associated with abnormal joint loading profiles that may trigger or accelerate cartilage degeneration and can ultimately lead to early development of posttraumatic knee OA [104–108].

We encourage the adoption of a philosophy of care incorporating a focus on assessing and restoring movement quality after ACLR [48]. Whilst a thorough overview

of movement assessment and restoration strategies after ACLR is beyond the scope of this manuscript, recognising its importance in planning and monitoring processes for football and other sporting athletes post-ACLR is important. To optimally restore movement quality after ACLR, Buckthorpe [48] suggests: (i) considering the factors which influence the expression of movement quality, which revolve around individual (e.g. neuromuscular, biomechanical, sensorimotor and neurocognitive factors), task-specific (e.g. intensity of movement, preplanned versus reactive) and environmental (e.g. number of players, scanning requirements, surface) constraints; (ii) incorporating a three-staged movement re-training approach aligned to the ACLR functional recovery process: (1) addressing the neuromuscular and biomechanical and sensorimotor control factors which affect movement quality and motor learning, (2) including a progressive movement re-training approach to re-learn an array of functional tasks optimising coordination and motor learning and (3) performing the final aspect of rehabilitation and movement training on the field, in realistic environments progressively simulating the sporting movement demands and environmental constraints; and (iii) effectively designing the movement programme for optimal load management, employing effective coach and feedback techniques and utilising movement analysis for transition between exercises, stages and for RTS.

In terms of movement screening, there is no consensus on what and how this should be done. An array of tasks, contexts, technologies and approaches to interpretation of movement exist. Advanced markerless motion capture analysis, wearable sensor technologies, and force plate assessments now offer clinicians and researchers increasingly accessible tools to identify movement compensation patterns that might otherwise go undetected. Often context will dictate which approach to movement screening is superior, including patient type (amateur versus professional), finances/budget of patient and/or team, facilities, philosophy of care and expertise in movement. We believe movement assessment should be a 'must have' as part of the rehabilitation and RTS/RTP_{erf} screening process and work towards providing stronger rationale and reducing barriers to implementation. Importantly, a test battery should reflect an array of tasks, as opposed to a single task. Buckthorpe [48] suggests an approach aligned to the stages of movement retraining, including first assessing foundation patterning (e.g. squat mechanics, mid-late stage); high load control (e.g. jump-land, deceleration mechanics; late-stage/RTS), and finally, sport-specific movement patterns (e.g. high intensity COD, in pre-planned and reactive situation; RTS retraining stage). It should incorporate an approach to identify common movement impairments which are considered important, including weight shift asymmetries in bilateral tasks, sagittal plane joint loading asymmetries (e.g. knee avoidance

strategy) and deviations on the frontal and/or transverse plane (e.g. dynamic knee valgus/alterd frontal plane projection angle, lateral trunk lean, pelvic drop, etc.). We believe a thorough overview of this topic is needed, which goes beyond the scope of this particular manuscript and encourages topic experts to provide guidance to practitioners.

The RTP_{erf} continuum provides the necessary time structure, specificity, intensity and exposure to implement these principles to allow movement quality to be restored and maintained considering football-specific constraints and match relevant demands, thereby contributing to ACL re-injury risk mitigation.

2.2 Pillar 2: Football Technical, Skills and Position Specific Re-training

The RTP_{erf} continuum recognises the need to progressively include football specific training to prepare players for the technical, tactical and movement demands of football. Technical and tactical performance are key RTP_{erf} discriminants after ACLR. The player will have spent substantial time away from football, which can negatively affect performance. The technical and tactical components of football form three distinct groups: (1) individual technical/techniques and skills, (2) small-group play and (3) full-squad play [23]. Technique is the performance of a task, such as passing or shooting, without pressure from other players. Skills are the performance of these techniques in the sporting context, that is, under pressure from an opponent at realistic speeds. Skills represent a transition from predictable pre-planned football actions to more reactive spontaneous actions and represent greater neurocognitive demands. Tactical relates to positional roles and responsibility and progresses to a game model (e.g. phases of play, team structure, set pieces, etc.). These components are considered essential. Whilst OFR utilises individual skill restoration and at times small group play, it cannot prepare players for the larger sided games and full squad play. Additionally, ACL injuries happen during game actions under pressure (e.g., pressing, tackling, being tackled, landing from jump often with indirect contact), meaning without football specific training, players will be under-prepared for the highly chaotic nature of competition, displaying an inherently greater risk of re-injury upon RTS.

It is the aim of the RTP_{erf} continuum to progressively restore technical and tactical and football specific movement performance in accordance with the health status of the athlete. Graft re-rupture risk is highest during the early RTS exposure period [5, 8], likely due to insufficient preparation, including a lack of appropriate sport-specific training. Techniques (e.g. passing, shooting, heading) and skills (e.g. pressing, controlling the ball under pressure, 1v1 scenarios and finishing practices, etc.) need to be completed in both a

‘proficient’ and ‘safe’ level and applied in game-like situations. A player will not feel psychologically ready for football and the medical professional cannot be sure of their readiness to re-perform unless exposed to sufficient football specific training as part of the recovery process.

2.3 Pillar 3: Football Physical Reconditioning and Workload Restoration

Players and coaches devote considerable time to enhancing physical fitness parameters, whilst severe injury such as ACLR will result in loss of function, detraining and subsequent deconditioning. Reconditioning can be defined as the process of ‘re-establishing and/or improving an athlete’s overall physical fitness after an injury or surgery’ and should occur alongside rather than after rehabilitation and movement restoration post-ACLR [21, 109]. Reconditioning ensures players possess the physical capacities required to tolerate and excel under training and match demands, can sustain performance across competition and minimise maladaptive fatigue responses that may elevate injury risk [21, 109].

Key physical qualities underpinning football performance includes endurance capacity, high-intensity running (acceleration and peak speed), deceleration and change-of-direction capacity. In addition, players must demonstrate the capacity to tolerate the cumulative workload demands imposed by training and congested match schedules. These qualities should be restored to sport-specific benchmark standards, or where appropriate enhanced beyond pre-injury levels, prior to RTC. Importantly, restoration of discrete physical capacities alone is insufficient; players must also accumulate progressive training exposure to tolerate the intensity, volume and density of football-specific loading.

2.3.1 Endurance

Restoration of cardiovascular (CV) fitness is fundamental following ACLR to re-establish work capacity and support the physical demands of competitive football. During a 90-min match, professional male football players typically cover 10–13 km and perform ~1200 discrete actions with activity changes every 4–6 s, including 150–250 high-intensity efforts involving approximately 200–400 m of sprinting ($> 7.0 \text{ m s}^{-1}$) [110–114], alongside substantial volumes of acceleration and deceleration [115].

Whilst accelerations impose considerable metabolic cost [82, 83], decelerations place high mechanical loads on the musculoskeletal and tendinous structures of the lower limb [82, 84]. Importantly, these physical demands, especially the high-intensity actions, have increased progressively over recent seasons [110, 116, 117], raising the fitness and

workload-tolerance requirements of players returning from injury.

Competitive matchplay typically elicits sustained heart rates of ~85% of maximum, corresponding to ~70% of VO_2max [114, 118], whilst also imposing repeated anaerobic demands during intense passages of play. Blood lactate concentrations recorded during football match play typically range from 2 to 12 mmol L^{-1} , with recorded individual values more than 12 mmol L^{-1} [119]. Higher aerobic capacity is associated with greater high-intensity distance during match play and enables players to perform football-specific tasks at lower relative effort [120]. Insufficient CV fitness limits workload tolerance and accelerates fatigue accumulation, which may compromise performance, impair decision-making capacity, negatively affect movement quality and potentially increase injury risk [121–126].

Aerobic fitness is commonly impaired following ACLR, with reductions of approximately 15% in VO_2max reported at around 6 months after surgery [127], coinciding with typical RTT timelines [3, 128]. Such a reduction in aerobic capacity at a time when players are typically progressing towards team training may compromise tolerance to subsequent football-specific loading and delay optimal progression through the RTP_{erf} continuum. Endurance restoration is therefore a critical prerequisite for safe and effective progression and should be systematically assessed and progressively developed from the early stages of rehabilitation to limit deconditioning and support sustained performance restoration [19].

2.3.2 Acceleration, Peak Speed, Deceleration and Change of Direction Ability

Many decisive football actions are anaerobic in nature and frequently involve directional changes [129]. Acceleration, maximal running speed, deceleration and COD abilities are considered essential determinants of football performance [130–133]. These capacities underpin the ability to evade opponents, reach the ball first and apply effective pressing at high intensity [130]. There is strong evidence that acceleration, sprint speed and COD performance discriminate between competitive playing levels [130, 131, 133], whilst deceleration ability is increasingly recognised as critical for both performance execution and injury risk reduction [115, 134, 135]. Players need to be progressively exposed to these tasks to restore these physical characteristics to ensure readiness for match-demands and reduce re-injury risk.

2.3.3 Workload Management and Physiological Resilience

Players must also demonstrate sufficient neuromuscular resilience and fatigue resistance to tolerate the cumulative internal and external loads of training and competition

without excessive fatigue or injury. Musculoskeletal injury ultimately reflects mechanical failure, occurring when a single high-magnitude load exceeds tissue capacity or when repetitive submaximal loading surpasses fatigue tolerance [136]. Accordingly, training-load management during the RTP_{erf} phase must balance fitness development with injury–risk mitigation [137–139]. Both insufficient chronic loading and excessive acute loading, particularly when short-term demands exceed underlying fitness, have been associated with elevated injury risk in football and other team sports [135, 140–145].

Many football-specific actions performed whilst fresh and under fatigue are recognised injury-inciting events. For example, sprinting is strongly associated with hamstring injuries [146, 147], whilst deceleration, landing and pressing actions are common mechanisms for ACL injury [45–47]. Acceleration from static or low-speed conditions is frequently implicated in calf injuries [146], and explosive plantarflexion actions are associated with Achilles tendon injury [148]. These actions impose substantial loads on tissues at long muscle lengths, often during eccentric or stretch–shortening cycle contractions. Inadequate exposure to movement intensity prior to competition may therefore result in abrupt load spikes that exceed tissue tolerance thresholds. For example, players who have only achieved ~85% of peak running speed during rehabilitation may experience disproportionately large increases in muscle-specific forces due to maximum effort, upon RTC, elevating hamstring loading [149] and injury risk [147, 150, 151].

Football match and training demand also involves a high volume of these intense actions, frequently resulting in exercise-induced muscle damage and transient neuromuscular fatigue [152–154]. Reductions of approximately 20% in maximal and explosive strength have been reported following match play [152–154], with recovery requiring up to 72 h for some players [155, 156]. Fatigue responses are highly individual and influenced by training status, exposure history and physical fitness attributes such as strength and aerobic fitness [156–158]. Consequently, players must progressively develop tolerance to eccentric loading demands whilst restoring both chronic (e.g. 28-day) and acute (e.g. 7-day and single-session) workload capacity. Acute workloads (e.g. 7-day) that substantially exceed habitual training workloads have consistently been associated with increased lower-limb injury risk [135, 140–144].

To mitigate these risks, players should be progressively exposed to football-specific training volumes and intensities to develop both tissue tolerance and neuromuscular fatigue resistance. Training that incorporates acceleration, maximal speed, deceleration and COD actions induces positive performance adaptations and represents a cornerstone of reconditioning within the RTP_{erf} continuum [21, 159]. Preparation should extend to at least match-relevant intensities and

volumes, and where appropriate, exceed them, to account for variability, fatigue accumulation and the unpredictable nature of competition. However, following late-stage rehabilitation, players often demonstrate low absolute training volumes relative to both training and match demands [12]. Even after completion of on-field rehabilitation (all five stages), exposure to high-intensity decelerations, sprint distance and peak running speeds frequently remains suppressed [12], leaving players under-prepared for the demands of competitive football match play. The RTP_{erf} continuum therefore provides a structured framework to progressively restore action-specific intensity, acute exposure and chronic workload development across key on-field workload metrics to ensure that players are physically prepared to tolerate competitive match workload demands whilst minimising fatigue-related injury risk.

2.4 Pillar 4: Maximal Strength and Explosive Neuromuscular Performance

The ability of the neuromuscular system to produce force defined as strength [160] is integral to the restoration of movement quality, athletic performance and training workload tolerance (fatigue resistance). An ACL injury, reconstruction and subsequent detraining results in major deficits in muscle strength, in part due to pain, swelling and arthrogenic muscle inhibition (AMI) [19, 161–163], but also due to the functional limitations and detraining process. The greatest deficits in muscle strength are at the knee level on the injured side (knee extension/ flexion), with typical deficits of 40–60% reported versus the contralateral limb at the end of early stage rehabilitation [164, 165]. A key aspect of the rehabilitation approach is to resolve these side-to-side asymmetries [19–21]. Typical goals of the rehabilitation stages are to recover knee extensor and flexor isometric and/or concentric strength to within 10% of the contralateral side. Many amateur and elite players do not achieve this 90% LSI for knee extensor and flexor strength, prior to RTS [79, 166, 167]. Residual deficits in knee extensor muscle size and strength after ACLR are associated with reduced knee function [168, 169] and are a key barrier to functional progression [83]. Knee extensor weakness is also associated with altered biomechanics during sporting type actions [83], decreased dynamic stability [170], persistent knee pain [171], increased risk of knee OA [172] and poorer RTS outcomes [7]. Appropriate programme design informed by monitoring can mitigate knee extensor strength deficits [173], but it is important to recognise potential on-going deficits, as this can have marked impact on performance, movement quality and load management/capacity. Similarly, the hamstrings are also vitally important for dynamic knee stability. Despite equivocal evidence, some research suggests deficits in hamstring strength increase ACL injury risk [86],

limit maximal sprint speed [174] and increase hamstring injury risk [175–177] and should therefore be targeted prior to and during the RTP_{eff} continuum.

Monitoring is also integral when targeting residual deficits. Typically, there is an overreliance on isometric and concentric strength during testing [178]. Deficits in knee extensor and flexor strength are often greater for maximal eccentric strength [179, 180] and rate of force development (RFD) [181–183] and can be long-standing [182, 183]. Given that many sporting actions involve high-force eccentric actions occurring with short ground contacts (e.g. 80–300 ms) [53, 184, 185], these aspects of neuromuscular performance are important but often not considered. Conventional resistance training typically prescribed in the rehabilitation stages (e.g. 3–5 sets of 8–15 repetition maximum [RM] depending on time from surgery) is an insufficient stimulus to target maximal eccentric strength [186] and RFD [187–189] gains. The use of high load isometric, isoinertial (3–5 RM) or eccentric (inclusive of supramaximal modes) strength and/or explosive training methods (e.g. ballistic training, plyometrics, explosive isometrics) are necessary to enhance maximal eccentric strength and/or RFD [186–193]. These higher-intensity training stimuli are typically contraindicated in the earlier rehabilitation stages, and as such, the RTP_{eff} continuum is an important stage to fully restore knee extensor and flexor eccentric and explosive strength characteristics.

It is also important to think beyond the knee and consider muscle function at proximal and distal joints (e.g. plantar flexors, hip extensors/adductors and abductors, core musculature). Whilst current evidence indicates residual deficits are not expected beyond the knee flexors/extensors [194], it is possible that deficits in adjacent joint muscle groups may have preceded any such injury or can present due to oversight in the rehabilitation process, which may warrant testing and restoration, if shown to be deficient. Similar to the knee extensors/flexors, a focus on maximal eccentric strength and RFD of these muscles is encouraged, but generally not considered [178]. Addressing adjacent joint deficits in muscle function should be considered as part of standard reconditioning during all long-term injuries.

The importance of testing and training multi-joint closed chain maximal strength is also being more widely considered [195]. Kinetic chain strength (e.g. isometric or dynamic squat strength relative to body mass) is a key determinant of performance in athletic tasks, such as jumping, sprinting and CODs [196–198]. Furthermore, sufficient kinetic chain strength (particularly eccentric strength) is important for optimal movement performance and injury avoidance. During movement, load is actively accepted/dissipated via the neuromuscular system and absorbed passively via the tendons, ligaments and joints. Internal hip, knee and ankle extension (plantar flexion) moments

must be produced via isometric, concentric or eccentric muscle contractions to stabilise and control joint motion and to produce body momentum and/or absorb the kinetic energy of the body [199]. Inability to accept load either due to deficits in strength or high task demands would mean a greater reliance on joint complexes (tendon, ligament and joint structures) for passive force absorption [200]. A higher strength-to-body mass ratio (supported by having a low percentage of body fat) would mean less passive absorption during sporting actions. Being stronger is also associated with more optimised landing and cutting biomechanics [91] and lower risk of lower limb musculoskeletal injury [201]. Furthermore, stronger athletes can better tolerate acute spikes in training load without sustaining injury [202]. Therefore, assessment and development of multi-joint, closed chain strength to normative standards relative to the sport is an important aspect of rehabilitation and the RTP_{eff} continuum. This extends to lower limb ballistic/explosive strength, which shares equal importance with maximal strength for athletic performance [191, 192, 203]. The use of vertical jump profiling has become common to guide rehabilitation progression and measure neuromuscular factors that support RTS decision-making [178] and can be valuable in identifying residual deficits in performance, as well as asymmetries in explosive force production. Evidence reports large deficits in compound power and explosive strength at 6, 9 and 12 months after ACLR and even years after RTS [92–94], suggesting that these asymmetries remain until appropriately addressed. Thus, these qualities should be monitored and targeted within the RTP_{eff} continuum to enhance readiness to re-perform.

To summarise, the RTP_{eff} continuum should focus on the full restoration of the neuromuscular performance profile. The rehabilitation stages often focus on resolving knee extensor and flexor strength to within 10% of the contralateral limb. This should also consider adjacent joint muscle function. Continued maximal and explosive strength and power training should ensue following these stages with a view to fully restoring strength (100% LSI) for isolated knee (e.g. knee extensors/flexors) and adjacent (plantar flexors, lumbo-pelvic hip muscle) joint function across all contraction modes (isometric, concentric and eccentric), as well closed chain multiple-joint maximal strength and explosive neuromuscular performance profiles.

2.5 Summary: Pillars Underpinning the Return-to-Performance Continuum

Successful RTP_{eff} after ACLR is underpinned by the integration of four foundational pillars. The first pillar is the restoration of movement quality, encompassing neuromuscular coordination, anticipatory control and biomechanical alignment under reactive, football-specific conditions that reflect

the feedforward nature of ACL injury mechanisms. The second pillar is football-specific technical, skill and tactical re-training, ensuring players regain proficiency, perceptual-cognitive function and positional competence within increasingly chaotic game scenarios. The third pillar is football fitness reconditioning and workload restoration involving restoration of on-pitch performance in acceleration and peak running speeds, deceleration and COD performance and endurance capacities, including repeated high intensity and sprint running performance, as well as load management, which includes sufficient exposure to match-relevant intensities and workloads to develop fatigue resistance and load tolerance. The fourth pillar is strength and explosive neuromuscular performance, which is integral to the restoration of movement quality, explosive movement performance and training load tolerance and fatigue resistance. Together, these interdependent pillars form the foundation of the RTP_{erf} continuum, ensuring players are not only medically cleared, but also physically, technically and cognitively prepared to sustain performance in elite football.

3 Implementing the RTP_{erf} Continuum for a Football Player After ACLR

The RTP_{erf} continuum is a structured, football-specific progression commencing after completion of late-stage rehabilitation and attainment of RTS training entrance criteria, extending to sustained competitive performance. It is designed to support the full restoration of (1) movement quality; (2) football-specific technical, skill and tactical re-training; (3) football-specific fitness and load tolerance and robustness/physical resilience; and (4) the full restoration and enhancement of the neuromuscular performance profile. The RTP_{erf} continuum presented is heavily focused on elite male football (soccer) settings with frequent references to professional environments (e.g. Global Positioning System [GPS] monitoring, multi-disciplinary teams). This does not limit its applicability to sub-elite/women/younger players and other active patients wanting to return to other team sports where resources are often limited. We see that the value of much of this process is that it is highly implementable, and in many cases, involves structuring exposure to activities that would happen in a more systematic and controlled way. As such, we believe this is a valuable and easy to apply framework which may have strong implications for player outcomes following ACLR. Of course, the framework should be modified according to context (e.g. professional versus amateur level, resource availability, competition constraints, player role and importance and time of season) and further research is needed to validate the framework. In practice this reflects the processes of many football medical and performance departments working with elite male football (soccer) players after ACLR.

3.1 Step 1: Football 'On-Field Rehabilitation'

OFR is considered the vital bridge to return to team activity [12, 22, 23, 29, 30]. High-quality OFR is achieved with a focus on rehabilitation factors, reconditioning and football-specific re-training. Two OFR frameworks specific to football after ACLR have been published, including the four-pillar five-stage approach by Buckthorpe et al. [22, 23] and the control-to-chaos continuum (with recent updates) by Taberner et al. [26–28]. The four OFR pillars (movement quality, physical conditioning, sport-specific skills and chronic workload development) [23] align with the broader goals of the RTP_{erf} continuum and should be progressed alongside supplementary strength and power training.

The OFR programme progresses through five stages (Table 2). Stages 1–2 emphasise coordination and controlled exposure, typically within the late-stage rehabilitation process. Stages 3–5 emphasise football-specific loading, reactive and football specific movements and training simulation, and often involve a shift in the primary practitioner responsible for delivery [204]. Training load is progressed via volume, intensity and frequency, supported by internal (e.g. heart rate) and external (e.g. GPS) monitoring and symptom response (e.g. pain/swelling) [23]. Table 2 provides specific values and targets for male professional football players at each stage based on a previously published clinical commentary by the author group [23] and extensive database and published values of a male ACL football cohort [12]. Target values should be adjusted for amateur and recreational players as well as female football players, with specific values for each level of play (e.g. recreational, amateur and professional) and where possible be relative to individual values for the player prior to injury and/or relevant team. Additionally, values should be adjusted depending on age group and similar processes can be employed with variation across sports. Further research is needed to confidently provide recommended values for each respective group.

3.1.1 Stages 1 and 2: The Coordination Stages

The initial stages of OFR (stages 1–2) focus primarily on restoring movement coordination and preparing the player for higher-load, football-specific demands. These stages emphasise progressive exposure to straight-line running and linear acceleration–deceleration tasks, with particular attention to deceleration control as a prerequisite for higher-angle cutting and multidirectional movements. Given that increasing movement speed and complexity substantially elevate knee joint loading, progression is deliberately gradual and criteria driven [205, 206].

Football-specific activity is intentionally constrained during these stages to minimise the risk to unpredictable and high injury risk situations. Nevertheless, basic, highly

Table 2 Five stages of on-field rehabilitation with the overall focus for each stage, the type of activity and specific examples of content. Workload values are representative for professional male football players and unique values should be used when working with amateur, recreational and

On-field rehabilitation programme					
Domain	Late-stage rehabilitation—coordination		RTP _{err} continuum—football-specific OFR and reconditioning		
	Stage 1—linear movement	Stage 2—multidirectional movement	Stage 3—football (soccer) specific technical skills	Stage 4—football (soccer) specific movements	Stage 5—training (practice) simulation
Primary objective	Restore basic movement control and tolerance to linear loading	Prepare the knee for pre-planned multidirectional demands	Introduce reactivity and decision-making under controlled conditions	Integrate football skills with high physical load	Prepare for full team training demands
Movement focus	Linear acceleration–deceleration, trunk control, sagittal-plane mechanics	Pre-planned CODs (<~80%), lateral and rotational control	Reactive CODs, unanticipated deceleration, agility introduction	High-intensity acceleration, deceleration, COD, high-speed running, performed under pre-planned, reactive, football-specific actions whilst both fresh and fatigued	Match-like movement variability, density and chaos
Football content	Minimal; basic ball contact only (e.g. touches, stationary passing)	Controlled technical drills in constrained spaces	Pre-planned technical drills; limited pressure	Skill-based drills progressions (e.g. passing drills under pressure with decision-making, crossing and finishing, pressing actions, landing from headers with perturbation, 1v1s)	Position-specific, small-group football scenarios
Conditioning focus	Low–moderate aerobic exposure; off-feet CV conditioning	Aerobic and neuromuscular conditioning via linear and COD drills	Increasing anaerobic and neuromuscular conditioning	Football-specific conditioning replaces generic running	Match-simulation conditioning
Load and intensity	Low–moderate intensity; gradual speed progression	Moderate intensity; progressive COD volume	High intensity (~85 to 90%); low–moderate volume	Near-training intensity (~85 to 95%)	Training-equivalent or greater intensity and volume
Peak running speed (km h ⁻¹)	17–21	22–25	≥ 28	≥ 30	≥ 30
Total distance (m)	3000–4500	4000–5000	≥ 4000	≥ 4500	≥ 4500
High-speed running distance (m) [†]	0–100	≥ 100	200–400	≥ 500	400–800
Sprint distance (m) [‡]	0	≤ 50	≤ 100	≥ 150	100–300
Acceleration + deceleration distance (m) [§]	≤ 55	≥ 80	100–200	≥ 250	≥ 300
Time ≥ 70–85% HRmax (min)	0–10	10–20	~ 30	20–30	20–30
Time ≥ 85% HRmax (min)	0	0–5	~ 15	15–20	≥ 20
Primary risk focus	Inadequate deceleration control	Poor control/kinematics during pre-planned CODs	Neurocognitive and reactive loading	Fatigue-related movement degradation	Contact exposure, chaos, cumulative fatigue
Key progression criteria	No pain or swelling response; good deceleration control	High-quality CODs; confidence at speed; strength and power benchmarks	Tolerance to reactive tasks with stable mechanics	Ability to tolerate repeated high-intensity football actions	Completion of OFR workload targets; readiness for RTT

Table 2 (continued)

Domain	Late-stage rehabilitation—coordination		RTP _{ref} continuum—football-specific OFR and reconditioning		
	Stage 1—linear movement	Stage 2—multidirectional movement	Stage 3—football (soccer) specific technical skills	Stage 4—football (soccer) specific movements	Stage 5—training (practice) simulation
Typical duration (days)	~5–10 days	~11–20 days	~14–21 days	~14–16 days	~6–12 days
Typical number of sessions	Amateurs: ~1–3; Professionals: ~3–4	Amateurs: ~3–5; Professionals: ~5–6	Amateurs: ~4–5; Professionals: ~6–7	Amateurs: ~3–4; Professionals: ~5–6	Amateurs: ~3–4; Professionals: ~5–8
Primary lead practitioner (indicative)	Late-stage rehabilitation/movement specialist	Late-stage rehabilitation/movement specialist	OFR or football-specific performance specialist	OFR or football performance specialist	OFR specialist with football coaching background or with coach involvement (coach led sessions)
Primary delivery environment	Rehab/clinic/controlled pitch	Controlled pitch/OFR area	OFR pitch (football-specific)	OFR pitch (football-specific)	OFR + modified training

The programme balances on-field re-training with different session types during the week (quality and quantity) with gym-based re-conditioning and recovery sessions. Words in *italic* indicate the environment and/or goal of the session

ACL anterior cruciate ligament, *HR* heart rate, *HSR* high-speed running, *OFR* on-field rehabilitation, *RTS* return to sport

*Seven key metrics are adopted, with progression through stages based on achieving the desired intensity and quality of work, alongside other rehabilitation criteria (e.g. movement quality, psychological readiness, strength and power, no pain or swelling)

†Defined as 20–25 km/h

‡Defined as greater than 25 km/h

§Defined as greater than $\pm 3 \text{ m/s}^2$

**Indicative targets; thresholds vary by league, position and monitoring system

controlled football technical tasks (e.g. simple passing, volleys, ball touches) are encouraged where appropriate and can be integrated to support postural control, balance and movement quality.

Stage 1 focuses on linear based movements including forward and lateral running, accelerations and decelerations. Stage 2 represents a progression from linear to pre-planned multidirectional movements (e.g. changes of direction up to ~ 80% intensity), with an increasing emphasis on movement quality, biomechanical control and confidence. Linear actions from stage 1 are progressed towards higher intensity, whilst football technical drills remain simple and spatially constrained to maintain control and minimise chaotic demands. Throughout both stages, gym-based strength and power training, off-feet cardiovascular conditioning and alternative modalities (e.g. pool or sand-based training) are used to support load management and physical development.

Collectively, stages 1–2 are typically brief, representing ~5 sessions over ~30 days in amateur players and ~8 sessions over ~16 days in professional players [12], though considerable contextual variability exists depending on how early OFR is introduced and integrated within the wider rehabilitation process. These stages primarily serve to prepare the athlete for the subsequent transition to more football-specific, reactive and performance-oriented OFR phases.

The OFR programme becomes more football-focused in stage 3, when players should have successfully completed standard late-stage rehabilitation exit criteria and demonstrate sufficient movement quality during pre-planned tasks, confidence in higher-speed linear and multidirectional actions and an appropriate strength and power profile to tolerate increased conditioning and football-specific training demands. We advocate for stricter criteria when transitioning from stage 2 to stage 3 (and as such from late-stage rehabilitation to RTS preparation), as this progression introduces reactive movements and football-specific situations that substantially increase neuromuscular and biomechanical demands, and consequently, injury risk. Inadequate preparation at this transition may negatively affect motor control, movement strategy and load tolerance. Entry into stage 3 therefore represents formal initiation of the RTP_{eff} continuum, with a shift in emphasis towards football-specific movement, technical execution and conditioning under progressively more complex and reactive conditions. This may involve a shift in personnel delivering/leading the process [204].

3.1.2 Stages 3–5: Football Specific On-Field Rehabilitation and Reconditioning Stage

Stages 3–5 of OFR represent more football specific training, involving a transition to reactive and more chaotic movement, greater focus on football specific work and increased

intensities and volumes of training to progress towards football training. The aim of the stage to arrive at on-field activity that looks and feels similar to team training to prepare the player technically, tactically, physically and psychologically for team training re-integration. On-pitch activity now provides an important reconditioning stimulus.

Stage 3 (reactive movement and technical reintegration) represents a critical transition phase, integrating reactive movement training and football-specific technical drills whilst further increasing ‘pre-planned’ linear and multidirectional movement intensity towards near-maximum levels. This stage introduces agility-type tasks (e.g. involving unanticipated direction changes and decision-making demands) [207], alongside structured football-technical actions performed under progressively increasing cognitive and physical load/intensity.

Delivery of this stage is particularly challenging for the clinician/practitioner, as reactive movements and technical actions must initially be trained separately before being progressively combined. Given the heightened injury risk associated with reactive tasks [64, 65, 71], careful progression in task complexity and intensity is required [48]. This stage is best delivered by practitioners with expertise in both movement retraining/coaching and football-specific demands, as it plays a pivotal role in preparing players for subsequent reintegration into football training.

Stage 4 (skill-based football conditioning) advances the integration of reactive movements and football-specific skills under higher intensities, whilst also shifting the focus towards reconditioning and restoration of performance-related capacities. Acceleration, deceleration, COD and running tasks are progressed towards volumes approaching those observed in team training and at near maximal (90–95%) intensity.

Technical drills are now embedded within football-specific conditioning tasks, allowing cardiovascular and neuromuscular demands to be developed in a sport-relevant context. By the end of this stage, players should be capable of tolerating training intensities close to full team practice, including controlled 1v1 scenarios and light contact exposure, thereby preparing them for either modified team training or higher-intensity OFR.

Stage 5 (training simulation and preparation for team integration) aims to simulate the physical, technical and cognitive demands of team training within a controlled OFR environment. This stage integrates all four OFR pillars (movement, physical conditioning, football specific skills and tactical restoration and load management) to create training sessions that closely resemble the intensity, complexity and variability of football team training. Delivery typically requires a specialised OFR practitioner with football-specific coaching expertise and an

understanding of ACL injury mechanisms, as these sessions extend beyond the skill set of most rehabilitation or conditioning specialists. Given the nature of OFR, which involves individual and small group-based scenarios, there is a stronger focus on technique, skills and position specific player actions. Thus, the ‘OFR specialist/coach’ does not need to be tactically excellent (e.g. game-based models).

This stage provides additional time to consolidate movement quality and progressively restore workload exposure prior to RTT. At this stage of recovery, a combination of delivery styles including OFR, individual one-on-one coach-led sessions and use of modified/constrained team training (see below) are present depending on the environment, practitioner skill set and club/coach philosophy. Recent evidence indicates that completion of this final OFR stage is associated with higher rates of return-to-football compared with earlier OFR termination, despite residual deficits in certain high-intensity workload metrics [12]. These findings highlight the value of extending OFR beyond minimal clearance thresholds to better prepare players for the demands of training and competition.

3.1.3 Criteria for Progression: Completion of OFR and Readiness for Return to Team Training (RTT)

Completion of the OFR process should augment RTT decision-making, as traditional batteries of tests to inform RTS decision-making are insufficient to determine readiness for RTT [21]. We recommend that players complete all OFR stages with adequate exposure to both volume and intensity, achieving workloads comparable to team training demands and demonstrating tolerance to repeated high-intensity acceleration, deceleration and high-speed running across multiple sessions.

Assessment at this stage should integrate objective workload monitoring (e.g. GPS-derived metrics), restoration of key physical performance qualities (strength, power, speed, deceleration and COD ability and endurance), and qualitative evaluation of movement quality during high-load functional tasks (see Table 3). Whilst there is no consensus regarding optimal movement quality assessments, structured qualitative analysis of pre-planned and reactive movements is strongly recommended given the elevated risk of re-injury during return to football.

Batteries of tests to inform RTS decision-making should be adapted to the competitive context, with professional players typically undergoing more comprehensive profiling and amateur players utilising pragmatic field-based or clinically accessible assessments (e.g. qualitative assessment of single leg squat [208], deceleration, landing and cutting [209–211] actions; the landing error scoring system (LESS)

[212]; cutting movement assessment score (CMAS) [213]). Irrespective of level, completion of a structured OFR process remains a critical and often missing component of the RTP_{erf} pathway.

3.2 Step 2: The Return to Train (RTT) Stage and Readiness for RTC

Completion of OFR and achievement of typical RTS criteria do not equate to readiness for competitive match play. Instead, players require a distinct ‘RTT stage’, in which football-specific conditioning, technical–tactical reintegration and progressive exposure to training and match demands are achieved to ready them for RTC.

Observational data from elite football suggest that a structured process prior to RTC following RTT is common practice, with typical durations ranging from 3 to 7 weeks [3, 5]. In Union of European Football Associations (UEFA) Champions League teams, players RTT at ~6.6 months and to RTC at ~7.4 months after ACLR, with a mean interval of just 23 days between RTT and first match exposure [5]. Importantly, 7% of players sustained a knee re-injury during this period and in early RTP process, and persistent deficits in physical capacity after RTP have been reported despite completion of rehabilitation [92–94]. Collectively, these findings suggest that short RTT-to-match timelines may be insufficient to bridge the gap between constrained training readiness and competitive match demands.

More recent data indicate slightly longer RTT-to-competition intervals in elite European football (~42 days) [3], though no consensus exists regarding optimal timelines, particularly outside elite settings. Given that competitive match play carries an ~20-fold greater ACL injury risk than training and an ~10-fold greater injury risk for all injuries overall [5, 214], and players after ACLR exhibit a 15–40 times greater ACL re-injury risk than uninjured peers [9–11], the RTT stage should be viewed as a risk-mitigating exposure phase, not simply a clearance milestone. From an applied perspective, the RTT stage typically spans ~4 to 8 weeks, consistent with observational data from elite European football [3, 5], although considerable variability exists depending on competition level, calendar congestion, player role and tolerance to progressive exposure. Within this period, time is not distributed evenly; early RTT is commonly shorter—meaning a short period of modified training prior to full RTT whilst the transition from full training to first match exposure often represents the most critical and prolonged phase. Importantly, timelines should be guided by exposure tolerance rather than calendar progression, with players demonstrating stable knee response and robust performance across consecutive weeks of increasing training and match-specific demands.

Table 3 Indicative criteria and assessment domains for completion of OFR and readiness for return to team training (RTT). The criteria below are intended to support MDT decision-making. They represent minimum readiness indicators rather than absolute thresholds and should be interpreted in the context of player level, competitive demands and available resources

Domain	Indicative assessment focus	Readiness indicators
Knee health and symptom response	Clinical monitoring across repeated high-load OFR sessions	No reactive joint effusion; pain-free or minimal symptoms during and after loading; stable knee response across consecutive sessions
OFR completion and exposure	Completion of all OFR stages with progressive volume and intensity	Demonstrated tolerance to repeated football-specific loading; no regression in performance or symptom response
Workload tolerance	Objective monitoring of external and internal loads (e.g. GPS, HR, session RPE)	Exposure > 90% and ideally 100% of team training intensity; ability to tolerate repeated high-intensity acceleration, deceleration and high-speed running
Movement quality	Structured qualitative and/or quantitative assessment of pre-planned and reactive football-specific tasks. Tasks to include squatting, jumping, landing, deceleration and COD mechanics	Stable mechanics under load and ideally fatigue; absence of clear compensatory strategies; confidence in deceleration, cutting and landing tasks. Assessment supported by video capture either indoor (ideally supported by kinetic data from force plates) or on field
Neuromuscular performance	Evaluation of lower-limb strength, explosive performance and inter-limb function	Restoration of key neuromuscular qualities within close proximity of normative values for their competing level to be able to tolerate football-specific demands; no major unresolved asymmetries impacting task execution
Football-specific actions	Completion of position-relevant football tasks within OFR	Tolerance of role-specific actions (e.g. pressing, decelerating into duels, landing from headers) performed with control
Fatigue robustness	Observation of movement quality during and following high-load sessions	Maintenance of coordination and control under fatigue; no marked degradation in technique
Psychological readiness	Practitioner observation and player feedback during OFR	Confidence to load the knee in football-specific contexts; absence of avoidance behaviours
MDT consensus and coach communication	Integrated MDT discussion and communication with coaching staff	Clear agreement on readiness for team training and defined constraints or modifications if required

3.2.1 Structure and Progression of RTT

RTT should progress the neurocognitive and contact demands (perception–action coupling, scanning, opponent pressure, duels) in a progressive manner, as these constraints drive many of the high-risk situations that cannot be fully replicated in OFR. Following clearance from OFR, players should progress through a RTT process, typically involving: (i) modified (constrained) team training, (ii) full (unrestricted) team training and (iii) incremental match exposure at reduced competitive levels or durations. During early RTT, modifications should be present to limit contact intensity, drill complexity and chaotic exposure (e.g. no sliding tackles, reduced drill sizes, role-based constraints such as floaters or attacking-only participation). These restrictions are particularly relevant given the higher incidence of ACL injuries during defensive actions, particularly high intensity pressing and whilst tackling/being tackled, typically with indirect contact mechanism [45–47, 69]. Modified team training may be combined with continued individual or OFR-style work, ideally coach led or via specialist OFR trainer when specific drills exceed the player's current tolerance.

Cultural and organisational factors present an inherent challenge at this stage, as some coaching environments do not support modified participation ('fit to train or not'). Where modified team training is not feasible, it becomes essential that the final stage of OFR adequately over-prepares the player for unrestricted training. This may involve incorporating additional players into OFR sessions to better replicate team training density, contact frequency and spatial demands, ideally with coaching staff support.

3.2.2 Restoring Match-Level Workload Exposure

Team training typically exposes players to only a fraction of competitive match workloads, often ~30 to 60% of match demands depending on the training day and micro cycle programming, with specific metrics such as high-speed running or sprinting and high-intensity decelerations commonly under-represented in training relative to matches [215–217]. This discrepancy highlights the need for structured exposure progression to bridge the gap between training and competitive match demands, with such strategies including individual top-ups post-training where players complete additional work after team training sessions to achieve a prescribed percentage of match demands (e.g. +10–20% match demands versus training session), often aligned to lower volume 'acquisition' training days; prescribed individual or match simulation sessions, delivered around the team schedule when training content or timing is not appropriate for the player, allowing controlled exposure to match-like workloads; and friendly or lower-level competitive matches,

including large-sided training games, in-house friendlies or competitive exposure at lower level (e.g. development or reserve team or younger age group where appropriate), providing high specificity and progressive increases in intensity and volume.

These approaches allow players to progressively tolerate match-like volumes and intensities of acceleration, deceleration, sprinting and contact in a more controlled manner. Throughout RTT, close monitoring of knee symptoms (pain, swelling), wellness and internal and external workloads is essential. Attention should be paid to sprint intensity and volume and deceleration exposure, which are often suppressed during OFR [12] and team training [215–217], but are critical for match readiness and hamstring injury risk mitigation [147, 150, 151], as well as potentially ACL injury risk (requiring further investigation).

3.2.3 Criteria for Progression: Completion of RTT and Readiness for RTC

Progression towards competitive match availability should be based on the player's ability to tolerate the RTT process without adverse joint response, alongside demonstration of an appropriate physical performance profile. Final selection decisions remain coach-led but should be supported by objective and qualitative information provided by the multi-disciplinary team. Initial match exposure is commonly achieved via substitute appearances (e.g. 15–30 min), though adequate warm-up and preparation are essential, as substitutes appear to sustain ACL injuries earlier than starters [66], likely due to insufficient preparation and altered pacing strategies. See Table 4 for objective and subjective testing considerations.

3.3 Step 3: Return to Competition and Performance, Prevention of Re-injury, and Long-Term Management

After a player has been cleared to return to their previous competitive level of match play (RTC), it is important to recognise that RTC does not equate to RTP_{erf} . Match availability typically precedes full restoration of performance capacity, robustness and load tolerance, which may require several competitive matches and extended training exposure. Players after ACLR should be considered load-compromised during the early RTP_{erf} phase. Whilst no evidence-based timelines exist, a pragmatic period of ~3 months may be considered as the early RTP_{erf} period, requiring ongoing monitoring and targeted management to balance performance restoration, knee health and injury risk.

Importantly, the early RTP_{eff} phase should not be viewed solely as a period of risk containment, but also as a phase of progressive performance re-emergence. Whilst initial match exposures primarily serve to restore availability and confidence, subsequent competitive appearances provide a unique and necessary stimulus to re-establish position-specific physical outputs, decision-making speed and tactical execution under true match constraints. Within this phase, competitive match exposure itself becomes an integral component of the reconditioning process, contributing to neuromuscular, metabolic and neurocognitive adaptations that cannot be fully replicated in training environments. Match exposure also supports technical, but more specifically tactical, recovery. RTP_{eff} therefore represents a shift from structured exposure control towards performance optimisation under carefully managed risk.

Although completion of criterion-based rehabilitation and successful RTS testing is associated with reduced re-injury risk [7, 86], athletes remain at elevated injury risk compared with uninjured peers upon RTS [3, 11, 86]. Many players are also unable to tolerate a full competitive training schedule or repeated match exposures (e.g. > 1 match per week) immediately following return, highlighting the need for continued performance and risk management beyond RTS.

3.3.1 Load Management and Chronic Workload Development

Informing players and performance staff regarding the need for ongoing prevention strategies is considered essential to ensure adherence and informed decision-making. The balance between performance progression and injury risk mitigation is highly context dependent and influenced by factors such as match availability, squad depth, competition demands and positional requirements.

When players RTC, we recommend limiting exposure to large acute workloads (e.g. avoiding three matches within 7–8 days). Practically, this may involve restricting players to a maximum of one full competitive match per week during the early RTP_{eff} phase. In parallel, chronic workload should be progressively developed to prepare the player for higher fixture density, where needed.

3.3.2 Persistent Injury Risk and Bilateral Vulnerability

Once players RTP_{eff}, they should be viewed as having persistent elevated injury risk, sometimes described clinically as an ‘injury shadow’, which may extend throughout the remainder of their career, particularly following an isolated non-contact ACL injury [3]. Re-injury risk following ACLR is bilateral, with similar rates of ipsilateral graft rupture and contralateral ACL injury reported across cohorts [12, 218,

219]. In professional players, contralateral ACL injury risk may exceed graft rupture risk [3]. Graft re-rupture risk may be influenced by surgical technique and graft choice, including the use of lateral extra-articular tenodesis [220, 221]. Elevated contralateral ACL injury risk likely reflects a combination of modifiable (e.g. strength asymmetry, movement alterations, increased loading on contralateral side) and non-modifiable (e.g., notch-width, ACL size, knee morphological, genetics and family history, sex) risk factors [222–225].

Given this persistent and bilateral ACL re-injury vulnerability, we recommend that all players after ACLR maintain a long-term emphasis on lower-limb strength development and maintenance, movement quality training and ongoing neuromuscular performance profiling, as well as appropriate load management. This risk profile extends beyond the knee, with increased incidence of secondary muscle injuries, particularly thigh muscle injuries, reported in the 2 years following RTP after ACLR [226].

Transition out of the early RTP_{eff} phase may be considered once players demonstrate the ability to tolerate repeated competitive match exposures, including higher fixture density, without disproportionate fatigue responses, symptom recurrence or secondary injury. At this point, players may no longer be considered load-compromised, although long-term risk-mitigation strategies and targeted neuromuscular training should remain embedded within the weekly training process for the remainder of the player’s career.

4 Summary: Integrating Reconditioning, On-field Rehabilitation and Return to Performance

Outcomes for football players (and athletes in most other team sports) following ACLR require improvement. Many sub-elite players do not RTS after ACLR, whilst professional players typically RTC but do so at an elevated risk of ACL re-injury and with reduced performance outcomes. Importantly, long-term joint health and career longevity may also be compromised following ACL injury.

Returning a player to football after ACLR is therefore not simply a matter of completing rehabilitation and achieving RTS benchmarks. Players must be prepared for the demands of football performance and the circumstances under which injury risk emerges. This requires an understanding of what constitutes football performance and how injury mechanisms are expressed within the sport-specific context.

In this commentary, we outlined four key pillars underpinning RTP_{eff}: (1) movement quality; (2) football-specific technical, skill and tactical re-training; (3) football fitness reconditioning and workload restoration; and (4) full restoration of the neuromuscular performance profile (maximal

Table 4 Indicative criteria and assessment domains for progression from return to train to first competitive match exposure. The criteria below are intended to support multi-disciplinary team-led decision-making for progression from return to train to competitive match exposure. They represent minimum readiness indicators rather than absolute thresholds and should be interpreted in relation to competitive level, positional demands, and contextual constraints

Domain	Indicative assessment focus	Qualitative readiness indicators
Knee health and symptom response	Clinical monitoring across consecutive unrestricted training sessions	No reactive effusion or pain; stable knee response following repeated high-load training sessions
Training tolerance	Exposure to full, unrestricted team training	Ability to complete $\geq 2-3$ weeks of unrestricted team training without adverse joint response or load-related symptom escalation
Match-relevant workload exposure	Integration of training, top-ups, simulations or friendly match exposure	Demonstrated tolerance to match volumes and intensities of acceleration, deceleration, sprinting, and contact
Movement quality under chaos	Qualitative and/or quantitative assessment of movement quality during high-intensity, reactive football tasks	Good kinematics during unanticipated actions (e.g. reactive 45-degree COD), defensive movements and duels; no clear compensatory strategies
Neurocognitive and decision-making demands	Exposure to perception-action coupling, scanning and opponent pressure	Effective execution of football actions under time pressure and cognitive load
Physical performance profile	Attainment of physical performance profile including speed, acceleration-deceleration and change-of-direction ability, strength and power and endurance (aerobic and anaerobic fitness)	Physical capacities sufficient to tolerate match demands and repeated high-intensity bouts
Fatigue robustness	Tolerance to dense training weeks and match simulations (fatigue testing post-match simulations)	Maintenance of coordination, control and decision-making under fatigue
Psychological readiness	Practitioner observation and player-reported confidence	Willingness to engage fully in contact, pressing and high-risk football actions
Multi-disciplinary team and coaching alignment	Multi-disciplinary team discussion and coach communication	Clear agreement on role, planned minutes, substitution strategy and progression plan

Table 5 Clinical framework for progression from late-stage rehabilitation through football-specific on-field rehabilitation, return to team training, return to competition and return to performance following ACL reconstruction in football

	Late-stage rehabilitation (<i>on-field coordination</i>)	Football-specific on-field rehabilitation (<i>RTS training</i>)	Return to team training (<i>RTT</i>)	Return to competition (RTC) and return to performance (<i>RTP_{eff}</i>)
Programme structure	OFR stages 1–2 Movement restoration and on-field coordination	OFR stages 3–5 Football specific technical → skills → training simulation	Modified team training → full team training	Return to competition → injury shadow (~3 months) → return to performance → long-term optimisation
Primary focus	Restore physical capacity and coordinated movement	Restore football-specific movement competency and prepare for RTT	Safely reintegrate into unrestricted team training whilst developing training workload tolerance	Safely return to competition whilst progressively restoring (or exceeding) pre-injury performance and minimising the risk of ACL, contralateral ACL and secondary injuries
Primary practitioner(s)	Rehabilitation specialist, physiotherapist and/or S&C coach	Rehabilitation specialist, S&C coach and fitness coach	Shared leadership between medical, performance and coaching staff	Coaching staff (lead), performance staff, with medical oversight as required
Programme duration* (<i>OFR activity only</i>)	~4–8 weeks	~4–8 weeks	~4–10 weeks	Ongoing (weeks to months following RTC); injury shadow typically first ~3 months
Training frequency	1–3 on-field sessions/week	3–5 on-field sessions/week	Progressive modified → unrestricted team training	Team training, competition and individual top-up sessions; initially restrict to one competitive match per week
Key objectives	Restore maximal strength, explosive neuromuscular performance, movement quality, coordination and conditioning	Develop football-specific movement, technical integration, perceptual-cognitive skills, position-specific conditioning and progressive football exposure	Achieve unrestricted training participation, tactical reintegration, competition readiness and continued development of strength, movement and conditioning	RTC: progressive match reintegration through planned exposure. <i>RTP_{eff}</i> : restore or exceed pre-injury physical and football performance, maximise availability and minimise future injury risk through ongoing individualised development
Movement emphasis	High-load pre-planned movement control including acceleration, deceleration, cutting, landing and sprint mechanics with progressive intensity and complexity	High-intensity football movements: agility, reactive actions, technical skills, perceptual integration and position-specific movement demands	Chaotic, position-specific movement within team training with progression of player numbers, pitch size, contact and tactical complexity	Efficient movement under maximal competitive demands with continued optimisation of movement quality and neuromuscular performance
Monitoring priorities	Strength, power, movement quality, coordination, conditioning and knee response	External and internal workload, GPS metrics, football exposure and movement quality and knee response	Training exposure, workload tolerance, symptoms, wellness and coach feedback and knee response	Match exposure, physical performance outputs, GPS metrics, availability, symptom surveillance (knee response) and injury-risk profiling
Progression criteria	Meets advanced laboratory- and field-based RTS criteria and demonstrates readiness for football-specific rehabilitation	Successfully completes football-specific OFR programme and demonstrates physical and psychological readiness for RTT	Completes unrestricted team training and is medically cleared for RTC	Restoration (or improvement) of pre-injury performance, sustained availability and no ongoing rehabilitation limitations
Common challenges	Persistent strength or power deficits, movement compensations, knee irritability (e.g. patellofemoral pain), reduced confidence and psychological barriers	Underloading, insufficient football specificity, limited technical integration, fear during chaotic actions or lack of an experienced OFR practitioner. Unable to tolerate high intensity reactive movements	Balancing player protection with performance demands whilst determining readiness for competition and managing coach expectations regarding modified training	Restoring pre-injury performance, preventing detaining and secondary injuries, and avoiding transition to standard team preparation before individual performance deficits have been fully addressed

*Typical duration refers to the dedicated on-field rehabilitation component and should be individualised according to injury severity, athlete characteristics, clinical progression and contextual factors

strength and explosive neuromuscular performance). Completion of late-stage rehabilitation and achievement of common RTS criteria do not indicate readiness for competition or performance, but rather readiness to enter a RTP_{eff} continuum. This is a simple yet important concept.

The continuum comprises OFR, RTT, RTC and ultimately RTP_{eff} (Table 4). Crucially, RTC reflects a return to availability, whereas RTP_{eff} represents the sustained capacity to tolerate football demands whilst optimising performance and managing re-injury risk. Given the long-term implications of ACL injury, RTP_{eff} should be viewed as a prolonged process requiring ongoing conditioning and enhanced prevention strategies to support performance and career longevity.

Whilst the pillars of reconditioning define the physical capacities required for football performance (e.g. strength and power, cardiovascular fitness, speed, deceleration capacity and workload tolerance), the RTP_{eff} continuum describes how these capacities are progressively expressed under football-specific constraints (Table 5). Rather than representing uncontrolled or arbitrary exposure, RTP_{eff} involves the intentional and progressive layering of task, environmental and cognitive challenges, allowing complexity and risk to be introduced in a structured and controlled managed manner.

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