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The impact of anterior cruciate ligament rupture on athletes return to sport - A Literature review

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Abstract

Introduction

Anterior cruciate ligament (ACL) rupture is one of the most common and most burdensome injuries in sport, particularly in disciplines requiring rapid changes of direction, braking, and jumping. Despite advances in surgery and rehabilitation, return to sport (RTS) remains a complex process: ~80% of athletes resume activity, yet only ~50-65% regain their preinjury level of competition. Additional challenges include a high risk of reinjury and long-term sequelae, including early degenerative changes in the knee. Psychological factors also play a key role, especially fear of reinjury and decreased trust in the operated limb.

Materials and Methods

This narrative review was based on original studies, meta-analyses and systematic reviews, as well as cohort, clinical, and qualitative studies concerning:

the epidemiology and consequences of ACL injury

outcomes of surgical and nonoperative treatment

RTS rates and reinjury risk

functional/psychological criteria for return to sports (RTS) decisions

rehabilitation protocols and secondary prevention, and prognostic factors (age, sex, discipline, concomitant injuries)

Selection of publications was guided by high clinical usefulness and direct relevance to return to sport.

Summary

The findings indicate that ACL reconstruction does not guarantee better RTS rates than modern nonoperative rehabilitation; the differences are clinically small. Decisions about return should not be based solely on time but on objective criteria: symmetry of strength and hop-test results, stable dynamic control, and psychological readiness. A criterion-based rehabilitation program lasting at least 9 months reduces the risk of re-injury, and neuromuscular programs reduce secondary risk by ~40-50%. The high risk of reinjury among young athletes and frequent long-term degenerative changes underscore the need for a holistic approach combining sports medicine, physiotherapy, psychological support, and long-term prevention.

Keywords

ACL; anterior cruciate ligament; return to sport (RTS); ACL reconstruction; nonoperative management; neuromuscular rehabilitation; return criteria; fear of injury; young athletes; reinjury; secondary prevention; knee osteoarthritis.

1. Introduction

Anterior cruciate ligament (ACL) rupture is one of the most common and most burdensome injuries in sport [1]. This problem particularly concerns disciplines requiring sudden changes of running direction, braking, jumping, or rapid acceleration, such as soccer, basketball, handball, alpine skiing, or other high-intensity team sports [2]. The literature emphasizes that ACL injuries pose a significant threat to the continuation of a sports career and are also a risk factor for the development of early degenerative changes in the knee joint [3].

Despite advances in diagnostics, surgical treatment, and rehabilitation protocols, return to sport after ACL rupture remains a complex and multifactorial process. Statistics indicate that most athletes return to physical activity; however, only about half regain the ability to compete at their preinjury level. Moreover, reinjuries are a significant problem, both in the operated knee and in the contralateral limb [4].

Contemporary approaches to return to sport (RTS) emphasize not only the importance of surgical reconstruction and properly conducted rehabilitation, but also the role of psychological factors such as fear of reinjury, lack of self-confidence, or concerns about the future of one’s sports career [5]. Qualitative studies show that athletes ’experiences are often ambivalent - on the one hand, determination to return to the preferred discipline, and on the other, awareness of the risk of reinjury and health consequences.

For this reason, assessing the impact of ACL rupture on return to sport requires a multidimensional perspective that takes into account not only the outcomes of surgical and nonoperative treatment but also psychosocial aspects and athletes 'adaptive strategies [6].

2. Materials and Methods

This paper is a narrative review prepared on the basis of the available scientific literature concerning the impact of anterior cruciate ligament rupture on athletes 'return to activity. The analysis was limited exclusively to publications that included original studies, meta-analyses, systematic reviews, and qualitative and perspective articles.

The publications included in the analysis encompass various types of studies:

- systematic reviews and meta-analyses - concerning comparisons of outcomes of surgical and nonoperative treatment, RTS rates, and the risk of reinjury
- cohort and prospective studies - assessing the long-term consequences of ACL injury, including the development of degenerative changes and differences in prognosis depending on age, sex, and type of sport
- clinical studies - describing the effectiveness of specific rehabilitation protocols, functional tests, and decision criteria for return to sport
- qualitative studies - depicting athletes 'experiences during convalescence, their fears, motivating factors, and psychosocial aspects of returning to activity

The selection of materials for analysis was dictated by their clinical significance and the possibility of obtaining data concerning the main research problem, namely the impact of ACL rupture on athletes 'return to sport. The studies included focused both on biomechanical and medical aspects (surgical treatment, rehabilitation, functional criteria) and on psychosocial aspects (anxiety, motivation, therapeutic support).

Such a broad approach made it possible to compile a comprehensive picture of the phenomenon, encompassing epidemiology, treatment strategies, long-term outcomes, prevention of recurrences, and psychological and prognostic factors that influence the ability to return to sports activity after ACL injury.

3. Literature Review

3.1 Epidemiology and Consequences of ACL Injury

Anterior cruciate ligament rupture is one of the most common and most burdensome injuries in sport. Epidemiology indicates that in the general population the incidence is approximately 68-81 cases per 100,000 persons per year, whereas in athlete groups the rates are many times higher [7]. In soccer, ACL injuries occur at a rate of 0.23-0.32 per 1,000 hours of play, with the risk in female athletes even 2-3 times higher than in males. This phenomenon is explained by anatomical, biomechanical/neuromuscular, and hormonal differences [8].

The greatest threat concerns disciplines requiring rapid changes of direction, sudden stops, jumps, and landings - such as soccer, basketball, handball, or alpine skiing. Injuries occur both due to contact and non-contact mechanisms, the latter accounting for as many as 70% of all cases [9][10].

The most commonly described mechanism is knee rotation with a planted foot and simultaneous valgus of the joint [11]. A particularly exposed group comprises young athletes in their teens and under 20 years of age, in whom training loads and not yet fully developed neuro-muscular control increase susceptibility to injury [12].

The consequences of ACL damage have both short-term and long-term dimensions. Immediately after the injury there is pain, effusion, limited range of motion, and loss of functional stability of the knee, which makes it impossible to continue sports activity. Even after ligament reconstruction or intensive rehabilitation, a return to the preinjury level is uncertain - about 81% of athletes return to some sports activity, but only about 65% achieve their previous level, and 55% take up competition at the elite or professional level. In some studies, a full return was recorded in fewer than 60% of those examined [13][14][15].
Another important problem is the risk of reinjury, both in the operated knee and in the contralateral limb. It is estimated at 5-6% in the operated limb and 10-12% in the opposite limb, with young athletes (<20 years) reaching a reinjury rate of even 20-30% within the first two years after returning to play. Such high susceptibility in this group has led to increasing emphasis on delaying the decision to return and implementing extensive secondary prevention programs [16][17].

Long-term sequelae include the development of early degenerative changes in the knee joint. Observational studies have shown that within 10-20 years after injury, 20-50% of patients develop radiographic or clinical signs of osteoarthritis. The degenerative process results from joint instability, concomitant damage (menisci, cartilage), repetitive overloads, and disturbances of the movement axis after reconstruction. Symptoms such as pain, stiffness, reduced range of motion, and decreased functional capacity further lower quality of life and shorten a sports career [18].

Psychosocial aspects cannot be overlooked either. Qualitative studies show that, in addition to physical limitations, athletes often struggle with fear of reinjury, decreased self-confidence, and concerns about the future of their career. In many athletes, psychological factors become as serious a barrier to returning to sport as functional deficits. Fear and lack of trust in the knee lead to avoidance of full engagement in training, compensatory movement patterns, and decisions to withdraw from top-level sport [5][19][20].

3.2 Operative and Nonoperative Treatment

Outcome comparison

Treatment of anterior cruciate ligament rupture has traditionally been associated with surgical reconstruction. For many years, surgery was considered the gold standard in athletes, particularly those planning to return to disciplines requiring high knee stability. However, the results of recent meta-analyses and long-term studies indicate that the effectiveness of reconstruction compared with conservative treatment is not as clear-cut as previously thought. 1) After ACL reconstruction, 72-83% of athletes return to sport, 2) After conservative rehabilitation, 65-80% [21].

Although patients after reconstruction often achieve a minimally higher level of physical activity in the short term, this difference is clinically small. After accounting for study quality and excluding those at higher risk of bias, statistical differences between groups disappear [22][23].

Time to return

The average time to return after surgery is 9-12 months, with the possibility of earlier resumption of less demanding activities (e.g., cycling, swimming). In conservative treatment, the recovery time is more difficult to define - it depends on knee stability, the level of muscle strength, and neuromuscular control. In some athletes, particularly in disciplines less demanding in terms of rotational stability, a return is possible after just a few months of intensive rehabilitation [24].

Conservative rehabilitation

Conservative rehabilitation, carried out according to modern protocols, is based on progressive loading, proprioceptive exercises, neuromuscular training, and strengthening of muscles stabilizing the knee. In some groups of athletes, it enables an effective return to activity without the need for surgical reconstruction. At the same time, close clinical supervision and individualization of the process are emphasized - not every patient is an appropriate candidate for conservative treatment, and knee instability, concomitant damage, or the specifics of the sport practiced may argue for surgery [23].

Surgical reconstruction

On the other hand, ACL reconstruction is associated with its own risk of complications, such as reinjury, joint stiffness, or the development of degenerative changes in the longer term. Even in athletes who return to a high level of competition, the risk of further injury remains significant both in the operated limb and in the contralateral one [25].

Currently, it is emphasized that the choice between operative and nonoperative treatment should be based on an individual assessment - taking into account the athlete's goals, age, activity level, expectations, and psychological factors. The trend in contemporary practice is to move away from routinely treating reconstruction as the only proper solution and to promote a personalized approach in which rehabilitation plays a role equal to surgery [26].

3.3 Return-to-Sport (RTS) Rates after ACL Reconstruction

Return to sport after ACL reconstruction is the main objective of treatment among athletes; however, literature data indicate that achieving this goal is more difficult than commonly assumed. Despite advances in surgical techniques and rehabilitation protocols, full restoration to the preinjury level is achieved only by a portion of athletes.

Overall return rates

Meta-analyses and observational studies indicate that: 1) about 81% of athletes return to some sports activity after ACL reconstruction, 2) about 65% return to their preinjury level, 3) only 50-55% return to competition at the professional or elite level. This means that even with successful surgery and intensive rehabilitation, a significant proportion of athletes do not regain the sports level that would allow them to continue their careers in the same form [14][27][28].

Time to return and differences between disciplines

The average time to return to full sports activity is 9-12 months. In sports requiring high dynamics, such as soccer, basketball, or handball, this process is usually longer and carries a higher risk of reinjury. In disciplines that place less load on the knee joint, such as cycling or swimming, an earlier return is possible, often within 6-9 months. In practice, however, there is growing advice to move away from rigid time-based criteria and to base return decisions on functional testing and psychological assessment [29].

Risk of reinjury

Reinjuries remain a significant problem: 1) the risk of another rupture in the operated limb averages 5-6%, 2) in the contralateral limb - 10-12%, 3) in young athletes (<20 years), the rate of reinjury within two years of return to play reaches 20-30% [30].

The risk is particularly high in the first 24 months after return, highlighting the need to use preventive programs even after completing rehabilitation and obtaining clearance to play [16].

Factors limiting full return

Failure to fully return to sport results from a combination of factors:1) functional deficits - weakness of muscle strength, proprioceptive disorders, persistent inter-limb asymmetries, 2) psychological factors - fear of reinjury, lack of trust in the knee, decreased self-confidence, 3) recurring pain or joint effusion, 4) concomitant injuries - e.g., meniscal damage, which worsens prognosis and increases the risk of early degenerative changes [31].

Long-term consequences

In the long term, ACL reconstruction does not eliminate the risk of degenerative changes. Studies show that 20-50% of patients develop radiographic or clinical features of osteoarthritis 10-20 years after injury, regardless of whether they returned to sport. Osteoarthritis limits range of motion, causes pain and stiffness, and consequently decreases the ability to engage in high-intensity sports activity [25][31].

3.4 Criteria and Decision Frameworks for Return to Sport

The decision to return to sport after reconstruction or conservative treatment of the anterior cruciate ligament is one of the most complex stages of the therapeutic process. Traditionally it was based mainly on time, with arbitrary values of 6-9 months from injury or surgery as a reference point. The latest studies show, however, that time alone is insufficient and carries a high risk of reinjury. Increasingly, the importance of objective criteria is emphasized, encompassing physical, functional, and psychological parameters [24].

Functional and biomechanical criteria

Contemporary protocols indicate that return to sport should be based on a qualitative and quantitative assessment of limb function. The most commonly used indicators include: 1) Strength symmetry - a recommended threshold of ≥90% of quadriceps and hamstrings strength in the operated limb compared with the healthy limb, assessed by isokinetic tests; 2) Hop tests - including single-leg hop for distance, triple hop, crossover hop, and timed hop. A result of

≥90% symmetry is considered the minimum criterion for return; 3) Dynamic control - a proper movement pattern, no compensatory knee positions (e.g., dynamic valgus), and stability of the trunk and pelvis under load; 4) Absence of clinical symptoms - such as pain, effusion, or limitation of range of motion.

Meeting these criteria significantly reduces the risk of reinjury. Studies have shown that athletes who did not reach the symmetry thresholds had up to a 2.5-fold higher risk of reinjury compared with those who met the criteria [32][33].

Psychological criteria

Return to sport depends not only on physical condition but also on psychological readiness. A tool commonly used to assess this aspect is the ACL-RSI (Return to Sport after Injury Scale). A score below 60 points is strongly correlated with a lower likelihood of returning to the preinjury level and a higher risk of withdrawing from a sports career [34][35].

Psychological barriers such as fear of reinjury or lack of trust in the knee can lead to compensatory movement patterns and avoidance of full engagement in competition. For this reason, assessing psychological readiness has become as important as functional tests [32].

Decision frameworks and activity progression

Modern decision frameworks integrate different dimensions of athlete assessment - biomechanical, clinical, and psychological - to minimize the risk of reinjury. Key elements include: 1) Staged return - from “return to participation” (resumption of lower-intensity training), through “return to sport” (full training and scrimmages), to “return to performance” (competition at the preinjury level). 2) Gradual increase in loads - from low-intensity exercises to sport-specific high-risk maneuvers, such as sudden changes of direction or physical contact. 3) Integrated teamwork - the decision should be made jointly by the orthopedist, physiotherapist, strength and conditioning coach, and sports psychologist. This approach increases the safety and effectiveness of return [36].

Importance of composite criteria

It is increasingly emphasized that the ≥90% symmetry threshold should not be treated as the sole condition for return[33]. Studies have shown that athletes who met only strength criteria but had low psychological readiness showed reduced return rates and a higher risk of reinjury. Therefore, the decision should be based on a combination of multiple indicators rather than single tests [32].

3.5 Psychological Factors and Athletes’ Experiences

Returning to sport after anterior cruciate ligament rupture is a process in which psychological factors are as important as physical ones. Even in athletes who meet functional criteria, psychological barriers can hinder a return to the previous level of competition.

Fear of reinjury

One of the most frequently cited limitations is fear of a repeat ligament rupture. Studies indicate that most of athletes identify it as the main obstacle to returning to competition, even though objective strength and stability tests indicate full readiness. Fear of another injury leads to:

avoidance of match situations requiring maximal intensity, compensatory movement patterns, reduced engagement in training, in some cases, complete withdrawal from a sports career [32].

Lack of trust in the operated knee

Another important factor is lack of full trust in the operated limb. In one study, athletes who rated their knee as "unstable" had a 3-fold lower chance of returning to sport at their previous level. The subjective sense of instability can be stronger than the results of objective tests and affects the way of moving and the willingness to perform high-risk movements [32].

Psychological scales and assessment tools

In clinical practice, tools such as the ACL-RSI (Return to Sport after Injury Scale) are used to assess psychological readiness. A score below 60 points strongly correlates with a lower probability of returning to the previous level of sport. The scale assesses, among other things, self-confidence, motivation, and fear of reinjury [34].

Athletes 'experiences

Qualitative studies show that the rehabilitation process after ACL injury is a source of ambivalent emotions for athletes. On the one hand, determination and longing for competition dominate; on the other - frustration due to slow progress, a sense of lack of control over the process, and concerns about the future of the career [6].

In studies conducted among Swiss athletes, more than 70% indicated that the most important factors for them were: gradual increase in loads, lack of pressure for a quick return, regular support from physiotherapists and psychologists, the use of preventive exercises [6].

Athletes also emphasized the importance of social support from family, coaches, and the medical team. The presence of people who motivated and helped in difficult moments of rehabilitation reduced anxiety and strengthened the sense of agency [6].

3.6 Rehabilitation and Prevention of Reinjury

Rehabilitation after anterior cruciate ligament rupture is a complex, multi-stage, and long-term process. Its goal is not only to restore the functionality of the knee joint but also to reduce the risk of reinjury. The literature emphasizes that the effectiveness of treatment depends to a large extent not on reconstruction itself but on the quality and duration of the rehabilitation program.

Rehabilitation stages

Contemporary rehabilitation protocols include several main phases: 1) Early phase - reduction of pain and swelling, restoration of full extension, activation of the quadriceps muscle, learning proper gait; 2) Strength-control phase - strengthening the quadriceps and knee flexors, core stabilization exercises, improvement of proprioception and neuromuscular contro; 3) Plyometric and running phase - introduction of jumps, accelerations, decelerations, changes of direction, and sport-specific exercises; 4) Return-to-sport phase - integration of technical and tactical elements, progression of intensity, exposure to match situations and physical contact [37].

Importance of rehabilitation duration

Studies have shown that athletes who return to play before 9 months after surgery have as much as a 51% higher risk of reinjury compared with those who adhere to a longer program. For this reason, it is recommended that return to sport occur only after meeting functional and psychological criteria, not merely after a specified time from surgery [38].

Risk of reinjury

The first two years after return to sport are a critical period. In this phase, the reinjury rate in young athletes (<20 years) reaches 20-30%. The risk concerns both the operated knee and the contralateral limb, which is exposed to compensatory overload. Therefore, it is recommended that rehabilitation and preventive programs be continued even after the formal return to competition [16].

Secondary prevention programs

In secondary prevention, neuromuscular programs - such as FIFA 11+ used in soccer - are gaining importance and can reduce the risk of another injury by even 40-50%. These programs include strengthening, stabilization, coordination, and plyometric exercises aimed at improving control of movement dynamics and reducing unfavorable patterns such as dynamic knee valgus during landing [39].

Psychological support in rehabilitation

An equally important element is consideration of psychological factors. Fear of reinjury or lack of trust in the knee can hinder implementation of the rehabilitation program, limit engagement in exercises, and contribute to recurrence of injury. Involving a sports psychologist, educating the patient, and gradual exposure to high-risk situations allow the rebuilding of self-confidence and reduction of psychological barriers [40].

3.7 Individual Differences and Prognostic Factors

Return to sport after anterior cruciate ligament injury is not a uniform process. The literature clearly emphasizes that treatment outcomes and reinjury risk depend on many individual biological, psychological, and environmental factors. Considering these variables is crucial when planning treatment and rehabilitation programs.

Age

Age is one of the most important predictors of risk. In young athletes (<20 years), the rate of reinjury within the first two years after return to play is 20-30%, which constitutes the highest-risk group. This stems from a high level of activity, neuromuscular immaturity, and pressure for a rapid return. In athletes over 25 years of age, the risk of recurrence drops to below 10%, but in this group there is more frequent withdrawal from competition at the highest level due to concern for long-term health and fear of accelerated development of degenerative changes [4].

Sex

Studies indicate that women are particularly exposed to ACL injuries - the risk is about twice

as high as in men. The causes include differences in anatomical structure (greater Q angle, narrower intercondylar notch), different patterns of muscle activation (weaker engagement of knee flexors, greater load on the quadriceps), and the influence of hormones on ligament laxity. Women also show a higher frequency of returning at a lower sports level due to persistent fear of reinjury [41].

Type of discipline

The risk of reinjury depends on the characteristics of the discipline. The most exposed are athletes involved in team and contact sports such as soccer, basketball, and handball, where sudden changes of direction, landings after jumps, and physical contact predominate. In these groups, recurrences are more frequent and occur sooner after return. In endurance sports such as cycling or long-distance running, the load on the knee joint is lower, which reduces the risk of re-injury and allows a quicker return [29].

Sporting level and experience

Professional athletes return to sport more often than amateurs, which results from access to better medical facilities, individualized care, and motivation related to career. However, the intensity of training and match loads means that despite effective rehabilitation, their risk of recurrence remains high. In amateur athletes, the problem more often is lack of systematic rehabilitation, limited motivation, and lack of specialist support, which leads to resignation from a full return to competition [42].

Psychological and social factors

Mental state plays a role as significant as biological factors. Athletes with a high level of fear of reinjury have lower return-to-sport rates compared with those who report self-confidence and a sense of control over the process. Lack of social support from family, coaches, or physiotherapists further hinders return and increases the risk of leaving the sport. Conversely, well-organized psychological support and systematic education increase the chances of returning to the previous level of competition [43].

Concomitant injuries

The presence of coexisting damage, such as meniscal or articular cartilage injuries, significantly worsens prognosis. Studies show that in patients with meniscal injuries, the risk of developing degenerative changes within 10 years is as high as 50%, compared to 20-30% in cases of isolated ACL injury. Additional lesions prolong rehabilitation, increase the risk of recurrence, and limit the long-term ability to continue a sports career [18].

4. Summary

Anterior cruciate ligament rupture is one of the most serious injuries in sport and has a multidimensional impact on athletes ’further activity. The collected research findings indicate that return to sport after this type of injury is a complex process, dependent on medical as well as psychological and social factors.

Comparative analyses and meta-analyses show that surgical ACL reconstruction does not unequivocally guarantee better outcomes than intensive conservative rehabilitation. Although

in the short term post-operative patients may achieve a minimally higher level of activity, these differences turn out to be small and often clinically insignificant. This means that the decision on the treatment method should be individualized and based on the specifics of the discipline, the athlete's expectations, and their readiness to adhere to rehabilitation protocols.
RTS rates remain lower than commonly assumed - about 80% of athletes return to physical activity, but only 50-65% regain their preinjury level of competition. Reinjuries are a significant problem in both the operated knee and the contralateral limb. The risk of another injury is particularly high in young athletes who return to disciplines requiring high movement dynamics.

In the long term, ACL injury is also associated with the development of degenerative changes in the knee joint, affecting 20-50% of athletes within 10-20 years after injury, regardless of the treatment method used. This poses a serious threat to quality of life and the possibility of engaging in sports activity in later years.

Increasing attention is paid to psychosocial factors. Fear of reinjury, lack of trust in the operated knee, and reduced self-confidence are the main reasons for not returning to high-level competition, even in athletes who meet objective functional criteria. In this context, the importance of psychological support, education, and strategies that increase the sense of control over the rehabilitation process is growing.

Another important element of return is secondary prevention - using neuromuscular and strengthening programs, monitoring loads, and educating about safely increasing training intensity. Such measures help limit the risk of reinjury, especially in the first years after returning to sport.

In summary, return to sport after ACL rupture requires a holistic approach that combines elements of surgical or conservative treatment, advanced rehabilitation, functional and psychological criteria, and long-term prevention. Only such a comprehensive approach gives a chance for a durable, safe, and satisfying return of the athlete to the previous level of competition.

Disclosure

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