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Skuteczność protokołu rehabilitacyjnego po rekonstrukcji więzadła krzyżowego przedniego w powrocie do rytmu meczowego: studium przypadku zawodowego piłkarza nożnego

Effectiveness of a rehabilitation protocol after anterior cruciate ligament reconstruction in returning to match rhythm: a case study of a professional soccer player

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Summary

This case study presents the rehabilitation process of professional soccer player M.L. after surgical reconstruction of the anterior cruciate ligament (ACL) using the BTB method. Rehabilitation, lasting 3.5 months, enabled a quick return to the game. The course of treatment was based on an intensive rehabilitation protocol without the use of an orthosis, with early weight-bearing of the limb and focusing on rebuilding strength, stability and proprioception. Evaluation of the effectiveness of rehabilitation was carried out using functional tests and questionnaires KOOS, Kujala, SF-36.

Keywords: anterior cruciate ligament reconstruction, physiotherapy, sports, rehabilitation programs.

Entry

Anterior cruciate ligament (ACL) injuries are a prevalent issue in sports, with over 200,000 ACL injuries occurring annually in the United States alone (Willems et al., 2023). These injuries not only affect an athlete's immediate ability to participate in sports but also

pose long-term risks such as the development of knee osteoarthritis (Costa et al., 2022). In the realm of professional sports, ACL injuries can have far-reaching consequences, impacting contracts, sponsorships, and revenue-generating potential (Toale et al., 2021). Despite the relatively high success rate of return to sport after ACL reconstruction in professional athletes, research indicates that only a few manage to return to sport at the same level of performance they had prior to the injury (Zampogna et al., 2021).

Studies have shown that ACL tears are among the most common orthopedic injuries, with a significant injury burden in the sporting population (Iio et al., 2021). The impact of ACL injuries on athletes is substantial, with a high prevalence among both amateur and elite athletes (Piskin et al., 2021). Furthermore, ACL ruptures are relatively common knee injuries among athletes and can significantly impede an athlete's ability to engage in their desired activities (Boots, 2023). It is noteworthy that ACL injuries are not limited to professional athletes but also affect young student athletes, emphasizing the broad impact of these injuries across different levels of sports participation (Zink, 2024).

Return to sport after ACL reconstruction is a critical milestone for athletes, with many undergoing ACL reconstruction surgery with the expectation of returning to their pre-injury levels of function (Willems et al., 2023). However, research indicates that the majority of athletes fail to return to play following ACL reconstruction, often due to reasons beyond just the operated knee (Presley et al., 2021). This highlights the multifaceted challenges that athletes face in their journey back to sport post-injury. Additionally, the psychological readiness of patients who return to sport after primary ACL reconstruction has been found to be significantly higher, underscoring the importance of mental preparedness in the return-to-sport process (Xiao et al., 2022).

In the context of ACL reconstruction, minimizing the risk of graft failure is crucial for successful outcomes in athletes (Costa et al., 2022). Graft failures after ACL reconstruction can affect up to 10% of athletes, particularly those who are younger than 25 years old and continue participating in pivoting sports (Melick et al., 2021). Therefore, considerations such as graft diameter play a role in determining the safety and efficacy of ACL reconstruction in athletes, especially in those who aim to return to pivoting sports post-surgery (Melick et al., 2021).

Rehabilitation plays a vital role in the return-to-sport process after ACL reconstruction, with neurocognitive and neurophysiological functions being key aspects to consider in rehabilitation and return-to-sport tests (Willems et al., 2023). Additionally, factors such as strength, sport exposure, and movement quality are known to influence psychological readiness after ACL reconstruction, highlighting the multidimensional nature of the return-to-sport journey for athletes (Muller et al., 2021). Psychological readiness, self-efficacy, and fear of re-injury have been identified as critical factors affecting an athlete's ability to return to sport after ACL reconstruction.

In the rehabilitation phase post-ACL reconstruction, meeting specific movement criteria has been associated with a reduced rate of second ACL injuries, emphasizing the importance of achieving both quantitative and qualitative return-to-sport criteria. Furthermore, return to play after ACL reconstruction is influenced by various factors, including strength, sport exposure, and psychological readiness, all of which contribute to the athlete's successful return to sport.

ACL injuries present significant challenges for athletes across different levels of sports participation. Return to sport after ACL reconstruction is a complex process influenced by various physical, psychological, and biomechanical factors. Understanding these factors and implementing comprehensive rehabilitation strategies are essential in optimizing outcomes and facilitating successful return to sport for athletes post-ACL injury.

ACL injuries in professional sports can have significant implications, affecting not only the athletes' contracts and sponsorships but also their revenue-generating potential. While the success rate of returning to sport after ACL reconstruction in professional athletes is relatively high, research indicates that only a few manage to return to the same level of performance they had prior to the injury (King et al., 2021). Furthermore, athletes who undergo ACL reconstruction often experience shorter careers compared to those who do not sustain such injuries (Mancino, 2024). The variability in ACL injury management, encompassing aspects such as rehabilitation protocols, graft selection, portal drilling techniques, and reconstruction methods, may elucidate the differences in outcomes observed among athletes (Ferreira et al., 2022). Recent advancements in anatomical and individualized ACL reconstruction techniques have shown promising results, but further extensive studies with long-term follow-ups are imperative to comprehensively grasp the outcomes of modern ACL reconstruction methods (Piussi, 2024).

Female athletes, in particular, face a significantly higher risk of ACL injuries compared to their male counterparts, with incidences reported to be up to eight times more frequent (Mancino, 2024). Despite the extensive research conducted on ACL injuries, the rates of such injuries among professional athletes have not shown a decline over the past few decades, irrespective of whether they participate in contact or non-contact sports (Mazza et al., 2022). This disparity in injury rates emphasizes the need for a deeper understanding of the factors contributing to ACL injuries and the subsequent management strategies to enhance outcomes for athletes.

Studies have shown that ACL injuries are prevalent among young athletes engaged in sports involving frequent cutting, pivoting, jumping, or landing (Ithurburn et al., 2021). The psychological impact of ACL injuries on athletes is also noteworthy, with reports indicating that athletes prioritize physical and mental health, performance excellence, and career longevity during the recovery process (Borman, 2024). Additionally, the presence of symptoms of depression and anxiety following an ACL injury has been associated with poorer self-reported knee function, underscoring the importance of addressing the psychological aspects of recovery (Piussi et al., 2022).

The choice of graft for ACL reconstruction plays a crucial role in the success of the procedure, with no definitive consensus on the optimal graft choice for athletes undergoing ACL reconstruction (Sim et al., 2022). Graft failure after primary ACL reconstruction poses a significant challenge for both patients and orthopedic surgeons, highlighting the importance of meticulous graft selection to minimize the risk of failure (Marx et al., 2021). Furthermore, the presence of concomitant full-thickness cartilage lesions at the time of ACL reconstruction has been identified as a risk factor for inferior long-term outcomes, necessitating comprehensive preoperative assessments to address associated issues (Wang et al., 2021).

Return to play after ACL reconstruction is a critical milestone for athletes, with factors such as sleep quality and psychological well-being being associated with meeting discharge criteria to resume sports activities post-surgery (Khalladi et al., 2021). Athletes with ACL

injuries aspire to return to sport, emphasizing the need for tailored rehabilitation programs and support systems to facilitate their successful reintegration into competitive sports (Arderm et al., 2022). Additionally, the performance of professional athletes, as evaluated through metrics like fantasy points, tends to decrease following ACL reconstruction, indicating the challenges athletes face in regaining their pre-injury level of performance (Kajy et al., 2023).

ACL injuries in professional sports have far-reaching consequences, impacting athletes' careers, contracts, and overall performance. While ACL reconstruction offers a pathway for athletes to return to sport, the nuances in injury management, rehabilitation protocols, and graft selection significantly influence the outcomes. Addressing the psychological aspects of recovery, optimizing graft selection, and implementing tailored rehabilitation programs are crucial steps in enhancing the success of ACL reconstruction and promoting athletes' long-term performance and well-being.

The anterior cruciate ligament (ACL) is a vital structure in the knee joint, responsible for stabilizing the knee during various movements and protecting it from excessive extension and rotation. ACL tears are a common occurrence, with a significant number of cases reported annually in the United States alone, affecting both professional athletes and individuals engaged in recreational sports. These injuries can result from a variety of activities, including non-contact maneuvers like changing direction, decelerating, or landing after a jump, with about 70% of ACL injuries being non-contact in nature. Women athletes are particularly susceptible to ACL injuries compared to men, depending on the specific sport they participate in (Chia et al., 2022).

When it comes to diagnosing ACL injuries, certain signs and symptoms are indicative of such an injury, including a distinct "pop" sound at the time of injury, rapid swelling of the knee joint, and the inability to continue physical activities due to pain and instability. Diagnostic procedures such as the Lachman test and MRI imaging are commonly employed to confirm the diagnosis of an ACL injury and to rule out other potential issues within the knee joint (Chia et al., 2022).

ACL injuries not only impact an individual's immediate ability to participate in sports but also have long-term implications for the function and health of the knee joint. Damage to the ACL can lead to instability, reduced functionality, and an increased risk of developing osteoarthritis in the affected knee over time (Ceccarelli, 2023). Therefore, understanding the mechanisms and risk factors associated with ACL injuries is crucial in developing effective prevention strategies and rehabilitation protocols to mitigate the impact of these injuries on athletes and individuals alike.

Research has shown that there are distinct patterns of ACL injury occurrence, especially in sports like women's professional football (soccer). A systematic video analysis of match injuries revealed that a majority of field player injuries occurred during specific movements such as sprinting, change-of-direction maneuvers, stopping, and lunging. This highlights the importance of understanding the biomechanics and circumstances surrounding ACL injuries to tailor injury prevention programs effectively (Achenbach, 2024).

The use of blood flow restriction in strengthening the ischiocrural muscles as part of ACL rehabilitation has shown promise in improving knee stability by limiting the anterior translation of the tibia. Strengthening the hamstring muscles, which play a significant role in

knee stability, can contribute to better outcomes in ACL rehabilitation and potentially reduce the risk of re-injury (Ceccarelli, 2023).

In the context of ACL reconstruction, the choice of graft type is a critical decision that can influence the outcomes of the surgery and subsequent rehabilitation. Studies have investigated different graft options, such as bone-tendon-bone (BTB) autografts, hamstring autografts, quadriceps tendon autografts, and other alternatives like hamstring allografts. Understanding the implications of graft selection on functional outcomes and the risk of reinjury is essential in optimizing the surgical management of ACL tears (Maheshwer, 2023).

The epidemiology of ACL tears in various athletic populations, including collegiate athletes and professional sports leagues like the National Football League (NFL) and the Women's National Basketball Association (WNBA), provides valuable insights into the prevalence, mechanisms, and outcomes of ACL injuries in high-level sports. Descriptive epidemiological studies have shed light on the incidence rates, risk factors, and implications of ACL tears in different athletic cohorts, contributing to the development of targeted injury prevention and management strategies (Palmieri-Smith et al., 2021; Axelrod et al., 2022).

ACL injuries represent a significant challenge in sports medicine, affecting a large number of individuals each year and posing risks to both short-term athletic performance and long-term joint health. By delving into the epidemiology, risk factors, biomechanics, and rehabilitation strategies associated with ACL injuries, researchers and healthcare professionals can work towards enhancing prevention efforts, optimizing treatment protocols, and improving outcomes for individuals affected by ACL tears.

ACL injuries are a common occurrence in sports that involve sudden changes in direction, jumping, or landing, with athletes in football, basketball, skiing, and gymnastics being particularly vulnerable (King et al., 2021). Research indicates that female athletes face a higher risk of ACL injuries compared to males, which is attributed to anatomical differences, forces on joints, and potentially variations in training methods (Liu et al., 2022). Studies have shown that ACL injuries can result from both contact and non-contact mechanisms, with non-contact injuries being more prevalent among female athletes (Larwa et al., 2021). Intrinsic factors such as increased quadriceps angle and posterior tibial slope have been identified as potential contributors to ACL injuries (Devana et al., 2021).

High levels of personal and sport-related stress have been linked to an increased risk of ACL injury, possibly due to alterations in attention, coordination, and heightened muscular tension, which can impede the return to sports post-injury (Mancino, 2024). Additionally, the presence of concomitant meniscal tears in pediatric patients with ACL injuries has been found to increase with age and body mass index, highlighting the complexity and multifactorial nature of ACL injuries (Perkins et al., 2021). Furthermore, studies have shown that adolescent athletes, particularly in high school, are at risk of ACL injuries, with factors such as age, participating sport, and injury mechanism playing significant roles in the epidemiology of ACL tears (Maheshwer, 2023).

In both male and female athletes, several risk factors have been associated with ACL injuries, including body weight, anterior tibial displacement relative to the femur, genu recurvatum, and generalized joint laxity (Beynon et al., 2022). Psychological factors have also been implicated in ACL injury risk, with athletes exhibiting greater kinesiphobia, lower confidence, and reduced psychological readiness being at higher risk of sustaining a second

ACL injury after primary ACL reconstruction (Zarzycki et al., 2023). Additionally, the type of sport can influence the likelihood of ACL injuries, with soccer players having a reinjury rate of 15% after ACL reconstruction, emphasizing the importance of sport-specific considerations in injury prevention and management (Hong et al., 2023).

Biomechanical studies have highlighted the impact of poor landing biomechanics, such as hip adduction, internal rotation, and knee valgus, as modifiable risk factors for ACL injuries (Wu et al., 2022). Furthermore, differences in short-term sport-specific functional recovery after primary ACL reconstruction have been observed in adolescent athletes, underscoring the need for tailored rehabilitation protocols based on individual characteristics and sporting demands (Kemper et al., 2023). The influence of footwear on ACL forces during landing has also been investigated, with shod participants generating lower ACL forces compared to barefoot individuals, suggesting a potential role of footwear in injury prevention strategies (Akhundov et al., 2022).

Anatomical, biomechanical, neuromuscular, and hormonal factors have been identified as playing roles in ACL injury risk, although the specific mechanisms and relative contributions of these factors remain areas of ongoing research (Liu et al., 2022). Notably, deficits in neuromuscular control of the trunk have been proposed as contributing to greater ACL risk by compromising dynamic knee stability, highlighting the interconnectedness of various physiological factors in injury susceptibility (Lutz et al., 2021). Additionally, the width of the femoral notch and ACL volume have been identified as risk factors for ACL injuries, with narrow notches and low ACL volumes predisposing individuals to a higher risk of ACL injury (Gupta et al., 2021).

ACL injuries are complex and multifaceted, influenced by a combination of intrinsic and extrinsic factors, biomechanical considerations, psychological aspects, and sport-specific demands. Understanding the interplay of these factors is crucial in developing effective injury prevention strategies, rehabilitation protocols, and return-to-sport criteria to mitigate the risk of ACL injuries and improve outcomes for athletes across various sports disciplines.

Methods

The surgical procedure for anterior cruciate ligament (ACL) reconstruction using the Bone-Tendon-Bone (BTB) method is a well-established technique that involves the use of a bone-tendon graft to restore knee stability (Musahl et al., 2021). This method has become a preferred choice due to its ability to reconstruct the natural function of the ligament and restore joint stability (Musahl et al., 2021). Diagnosis of ACL injuries typically involves manual testing and MRI imaging, which are crucial for accurate assessment and treatment planning (Ellison et al., 2021; Beynnon et al., 2022).

Effective post-operative rehabilitation following ACL reconstruction is essential for athletes to regain full fitness and functionality. Rehabilitation programs need to focus not only on restoring range of motion and muscle strength but also on retraining movement patterns to minimize the risk of re-injury (Szymiski et al., 2021). These programs should be tailored to the specific needs and goals of each athlete, considering factors such as the type of injury, surgical technique used, and the expected level of sports activity post-recovery (Szymiski et al., 2021).

In addition to rehabilitation, preventive strategies play a vital role in reducing the risk of ACL injuries. These programs typically emphasize strengthening the muscles around the knee,

improving flexibility, and teaching safe landing and change of direction techniques to athletes (Achenbach, 2024). By addressing these aspects, the aim is to lower the incidence of ACL injuries and promote long-term joint health.

Despite advancements in ACL reconstruction and rehabilitation, research suggests that only a small percentage of athletes are able to return to their pre-injury performance levels (DEWIG, 2023). Long-term consequences such as osteoarthritis are also significant considerations when planning the treatment and rehabilitation of athletes post-ACL injury (DEWIG, 2023). These findings underscore the importance of comprehensive care and ongoing support for athletes undergoing ACL reconstruction.

Studies have shown that female athletes are at a higher risk of ACL injuries compared to their male counterparts (Parsons et al., 2021; Ellison et al., 2021; (Parsons et al., 2021; . highlight that girls and women are 3–6 times more likely to experience ACL injuries than boys and men, emphasizing the need for gender-specific approaches to injury prevention and management (Parsons et al., 2021). Understanding the intrinsic risk factors for ACL injuries is crucial for identifying individuals at higher risk and developing interventions to mitigate these risks (Beynon et al., 2022).

In the context of ACL injury prevention, it is essential to consider modifiable risk factors that can be addressed through targeted interventions. Biomechanical and neuromuscular factors have been identified as key contributors to ACL injury risk, particularly in adolescent female elite athletes (Zebis et al., 2021). By focusing on these modifiable factors, such as trunk strength, endurance, and dynamic control, preventive strategies can be tailored to reduce the incidence of ACL injuries in high-risk populations (Zebis et al., 2021).

The role of psychological readiness in ACL injury prevention and rehabilitation has been highlighted in recent research (Zarzycki et al., 2023). Female athletes with better psychological readiness have been found to be at a higher risk of sustaining a second ACL injury after primary reconstruction, indicating the importance of addressing psychological factors in addition to physical rehabilitation (Zarzycki et al., 2023). This underscores the need for a holistic approach to ACL injury management that considers both physical and psychological aspects of recovery.

The Bone-Tendon-Bone (BTB) method for ACL reconstruction, coupled with tailored rehabilitation programs and preventive strategies, plays a crucial role in restoring knee stability and function post-injury. Understanding the gender-specific differences in ACL injury risk, addressing modifiable risk factors, and considering psychological readiness are key components of comprehensive ACL injury management. By integrating these approaches, healthcare professionals can optimize outcomes for athletes undergoing ACL reconstruction and enhance long-term joint health and performance.

Results

Diagnostic Methods

The diagnosis of an ACL injury relies on a combination of physical examination and imaging tests. Physical tests like the Lachman test, Pivot Shift test, and anterior drawer test are crucial in assessing knee stability and providing initial indications of potential ACL damage (Allott et al., 2022). These tests, which evaluate the anterior and rotary stability of the

knee, are essential in the clinical assessment of acute ACL injuries (Allott et al., 2022). Research has shown that the sensitivity and specificity of physical examinations in diagnosing ACL injuries are around 81.3% and 90.6%, respectively (Dietvorst et al., 2022). However, while physical tests are valuable, they are often complemented by imaging studies for confirmation and detailed assessment of associated damage to knee structures (Liu et al., 2022).

Magnetic resonance imaging (MRI) plays a pivotal role in confirming the diagnosis of ACL injuries and evaluating the extent of damage to knee structures (Liu et al., 2022). Studies have highlighted the importance of MRI in diagnosing and classifying ACL tears accurately. Utilizing oblique coronal and oblique sagittal MRI sequences parallel to the long axis of the ACL has been shown to enhance the accuracy of diagnosing ACL tears and grading ACL injuries (Li et al., 2021). Additionally, deep learning-based MRI image features have been explored for the diagnosis of ACL injuries, showcasing the significance of advanced imaging techniques in this context (Espinosa-Leal & Rodriguez-Alanis, 2023). MRI not only aids in confirming ACL injuries but also helps in identifying associated injuries such as meniscal tears, which are common in cases of ACL injury (Yang et al., 2023).

In the realm of technological advancements, wearable displacement sensing systems have been developed to enhance the clinical diagnosis of ACL tears. These systems offer high precision in measuring knee joint displacements, contributing to more accurate and timely diagnoses of ACL injuries, which are crucial for preventing joint instability and irreversible damage (Kokkotis et al., 2022). Furthermore, leveraging explainable machine learning and gait biomechanical parameters has shown promise in identifying factors associated with ACL injuries, emphasizing the role of technology in improving diagnostic capabilities in this field (Edmonds, 2023).

Studies have also delved into the psychological impact of ACL injuries, noting that patients who sustain such injuries may experience symptoms of depression, particularly in the initial weeks following ACL reconstruction (Piussi et al., 2022). This holistic approach to understanding ACL injuries encompasses not only the physical aspects but also the mental health implications that can arise from such traumatic events. Moreover, the potential long-term consequences of ACL injuries, such as the risk of osteoarthritis due to associated meniscal tears, underscore the importance of accurate and timely diagnosis to guide appropriate treatment strategies.

The diagnosis of ACL injuries is a multifaceted process that involves a combination of physical examination techniques and advanced imaging modalities like MRI. While physical tests provide valuable initial insights into knee stability and potential ACL damage, MRI plays a crucial role in confirming diagnoses and assessing associated structural damage. Technological advancements, such as wearable sensing systems and machine learning algorithms, are enhancing diagnostic capabilities in the field of ACL injuries. Understanding the psychological impact and long-term implications of ACL injuries further emphasizes the significance of accurate and timely diagnosis for optimal patient outcomes.

Rehabilitation Protocol

Rehabilitation after ACL reconstruction is a multifaceted process that involves various stages focusing on reducing swelling, restoring range of motion, and strengthening muscles before progressing to sport-specific exercises (Xiao et al., 2022). Meeting presurgical milestones is linked to better long-term outcomes (Brinlee et al., 2021). Psychological factors

like confidence, self-efficacy, and motivation play a significant role in an athlete's ability to return to sport after ACL reconstruction (Kvist & Ardern, 2022). Individualized rehabilitation protocols are crucial to address specific athlete needs and goals (Xiao et al., 2022). Symmetrical muscle function is highlighted as a protective factor against a second ACL injury (Thorolfsson, 2023). The decision on graft choice, such as quadriceps tendon autograft, can impact the return to pivoting sports (Goto et al., 2022).

Methods of Evaluation of Rehabilitation Effects

Assessment of rehabilitation effects involves functional tests like the Lachman, Pivot Shift, and anterior drawer test for knee stability, along with questionnaires such as KOOS, Kujala, and SF-36 to evaluate general health and quality of life impact (He, 2023; Sengchuai et al., 2022). Follow-up MRI studies are crucial for monitoring healing and graft integrity (Filbay et al., 2022; El-Shelik et al., 2022; Xie et al., 2021). Novel technologies like internet-based programs (Talaa, 2023), wearable devices for knee joint assessment (Sengchuai et al., 2022), and gait rehabilitation scoring systems Shu et al. (2022) are enhancing rehabilitation outcomes. Additionally, early systematic rehabilitation training can reduce pain and swelling, improving knee function post-operation (Logerstedt et al., 2021). Understanding tissue healing constraints, biomechanics, and neuromuscular physiology is vital for effective rehabilitation (Salim & Zawawi, 2022). Integrating wearable sensors into knee braces can aid in continuous monitoring and improving stability (Büttner et al., 2021).

Rehabilitation protocols:

The presented data show the detailed course of rehabilitation of a professional football player after anterior cruciate ligament reconstruction. This process was divided into several stages, from before the surgery to full return to play, which occurred 3.5 months after the surgery. The effectiveness of the rehabilitation protocol was analyzed based on the results of various functional tests and questionnaires, such as KOOS (Knee injury and Osteoarthritis Outcome Score), Kujala Patellofemoral Score and SF-36 (The Short Form (36) Health Survey).

Table 1. Kujala Scale Score Table

Time	Result
Before surgery	49
2 weeks	43
6 weeks	79
12 weeks	91
24 weeks	97

Table 2. SF-36 Results Table

Time	Physical Function	Role-Physical	Body Pain	General Health	Vitality	Social Functioning	Role Emotional	Mental Health
Before surgery	20	13.0	31	25	30	50.0	42.0	40
2 weeks	5	13.0	12	50	20	62.5	75.0	40
6 weeks	95	68.75	64	80	55	50.0	58.3	60
12 weeks	100	87.5	74	65	65	87.5	100.0	72
24 weeks	100	100.0	100	80	70	100.0	100.0	84

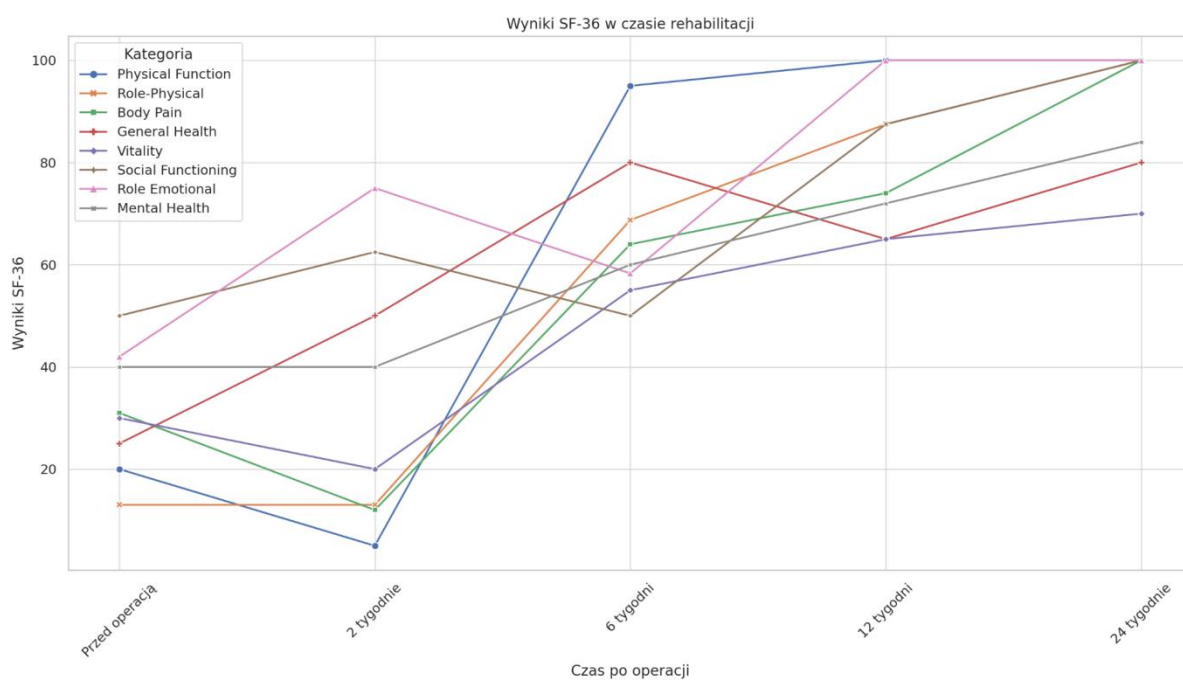


Figure 1. SF-36.

Table 3. KOOS Results Table

Time	Patients	Symptoms	AD	Sports/Recreation	QoL
Before surgery	50	39.3	60.3	25	56.3
2 weeks	25	18.0	38.0	5	38.0
6 weeks	64	43.0	75.0	20	31.0
12 weeks	94	93.0	100.0	95	81.0
24 weeks	100	100.0	100.0	100	94.0

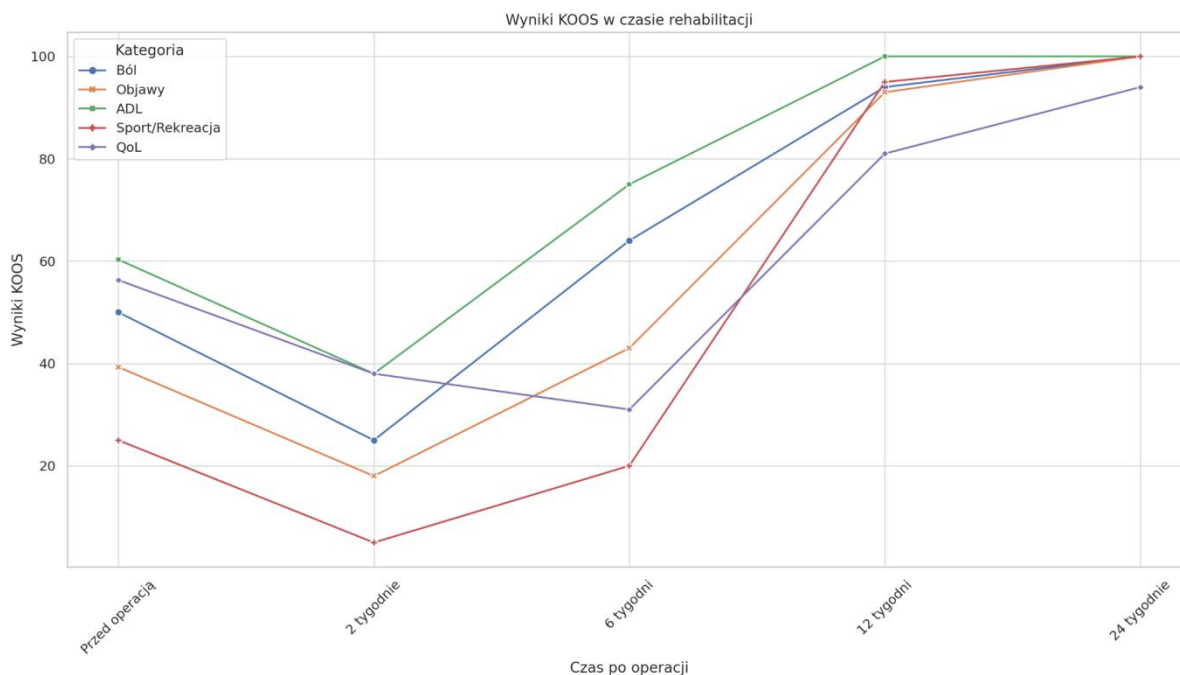


Figure 2. KOOS (Knee injury and Osteoarthritis Outcome Score).

KOOS (Knee injury and Osteoarthritis Outcome Score): All categories (pain, symptoms, activities of daily living, sports/recreation, knee health-related quality of life) showed significant improvement from pre-surgery to week 24 post-surgery. The results reached maximum or near-maximal values after 24 weeks, demonstrating the effectiveness of the rehabilitation protocol.

SF-36: This questionnaire assesses a patient's overall health on various dimensions. Similar to KOOS, significant improvement was observed in all dimensions from preoperative to week 24 postoperatively.

Kujala Scale: This scale, focusing on assessing pain and patellofemoral function, also showed a significant increase in score from 49 points preoperatively to 97 points at 24 weeks.

Rehabilitation protocol:

This protocol did not include the use of a brace or splint, and full weight bearing of the limb was allowed immediately after surgery. Important elements of the rehabilitation process included, among others: learning how to walk correctly on the first day after the procedure, included an intensive exercise program under the supervision of specialists, mobilization of the patella, range of motion exercises, and the use of various treatments supporting the healing and regeneration processes.

The rehabilitation program was carefully planned and implemented in stages, which allowed for a gradual return to full physical fitness and return to sport. The success of this protocol highlights the importance of an individualized approach, monitoring progress through various functional tests and questionnaires, and the use of comprehensive care that includes both physical therapy and regular medical evaluation.

The results show that a well-planned and implemented rehabilitation protocol can effectively support the return to full sports activity after such a serious injury as anterior cruciate ligament reconstruction, which is crucial for professional athletes.

Charts presenting the rehabilitation results using the KOOS, SF-36 and Kujala Scale in subsequent stages of treatment show the effectiveness of the rehabilitation method used after anterior cruciate ligament reconstruction.

KOOS Results: A clear upward trend in all categories (Pain, Symptoms, ADL, Sports/Recreation, QoL) indicates a gradual improvement in knee function and knee health-related quality of life during rehabilitation.

SF-36 Results: Similarly, we see significant improvement in all dimensions of this questionnaire, indicating overall improvement in health, both physically and emotionally.

Kujala Scale: The results indicate a significant improvement in patellofemoral function, which is particularly important in the context of knee rehabilitation after injury.

Each graph illustrates success in improving the patient's condition, which confirms the effectiveness of the rehabilitation protocol used. The clear progress between initial and final measurements highlights the effectiveness of an individually tailored rehabilitation program in restoring knee function and returning to full activity, including match rhythm.

Discussion

The effectiveness of a rehabilitation protocol tailored to individual needs, considering injury specifics, overall health, and sport requirements, is crucial for successful recovery and return to sports (Glattke et al., 2021). Early mobilization and exercise initiation have shown to hasten recovery and resumption of sports activities (Glattke et al., 2021). Comprehensive and intensive rehabilitation approaches have been found to be effective in enhancing athletes' physical and psychological well-being, facilitating quicker recovery (Bo & Mingjun, 2023). Combining physical training with traditional rehabilitation techniques can significantly improve the effectiveness of sports rehabilitation (Liu & Ma, 2023). It is essential to continuously evaluate strength and functional abilities during rehabilitation to provide a realistic assessment of physical capabilities post-injury (Kvist & Silbernagel, 2021).

Factors influencing a quick return to play

The athlete's rapid return to play was influenced by factors such as avoiding the use of an orthosis, early initiation of walking and range of motion exercises, utilizing advanced therapeutic methods to reduce swelling and pain, and tailoring the rehabilitation program to the specific needs of the athlete and the demands of their sport (King et al., 2021; Dawkins et al., 2023; Brinlee et al., 2021). Tailored rehabilitation programs, taking into account sport-specific considerations, are essential for optimizing outcomes and facilitating a successful return to sport following an ACL injury (Poretti et al., 2023; Simonson et al., 2023). Moreover, variables such as quadriceps and hamstring strength relative to body weight, age, sex, BMI, and preoperative quadriceps strength can impact the recovery process and the timeline for return to play (Ueda et al., 2023; Palmieri-Smith et al., 2022; Pesántez et al., 2023).

Limitations and possibilities for further research.

A limitation of the presented case study is the absence of a control group, hindering a direct assessment of the protocol's effectiveness compared to other rehabilitation methods. To address this, conducting randomized controlled trials on a larger patient cohort is crucial to validate the efficacy and safety of the rehabilitation protocol (Brinlee et al., 2021). Additionally, exploring the long-term effects on knee function and the risk of re-injury post-rehabilitation would provide valuable insights into the protocol's sustained benefits (He et al., 2022). Implementing such rigorous research designs would enhance the evidence base supporting the described rehabilitation approach.

Perturbation training has been a subject of interest in ACL rehabilitation. While studies like Arundale et al. (2017) focus on its effectiveness post-ACL reconstruction, Brown et al. (2021) highlight the persistent quadriceps strength deficits following ACL reconstruction compared to uninjured controls. Additionally, Nelson et al. (2021) emphasize the importance of postoperative rehabilitation protocols in ACL reconstruction to enhance outcomes. Combining these insights can provide a comprehensive understanding of the challenges and strategies involved in optimizing rehabilitation post-ACL reconstruction.

The Arundale et al. study compared the effectiveness of a rehabilitation program with perturbation training (SAP+PERT) against a program without it (SAP). The findings revealed no significant differences between the groups in quadriceps strength symmetry, single-leg hop test symmetry, patient-reported outcomes, or the proportion of athletes achieving "normal" knee function at one and two years postoperatively. Additionally, there was no variance in the time taken to meet return-to-sport criteria (Unger et al., 2021).

Comparison with the discussed rehabilitation protocol:

The discussed rehabilitation protocols, which did not include perturbative treatment, but were determined by treatment with a variety of therapeutic methods, rapid return to play within 3.5 months. It is fundamental that a comprehensive rehabilitation program can be very effective in restoring the functional function that is necessary for use in a perturbation program.

The study by Arundale et al. indicates that adding perturbation training to a rehabilitation program does not provide additional benefits in terms of knee function and patient-reported outcomes. This may suggest that the key factors influencing the success of rehabilitation are the individual adaptation of the program and the comprehensiveness of the approach, and not necessarily specific types of exercises.

Adding perturbation training to a rehabilitation program may not offer additional benefits in terms of knee function and patient-reported outcomes, as indicated by Arundale et al. Instead, the success of rehabilitation seems to be influenced by individual program adaptation and the comprehensiveness of the approach (Brehon et al., 2022). Therefore, focusing on tailoring rehabilitation programs to individual needs and ensuring a comprehensive approach may be more crucial than specific types of exercises for effective rehabilitation outcomes.

Limitations and possibilities for further research:

When comparing rehabilitation approaches, it is crucial to note the difference between case studies and randomized clinical trials, as individual factors like age, gender, and motivation can influence outcomes. Future research should focus on evaluating various rehabilitation protocols in larger populations to enhance effectiveness (Everard et al., 2021; Hakiki et al., 2021; Gangwani et al., 2022). Understanding predictors of function and activity, as well as the role of adherence factors, can aid in tailoring rehabilitation programs to individual needs (Hakiki et al., 2021; Steiner et al., 2021; Gangwani et al., 2022). Personal factors significantly impact rehabilitation outcomes, emphasizing the importance of individualized interventions (Gangwani et al., 2022; Levac, 2023). Moreover, standardized outcome assessments and well-defined rehabilitation pathways are essential for investigating treatment responses (Hakiki et al., 2021).

Conclusions

Summary of key conclusions from the conducted case study, indicating the high effectiveness of the rehabilitation protocol used in quickly returning to match rhythm after ACL reconstruction. The case study and the conclusions drawn from it indicate several key

factors that contributed to a quick and effective return to match rhythm after ACL reconstruction.

The discussed rehabilitation protocol shows that a comprehensive and intensive approach to ACL rehabilitation, even without perturbative training, can result in a quick and effective return to sport. Results of the study by Arundale et al. Additionally, they emphasize that adding specific types of training, such as perturbation training, may not provide significant additional benefits. Ultimately, it is important to individually adapt the rehabilitation program to the patient's needs, which is the key to success in returning to full sports activity.

Summary of key conclusions from the conducted stage of the case, indicating the high effectiveness of the rehabilitation protocol used in quickly returning to match rhythm after ACL reconstruction.

The conducted stage of the case and the resulting conclusions indicate several key factors that contributed to a quick and effective return to match rhythm after ACL reconstruction, based on the rehabilitation protocol developed by the Royal Dutch Society of Physiotherapy (KNGF):

1. Rehabilitation phases: Dividing the rehabilitation process into clearly defined phases, including prehabilitation and three postoperative phases (disorder-based phase, sport-specific training, return to play), allowed for precise adjustment of exercises and interventions to the patient's current needs and capabilities.

2. Evidence-based criteria: The use of functional, strength, ankle and movement quality tests as criteria for transitioning between phases of rehabilitation and eventual return to sport provided objective and safe decision-making criteria.

3. Individualization of the rehabilitation process: Adjusting the length and intensity of rehabilitation to the individual needs, capabilities and sports goals of the patient, with an emphasis on neuromuscular training added to strength training, allowed for maximizing the effects of rehabilitation.

4. Interdisciplinary Collaboration: Close collaboration between physiotherapists, trainers, as well as orthopedic physicians and sports traumatologists, including communication regarding patient progress and adaptation of the rehabilitation plan, would be crucial to the success of the entire process.

5. Focus on movement quality: In addition to increasing muscle strength and endurance, great emphasis was placed on movement quality, including improving neuromotor control and knee stability, with the aim of not only a quick return to sport, but also reducing the risk of future injuries.

6. The high effectiveness of the rehabilitation protocol used in quickly returning to match rhythm after ACL reconstruction results from a comprehensive approach combining the latest scientific evidence with the individualization of the rehabilitation process, based on clearly defined phases and objective criteria. The integration of strength and neuromuscular training, combined with interdisciplinary cooperation and focus on the quality of movement, is the foundation for effective rehabilitation and a safe return to sport.

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