MARIO BIZZINI, PT, PhD[1] • DAVE HANCOCK, MSc, MCSP, BHSc, HPC[2] • FRANCO IMPELLIZZERI, PhD[3]

Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: Soccer

Football (soccer) is the most popular sport worldwide, with an estimated 300 million active players (as documented by the Fédération Internationale de Football Association). Anterior cruciate ligament (ACL) injury is one of the most serious injuries in soccer and a potentially career-ending one.[54] The incidence of ACL injuries in soccer players accounts for thousands of ACL tears per year.[1] Despite the high number of injuries[1,3,14] and related literature, there is still no consensus on the optimal surgical technique for ACL reconstruction[5] and even less agreement on the ideal rehabilitation protocol following surgery.[30,51] Recently, van Grinsven et al[51] proposed an optimal evidence-based rehabilitation program. Their systematic review indicated that interventions for the early rehabilitation phases, which included pain/swelling control, neuromuscular training, and early weight-bearing, range-of-motion, and strengthening exercises, are supported by evidence. Criteria for return to sports include "hop tests and strength of the hamstrings and quadriceps at least of 85% compared to the contralateral side" and "when the patient tolerates sport-specific activities."[51] This description, albeit offering a minimal standard for the knee, is clearly not detailed enough when dealing with athletes (ie, soccer players) aiming for a return to competitive sports after ACL reconstruction.

SUPPLEMENTAL VIDEO ONLINE

Some authors have described guidelines for return to play after ACL surgery[10,28,34]; however, few publications have specifically discussed the return to competitive soccer.[43,44] In a recent review, Kvist[28] located 39 articles that presented outcomes after ACL reconstruction and criteria for returning to sports. In most cases, the decision of when to allow the patient/athlete to return to sport was empirical and time based, ranging from 3 to 12 months postsurgery. Functional training and testing have also been advocated, ranging from plyometrics and running programs to isokinetic training/testing and jump/hop training/testing.[10,20,37] However, descriptions of the late phases of the rehabilitation process often remain generic. Myer et al[34] also introduced a detailed criteria-based rehabilitation protocol for the return to sport after ACL reconstruction; however, the "reintegration to interval sport participation" was not specifically described. Therefore, it is perhaps understandable

SYNOPSIS: Successful return to play remains a challenge for a soccer player after anterior cruciate ligament reconstruction. In addition to a successful surgical intervention, a soccer-specific functional rehabilitation program is essential to achieve this goal. Soccer-like elements should be incorporated in the early stages of rehabilitation to provide neuromuscular training specific to the needs of the player. Gym-based and, later, field-based drills are gradually intensified and progressed until the player demonstrates the ability to return to team practice. In addition to the recovery of basic attributes such as mobility, flexibility, strength, and agility, the surgically repaired knee must also regain soccer-specific neuromuscular control and conditioning for an effective return to sports. The individual coaching of the player by the sports physiotherapist and compliance with the training program by the player are key factors in the rehabilitation process. To minimize reinjury risk and to maximize the player's career, concepts of soccer-specific injury prevention programs should be incorporated into the training routine during and after the rehabilitation of players post–ACL reconstruction.

LEVEL OF EVIDENCE: Therapy, level 5. *J Orthop Sports Phys Ther 2012;42(4):304-312. doi:10.2519/jospt.2012.4005*

KEY WORDS: *ACL, football/soccer, functional training, injury prevention*

[1]Research Associate, FIFA-Medical Assessment and Research Centre (F-MARC), Schulthess Clinic, Zürich, Switzerland. [2]Director of Training and Conditioning, New York Knicks (NBA), New York, NY; Physical Therapist of the England National Football Team (UK); Former Head Physical Therapist, Leeds United Football Club and Chelsea Football Club (Premier League, England), UK. [3]Scientific Director of CeRiSM, Research Center for Sports, Mountain and Health, University of Verona, Rovereto (TN), Italy. Address correspondence to Dr Mario Bizzini, F-MARC, Schulthess Clinic, Lengghalde 2, 8008 Zürich, Switzerland. E-mail: mario.bizzini@f-marc.com

TABLE 1 PHASES OF REHABILITATION

	Phase 1	Phase 2	Phase 3	Phase 4	
				Return to Reduced Soccer Practice	Return to Full Soccer Practice
Timing*	4-6 wk	4-6 to 8-12 wk	8-12 to 16-24 wk	16-24 to ? wk	
Criteria to enter this phase		• Minimal pain/swelling • Near full ROM • Good patella mobility • Sufficient quadriceps control • Normal gait pattern	• No pain/swelling • Full ROM • Good neuromuscular control at knee, hip, trunk • Quadriceps and hamstrings strength >75% of noninvolved limb • Good hop/jump and landing techniques	• No pain/swelling • Symmetrical ROM • Optimal soccer-specific neuromuscular control • Quadriceps and hamstrings strength >85% of noninvolved limb • Hop index >80% of noninvolved limb	• No pain/swelling • Symmetrical ROM • Optimal soccer-specific neuromuscular control • Quadriceps and hamstrings strength >95% of noninvolved limb • Hop index >90% of noninvolved limb • Satisfactory Yo-Yo and RSSA test results
Goals of this phase	• Control pain/swelling • Improve ROM • Quadriceps activation • ADL activities	• Prepare basic soccer-specific neuromuscular control • Prepare the player for the more intense phase 3	• Optimize soccer-specific neuromuscular control • Prepare the player for return to team practice	• Bring the player back to unrestricted team practice, with full possession of his soccer skills and conditioning	• Final preparation of the player for the needs and demands of competitive soccer
Functional training†					
Additional training	• Strengthen noninvolved limb • Trunk and hip basic core stability exercises • Cardiovascular (upper-body ergometer)	• Core stability • Strengthen involved limb (open/closed chain) • Cardiovascular training (basic, bike) • Flexibility	• Core stability/strength • Strength training (body-machine exercise) • Cardiovascular soccer-specific training (interval, bike) • Flexibility	• Core stability/strength • Strength training (body-machine exercise) focused on addressing remaining deficits • Flexibility	• Continue additional training, in the form of a soccer-specific warm-up (11+)
Pool activities	• Gait training • Simple exercises (ROM, balance)	• Progression toward water running (wet vest) • Flexibility/ROM • Simulated basic soccer drills (heading the ball)	• Water running: endurance training		

Abbreviations: ADL, activities of daily living; ROM, range of motion; RSSA, repeated-shuttle-sprint-ability test; Yo-Yo, Yo-Yo intermittent recovery test.
**The timing of each phase is dependent on additional surgical procedures and individual progress in rehabilitation/training.*
†Details provided in the text.

that Walden et al[53] found a significantly higher risk of new knee injury (either reinjury or contralateral injury) in elite soccer players who had a previous ACL injury/reconstruction.

The major challenge is to integrate sports-specific elements within the rehabilitation and training of the soccer athlete, considering that a soccer player has different neuromuscular and physiological demands than an ice hockey or basketball player.[49] One of the key elements to a soccer-specific rehabilitation program is an understanding of the physical demands of the sport and the level of play to which the player needs to return. Consideration of the frequency and intensity of training sessions and games is very important. Soccer is a physically demanding sport, with match analysis studies showing that soccer players repeatedly produce maximal or near maximal actions (eg, striding, turning, cutting, sprinting, jumping) of short duration with brief recovery periods.[33,48,49] These activities, which require coordination and power, place considerable demands on the neuromuscular system. A carefully planned rehabilitation program that addresses all aspects of the game is vital to return the player to maximum function, while minimizing risk of reinjury. The following is our

FIGURE 1. Male professional soccer player on swinging platform (simulation of kicking ball with nonoperated leg).

perspective on a return-to-play model to prepare soccer players to compete after ACL reconstruction.

PHASES OF THE PROGRAM

A KEY ASPECT FOR SUCCESSFUL REHABILITATION of a professional soccer player is a one-to-one (sports physiotherapist-to-athlete) approach. This allows daily monitoring of the knee status and progress, and also permits optimal adaptation of the intensity and content of the rehabilitation program. A close cooperation between the athlete, physiotherapist, surgeon, athletic trainer, and coach is another key factor.

The rehabilitation may arbitrarily be divided into 4 phases: (1) protection and controlled ambulation, (2) controlled training, (3) intensive training, and (4) return to play.[7,8] The time frame for each phase varies depending on the surgical procedure and individual response to treatment. The overall guiding principle is that the program should be soccer specific, criteria based, and intensive but not aggressive (**TABLE 1**).[7,17,21,43]

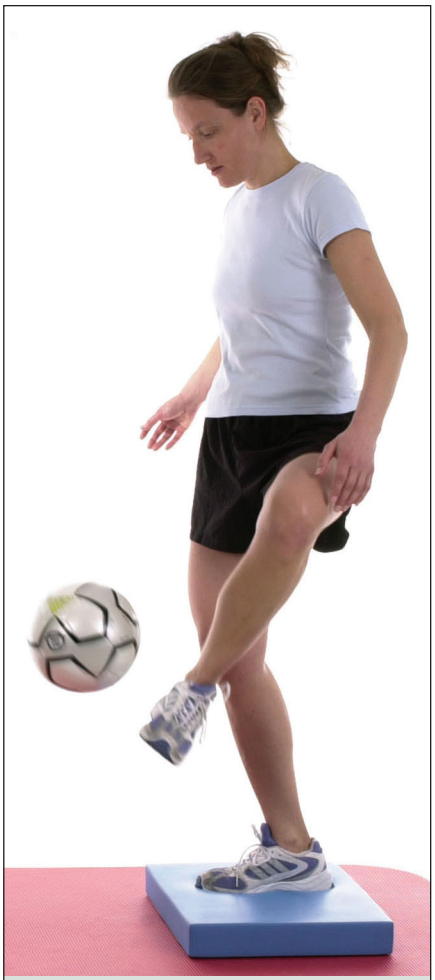

FIGURE 2. Female amateur soccer player on foam pad (passing back the soccer ball with nonoperated leg).

Myer et al[34] presented a criteria-driven progression through the return-to-sport phase of rehabilitation following ACL reconstruction. The authors proposed objective assessments of strength, stability, balance, limb symmetry, power, agility, technique, and endurance to guide the athlete back to sports. Recently, Impellizzeri and Marcora[23] critically discussed the validity of physiological and performance tests in sports. As the focus of this paper is on functional rehabilitation, we will not cover the assessments for all phases in detail but, rather, provide updated evidence-based and clinical-expertise guidelines.

FIGURE 3. Male professional soccer player sitting on a soccer ball (and juggling another ball).

Phase 1

This phase, focusing on recovery of motion and ambulation and control of swelling immediately postsurgery, will not be discussed. The criteria that the patient has to fulfill to enter phase 2 are described in **TABLE 1**.

Phase 2

This phase includes soccer-specific neuromuscular training. Initially, the focus is on knee (and lower extremity) stabilization in weight-bearing positions, starting with static, then dynamic, and eventually reactive exercises.[41] Particular attention is given to the varus/valgus and rotational control of the surgically repaired knee and lower extremity, emphasizing proper lower extremity alignment (avoiding collapse of the knee medially) and pelvis and trunk stabilization.[6,40] Training on unstable surfaces is particularly useful to enhance neuromuscular activation and control (**FIGURE 1**). Rotational stabilization can be trained on a simple rotatory unstable surface.[7]

According to motor-learning principles (blocked/random practice),[46] it is important to exercise in different environmental conditions (eg, in the gymnasium, indoor hall, and on the pitch) and with different footwear (eg, with no shoes, athletic shoes, and soccer shoes). The soccer ball should be used, as much as possible, as a tool to enhance reactive stabilization strategies (**FIGURE 2**). With a field player, the basic passes (feet) are simulated, while basic ball receptions

TABLE 2 Progression of Running and Soccer Drills

	Part 1	Part 2	Part 3
Level 1	Running: straight line a. Endurance (time/distance) b. Player-specific runs, midfield/center forwards distances c. Shorter distances d. Gradually increasing speed e. Forward/backward runs: 1:4 min run-rest ratio building up to 1:1 min (×4) and 2:1 (×3) to train the anaerobic lactate threshold. A long recovery time is needed between each set of exercises (4 min)	Passing Side footing: start with standing ball and move through the progressions, then progress to a moving ball both on the floor and on the volley. a. Short distances b. Longer distances c. Greater velocity on the pass	Dribbling a. Straight-line ball control b. Forward/backward turns c. Instep ball control d. Outstep ball control
Level 2	Running: figure-of-eight runs With the same progressions as straight line	Passing: forefoot (on the laces) a. Short distances b. Longer distances c. Greater velocity on the pass: same as with the side-foot pass once, moved through the progressions, progress to moving the ball on the floor first to eventually on the volley a. Volleys side foot/laces/outside of foot b. Volleys with quick-feet: incorporate quick-feet and volley to ladders/hurdles/left-right foot on command, quick reaction volley drills	Lateral dribbling movements a. Long distances b. Short distances c. At speed d. Side movement with the ball, changing direction on command, at speed
Level 3	Running: open lateral zigzag runs a. Endurance base with long turns b. Gradually reducing distance between cones c. Increase number of turns and increase speed of turn	Corners Goal kicks from the hands to on the floor Follow the above kicking progressions	
Level 4	Running: rotations a. Without the ball b. With the ball c. Including pass increase as with the above Progressions: endurance/distance/repetitions/speed	Free kicks Follow the above progressions on kicking the ball (distance/force/speed) Shooting As above with regard to progression	Rotation dribbling movements a. Long rotations with the ball at the feet b. Short rotations with the ball c. Quick, sharp turns with the ball to both left and right sides d. Sharp turns on receiving a pass or volley

(hands) are used with a goalkeeper. The athlete is allowed to bounce/juggle the ball, and also to execute simple passes (using the internal and external sides of the foot) with the operated leg. Sometimes the athlete may combine specific training with less-focused activities (**FIGURE 3**). Incorporating the soccer ball and soccer-specific equipment (shoes) in phase 2 is not only important to enhance soccer-specific neuromuscular stabilization strategies but also to promote a positive psychological attitude in rehabilitation.

Later in phase 2, the goal is to control forward, backward, lateral, diagonal, and rotational body displacements, while focusing on knee stabilization. Working against elastic resistance is considered a powerful tool to train neuromuscular control, as the knee, lower extremity, pelvis, and upper body need to be controlled based on the direction of the resistance. First, the focus is on proper stabilization at slower speeds (side to side, without jumping), then speeds and dynamic movements are gradually increased. Basic exercises, such as lunges (front, lateral, or diagonal), performed with and without trunk rotations, are useful in promoting multiplanar stabilization of the surgically repaired knee.

Some simple forms of quickness drills are also included in this phase. For example, the athlete stands still, then, at the start signal, performs soft sprinting over a few meters before stopping and stabilizing on the operated knee, then kicks the ball with the nonoperated leg. This may be performed first in the gym and then on the pitch to best stimulate the motor-learning process.

The basic plyometric techniques (proper landing and stabilization) are progressed from double-leg to single-leg activities (horizontal and vertical jump), emphasizing quality versus quantity of movement. Heading the ball is also practiced, with proper take-off and landing technique(s).

Pool activities are a popular form of

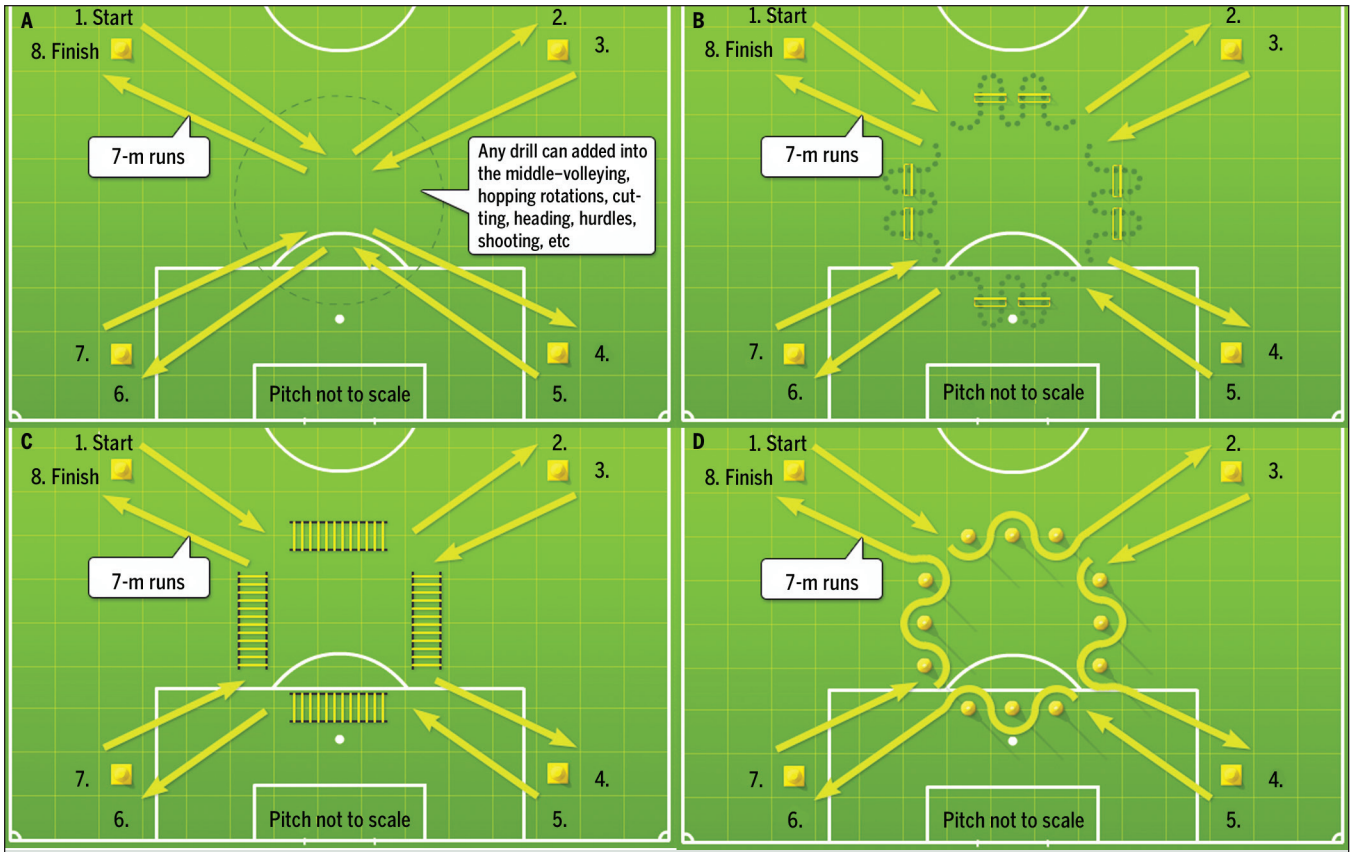

FIGURE 4. Star run drill. Basic setup and different drills: (A) star run outline, (B) star run with zigzag cutting drill, (C) star run with forward/backward ladder drills, (D) star run with running curves through poles.

additional training for soccer players in this controlled phase.[43] Using the properties of water, the athlete may exercise balance and coordination, in addition to performing running exercises (eventually with a wet vest), with minimal loading on the operated knee.

The athlete is ready to move to phase 3 when he/she has reached the criteria described in **TABLE 1**.

Phase 3

More complex and challenging soccer-specific drills characterize phase 3 (**TABLE 1**).

Soccer-Specific Drills **TABLE 2** shows an outline of a "classical" progression (3 parts with 4 levels each) for running and soccer drills. Specific parts/levels can be added or removed as the player progresses. There are no set time frames to complete each part at a given level, but performing each point (*a*, *b*, *c*, etc) of the progression for a level at the same frequency for 3 days is recommended before moving to the next level, whether it be distance, time, repetitions, or intensity. This allows for a gradual progression of each part and thus ensures correct function and that no adverse knee reaction is noted before moving on to the next level. Rehabilitation programs have been shown to fail due to a rapid increase in exercise load, whether of speed or duration, or the addition of different exercises that place a higher demand on the knee and graft.[34]

Star Run Drill This drill can be adapted to running and soccer-specific training. It can incorporate all aspects of soccer, including forward, backward, or multidirectional drills, and explosive and reactive drills with cutting. The outline of the drill is simple (**FIGURE 4**). The distances may be increased or decreased, but player position tends to dictate the size of the square and the intensity with which the player is working. Research from match analyses[49] has shown that the sprints are between 10 and 25 m in length and 3 and 5 seconds in duration. The energy systems being used are also an important consideration during these phases of rehabilitation. Soccer players need to train both the anaerobic and aerobic systems, as distances up to 10 km (central defenders) or 12 km (midfielders) are covered by top-level professional players in a match.[49]

Combined Drills Different activities such as quick-feet, short sprints, cutting and accelerating, and body rotations can be trained in a rapid sequence over a predefined distance (eg, 20 m). Incorporating various skills into a rapid sequence has proven to be an effective specific quickness and dynamic body control training method for soccer players after knee surgery (**ONLINE VIDEO 1**).

FIGURE 5. Block tackles at different angles and intensities, on different types of surfaces, from a soft deflated soccer ball to a harder leather medicine ball.

FIGURE 6. Kicking action into pads while balancing on an unstable surface, incorporating standing balance while making contact. The use of unstable surfaces helps to promote different reactive stabilization strategies.

Contact Situations One aspect of the later sport-specific drills is contact, which is a major element of the game of soccer. Although ACL ruptures tend to occur more often without contact,[42] those occurring from contacts cannot be ignored. Roi et al,[44] analyzing data from the Italian Serie A League, determined that ACL contact injuries occurred more frequently during competitive games, while noncontact injuries occurred more often during training and nonofficial games. Mihata et al[32] compared a number of different sports (basketball, soccer, and lacrosse) and suggested that the level of allowed contact in pivoting sports may be a factor in determining sport-specific ACL risk.

Often, the level of contact of the sport is overlooked in the rehabilitation program and left to players to manage as they gradually rejoin training. Although there is always risk with contact, we suggest that it may be better to include this aspect of the game in a controlled environment of rehabilitation rather than leave it to the unpredictable environment of a training session. If the player's knee is able to gradually withstand forces of valgus/varus with and without rotation, they must be able to cope with the gradual load/forces of contact. Controlling the decelerating forces from a contact is vital, as it has been shown to reduce the incidence of ACL rupture.[9,16] Repetitive training of proper landing techniques has enabled athletes to develop learned responses that may help minimize or prevent injury when they are placed in game or practice situations.[34,52]

FIGURE 7. In-air body contact, trying to simulate heading and body contact in the gym environment. Specific instructions are given on landing correctly on the forefoot/toes and absorbing the landing forces. Progressions can be added by different directional forces and intensity of body weight contact.

Contact can be controlled with block tackles (**FIGURE 5**) and single-leg kicking of objects that move (**FIGURE 6**), eventually progressing to actual body load, whether on the ground or in the air (**FIGURE 7**).

Tackle Situations The sliding tackle is another type of contact that must be addressed, as it is an important function of the knee in the defensive side of the game. Graded progressions of landing on the floor and kicking a ball away can be included first without another person, and eventually with a therapist asking the patient to slide in and kick the ball away from the therapist's feet. Sets and repetitions can be added gradually, with speed only being added as the patient is starting to join group training. It is vital, however, that before adding these late-stage drills, all aspects of single-leg hopping and rotation training have been completed. The grass surface must also be inspected prior to performing these types of drills, as external conditions, such as a slippery wet surface, could place the athlete at greater risk. The criteria to allow the athlete to progress to phase 4 are described in **TABLE 1**.

Phase 4, Return to Play: What Does It Mean?

Respecting a gradual and progressive return to competitive soccer is crucial for the player following ACL reconstruction. Therefore, it is necessary to differentiate between various types of return:

- Return to reduced team training practice (no contact)
- Return to full (normal) team training practice (with contact)
- Return to "friendly" games (initially not over the full duration of a match)
- Return to competitive match (initially not over the full duration of a match)

This first return is often the most crucial. The player must be physically and psychologically ready to shift from individual training, where most situations are intense but controlled, to team training, where the player is also exposed to uncontrolled situations. In this phase, the player also continues to perform specific training, focusing on improving identified deficits (strength, coordination, and endurance) under supervision. Recent research has clearly shown that strength/power and functional deficits in the involved lower extremity may persist up to 6 or more months after primary ACL reconstruction,[20,35,36] and that persistent strength imbalances may be linked with an increased risk of reinjury in soccer.[12,29]

Thomeé et al[50] critically discussed the common muscle strength and hop per-

formance criteria used prior to return to sport, which may not be demanding and sensitive enough to detect side differences, and proposed new recommendations for muscle function tests in individuals after ACL reconstruction.

Because soccer is a high-intensity intermittent activity, training should include physical exercises aimed to enhance aerobic fitness, anaerobic power and capacity, repeated sprint ability, and muscle power and strength. Other than coping with the physiological demands of the match, physical training can counteract the decline in technical proficiency caused by fatigue.[26] Several studies have shown different effective training strategies for improving these fitness components.[13,15,19,22,24]

Functional Tests to Clear Return to Play

Myer et al[35] recently presented a battery of performance tests (modified NFL Combine testing) to show how unilateral deficits are present and may be hidden in double-leg activities in athletes 1 year after ACL reconstruction. Therefore, the sports physiotherapist needs to regularly check single-leg hop tasks of the involved limb, while ensuring that the player continues to demonstrate good overall quality of movement (knee, hip, and trunk).

Unrestricted participation in team practice (without any adverse knee joint reactions) is, of course, an important criterion to be able to return to compete in a soccer match. There are no validated sports-specific tests to determine readiness to return to full participation in team practice and competitive matches for soccer players after ACL surgery. However, the 2 performance tests considered the best, in terms of validity and reliability in healthy soccer players, are the Yo-Yo intermittent recovery (Yo-Yo) test[4] and the repeated shuttle-sprint ability (RSSA) test.[25] Data are available for different players' roles (defender, fullback, midfielder, and forward) that, even if cut-off values do not exist, may help in judging the performance and return-to-play readiness of the player.[27] The Yo-Yo and RSSA tests may also be used to monitor improvement of the athlete over time. Additional specific tests, such as speed dribbling, short-long passing, and shooting, have been proposed in the literature[45] but have never been fully scientifically validated. These and other skills are practiced daily, and, similar to playing against an opponent, physical and mental preparation must be gradually optimized (**TABLE 2**).

Therefore, to return to full participation after ACL surgery, the soccer player must make a successful progression through the described rehabilitation phases and show satisfactory (as judged by the sports physiotherapist) Yo-Yo and RSSA test results.

PREVENTION OF REINJURY AFTER ACL RECONSTRUCTION

In the last few years, ACL injury prevention programs for female and male soccer players have been developed and their effectiveness scientifically confirmed.[2] A reduction of 30% to 50%, and even higher for females,[18] has been shown in the incidence of noncontact ACL injuries.[47] Programs such as the Perform and Enhance Performance[31] and the 11+ (**ONLINE VIDEO 2**),[47] which combine cardiovascular and specific injury prevention exercises, should be performed as a warm-up prior to technical and tactical training. Considering the risk of reinjury[39,53] and that some aspects of biomechanical and neuromuscular function may be deficient up to several years after the ACL reconstruction,[11,34,36] players should ideally continue post–ACL reconstruction neuromuscular training on a regular basis for the remainder of their career.

In this respect, the use of screening tests to identify players at risk for ACL injury may be recommended. The Landing Error Scoring System, developed by Padua et al,[38] is a valid and reliable clinical assessment tool for jump-landing biomechanics, and may have the potential to predict ACL injury or reinjury.

SUMMARY

A soccer player faces many challenges following ACL reconstruction. The player has to deal with the pressure of his entourage (club, coach, other) and the risk of jeopardizing his career, while pursuing the goal of a successful return to play. The sports physiotherapist plays an important role in monitoring a closely supervised criteria-based program and in guiding the athlete during the rehabilitation and training process. Functional training is a key element in regaining the soccer-specific neuromuscular control necessary to perform skills ranging from basic to soccer-specific drills. Particular attention should be given to the quality of the movement patterns and stabilization strategies. Residual impairments in strength, power, agility, and sensorimotor capacity should be specifically addressed while the athlete undergoes soccer-specific conditioning and fitness training.

The goal is to reintegrate the player gradually in the game, taking into account his/her individual characteristics. Several evidence-based and empirical criteria are needed to plan and monitor the efficient return to competitive soccer. Injury prevention education should be part of this process to maximize the chance of a durable career. Further research is necessary to better understand and assess different aspects of muscle function and motor control after ACL reconstruction in soccer players.

REFERENCES

1. Alentorn-Geli E, Myer GD, Silvers HJ, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: mechanisms of injury and underlying risk factors. *Knee Surg Sports Traumatol Arthrosc*. 2009;17:705-729. http://dx.doi.org/10.1007/s00167-009-0813-1
2. Alentorn-Geli E, Myer GD, Silvers HJ, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 2: a review of prevention programs aimed to modify risk factors and to reduce injury rates. *Knee Surg Sports Traumatol Arthrosc*. 2009;17:859-879. http://

dx.doi.org/10.1007/s00167-009-0823-z
3. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med*. 2004;32:5S-16S.
4. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Med*. 2008;38:37-51.
5. Beynnon BD, Johnson RJ, Abate JA, Fleming BC, Nichols CE. Treatment of anterior cruciate ligament injuries, part I. *Am J Sports Med*. 2005;33:1579-1602. http://dx.doi.org/10.1177/0363546505279913
6. Bizzini M. *Sensomotorische Rehabilitation nach Beinverletzungen. Mit Fallbeispielen in allen Heilungsstadien*. Stuttgart, Germany: Thieme; 2000.
7. Bizzini M, Gorelick M, Drobny T. Lateral meniscus repair in a professional ice hockey goaltender: a case report with a 5-year follow-up. *J Orthop Sports Phys Ther*. 2006;36:89-100. http://dx.doi.org/10.2519/jospt.2006.2015
8. Bizzini M, Notzli HP, Maffiuletti NA. Femoroacetabular impingement in professional ice hockey players: a case series of 5 athletes after open surgical decompression of the hip. *Am J Sports Med*. 2007;35:1955-1959. http://dx.doi.org/10.1177/0363546507304141
9. Caraffa A, Cerulli G, Projetti M, Aisa G, Rizzo A. Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training. *Knee Surg Sports Traumatol Arthrosc*. 1996;4:19-21.
10. Cascio BM, Culp L, Cosgarea AJ. Return to play after anterior cruciate ligament reconstruction. *Clin Sports Med*. 2004;23:395-408. http://dx.doi.org/10.1016/j.csm.2004.03.004
11. Chmielewski TL. Asymmetrical lower extremity loading after ACL reconstruction: more than meets the eye. *J Orthop Sports Phys Ther*. 2011;41:374-376. http://dx.doi.org/10.2519/jospt.2011.0104
12. Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. *Am J Sports Med*. 2008;36:1469-1475. http://dx.doi.org/10.1177/0363546508316764
13. Dupont G, Akakpo K, Berthoin S. The effect of in-season, high-intensity interval training in soccer players. *J Strength Cond Res*. 2004;18:584-589. http://dx.doi.org/10.1519/1533-4287(2004)18<584:TEOIHI>2.0.CO;2
14. Dvorak J, Junge A. Football injuries and physical symptoms. A review of the literature. *Am J Sports Med*. 2000;28:S3-S9.
15. Ferrari Bravo D, Impellizzeri FM, Rampinini E, Castagna C, Bishop D, Wisloff U. Sprint vs. interval training in football. *Int J Sports Med*. 2008;29:668-674. http://dx.doi.org/10.1055/s-2007-989371
16. Fitzgerald GK, Axe MJ, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. *Phys Ther*. 2000;80:128-140.
17. Fuller CW, Walker J. Quantifying the functional rehabilitation of injured football players. *Br J Sports Med*. 2006;40:151-157. http://dx.doi.org/10.1136/bjsm.2005.021048
18. Gilchrist J, Mandelbaum BR, Melancon H, et al. A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. *Am J Sports Med*. 2008;36:1476-1483. http://dx.doi.org/10.1177/0363546508318188
19. Gorostiaga EM, Izquierdo M, Ruesta M, Iribarren J, Gonzalez-Badillo JJ, Ibanez J. Strength training effects on physical performance and serum hormones in young soccer players. *Eur J Appl Physiol*. 2004;91:698-707. http://dx.doi.org/10.1007/s00421-003-1032-y
20. Gustavsson A, Neeter C, Thomeé P, et al. A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2006;14:778-788. http://dx.doi.org/10.1007/s00167-006-0045-6
21. Hagglund M, Walden M, Ekstrand J. Lower reinjury rate with a coach-controlled rehabilitation program in amateur male soccer: a randomized controlled trial. *Am J Sports Med*. 2007;35:1433-1442. http://dx.doi.org/10.1177/0363546507300063
22. Hill-Haas SV, Coutts AJ, Rowsell GJ, Dawson BT. Generic versus small-sided game training in soccer. *Int J Sports Med*. 2009;30:636-642. http://dx.doi.org/10.1055/s-0029-1220730
23. Impellizzeri FM, Marcora SM. Test validation in sport physiology: lessons learned from clinimetrics. *Int J Sports Physiol Perform*. 2009;4:269-277.
24. Impellizzeri FM, Marcora SM, Castagna C, et al. Physiological and performance effects of generic versus specific aerobic training in soccer players. *Int J Sports Med*. 2006;27:483-492. http://dx.doi.org/10.1055/s-2005-865839
25. Impellizzeri FM, Rampinini E, Castagna C, et al. Validity of a repeated-sprint test for football. *Int J Sports Med*. 2008;29:899-905. http://dx.doi.org/10.1055/s-2008-1038491
26. Impellizzeri FM, Rampinini E, Maffiuletti NA, Castagna C, Bizzini M, Wisloff U. Effects of aerobic training on the exercise-induced decline in short-passing ability in junior soccer players. *Appl Physiol Nutr Metab*. 2008;33:1192-1198. http://dx.doi.org/10.1139/H08-111
27. Krustrup P, Mohr M, Amstrup T, et al. The Yo-Yo intermittent recovery test: physiological response, reliability, and validity. *Med Sci Sports Exerc*. 2003;35:697-705. http://dx.doi.org/10.1249/01.MSS.0000058441.94520.32
28. Kvist J. Rehabilitation following anterior cruciate ligament injury: current recommendations for sports participation. *Sports Med*. 2004;34:269-280.
29. Lehance C, Binet J, Bury T, Croisier JL. Muscular strength, functional performances and injury risk in professional and junior elite soccer players. *Scand J Med Sci Sports*. 2009;19:243-251. http://dx.doi.org/10.1111/j.1600-0838.2008.00780.x
30. Logerstedt DS, Snyder-Mackler L, Ritter RC, Axe MJ, Godges JJ. Knee stability and movement coordination impairments: knee ligament sprain. *J Orthop Sports Phys Ther*. 2010;40:A1-A37. http://dx.doi.org/10.2519/jospt.2010.0303
31. Mandelbaum BR, Silvers HJ, Watanabe DS, et al. Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up. *Am J Sports Med*. 2005;33:1003-1010. http://dx.doi.org/10.1177/0363546504272261
32. Mihata LC, Beutler AI, Boden BP. Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med*. 2006;34:899-904. http://dx.doi.org/10.1177/0363546505285582
33. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*. 2003;21:519-528. http://dx.doi.org/10.1080/0264041031000071182
34. Myer GD, Paterno MV, Ford KR, Quatman CE, Hewett TE. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther*. 2006;36:385-402. http://dx.doi.org/10.2519/jospt.2006.2222
35. Myer GD, Schmitt LC, Brent JL, et al. Utilization of modified NFL combine testing to identify functional deficits in athletes following ACL reconstruction. *J Orthop Sports Phys Ther*. 2011;41:377-387. http://dx.doi.org/10.2519/jospt.2011.3547
36. Myklebust G, Bahr R. Return to play guidelines after anterior cruciate ligament surgery. *Br J Sports Med*. 2005;39:127-131. http://dx.doi.org/10.1136/bjsm.2004.010900
37. Neeter C, Gustavsson A, Thomeé P, Augustsson J, Thomeé R, Karlsson J. Development of a strength test battery for evaluating leg muscle power after anterior cruciate ligament injury and reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2006;14:571-580. http://dx.doi.org/10.1007/s00167-006-0040-y
38. Padua DA, Marshall SW, Boling MC, Thigpen CA, Garrett WE, Jr., Beutler AI. The Landing Error Scoring System (LESS) is a valid and reliable clinical assessment tool of jump-landing biomechanics: the JUMP-ACL study. *Am J Sports Med*. 2009;37:1996-2002. http://dx.doi.org/10.1177/0363546509343200
39. Paterno MV, Schmitt LC, Ford KR, et al. Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. *Am J Sports Med*. 2010;38:1968-1978. http://dx.doi.org/10.1177/0363546510376053
40. Powers CM. The influence of abnormal hip

mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther*. 2010;40:42-51. http://dx.doi.org/10.2519/jospt.2010.3337

41. Risberg MA, Holm I, Myklebust G, Engebretsen L. Neuromuscular training versus strength training during first 6 months after anterior cruciate ligament reconstruction: a randomized clinical trial. *Phys Ther*. 2007;87:737-750. http://dx.doi.org/10.2522/ptj.20060041

42. Rochcongar P, Laboute E, Jan J, Carling C. Ruptures of the anterior cruciate ligament in soccer. *Int J Sports Med*. 2009;30:372-378. http://dx.doi.org/10.1055/s-0028-1105947

43. Roi GS, Creta D, Nanni G, Marcacci M, Zaffagnini S, Snyder-Mackler L. Return to official Italian First Division soccer games within 90 days after anterior cruciate ligament reconstruction: a case report. *J Orthop Sports Phys Ther*. 2005;35:52-61; discussion 61-66. http://dx.doi.org/10.2519/jospt.2005.1583

44. Roi GS, Nanni G, Tencone F. Time to return to professional soccer matches after ACL reconstruction. *Sport Sci Health*. 2006;1:142-145. http://dx.doi.org/10.1007/s11332-006-0025-8

45. Rosch D, Hodgson R, Peterson TL, et al. Assessment and evaluation of football performance. *Am J Sports Med*. 2000;28:S29-S39.

46. Schmidt RA, Lee TD. *Motor Control and Learning: A Behavioral Emphasis*. 3rd ed. Champaign, IL: Human Kinetics; 1999.

47. Soligard T, Myklebust G, Steffen K, et al. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. *BMJ*. 2008;337:a2469.

48. Spencer M, Bishop D, Dawson B, Goodman C. Physiological and metabolic responses of repeated-sprint activities specific to field-based team sports. *Sports Med*. 2005;35:1025-1044.

49. Stolen T, Chamari K, Castagna C, Wisloff U. Physiology of soccer: an update. *Sports Med*. 2005;35:501-536.

50. Thomeé R, Kaplan Y, Kvist J, et al. Muscle strength and hop performance criteria prior to return to sports after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2011;19:1798-1805. http://dx.doi.org/10.1007/s00167-011-1669-8

51. van Grinsven S, van Cingel RE, Holla CJ, van Loon CJ. Evidence-based rehabilitation following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2010;18:1128-1144. http://dx.doi.org/10.1007/s00167-009-1027-2

52. Voight M, Cook G. Clinical application of closed kinetic chain exercise. *J Sport Rehabil*. 1996;5:25-44.

53. Walden M, Hagglund M, Ekstrand J. High risk of new knee injury in elite footballers with previous anterior cruciate ligament injury. *Br J Sports Med*. 2006;40:158-162. http://dx.doi.org/10.1136/bjsm.2005.021055

54. Walden M, Hagglund M, Magnusson H, Ekstrand J. Anterior cruciate ligament injury in elite football: a prospective three-cohort study. *Knee Surg Sports Traumatol Arthrosc*. 2011;19:11-19. http://dx.doi.org/10.1007/s00167-010-1170-9