Management of ACL Injuries in Basketball

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30.1 Introduction

30.1.1 Incidence

Tears of the ACL are among the most common sports injuries treated by orthopedic surgeons, with an incidence between 30 and 81 per 100,000 people [1, 2]. ACL tears are particularly prevalent in pivoting and cutting sports such as basketball, accounting for up to 64% of all knee injuries [3–6]. The incidence of ACL reconstruction has increased over the recent years, particularly in the young and female athletes, who more commonly undergo reconstruction in order to restore rotatory and translational stability to the knee and maintain performance level [5, 7–9]. The incidence of ACL injury in basketball has also been widely reported, with a meta-analysis of epidemiologic studies showing female and male basketball player tear rates of 0.29 and 0.08 per 1000 athletic exposures (defined as a practice or game), respectively [10].

30.1.2 ACL Function

The ACL functions as the primary restraint against anterior translation of the knee, providing ~86% of the stability required to prevent anterior translation of the tibia. The ACL also provides rotatory stability, limits hyperextension, and provides secondary coronal stability [11]. Together with the posterior cruciate ligament (PCL), the ACL allows controlled rollback of the femur on the tibia as the knee center of rotation moves posteriorly during flexion. When nearing terminal extension, the tibia externally rotates under the femur, resulting in the tightening of both the ACL and PCL, which stabilizes the knee and allows for stance [11, 12].

30.1.3 Anatomy

The ACL is composed of type I collagen fibers (90%) and type III collagen fibers (10%). The ligament originates from the posterior aspect of the lateral femoral condyle and inserts anterior to the medial tibial eminence, travelling an average distance of 31 ± 3 mm [11, 13]. The ACL is composed of a complex of fascicles which is commonly simplified into two functionally and biomechanically synergistic bundles: the anteromedial bundle, which endures increased tension during flexion, and the posterolateral bundle, which becomes taut in extension [14, 15].

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Biomechanical studies have estimated that the ACL has an ultimate strength of between 1730 and 2500 Newtons [16, 17]. The ACL receives blood supply from the middle geniculate artery and innervation from the tibial nerve [18, 19].

30.2 Diagnosis of ACL Tears

30.2.1 History

A thorough history and evaluation is necessary in diagnosing ACL tears and other associated injuries in the basketball athlete. Patients often report an instability event following landing or cutting in a non-contact fashion. Most commonly, the event involves pivoting while accelerating or decelerating while landing forcefully on the heel with slight knee flexion. Although a non-contact mechanism at the time of injury is more common in basketball players, the injury likely includes movement to be perturbed by or contacted by an opposing player earlier in the sequence [20]. Alternatively contact injury mechanism involves a substantial valgus force to the fixed and extended knee [20, 21]. An audible or palpable pop is often described with immediate knee swelling. That athlete is typically unable to continue sports activity.

30.2.2 Physical Examination

Examination should begin with the inspection of the athlete's lower extremity. An effusion is typically representative of an intra-articular pathology. The Lachman test is the key examination maneuver when detecting an ACL injury as it has a high sensitivity and specificity. The patient is placed in the supine position with the knee in approximately 30° of flexion. Instructions on complete relaxation are given while the examiner stabilizes the thigh with one hand and delivers an anterior translation force to the tibia with the other. Amount of translation is noted as well as the presence of a firm end-point. Translation greater than 3 mm compared with the opposite knee and a soft end-point are indicative of ACL injury. The pivot shift test is an important indicator of rotational instability. The test is performed with the leg in extension and the ankle in internal rotation, a valgus force is then applied to the leg with gentle flexion of the knee. In an ACL-deficient state, this causes an anterior subluxation of the lateral tibia from beneath the lateral femoral condyle. The iliotibial band initially acts as an extensor when its center of rotation is in front of the knee; as the knee is flexed, the ITB becomes a flexor and causes the tibia to be reduced posteriorly. This sudden reduction force is considered a positive test. Although the test is not very sensitive (24%), it is extremely specific (98%). The test is more sensitive in a completely relaxed patient or when performed under general anesthesia (74%) [22]. The anterior drawer test is also valuable in the evaluation of an athlete with an ACL tear, although it is less sensitive and specific than the Lachman test. The test is more useful in patients with chronic ACL tear and is performed with the patients in supine and the knee in 90° of flexion. An anterior force is then applied to the tibia, and the difference in anterior translation between the two knees is evaluated [22]. The above examination maneuvers are very user dependent and are most useful when performed by experienced clinicians, whereas the KT-1000 (or 2000/3000) arthrometer provides a more standardized measurement but is used mostly for research purposes [23].

30.2.3 Imaging

Imaging is an important adjuvant of the clinical examination for an athlete. Although radiographic imaging will not identify ligamentous injury, it allows the assessment of associated bony abnormalities such as avulsion fractures of the tibial spine or anterolateral ligament (Segond fracture). An MRI is useful in confirming ligament injury as well as other soft tissue pathology but is not required for the diagnosis of an ACL rupture (Fig. 30.1). Due to injury mechanism with an acute ACL rupture, the most commonly identified pathology on MRI is ACL rupture, MCL sprain/tear, and posterior lateral meniscus

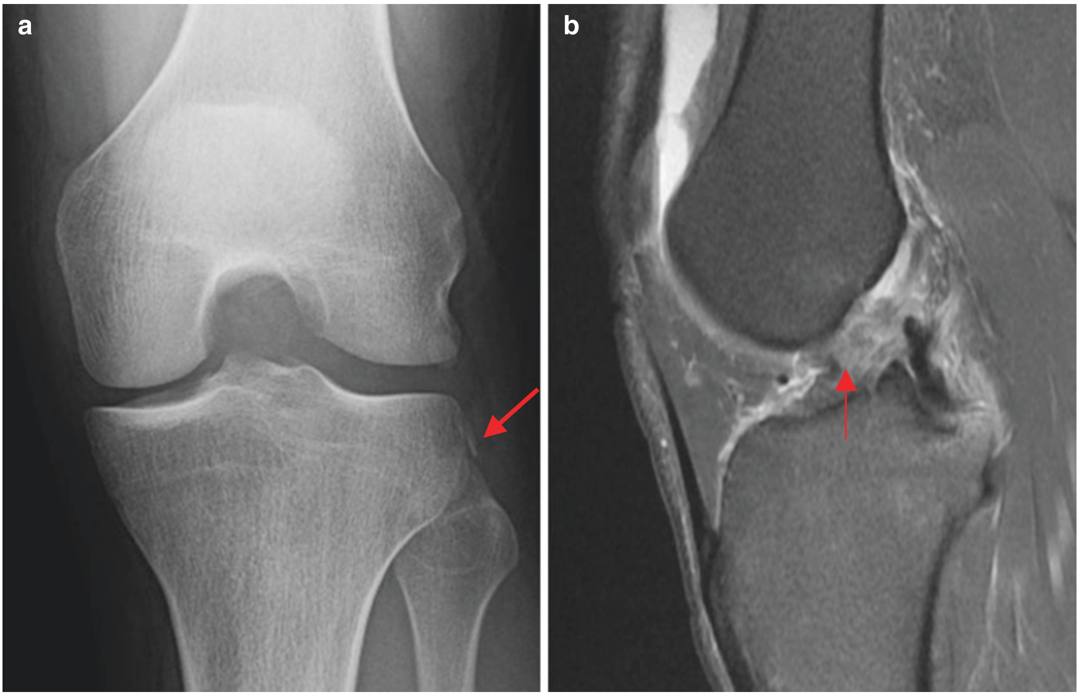

Fig. 30.1 (**a**) AP X-ray of patient with acutely ruptured ACL. Segond fracture indicated by red arrow. (**b**) MRI demonstrating acute ACL rupture

tear. Bone bruising occurs on the central lateral femoral condyle and the posterior lateral tibial plateau [24]. With chronic ACL tears, the posterior horn of the medial meniscus becomes a more substantial restraint to anterior translation which may subsequently result in tearing. The practitioner should also be aware of any cartilage injury which may need to be addressed during arthroscopy.

30.3 Management of ACL Injury in Athletes

30.3.1 Conservative Management

Although non-surgical management of ACL injuries can be employed in patients without high athletic demand, there is a limited role for non-surgical management of ACL tears in the basketball athlete. This is primarily due to the high translational forces placed on the knee while playing basketball and the requirement of cutting and pivoting motions. Physical therapy prior to surgery, or "pre-hab," is primarily focused on normalization of range of motion, elimination of effusion, and strengthening the secondary stabilizers of the knee.

30.3.2 Surgical Management: Graft Selection

Following preoperative rehabilitation and normalization of range of motion of the knee (usually 3–4 weeks), surgical management can be employed with a decreased risk of arthrofibrosis [25]. Primary repair of the ACL does not demonstrate adequate healing due to the intra-articular nature of the tendon; therefore, ligament reconstruction is necessary. Various options for ACL grafts exist including: bone–patellar tendon–bone (BTB), hamstring, and quadriceps autografts. Either soft tissue or bony ACL allograft options exist, which eliminate donor site morbidity and decrease operative time. Additionally, graft preservation and disease transmission are less of a concern with modern day harvesting techniques. However, allografts are less commonly utilized in basketball athletes as they have been found to have a higher re-rupture rate in the younger, more active, athletic population [26].

Autograft reconstruction continues to be the mainstay of treatment in the young athletic patient. BTB autografts utilize bone on each side of the tendon which incorporate more quickly into bony tunnels and have been shown by some to have lower re-rupture rates than hamstring grafts (Fig. 30.2). However, donor site morbidity can present in the form of anterior knee pain, and some studies have shown increased late stage arthritis [27]. Hamstring grafts demonstrate increased tensile strength in the laboratory when quadrupled and have lower donor site morbidity, but have slower incorporation into the bony tunnels at the tendon–bone interface [28]. Quadriceps autografts are increasingly performed and provide a thicker soft tissue graft option than the hamstring. Patella fractures and quadriceps rupture are potential complications postoperatively that should be discussed. Ultimately, graft choice is a cumulative decision between the patient and the surgeon based on pertinent factors. Commonly in the high-level basketball player, BTB autograft is performed when possible.

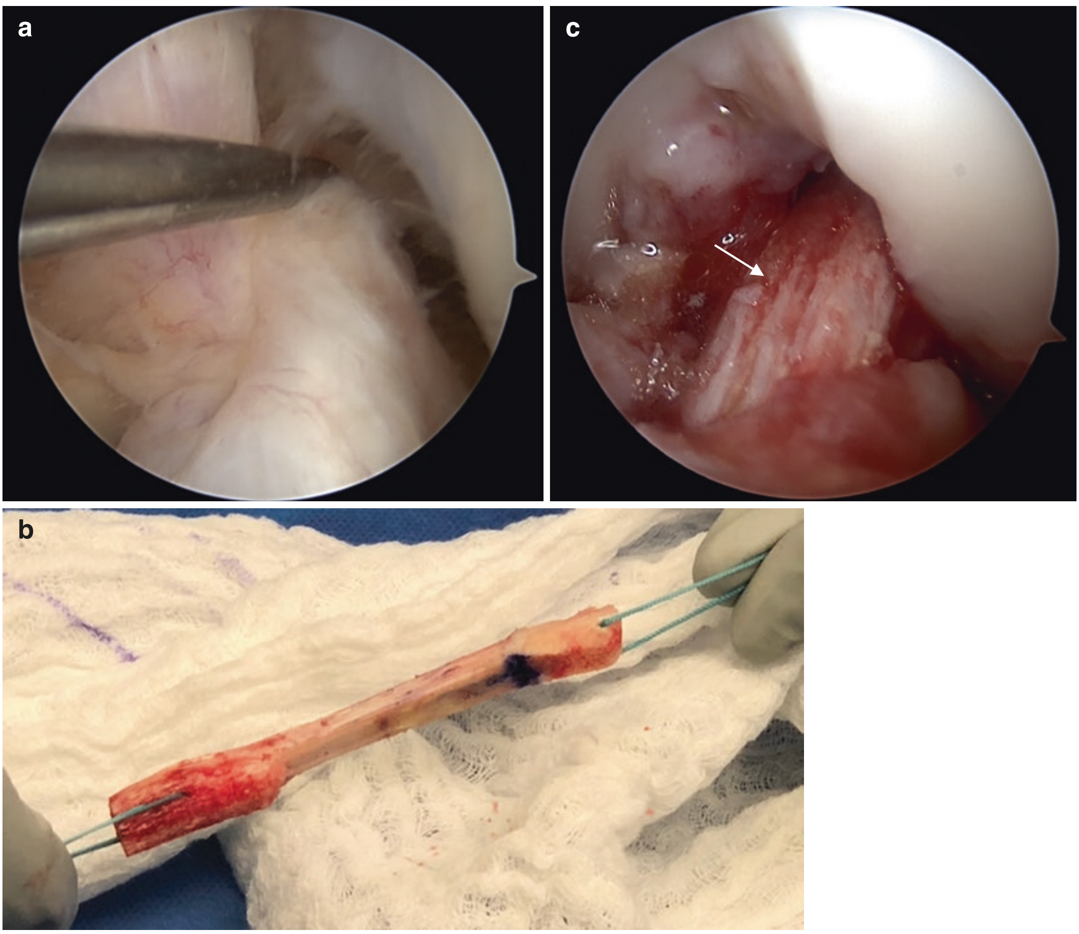

Fig. 30.2 ACL reconstruction with BTB autograft. (**a**) Arthroscopic view on an acute ACL tear. Detachment of the ACL from its insertion to the femur is demonstrated using a probe. (**b**) Prepared BTB autograft prior to reconstruction. (**c**) Reconstructed ACL with a BTB (white arrow)

30.3.3 Surgical Technique and Fixation

Several surgical methods exist when performing ACL reconstruction including trans-tibial drilling, anterior medial portal drilling, two-incision technique, and all-inside methods. Each technique entails pros and cons and is best managed by a physician experienced with the technique. Ultimately, literature has not demonstrated clinical differences between surgical techniques. Additionally, single-bundle or double-bundle ACL reconstruction can be performed.

The anatomic double-bundle technique uses two separate grafts to recreate each natural bundle of the ligament and is aimed at providing more natural knee motions. Although biomechanical studies have found superior results in terms of knee translation and rotation, this has not translated into superior clinical results [29, 30].

30.3.3.1 Fixation

Graft fixation of the reconstructed ligament should be strong enough to withstand close-chain exercises for at least 12 weeks until the bone or tendon is able to incorporate into the bone tunnels. There is a risk of graft slippage or ultimate failure if graft fixation is poor [31]. Many commercially available graft fixation options exist. Patellar bone blocks demonstrate the highest stiffness and fixation strength with interference screw fixation [32]. Optimal screw placement is parallel to the bone block, with screw divergence more than 30° demonstrating increased risk of pullout and failure [32]. Screw length and diameter are also factors which influence fixation strength, whereas composition of the screw (bioabsorbable/metallic) and the use of dilators has not been shown to affect fixation strength [33, 34]. Soft tissue grafts have several options for fixation. These include interference screws, screw and washer constructs, suture posts, tibial staples, and cross-pins and buttons on the femoral side. Screw and washer constructs, cross-pins, and buttons all provide indirect fixation, meaning the graft is suspended in the bony tunnel. All other options provide direct fixation by compressing the graft against the wall of the tunnel.

Fact Box: ACL Injury Management

- For athletes wishing to return to prior level of sport after ACL injury, surgical reconstruction remains the mainstay of treatment.
- Graft selection remains individualized, with most high-level athletes undergoing reconstruction with BTB autografts.
- Proper surgical fixation is critical to surgical outcome, with strongest fixation utilizing patellar bone blocks with screw placement parallel to the blocks.

30.4 Principles of ACL Injury Rehabilitation

Post ACL reconstruction, rehabilitation progression and duration recommendations vary widely from provider to provider. While some providers utilize defined time-points from surgery as milestones to advance rehabilitation, others require patients to complete both objective and subjective benchmarks before advancing. For any athlete, the ultimate goal of a rehabilitation program is to return to sport at pre-injury level, but the optimal therapy program and duration remain highly individualized and dependent on the athlete's level of play, type of sport, and concomitant injuries sustained at the time of ACL rupture. However, based on a systematic review of the current literature on ACL rehabilitation, an evidence-based clinical practice guideline has been created for recommendations [35].

30.4.1 Preoperative Rehabilitation (Pre-Hab)

Prior to undergoing surgery for an ACL tear, there are several milestones that should be achieved. Preoperative rehabilitation focuses on elimination of effusion, normalization of range of motion, and strengthening of the secondary stabilizers of the knee. Preoperative stiffness has been found to closely correlate with postoperative range of motion loss, and therefore obtaining near normal range of motion prior to surgery is essential [36]. Quadriceps weakness/atrophy is another preoperative concern, as quadriceps strength deficits >20% have been identified as a predictor for persistent weakness following surgery [37]. Strengthening of the quadriceps prior to surgical intervention can potentially alleviate this complication.

30.4.2 Postoperative Rehabilitation

30.4.2.1 Initial Phase

Following surgery, athletes are progressed through a structured physical therapy regimen before returning to their sport. Rehabilitation consists of three advancing stages of therapy. As quadriceps activation failure and flexion contracture can occur postoperatively, the initial phase of rehabilitation is centered on quadriceps activation and obtaining full range of motion [38]. Knee extension exercises are used to obtain full extension to 0° by 2–4 weeks. Flexion to 120–130° is obtained by 4–6 weeks using heel-slide exercises. Focus should also be placed on passive mobilization of the patella to ensure good patellofemoral mobility by 4–6 weeks after surgery.

Strength training should focus on quadriceps reactivation with active straight leg knee extensions. Gradually, patients should progress from isometric to concentric quadriceps exercises as tolerated once the quadriceps are reactivated. When the patient has sufficient quadriceps strength, as evidenced by performance of straight leg raises without a lag, they can unlock their postoperative brace and begin advancing their strength training [39]. As strength returns, patients can start progressive weight-bearing until they resume a normal gait pattern, after which crutches can be discontinued. Thereafter, patients should progress to closed kinetic chain exercises (including leg press, squats, step-ups) prior to initiating open kinetic chain exercises approximately 4–6 weeks after surgery [35]. Early precautions should include both closed and open kinetic chain exercises confined to a limited range of motion, with gradual increases in range of motion during exercise as tolerated.

Another important aspect of early rehabilitation is neuromuscular training, as impaired neuromuscular control can often persist despite recovery of normal strength levels [40]. Training with balance-boards and emphasizing proper mechanics and form during exercises and ambulation are useful adjuncts in regaining neuromuscular control.

30.4.2.2 Intermediate Phase

Once the goals of the immediate postsurgical period have been met—including wound healing, resolution of effusion, voluntary control of quadriceps, restoration of normal gait, knee extension to at least 0°, and knee flexion to at least 120–130°—athletes may advance to the second phase of therapy. The time period to reach these criteria varies but should be considered abnormal if not obtained within 6–8 weeks following surgery.

Many of the principles of this phase follow progressions of the neuromuscular, range of motion, and strength exercises of the initial phase. Neuromuscular training should be continued with increased difficulty, such as transitioning from static to dynamic training and adding perturbation training with varying speed, direction, and amplitude of disturbance. Strength training should gradually progress to closed and open kinetic chain exercises at all ranges of motion. At week 10–12, athletes can resume jogging, assuming they are able to do so with correct form. Sport-specific training can also be initiated at this time with close supervision.

30.4.2.3 Final Phase

Once athletes are able to perform all closed and open kinetic chain exercises without pain and have a Limb Symmetry Index (LSI) greater than 80% for quadriceps and hamstring strength, they can progress to the final phase of rehabilitation before returning to sport. The goal of this phase is to transition back into sports by intensifying sport-specific training. Neuromuscular and perturbation exercises should be intensified and focused on sport-specific movement. Athletes should also increase agility training, with resumption of training with their sports team in preparation for returning to sports (RTS) and return to play (RTP).

30.4.3 Rehabilitation Considerations in Basketball Players

Much of the investigation in ACL reconstruction rehabilitation has focused on general principles and guidelines for all patients, with few studies focusing directly on rehabilitation in basketball players. One level V commentary published on rehabilitation in basketball players by an NBA trainer [41] outlined a similar three phase progression with early focus on minimizing effusion, allowing for incision closure, and gradual restoration of knee range of motion. In addition to the general intermediate phase exercises outlined above, the author proposed several basketball-specific exercises, including low-intensity cutting drills and single-leg squatting on tilt boards while catching and passing basketballs. With progression to the last rehabilitation phase prior to returning to sport, drills simulating basketball situations can be implemented. This includes ball chase drills, where players chase balls thrown randomly around the court, and sprint-backpedal drills with and without basketball dribbling.

In addition, rehabilitation in basketball players should also emphasize jump-landing training and plyometric-type exercises, focusing on training to improve basketball-specific motions with the potential for ACL injury. The goal of completing these tailored basketball exercises is to progressively expose recovering athletes to in-game movements and scenarios, thus optimizing the neuromuscular and strength training unique to basketball players. Further study is needed to investigate basketball-specific programs before evidence-based recommendations can be made.

30.4.4 Establishing Safe Return-to-Play Criteria Following Rehabilitation

Standardized, objective, and evidence-based criteria for return to sport in basketball, as in all sports, have yet to be established. A recent systematic review of level I and II studies reporting return-to-play protocols demonstrated that 90% failed to utilize objection criteria and 65% of studies failed to use any criteria for return to sports readiness [42]. There are several obstacles in obtaining unified return-to-play criteria. One barrier is a lack of consensus on what level an athlete can safely return after ACL reconstruction [43]. Another obstacle is that multiple factors contribute to athlete RTP that cannot be controlled uniformly. One such factor is the psychological state of the athlete. Reports have shown that psychological factors can significantly decrease return-to-sport rate and performance despite obtaining equivalent functional outcome measures in athletes [44]. Additionally outcome scores do not necessarily correlate with return-to-sports rates. A recent study evaluating ACL reconstruction outcomes demonstrated that only 44% of athletes RTP despite 90% of the same athletes having normal or near-normal function on objective outcome scores and 85% having normal or near-normal function on IKDC subjective outcome scores [45].

Although limitations to uniform return-to-play criteria exist as detailed above, a recent review on rehabilitation following ACL reconstruction introduced several evidence-based criteria for establishing safe return to play [35]. Before a basketball player can safely RTS, at minimum the following criteria should be met:

- No knee pain with basketball-related movements (running, jumping, pivoting, decelerating, cutting).
- No knee buckling or apprehension of buckling during basketball-related movements.
- Restoration of normal and symmetric gait and running pattern.
- An LSI >90% for both hamstring and quadriceps strength.
- An LSI >90% for a hop test battery (including vertical jump, hopping for distance, single-leg hop-and-hold test, and side hopping) [46].
- Drop jump testing with absence of valgus movement, symmetric knee flexion, and maintenance of upright and lateral truncal posture.

Fact Box: Rehabilitation

- Preoperative rehabilitation is essential in optimizing postoperative restoration of range of motion and strength.
- Postoperative rehabilitation should include range of motion, strength, and neuromuscular exercises with progression to sport-specific exercises.
- Return-to-sport criteria are evolving but should ensure symmetric quadriceps and hamstring strength and absence of pain or buckling with sport-specific movements.

30.5 Outcomes of ACL Reconstruction

30.5.1 Functional Outcomes of ACL Reconstruction

Long-term results of ACL reconstruction have been investigated. At the 20-year follow-up, intact hamstring autografts in both adults and adolescents had favorable subjective outcome scores and return to play rate. However, ACL re-injury rates were significant, particularly in adolescents, with survival rates of 86% and 61% for adults and adolescents, respectively. Moreover, in final follow-up 17% of subjects had radiographic evidence of moderate to severe osteoarthritis based on IKDC radiological grade [47]. A longitudinal evaluation of patellar tendon autografts at mean 10.3 years found similar results, with favorable subjective outcomes, graft survival rates, and common progression of osteoarthritis [48]. A recent study comparing outcomes of hamstring and BTB reconstruction at mean 9 years corroborated the short-term findings, showing insignificant differences in laxity and graft failure. However, patellar tendon autografts were associated with increased rates of arthritis and pain with kneeling.

30.5.2 Repeat Tears of the ACL

A well-described and devastating outcome following successful ACL reconstruction and rehabilitation is an ACL re-tear. Incidence of ipsilateral graft tear in the reconstructed knee and tearing of the contralateral native ACL are comparable in the first 2 years after ACL reconstruction, occurring in approximately 3% of patients [49]. At 5 years, incidence of tears of the contralateral ACL is significantly higher than that of reconstructed ACLs, with rates of 11.8% and 5.8%, respectively [50]. Several risk factors for re-tear have been identified, including the use of an allograft (5.2× more likely to tear than autografts), younger age, and higher activity levels. There were no significant differences when considering sex, sport played, concurrent meniscus tears, or autograft type [51]. In addition to needing to repeat the significant time and effort in post-surgical rehabilitation, re-tears of the ACL are particularly devastating as they have been shown to have inferior outcomes to primary ACL reconstruction. In particular, patients with repeat ACL ruptures have lower activity levels following rehabilitation, higher incidence of cartilage injury in the medial and patellofemoral compartments of the ipsilateral knee, and higher rates of subsequent recurrent nontraumatic graft injury [52].

30.5.3 Return to Sport Following ACL Reconstruction

With a high number of athletes playing basketball and across all sports opting for ACL reconstruction, the time and success rate of returning to sport have been significantly investigated in recent years. A recent systematic review of ACL reconstruction outcomes analyzed 69 published reports on return rates across many different sports. The investigation found that 81% of athletes were able to return to sport, but only 65% returned to pre-injury level of play, and only 55% were able to return to competitive play [53]. A number of factors associated with favorable outcomes were identified, including younger age, male gender, and a positive psychological response after injury. Interestingly, ACL reconstruction with a hamstring tendon autograft was associated with higher rates of return to competitive sport, whereas repair with a patellar tendon autograft was associated with higher rates of return to pre-injury performance levels [53].

While rates of return to pre-injury sports performance following ACL injury and reconstruction in general have been low, rates among elite and professional athletes have been more favorable. A recent systematic review on return to sport outcomes in elite athletes found a pooled return to sport rate of 83% across several sports with a mean return to sports time ranging from 6 to 13 months [54]. Factors that were associated with higher return to sport rates at pre-injury level included measures suggestive of greater levels of skill and value to elite teams, such as earlier draft selection, a collegiate scholarship, and a higher depth chart position. One study found concomitant meniscus injury to shorten careers of hockey players undergoing ACL reconstruction, but otherwise, no concurrent injuries significantly affected return-to-sport rates across all sports. Similarly, one study found that elite athletes undergoing ACL reconstruction with autografts was associated with higher return to sport rates, but otherwise no investigations identified significant relationships between graft selection and return to sport rates [54].

The ability to return to sport specifically in elite basketball players after ACL tears and reconstruction has also been investigated. A recent case series and systematic review of professional basketball players undergoing ACL reconstruction found that 11 out of 12 players returned to their prior level of play. Of those in the NBA, eight out of nine returned to play at a mean 9.8 months, with average per game statistical decreases in points, minutes, rebounds, assists, steals, blocks, and turnovers, none of which reaching statistical significance. There was a significant decrease in player efficiency in the first season following reconstruction, but by the second season, performance metrics had all returned to pre-injury levels [55]. Similar findings (Table 30.1) have been identified in other investigations of professional players, with reported return-to-sport rates of 78–86% and similar declines in functional performance upon initial return to sport.

Table 30.1 Investigations comparing return-to-sport rates and performance after ACL reconstruction in elite basketball players

Author (year)	Number of patients	%RTS	Performance compared with pre-injury	Performance compared with control group
Nwachukwu et al. (2017)	12	92	Decrease in player efficiency rating in year 1, returning to pre-injury level in year 2. Insignificant decreases in multiple individual statistics	–
Mehran et al. (2016)	21	–	—	No significant difference
Kester et al. (2016)	79	86	—	Decreases in games started, games played, and player efficiency rating. Mean length of postoperative play is 1.86 years shorter after ACL reconstruction
Minhas et al. (2016)	65	85	Statistically significant decreases in games played for 3 years. Decrease in player efficiency rating at 1 year before returning to pre-injury level at 3 years	–
Harris et al. (2013)	58	86	Decreases in games played per season, points, rebounds, field goal percentage, All-Star selections	Decrease in games played
Namdari et al. (2011)	18	78	Decreases in steals per game and shooting percentage. Insignificant decreases in multiple other individual statistics	No significant difference
Busfield et al. (2009)	27	78	Decreases in player efficiency rating, games played, shooting percentage. Insignificant decreases in multiple other individual statistics	No significant difference

Fact Box: Outcomes

- Both hamstring and BTB autografts provide superior functional outcomes to allografts and should be utilized for young athletes seeking to RTP.
- ACL graft re-tear and contralateral ACL ruptures occur at low rates following ACL reconstruction, particularly in young and active patients.
- RTS rates vary, with more favorable outcomes and return to prior level of play in elite athletes as compared with recreational players.

30.6 Conclusion

ACL rupture remains a common and devastating injury in basketball players, nearly always requiring surgical intervention and lengthy rehabilitation before RTP. Diagnosis should be obtained clinically with a detailed history and physical examination and confirmed with radiographic studies prior to assessing management. Surgical reconstruction with either hamstring or BTB autografts should strongly be considered in any player wishing to return to basketball following an ACL rupture, along with immediate preoperative rehabilitation. Postoperative rehabilitation should follow performance-based progression in range of motion, strengthening, and neuromuscular exercises before initiating gradual return to basketball activity. The success of these interventions in returning players to basketball varies based upon both modifiable and non-modifiable factors, but generally these measures are successful in returning players to their prior level of play.

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