REVIEW

Nr 2025;15 (4):389-400

Walking-to-Jogging Transition Criteria after Anterior Cruciate Ligament Reconstruction in Soccer Players: A Narrative Review

Rosario D'Onofrio[1,2], Matteo Masucci[3,4], Dario Pompa[5,6], Vincenzo Manzi[1]

[1] *Department of Education and Sports Science, Pegaso Open University, Naples, Italy*
[2] *Medical-Scientific Multidisciplinary Commission, Italian Football Doctors Association-L.A.M.I.CA. Italy*
[3] *Department of Kinesiology and Health Sciences, University of Waterloo, Canada*
[4] *Technical Director of the Juventus Academy of Los Angeles, California, U.S.A.*
[5] *BIND-Behavioral Imaging and Neural Dynamics Center, University "G. D'Annunzio" of Chieti-Pescara, Chieti, Italy*
[6] *Department of Medicine and Aging Sciences, University "G. D'Annunzio" of Chieti-Pescara, Chieti, Italy*

CORRESPONDING AUTHOR:
Rosario D'Onofrio
Department of Education
and Sports Science
Pegaso Open University
Centro Direzionale Isola F2
80143 Naples, Italy
E-mail: r.donofrio@alice.it

DOI:
10.32098/mltj.04.2025.04

LEVEL OF EVIDENCE: 5

SUMMARY

Objective. To identify the criteria for transition from walking to jogging training in soccer players after ACL reconstructive surgery.

Methods. We have conducted a literature synthesis process using Arksey & O'Malley's methodology to answer precise research questions. The questions identified for conducting it were: A) *What are the clinical criteria and the timing for prescribing return to running after anterior cruciate ligament reconstruction in soccer players?* B) *What are the postural/functional criteria for prescribing a return to jogging after ACL reconstruction in soccer players?* To answer these questions, we performed a literature search of the last six years (January 2018- February 2024) on Web of Science, PEDro, SPORTDiscus, Google Scholar, and PubMed electronic biomedical database.

Results. The return to jogging is not related to the time of surgery but to the achievement of the following goals: a) Complete range of motion (ROM) of the knee; b) No pain; c) No effusion (swelling); d) IKDC >90/100; e) Triple crossover hop test of uninjured side; f) Single leg hop tests >90% of uninjured side; g) Single leg squat test or step up without increase in knee valgus/varus; h) Trendelenburg sign negative; i) Pelvic drop negative; l) physiological ratio Q/H; m) Sufficient quality of movement during foundation technical and athletic skills. The timing for return to jogging is about 12 weeks after reconstructive surgery.

Conclusions. Transitioning from walking to jogging training requires the athlete to achieve precise clinical, rehabilitation, and postural/functional objectives.

KEY WORDS

Knee; return to sports; rehabilitation; exercise; training; performance.

INTRODUCTION

ACL injuries in soccer are frequently encountered especially in women's soccer, accounting for 16% to 43% of all injuries during the season (1). These are attributable to noncontact mechanisms related to gestural expressiveness and tactical situational skills (1).

Reconstructive surgery is the elective treatment. The rationale for the surgery is: a) to improve knee function and stability; b) to prevent high Ipsilateral and Contralateral Reinjury; c) to slow early degradation of the knee joint environment (post-traumatic osteoarthritis) present with high rates in Professional Soccer athletes (2).

The timing of return to sport is related to the objectives achieved in the various stages of rehabilitation (3). This process is conditioned by predictive indicators that can influence the outcome: age, gender, time since reconstruction, time between injury and reconstruction, concomitant intra-articular injuries (isolated cruciate ligament tear, meniscal tear, lateral ligament, unfortunate triad), the type of graft (hamstring, patellar tendon or quadriceps tendon autograft) type of sport practiced (team, individual), and previous injuries and rehabilitation process (4).

We should not forget how cruciate ligament graft healing after reconstructive surgery is an essential prerogative regarding rehabilitation progression and timing of return to full sports activity (5).

Considering recent indications (6, 7), delaying the return to training to align with graft integration and maturation reduces the risk of second injuries. Therefore, return to full unrestricted competitive activity is not recommended until 9-12 months (6, 7).

Also, Beischer *et al*. reported a 7-fold increased risk of new ACL injuries for athletes who returned to sport before 9 months (8).

ACL injury mechanism in soccer players

Soccer like other team sports is considered as a casually intermittent activity involving sudden variation in directional modes that parallel game-related changes in intensity (9). Executing these simple and complex movements imposes great physiological loads on players during competition. Consequently, the metabolic pathway is highly stressed to meet the physical and physiological demands during the official game (10).

Elite players train at 85-90% of their maximum heart rate, with an average oxygen uptake ($\dot{V}O2$) of 70-80% of the maximum. Despite the low average match speed (110-140 m/min in a 90-minute match), soccer players may experience considerable neuromuscular fatigue and energy expenditure during the match. Indeed, the intermittent nature of a soccer match imposes 1,200-1,400 activity changes and 150-200 short, high-intensity (1-6 seconds) multidirectional efforts on elite players during a 90-minute match (10).

During a match, soccer players make about 700 direction changes during a game of varying intensity, and 600 of these direction changes are performed from 0 to 90°. About 50 of the direction changes in a soccer match are performed at maximum intensity (11). High-level soccer players typically travel 10-13 km during a match, perform about 1,200 activities that change every 4-6 s, 150-250 short and intense actions, and 200-400 m of sprinting (distance traveled greater than 7 m.s-1) (12).

Technical/athletic gestures such as cutting maneuvers, change of direction, sidestep cuts, crossover cuts, accelerations, decelerations, jumps and landings, "tackles", lateral and frontal sliding, and tactical expressions related to regaining the ball (high intensity pressing and re-aggression) are classified as key mechanisms in the onset of Anterior Cruciate Ligament (ACL) injuries (13, 14). Thus, pathological movements during a soccer match follow one another in a repetitive manner, inconsistent with asymmetrical technical-athletic expressiveness, laterality, and torsional with runs performed at various intensities seldom unidirectional (14).

During these gestures, the joints a) patellofemoral (compressive forces); b) femoro-tibial (in terms of anterior shear force and compressive forces) are placed under diverse overstress. The magnitude of these stresses on the joint can be related to a) the level of muscular activity; b) the integrity of the joint environment; c) postural/dysfunctional frameworks; d) a decrease in the quality of technical-athletic movements; e) past injuries (14-16).

The laterality and rotationality of technical/athletic expressions create, from a biomechanical point of view, varo-valgus knee movements, combined with internal/external rotation that is associated with pathological lesion mechanisms at the knee capsuloligamentous apparatus (13, 14, 16).

These injuries are probably attributed to multiplanar mechanisms (combined sagittal, frontal, and transverse). Postural/dysfunctional alterations, post-reconstructive surgery, of the lower limb can, during jogging, have a negative influence: a) on joint loading; b) on the mechanical efficiency of the tendon muscle apparatus; c) on the orientation of proprioceptive control of the pivot joints of the lower limb: hip and knee (14, 16).

Particularly, during running-cutting maneuvers, soccer players generate a greater adduction moment at the beginning of the cutting, followed by a greater abduction moment toward the end of the cutting, which can substantially impact the loading of the anterior cruciate ligament. In addition, athletes should pay attention to changes in contact forces in the coronal plane (17).

Side-step maneuvers and abrupt decelerations with direction changes are associated with non-contact/contrast ACL injuries (18).

It has been stated that after an ACL injury, the movement quality of technical and tactical skills is significantly impaired, leading to increased risk factors for further injury and re-injury during the process of returning to full competitive specific activity. Movement dysfunction is believed to be a risk factor for primary and secondary ACL injuries (14, 19).

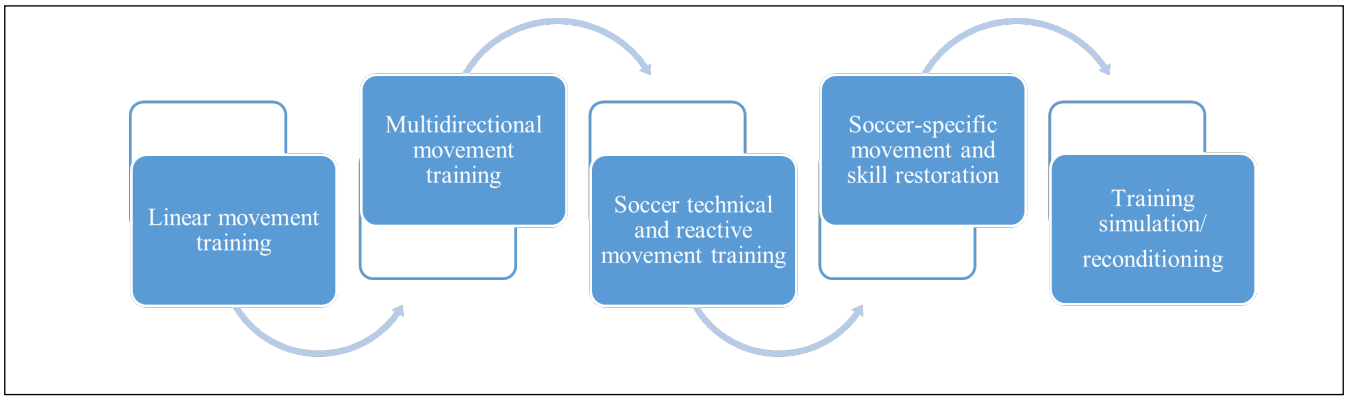


Figure 1. Key points for returning to soccer-specific athletic technical skills.

The re-learning of sport-specific skills, both technical and athletic, must be included in a progression from linearity of movement to restoration of sport-specific skills (13, 14, 19) (**figure 1**). In this context, the return to jogging is preceded by a remodeling/re-learning of running technique.

An early transition from walking to jogging may correlate with an increased risk of complications and re-injury (ipsilateral graft rupture or contralateral rupture of the native ACL) (16).

The knowledge of the performance pattern will allow us to know the end goal and reprogram the return to jogging progressively and objectively. Progression is based on respect for joint, strength, quality of motion, and muscle soreness (19). Many aspects of function generally do not normalize within the first year after anterior cruciate ligament reconstruction (ACLR), and more attention is needed to achieve symmetrical optimal quality of movement (19).

This review aimed to summarize, synthesize, and answer 2 questions: A) *What are the criteria and timing for prescribing return to jogging after anterior cruciate ligament reconstruction in soccer players?* and B) *What are the criteria and postural/functional reasoning for prescribing a return to jogging (RTJ) after anterior cruciate ligament reconstruction in soccer players?*

Better identification of transition criteria can improve and optimize rehabilitation steps and reduce the risk of injuries related to return to sport.

MATERIALS AND METHODS

This narrative review allows us to overview the literature, enabling us to have a rapid qualitative and subjective summary of the current state of science on the specific topic through precision research to answer a precise question (20).

This narrative review, which consists of six steps, is based on the methodology of Arksey & O'Malley (21). The six-stage are: 1) Identification of the questions; 2) Identification and selection of studies; 3) Selection of studies; 4) Data extraction; 5) Summary of the results of the selected studies; 6) Expert consultation exercise.

Stage 1. The identification of the questions

The questions identified in our scoping review were: A) *What are the clinical criteria and timing for prescribing return to jogging after anterior cruciate ligament reconstruction in soccer players?* B) *What are the criteria and postural/functional reasoning for prescribing return to jogging after anterior cruciate ligament reconstruction in soccer players?*

Stage 2. Identification and selection of studies

To ensure the incorporation of the latest information considering the continuous evolution of medical treatments, a search for studies was conducted within the timeframe of the past six years (January 2018-February 2024). Scanning was done on Web of Science, PEDro, SPORTDiscus, Google Scholar, and PubMed electronic biomedical database. The so-called gray literature (*i.e.*, unpublished lectures, abstracts, theses, and reports) was not considered. For indexing, we used MeSH (Medical Subject Headings) Terms.

Stage 3. Selection of studies

The inclusion criteria adopted for this scoping review were studies focusing on ACL, return to sport, and return to jogging and running after ACL reconstructive surgery in soccer players.

All articles meeting the inclusion criteria in relation to the research question were evaluated for relevance, then typed by the senior reviewer (RD), and submitted for summa-

ry review to the remaining reviewers (FL, VM and DP). Subsequently, the opinion of an experienced soccer technician (CS) was provided. MM reviewed the activities and contributed to the drafting and editing of the manuscript. Any cross-references of the selected articles were screened for possible relevance; all duplicate citations were removed. For any discussion regarding inclusion or exclusion of articles, the opinion of the senior author (RD) experienced in sports rehabilitation and posturology was decisive.

Stage 4. Data extraction

In accordance with the recommendations made by Arskey & O'Malley (21), the data extraction tool (descriptive-analytic) was developed by the authors, placed for review by the senior author (RD), further revised by the authors (VM, PD, CS, MM and FL), and shared with the other authors. In the end, all authors evaluated the extracted data and gave a favorable opinion on the writing of the article. The proposed data extraction tool (descriptive-analytic) was proposed to contextualize and classify the content of the studies rationally.

Stage 5. Summary of the results of the selected studies

Content analysis was used to summarize the data from the selected studies. This Scoping Review is limited to a summary description of the main data obtained from the different studies considered by the authors in relation to the specific research question (A and B). Of the selected studies, duplicates unrelated to the research objectives were excluded after cross-discussion between the authors (VM, PD, MM and FL). The senior author (RD) selected the final articles suitable for the purpose of the study and to answer the research question.

Stage 6. Expert consultation exercise

Given the few studies related to the transition from walking to running after ACL reconstructive surgery and to validate the results, especially postural/dysfunctional, we carried out a further consultation exercise as provided by the Arksey & O'Malley (21) methodology through an additional parallel phase involving expert stakeholders apt to ratify the results of our study.

RESULTS

The decision-making process on when an athlete can return to jogging is still today very elaborate, and essentially lacking theoretical and practical guidelines. Regarding the questions (A and B) posed in this scoping review, we can point out that the timing for return to jogging is around 3 months. However, the prescription is not related to the time of surgery but to the achievement of the objectives: a) full range of motion (ROM) of the knee >95% of the uninjured knee; b) no pain (Pain < 2/10 visual analog scale (VAS)); c) No effusion (swelling); d) International Knee Documentation Committee score (IKDC) > 64/100; e) Extensor and flexor LSI > 70% of the uninjured side; f) Single leg hop tests > 70% of uninjured side; g) Single Leg Squat test (SLST) or step up without increase in knee valgus; h) Trendelenburg sign negative; i) pelvic drop negative; l) Isokinetic LSI of quadriceps and hamstrings > 70% physiological ratio Q/H (**table I**).

Relative to the postural/dysfunctional picture considerable importance in technical gestural expression is given by the stability of the Lumbo-Pelvic-Hip Complex. Often this assessment is left to subjective and/or clinical interpretation, without analyzing postural-dysfunctional patterns and the quality of gestural movement expression that could be risk factors for re-injury or complications

Considering the no homogeneity of the studies, we should interpret these results as general key points and customize the approach to jogging based on its relationship to the clinical and rehabilitation processes.

DISCUSSION

Few studies in the past 6 years have examined the transition period from walking to jogging, leaving clinicians uncertain about how and when to prescribe a gradual program of return to jogging (22).

Methodologically, the return to jogging opens the second phase of the post-surgical process. The transition period is from walking training on the Treadmill to running on the playing field (**figure 2**).

Lorenz and Domzalski (23) report a progressive jogging program of 4 weeks before switching to running. It is reported as timing the return to jogging around the 8th-16th postoperative week (22), on condition that the athlete passes the clinical examination and fitness test.

Grondin *et al.* (24), in a recent review, says that 99% of studies report time-based criteria for a return to jogging with a median of 12 weeks postoperatively, and only 18% reported to using additional criteria, which were clinical (range of motion, effusion, pain), strength-based with isometric or isokinetic criteria, or performance-based.

It has been highlighted, and it is important to consider, that unidirectional jogging does not result in the same increase in moments in the frontal (varus/valgus) and axial (internal/

Table I. Clinical and functional criteria for return to running.

Clinical and functional criteria for the return to jogging	Value cut off
Pain	No pain in passive or active movement. No pain before and after walking training
Swelling	No swelling. No pain before and after walking training
Instability	No subjective
Laxity tests	No positive
ROM	Symmetrical extension/flexion range of motion
Knee extension	Full active
International Knee Documentation Committee score (IKDC)	IKDC scores greater than > 90/100
Return to Sport after Injury Scale (ACL – RSI)	≥ 60/100
Trendelenburg sign*	Negative
Physiological ratio Q/H	Symmetrical
Single-leg hop test	Single hop LSI > 90% of contralateral side** Without an increase in knee valgus
Triple hop test	LSI > 90% of contralateral side Without an increase in knee valgus
Triple crossover hop test	LSI > 90% of the contralateral side Without an increase in knee valgus
Single-leg squat test***	Without an increase in knee valgus
Quality of movement	ufficient quality of movement during the foundation of technical and athletic skills.

*The Trendelenburg sign is a physical examination finding observed when assessing hip dysfunction. A positive Trendelenburg sign usually indicates weakness of the abductor muscles of the hip, consisting of the gluteus medius and gluteus minimus. A positive sign is defined by a fall of the contralateral pelvis during single-leg stance. ** LSI: Limb symmetry index. LSI is an index defined as [(lower limb after surgery / contralateral lower limb) – 100]. LSI > 90% is used as a cut-off. *** The single-leg squat test is executed with a knee angle of 45°, ensuring no loss of balance, valgus, or contralateral hip drop.

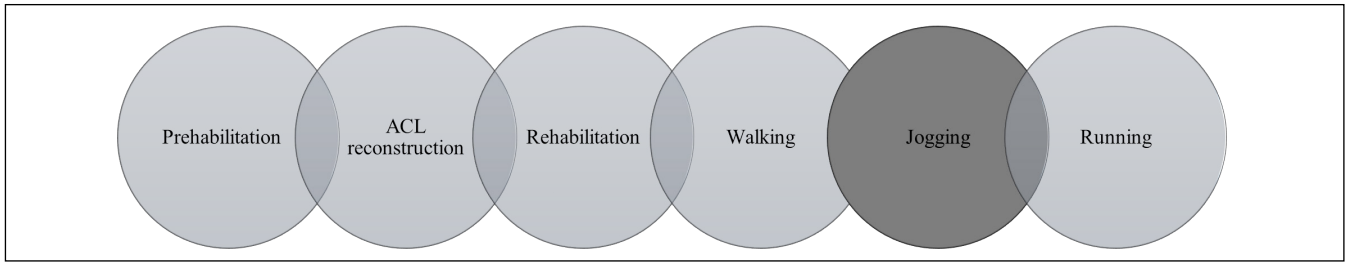


Figure 2. The methodological from pre-rehabilitation to return to running after ACL reconstructive surgery.

external rotation) planes as observed in changes of direction and cutting maneuvers (14, 16).

In discussion in responding to the questions identified in our scoping review, we can state:

A) What are the clinical criteria and timing for prescribing a return to running after anterior cruciate ligament reconstruction in soccer players?

It is emphasized, in a review, by Rambaud *et al.* (22) as 198

out of 201 reports, a time criterion for return to jogging, with a median of 12 weeks, although three arbitrary time frames were reported in 65% of the included studies: 8 weeks (11% of included studies), 12 weeks (42% of included studies) and 16 weeks (12% of included studies).

The authors report in their scoping review how, in addition to time, the most frequently reported criteria for return to running are: a) full range of motion of the knee or > 95% of the uninjured knee; b) absence of pain or pain < 2 on the visual analog scale; c) limb extensor isometric symmetry index; d) limb isometric symmetry (LSI) > 80%; e) plus LSI of the extensors and flexors LSI > 70%; f) jump test LSI>70% (22).

The "non-negotiable" (22) clinical key points for return to running should be:

a) pain < 2 on the visual analog scale (VAS); b) 95% ROM of knee flexion; c) ROM in full extension (0° of knee extension); d) absence of joint effusion.

Therefore, it is fair to point out that a symptomatic knee after walking training (which may be characterized by increased pain, joint effusion, and Range of Motion (ROM) restrictions) suggests delaying a return to jogging, regardless of how much time has passed since reconstructive surgery.

For Pairot de Fontenay *et al.* (25), the return to jogging after ACLR is a key step in the return to sport. However, how and when to start a jogging program is uncertain. Clinicians should use the International Knee Documentation Committee score (IKDC) > 64 as a criterion for switching from walking to jogging.

According to Kotsifaki *et al.* (26), there are no conclusive results on whether returning to jogging is safe around 12 weeks. Prospective studies investigating whether a return to jogging at 3 months is associated with new knee injury or exacerbation of the current clinical status are lacking (26).

The higher the IKDC, the greater is the success of returning to jogging after ACL reconstructive surgery. An IKDC score > 64/100 increases the chance of completing the return-to-jogging program without exacerbating symptoms by 3.11 times (25). A high IKDC score is associated with better jumping performance (27) and an uncomplicated return to sport (28).

To facilitate individualized clinical decision-making regarding return to jogging, it is proposed (16, 22) to use a battery of tests, including: 1) strength tests; 2) qualitative evaluations based on functional performance, with emphasis on dynamic knee control and single and double-legal jumping tests.

For Filbay *et al.* (29), evidence of anterior cruciate ligament healing on MRI at 3-month follow-up, is associated with improved knee function and quality of life and a higher rate of return to sport.

In the Dauty *et al.*'s study (30), a criterion including limb symmetry index (LSI) was established, and 103 patients (47.6%) were able to run between the fourth and sixth month after surgery. These patients had significantly fewer knee complications, better Lysholm scores, better quadriceps and tendon LSI, and better quadriceps strength related to body weight on the operated limb. The best model was established by including the LSI of the quadriceps and tendon at 60°/s and the Lysholm score. The cut-off for quadriceps LSI was 60%, hamstring LSI 90%, and Lyshom scored 97 points.

Buckthorpe *et al.* (19) point out that the return to jogging is typically recommended based on time rather than function, with recommendations around 3 months after surgery. It is worth highlighting how the main mistake, in our opinion, is often to correlate the return to jogging with the time of surgery and not specifically with the clinical, functional gesture goals that the athlete should achieve before switching from walking to jogging (3, 8).

Moon *et al.* (31) report how, during running at high speed (5-8 m/s), anterior cruciate ligament load in the sagittal plane increases injury risk.

According to Cavanaugh *et al.* (32), a running program is started after 3 months post-op if ROM is within normal limits and sufficient strength is demonstrated via a pain-free 82" step down without deviation. The running program is carried out with an emphasis on speed over shorter distances instead of running over slower distances (32).

However, decision-making on timing and clinical criteria for return to running must be analyzed for each athlete in relation to his or her clinical and rehabilitation history.

B) Are there any postural/functional criteria related to return to jogging after ACL reconstructive surgery?

Returning to sport after ACL reconstructive surgery involves a gradual transition from rehabilitation to jogging. Often, this phase is left to subjective and/or clinical interpretation without analyzing the postural-dysfunctional patterns and quality of expression of gestural movements that could be the risk factors for re-injury or complications (14, 16).

Buckthorpe *et al.* (19) propose a four-key point framework for planning progressions in the On-field Rehabilitation of the return to jogging:

A) Quality of movement; B) Physical conditioning; C) Sport-specific skills; D) Training load.

Restoring jogging/running-related gesture patterns should be addressed first, before increasing metabolic and mechanical demands, and then integrating neurocognitive and perceptual challenges to improve specificity (33).

Gestural dysfunctionality related to pathological technical and tactical movements

The return to jogging/running involves a progression from unidirectional linearity to more specific running training patterns, such as changes of direction that should be correlated successively with technical/tactical drills with and without ball possession (13, 14). To establish the proper progression and gradualness, in addition to knowing the clinical and functional status, it is important to know what might be the "pathological movements" (tackle by direct contact or indirect contact on the joint, jumps with relapses into monopodalic stance, collective pressing or individual pressure, lateral run-cut, changes of direction with and without the ball…) that might, proposed with improper timing, elevate the risks of re-injury or complications (14).

Overstress on the ACL occurs during football-specific running as a result of a complex interaction among the sagittal plane, anterior shear forces, and knee moments in the frontal and transverse plane (13, 15).

The knee is exposed, during run-to-cut maneuvers to increased lateral and rotational loading; this is due to increased varus/valgus and internal/external rotation moments (16) that have been associated with increased risk of primary and secondary ACL injuries and may contribute to anterior knee pain (34).

In addition, changes in anterior shear forces and internal rotation of the knee joint during running side-step cut tasks create more anterior cruciate ligament stress than an external rotation of the knee (31).

Moon *et al.* (31) reports how increasing speed during the running side-step cutting task, increases the load on the anterior cruciate ligament ($p < 0.017$), resulting in increased adduction ($p < 0.017$) and internal rotation moment of the knee joint.

Deficits in neuromuscular control on both the frontal and sagittal (valgus knee) during lateral Run Step and deficits in pelvic girdle postural stability (pelvic-drop) (16)may predict a second injury of the anterior cruciate ligament (16, 35).

Thus, an increasing knee valgus and external rotation during Shuttle Run Side to Side and Run-Cut have been identified as contributors to the increased posterior and lateral components of the load on the patellofemoral joint. Yang *et al.* (36) showed that amateur runners with patellofemoral pain (Runner's Knee) had an increased knee valgus angle and moment during walking training and increased knee external rotation angle during subsequent running compared with the control group.

Quality of movement in jogging/running and specific skills

Recovery of walking/running movement quality is a key aspect of high-quality ACL on-field rehabilitation (33) and follows 4 steps as shown in **figure 3**.

Studies (13, 14, 16, 19, 33) emphasize how movement quality is positively correlated with all game skills, forming a coherent and harmonious flow on a continuum encompassing athletic, technical, and tactical movements. Altered movement patterns and/or asymmetry during walking and jogging can contribute to abnormal and repetitive loading on joints, making them vulnerable to acute and chronic injury during the return-to-sport process. For example, increased medial hip rotation and adduction are associated with valgus knee, which has been linked to the risk of anterior cruciate ligament re-injury.

It is argued that, in athletes, the quality of dynamic movement (such as jumping and cutting maneuvers) after injury is significantly impaired, leading to increased risk factors for further injury and re-injury during rehabilitation and return to sport (19). To date, there is no standard consensus on procedures for assessing the quality of post-injury movement sports-related, with the analysis and study of the diverse running patterns. The lack of homogeneity, however, results in different assessment protocols that modify, with different results, the clinical/rehabilitation pathway that must be based on objective criteria and scientific evidence (3).

Buckthorpe *et al.* (19) identified an altered quality of motion in both the pathological and healthy limbs after anterior cruciate ligament reconstruction during various functional tasks. An anterior cruciate ligament injury appears to result in bilateral motion impairment when compared with the

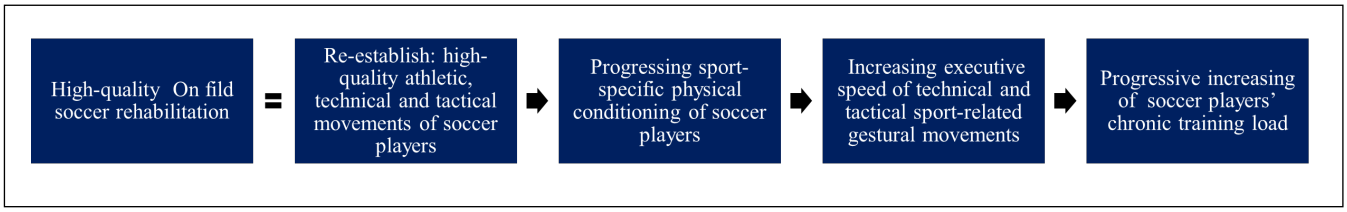


Figure 3. The 4 items of high-quality rehabilitation on the play field.

quality of motion prior to injury. Consequently, restoration of normal movement patterns of walking first and Jogging/running later is a top priority during on-field Rehabilitation. A study by Linek *et al*. (37) showed that poor quality of motion control in the pelvic region affects the kinetic chain of the lower limb, contributing during jogging/running to abnormal loads on the hip joints, knee, and ankle.

The risk of re-injury increases upon resumption of jogging/running and soccer skills in the presence of a) low-quality gesture patterns, b) a low level of flexibility, and c) previous injuries. Preventive strategies should include training in high-quality movement patterns, the right level of flexibility, and complete healing of injuries before resuming activities (38).

Koźlenia *et al*. (38) states how low acuity movement patterns (Functional Movement Screen – FMS score < 14) increased the level of injury risk by 7 times. A level of flexibility reduced by 1 cm increased the risk of injury by 6 percent. Previous injuries also increased the risk of recurrence by 6.4 times. Prediction of injury occurrence based on quality of movement patterns allows 73% accuracy, while flexibility allows 41% accuracy. Simultaneous use of these two factors did not improve the accuracy of injury prediction.

Athletes engage in stretching programs to reduce muscle soreness and injury risk, increase mobility, walking/running, and improve athletic performance (38).

Therefore, it seems counterproductive for aggressive stretching to be used for proper recovery and regeneration for a range of motion improvement or as a pre-jogging warm-up that is crucial for the athlete's rehabilitation (3, 44).

Posture and frameworks of dysfunctionality

In the transition from walking to jogging, one must remember how outcomes of dysfunctional/postural-osteopathic and functional frameworks may be associated with the resumption of running with an increased risk of musculoskeletal injury. Postural dysfunctions may contribute to movement asymmetry, increasing the risk of injury during the resumption of walking and jogging (40, 44).

Lumbo-pelvic-hip complex asymmetries

Dysfunctional patterns (unilateral weakness of the hip adductors, particularly the gluteal muscles) in the low back-pelvis-hip complex during walking/jogging, pelvic drop, dynamic Trendelerburg sign, and lower extremity misalignment during walking are associated with dynamic knee valgus (16).

A dysfunctional picture in the frontal and sagittal plane of the pelvic girdle on resumption of jogging predisposes footballers to microtraumatic overload injuries (one example is the groin pain, which is a prevalent injury in athletes who kick, pivot, and cut) (41). Therefore, prior to the resumption of walking/jogging/running, a postural/functional approach is necessary to identify any dysfunctional asymmetries in the pelvic girdle (16).

Thus, it has been shown (16) that Lumbo -Pelvic-Hip Complex and lower extremity asymmetries are related to the second anterior cruciate ligament injuries. Evaluation of the pelvic girdle through functional/postural assessment tests allows the identification of structural asymmetries and pelvic imbalances in the frontal plane that are extremely disabling upon resumption of running. Abnormal kinematics such as Lumbo-Pelvic-Hip Complex asymmetries and lower limb malalignment associated with injury are potentially identifiable using the SLST. Pelvic drop is associated with excessive knee valgus (16). Additionally, Patellofemoral Pain Syndrome (PFPS) is linked with excessive hip adduction, tibial external rotation, knee valgus, ankle pronation, pelvic obliquity, and ipsilateral trunk lean (16). Dynamic functional tests (*e.g.*, crossover hop for distance, triple hop for distance, single-leg squat) are reported in the literature as an assessment tool to validate return-to-sport decision-making (3, 4, 6).

Optimal neuromuscular, Lumbo-Pelvic-Hip Complex and lower extremity control are associated with decreased risk factors for secondary anterior cruciate ligament injury (16).

Ratio H/Q and jogging

Quadriceps and hamstring strength asymmetries and knee function, but not surgical techniques, are likely associated with knee kinematics and kinetics during jogging/running after ACL reconstructive surgery (42-44). Also, Pairot-de-Fontenay (42) reports how the compressive forces of the patellofemoral and tibiofemoral joints differed from those of the contralateral or control limbs until at least 2.5 years after ACLR.

These asymmetries significantly alter gait patterns, with reduced knee angles and knee extension moments in stance during walking and even more so during running (31, 41).

It is reported (43) how after anterior cruciate ligament reconstruction, quadriceps/hamstring asymmetries correlate with altered movement patterns during jogging/running (19, 20, 45, 46). Athletes who return to soccer-specific running with a strength imbalance associated with neuromuscular control deficits may be susceptible to increased risk of ACL re-injury or post-traumatic osteoarthritis (2).

Iwame (45) points out how the Quadriceps Strength to Body Weight ratio (QS/BW) is a significant indicator to

start jogging safely 3 months after ACL reconstruction.
Śliwowski *et al.* (48) in his study shows that isokinetic assessment can play an important role in identifying imbalances/asymmetries and developing preventive strategies to reduce the risk of muscle injury (44).
Thus, early jogging/running resumption with altered values of H/Q force ratio (< 0.6 per 60° s^{-1}) may increase the risk factors (48) of even re-injury (8) loading the ACL (ipsilateral or contralateral side) (44).
It is evidenced that asymmetries/imbalances in the functional H/Q ratio have a significant impact on increasing injury risk factors (48). Hence, it is inadvisable to prescribe jogging and running if side-to-side imbalances of the lower extremity persist (3, 22).
It is reported (3, 48) how muscle imbalances in the H/Q ratio can increase injuries of the ischium crurali during the jogging/running process. The force relationship between agonist/antagonist for knee extension and flexion can, however, be better described by the more functional ratios during:

- Knee extension phase: the eccentric force of the hamstrings and concentric force of the quadriceps (H.ecc/Q.con)
- Knee flexion phase: concentric force of the flexors and eccentric force of the quadriceps (H.con/Q ecc.)

Two studies (31, 49) have investigated that the early, high, and repetitive loading of the joint during jogging/running could be a risk factor, over time, for the development of osteoarthritis, which is the advanced stage of the clinical manifestation of cartilage damage.
Incorrect timing in the process of returning to running may be a risk factor in the development of post-traumatic knee osteoarthritis in soccer players. Knee extensor muscle weakness is a risk factor for the development of knee osteoarthritis (2).
For Rambaud *et al*. (22), quadriceps and hamstring strength are among the most frequently reported Return to Running (RTR) criteria at 16%. Since the hamstring and quadriceps play an important role in active knee stabilization and motor control strategy, it seems reasonable to include strength criteria as a priority in decision-making for returning to jogging/running. The most frequent recommendations for strength assessment for return to jogging were: 1) isometric assessment: a lower extremity LSI > 70% and a quadriceps LSI > 80%; 2) for isokinetic assessment: quadriceps and hamstrings LSI > 70%. A quadriceps limb symmetry index (Q-LSI) > 80% is the most cited isokinetic cut-off parameter in the literature (22).
To summarize the recommendations for the return to jogging and running, it is advisable (46) to adopt a three-phase retraining approach, aligning with the functional recovery process following Anterior Cruciate Ligament Reconstruction. This approach should encompass: 1) addressing neuromuscular, biomechanical, and sensorimotor control factors that influence movement quality and motor learning, 2) implementing a progressive movement retraining strategy to acquire proficiency in a range of functional tasks, optimizing coordination and motor learning, and 3) concluding the rehabilitation and movement training in realistic field environments that gradually simulate the demands of sports movements and environmental constraints.

Questions A and B: further considerations

Clinicians and therapeutics might prescribe the return to jogging around week 12 postoperatively. However, this approach does not consider the level and severity of the injury and the many variables that can be linked to the rehabilitation process.
Considering other evaluations, we must highlight how the jump tests pose important reflections. Gokeler[50] points out how: 1) only 14% of all patients achieved 100% LSI for strength testing at 2 years after ACLR, questioning the feasibility in daily practice; 2) LSI assumes that the uninjured leg can be used as a reference for strength.
However, a large percentage of patients show significant changes in flexion and extension strength of the contralateral limb between 6 and 9 months postoperatively, resulting from an initial strength deficit in the contralateral limb (51). This may limit the usefulness of the contralateral limb as a control for comparison with the pathologic limb during return-to-sport evaluation.
This implies that LSI may underestimate strength deficits and supports the need to implement an assessment of absolute strength and not just limb symmetry. Current evidence revealed persistent quadriceps and hamstring strength deficits both in the short (< 6 months) and long term (> 2 years) after ACL injury (50).
Relative to postural/dysfunctional frameworks, we should remember how the quality of simple and complex movement in the soccer player is as important, if not more important, than quantifiable measures (3, 13, 52).
Moreover, we must not forget that Semitendinosus and Gracilis tendons, used for reconstructive surgery, can cause a deficit of tibial internal rotation (53, 54). Reconstructions with patellar tendons are prone to induce greater deficits in the strength of the quadriceps compared to other types of grafts with a clear predisposing factor to overuse pathologies.
Finally, it is important to underline how a reduction in hip internal rotation results in increased tensional stress on the

ACL and may, therefore, increase risk factors for capsular ligamentous re-injury of the knee in sports that require specific cutting and pivoting gestures (53-56).

Limitations of the study and future indications

The variations in how the studies defined the return to jogging/running after reconstructive cruciate ligament surgery highlight the heterogeneous clinical and functional criteria underpinning their conclusions. Similar heterogeneity in clarity was observed in the description of clinical rehabilitation activity and the return to running and sports (3).
Among other considerations, the literature fails to establish a critical aspect: the classification of capsular ligamentous injuries of the knee, whether simple or complex. This limitation is not only a constraint but also an essential prerequisite for knowledge. The severity of the injury delineates different levels of surgery, rehabilitation, functional recovery, the timing of fieldwork, and the return to full competitive activity. Future directions must unequivocally emphasize the need for individualization and personalization throughout the entire process, from surgery to the return to sports, with the aim of reducing the risk factors for second injuries and complications that could potentially prolong or restrict a football player's career.

CONCLUSIONS

After ACL reconstruction, an important milestone is the return to running, whether jogging or running. The return to jogging marks the beginning of the transition from the disability-focused tasks in early rehabilitation (*e.g.*, knee range-of-motion (ROM) exercises, isometric quadriceps strengthening) to the functional, sport-specific tasks that characterize more advanced rehabilitation (sprinting, pivoting, cutting changes of direction).
There is currently a lack of consensus on clinical and rehabilitation criteria on when the patient can return to sports after ACLR. Steady progress through high-quality rehabilitation influences functional outcomes, and premature return to sport increases the risk of re-injury. Return to running remains a complex methodological process based on restoring quality of movement, performance on restoring sport-specific skills, and progressive development of chronic training load.

FUNDINGS

None.

DATA AVAILABILITY

N/A.

CONTRIBUTIONS

RD: methodology, investigation, formulation of study, idea, conceptualization, data collection, formal analysis, writing – original draft, writing – review & editing, literature revision.
MM, DP, VM: methodology, investigation, formal analysis, writing – original draft, literature revision .

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Lucarno S, Zago M, Buckthorpe M, et al. Systematic Video Analysis of Anterior Cruciate Ligament Injuries in Professional Female Soccer Players. Am J Sports Med. 2021;49(7):1794-802. doi: 10.1177/03635465211008169.
2. Russell ER, Spencer SJ, Atherton CM, et al. Increased risk of lower limb osteoarthritis among former professional soccer (football) players. Occup Med (Lond). 2023;73(9):547-53. doi: 10.1093/occmed/kqad132.
3. Alashram AR, D'Onofrio R, Sannicandro I, et al. Return to training in soccer players after anterior cruciate ligament reconstruction: reflections and considerations. J Sports Med Phys Fitness. 2024;64(6):578-87. doi: 10.23736/S0022-4707.23.15448-X.
4. Meredith SJ, Rauer T, Chmielewski TL, et al. Return to sport after anterior cruciate ligament injury: panther symposium ACL injury return to sport consensus group. Orthop J Sports Med. 2020;28(8):2403-14 doi: 10.1007/s00167-020-06009-1.
5. Brinlee AW, Dickenson SB, Hunter-Giordano A, Snyder-Mackler L. ACL Reconstruction Rehabilitation: Clinical Data, Biologic Healing, and Criterion-Based Milestones to Inform a Return-to-Sport Guideline. Sports Health. 2022;14(5):770-9. doi: 10.1177/19417381211056873.
6. Filbay SR, Grindem H. Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture. Best Pract Res Clin Rheumatol. 2019;33(1):33-47. doi: 10.1016/j.berh.2019.01.018.
7. Kaplan Y, Witvrouw E. When Is It Safe to Return to Sport After ACL Reconstruction? Reviewing the Criteria. Sports

Health. 2019;11(4):301-5. doi: 10.1177/1941738119846502.
8. Beischer S, Gustavsson L, Senorski EH, et al. Young Athletes Who Return to Sport Before 9 Months After Anterior Cruciate Ligament Reconstruction Have a Rate of New Injury 7 Times That of Those Who Delay Return. J Orthop Sports Phys Ther. 2020;50(2):83-90. doi: 10.2519/jospt.2020.9071.
9. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. Sports Med. 2005;35(6):501-36. doi: 10.2165/00007256-200535060-00004.
10. Manzi V, Annino G, Savoia C, et al. Relationship between aerobic fitness and metabolic power metrics in elite male soccer players. Biol Sport. 2022;39(3):599-606. doi: 10.5114/biolsport.2022.106389.
11. Nygaard Falch H, Guldteig Rædergård H, van den Tillaar R. Effect of Different Physical Training Forms on Change of Direction Ability: a Systematic Review and Meta-analysis. Sports Med Open. 2019;5(1):53. doi: 10.1186/s40798-019-0223-y.
12. Gokeler A, Grassi A, Hoogeslag R, et al. Return to sports after ACL injury 5 years from now: 10 things we must do. J Exp Orthop. 2022: 30;9(1):73. doi: 10.1186/s40634-022-00514-7.
13. Waldén M, Krosshaug T, Bjørneboe J, Andersen TE, Faul O, Hägglund M. Three distinct mechanisms predominate in non-contact anterior cruciate ligament injuries in male professional football players: a systematic video analysis of 39 cases. Br J Sports Med. 2015;49(22):1452-60. doi: 10.1136/bjsports-2014-094573.
14. Grassi A, Smiley SP, Roberti di Sarsina T, et al. Mechanisms and situations of anterior cruciate ligament injuries in professional male soccer players: a YouTube-based video analysis. Eur J Orthop Surg Traumatol. 2017;27(7):967-81. doi: 10.1007/s00590-017-1905-0.
15. D'Onofrio R, Alashram ARA, Annino G, Sannicandro I, Manzi V. The Interval Kicking Program (IKP) as a Reprogramming Technique for the Soccer Player in an Anterior Cruciate Ligament (ACL) Rehabilitation: A Technical Report . Muscles Ligaments Tendons J. 2023;13(4):541-9. doi: 10.32098/mltj.04.2023.04.
16. D'Onofrio R, Alashram AR, Annino G, et al. Prevention of Secondary Injury after Anterior Cruciate Ligament Reconstruction: Relationship between Pelvic-Drop and Dynamic Knee Valgus. Int J Environ Res Public Health. 2023;20(4):3063. doi: 10.3390/ijerph20043063
17. Shao E, Mei Q, Ye T,Kovács B, Baker J.S, Liu W, Gu Y. The Effects of 5 km Interval Running on the Anterior Cruciate Ligament Strain and Biomechanical Characteristic of the Knee Joint: Simulation and Principal Component Analysis. Appl Sci. 2023;13(11):6760. doi: 10.3390/app13116760.
18. Dos'Santos T, Thomas C, McBurnie A, Donelon T, Herrington L, Jones PA. The Cutting Movement Assessment Score (CMAS) Qualitative Screening Tool: Application to Mitigate Anterior Cruciate Ligament Injury Risk during Cutting. Biomechanics. 2021;1(1):83-101. doi: 10.3390/biomechanics1010007.
19. Buckthorpe M, Della Villa F, Della Villa S, Roi GS. On-field Rehabilitation Part 2: A 5-Stage Program for the Soccer Player Focused on Linear Movements, Multidirectional Movements, Soccer-Specific Skills, Soccer-Specific Movements, and Modified Practice. J Orthop Sports Phys Ther. 2019;49(8):570-5. doi: 10.2519/jospt.2019.8952.
20. Impellizzeri FM, Bizzini M. Systematic review and meta-analysis: a primer. Int J Sports Phys Ther. 2012;7(5):493-503.
21. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005;8(1):19-32. doi: 10.1080/1364557032000119616.
22. Rambaud AJM, Ardern CL, Thoreux P, Regnaux JP, Edouard P. Criteria for return to running after anterior cruciate ligament reconstruction: a scoping review. Br J Sports Med. 2018;52(22):1437-44. doi: 10.1136/bjsports-2017-098602.
23. Lorenz D, Domzalski S. Criteria based return to sprinting Progression following Lower extremity Injury. Int J Sports Phys Ther. 2020;15(2):326-32.
24. Grondin J, Crenn V, Gernigon M, et al. Relevant Strength Parameters to Allow Return to Running after Primary Anterior Cruciate Ligament Reconstruction with Hamstring Tendon Autograft. Int J Environ Res Public Health. 2022;19(14):8245. doi: 10.3390/ijerph19148245.
25. Pairot de Fontenay B, Van Cant J, Gokeler A, Roy JS. Reintroduction of Running After Anterior Cruciate Ligament Reconstruction With a Hamstrings Graft: Can We Predict Short-Term Success? J Athl Train. 2022;57(6):540-6. doi: 10.4085/1062-6050-0407.21.
26. Kotsifaki R, Korakakis V, King E, et al. Aspetar clinical practice guideline on rehabilitation after anterior cruciate ligament reconstruction. Br J Sports Med. 2023;57(9):500-14. doi: 10.1136/bjsports-2022-106158.
27. Lee DW, Yang SJ, Cho SI, Lee JH, Kim JG. Single-leg vertical jump test as a functional test after anterior cruciate ligament reconstruction. Knee. 2018;25(6):1016-26. doi: 10.1016/j.knee.2018.07.014.
28. Edwards PK, Ebert JR, Joss B, et al. Patient characteristics and predictors of return to sport at 12 months after anterior cruciate ligament reconstruction: the importance of patient age and postoperative rehabilitation. Orthop J Sports Med. 2018;6(9):2325967118797575. doi:10.1177/2325967118797575.
29. Filbay SR Dowsett M, Chaker Jomaa M, et al. Healing of acute anterior cruciate ligament rupture on MRI and outcomes following non-surgical management with the Cross Bracing Protocol. Br J Sports Med. 2023;57(23):1490-7. doi: 10.1136/bjsports-2023-106931.
30. Dauty M, Menu P, Daley P, et al. Knee Strength Assessment and Clinical Evaluation Could Predict Return to Running after Anterior Cruciate Ligament Reconstruction Using Patellar Tendon Procedure. Int J Environ Res Public Health. 2022;19(20):13396. doi: 10.3390/ijerph192013396.
31. Moon J, Koo D, Kim S, Panday SB. Effect of sprinting velocity on anterior cruciate ligament and knee load during sidestep cutting. Front Bioeng Biotechnol. 2023;11:1033590. doi: 10.3389/fbioe.2023.1033590.
32. Cavanaugh JT, Powers M. ACL Rehabilitation Progression: Where Are We Now? Curr Rev Musculoskelet Med. 2017;10(3):289-96. doi: 10.1007/s12178-017-9426-3.
33. Buckthorpe M, Della Villa F, Della Villa S, Roi GS. On-field Rehabilitation Part 1, 4 Pillars of high-quality on-field rehabilitation are restoring movement quality, physical conditioning, restoring sport-specific skills, and progressively developing chronic training load. J Orthopaedic Sports Phys Ther. 2019;49:565-9. doi: 10.2519/jospt.2019.8954.

34. Arundale AJH, Silvers-Granelli HJ, Marmon A, Zarzycki R, Dix C, Snyder-Mackler L. Changes in biomechanical knee injury risk factors across two collegiate soccer seasons using the 11+ prevention program. Scand J Med Sci Sports. 2018;28(12):2592-603. doi: 10.1111/sms.13278.
35. Vargas M, Chaney GK, Mejía Jaramillo MC, Cummings P, McPherson A, Bates NA. Video Analysis of 26 Cases of Second ACL Injury Events in Collegiate and Professional Athletes. IJSPT. 2023;18(1):122-31. doi:10.26603/001c.67775.
36. Yang C, Best TM, Liu H, Yu B. Knee biomechanical factors associated with patellofemoral pain in recreational runners. Knee. 2022;35:87-97. doi: 10.1016/j.knee.2022.02.007.
37. Linek P, Muckelt PE, Sikora D, Booysen N, Stokes M. Assessing Movement Quality in Youth Footballers: The Relationship between Hip and Lower Limb Movement Screen and Functional Movement Screen. Appl Sci. 2021:11:9298. doi.10.3390/app11199298.
38. Koźlenia D, Domaradzki J. Prediction and injury risk based on movement patterns and flexibility in a 6-month prospective study among physically active adults. PeerJ. 2021;9:e11399. doi: 10.7717/peerj.11399.
39. Zakas A, Grammatikopoulou MG, Zakas N, Zahariadis P, Vamvakoudis E. The effect of active warm-up and stretching on the flexibility of adolescent soccer players. J Sports Med Phys Fitness. 2006;46(1):57-61.
40. Cunha J, Solomon DJ. ACL Prehabilitation Improves Postoperative Strength and Motion and Return to Sport in Athletes. Arthrosc Sports Med Rehabil. 2022;4(1):e65-9. doi: 10.1016/j.asmr.2021.11.001.
41. Moran MW, Rogowski KR. Hip and pelvic stability and gait retraining in the management of athletic pubalgia and hip labral pathology in a female runner: a case report. Int J Sports Phys Ther. 2020;15(6):1174-83. doi: 10.26603/ijspt20201174.
42. Pairot-de-Fontenay B, Willy RW, Elias ARC, Mizner RL, Dubé MO, Roy JS. Running Biomechanics in Individuals with Anterior Cruciate Ligament Reconstruction: A Systematic Review. Sports Med. 2019;49(9):1411-24. doi: 10.1007/s40279-019-01120-x.
43. Arhos EK, Capin JJ, Buchanan TS, Snyder-Mackler L. Quadriceps Strength Symmetry Does Not Modify Gait Mechanics After Anterior Cruciate Ligament Reconstruction, Rehabilitation, and Return-to-Sport Training. Am J Sports Med. 2021;49(2):417-25. doi: 10.1177/0363546520980079.
44. Shi H, Huang H, Ren S, et al. The relationship between quadriceps strength asymmetry and knee biomechanics asymmetry during walking in individuals with anterior cruciate ligament reconstruction. Gait Posture. 2019;73:74-9. doi: 10.1016/j.gaitpost.2019.07.151.
45. Iwame T, Matsuura T, Okahisa T, et al. Quadriceps Strength to Body Weight Ratio Is a Significant Indicator for Initiating Jogging after Anterior Cruciate Ligament Reconstruction. Knee. 2021;28:240-6. doi: 10.1016/j.knee.2020.12.010.
46. Buckthorpe M. Recommendations for Movement Re-training After ACL Reconstruction. Sports Med. 2021;51(8):1601-18. doi: 10.1007/s40279-021-01454-5.
47. Brown C, Marinko L, LaValley MP, Kumar D. Quadriceps Strength After Anterior Cruciate Ligament Reconstruction Compared With Uninjured Matched Controls: A Systematic Review and Meta-analysis. Orthop J Sports Med. 2021;9(4):2325967121991534. doi:10.1177/2325967121991534.
48. Śliwowski R, Paillard T, Bojkowski Ł, Dudziński W, Patek M, Marynowicz J. Intra- and inter-limb strength imbalance and asymmetry in soccer: A comparison of elite senior and junior players. PLoS One. 2024;19(4):e0302474. doi: 10.1371/journal.pone.0302474.
49. Dong X, Li C, Liu J, et al. The effect of running on knee joint cartilage: A systematic review and meta-analysis. Phys Ther Sport. 2021;47:147-55. doi: 10.1016/j.ptsp.2020.11.030.
50. Gokeler A, Dingenen B, Hewett TE. Rehabilitation and Return to Sport Testing After Anterior Cruciate Ligament Reconstruction: Where Are We in 2022? Arthrosc Sports Med Rehabil. 2022;4(1):e77-e82. doi: 10.1016/j.asmr.2021.10.025.
51. Moran TE, Ignozzi AJ, Burnett Z, Bodkin S, Hart JM, Werner BC. Deficits in Contralateral Limb Strength Can Overestimate Limb Symmetry Index After Anterior Cruciate Ligament Reconstruction. Arthrosc Sports Med Rehabil. 20224(5):e1713-9. doi: 10.1016/j.asmr.2022.06.018.
52. Kaplan Y, Witvrouw E. When Is It Safe to Return to Sport After ACL Reconstruction? Reviewing the Criteria. Sports Health. 2019;11(4):301-5. doi: 10.1177/1941738119846502.
53. Hogg JA, Waxman JP, Shultz SJ. Examining the effects of femoral anteversion and passive hip rotation on ACL injury and knee biomechanics: a systematic review and meta-analysis. J Exp Orthop. 2022;9(1):40. doi: 10.1186/s40634-022-00479-7.
54. VandenBerg C, Crawford EA, Sibilsky Enselman E, et al. Restricted Hip Rotation Is Correlated With an Increased Risk for Anterior Cruciate Ligament Injury. Arthroscopy. 2017;33(2):317-25. doi: 10.1016/j.arthro.2016.08.014.
55. Daoukas S, Malliaropoulos S, Maffulli N. ACL biomechanical risk factors on single-leg drop-jump: a cohort study. Muscles Ligaments Tendons J. 2019;9(1):70-5. doi: 10.32098/mltj.01.2019.16.