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POST-SURGICAL REHABILITATION OF A SEMI ELITE SOCCER PLAYER UTILISING A BIOMECHANICAL AND NEUROCOGNITIVE APPROACH BY A SPORTS CHIROPRACTOR: A CASE REPORT.

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Abstract

Background

This case study underscores a sports chiropractor's comprehensive rehabilitation approach, integrating neurological rehabilitation into the post-surgical recovery of an ACL (anterior cruciate ligament) repair. Through the incorporation of neurocognitive training, specifically directed at enhancing visual processing and anticipatory reactions, the primary objective is to mitigate motor errors and minimise the susceptibility to secondary injuries.

Conventional protocols for managing ACL injuries may neglect the on-field neurocognitive demands imposed on athletes. Inadequate cognitive training may render athletes less equipped to manage biomechanical stresses and navigate the dynamic environment of a match, potentially resulting in compensatory movements and an elevated risk of reinjury.

Case Presentation

The patient, a 35-year-old female semi-elite soccer player, sustained a left knee injury during a game. Despite a normal orthopedic examination, subsequent MRI revealed extensive damage, including a complete ACL rupture, leading to successful ACL reconstructive surgery. The objective of this case study is to illustrate how the integration of biomechanical and neurocognitive rehabilitation can diminish the likelihood of reinjury and facilitate a successful return to high-level athletic performance.

Conclusion

The rehabilitation program prioritised incremental biomechanical loading and neurocognitive training, employing an external focus of control to mitigate compensatory movements. Throughout the intervention, the patient's capabilities were consistently evaluated using the BalanceTrackS system, enabling adjustments to the rehabilitation plan. Standardised questionnaires were also administered at various intervals (one week, one month, three months, and six months) to assess progress and determine readiness for a secure return to play.

KEY WORDS:
sports chiropractic, multimodal, post-surgical, rehabilitation, neurocognitive, ACL

Introduction

ACL (anterior cruciate ligament) rehabilitation plays a crucial role in recovering from ACL injuries and reconstructive surgery. While approximately 80% of individuals can return to physical activity, only 55% are able to resume high-level competitive sports. Additionally, ACL injuries come with substantial costs. In a three-year study of football injuries in NSW Australia, ACL injuries accounted for 26.2% of the total injury cost, with an average claim cost of $4,564 per injury. (1)

Traditionally, ACL injury prevention and rehabilitation have focused primarily on biomechanical factors related to knee loading in the frontal plane, often overlooking neuromuscular control. However, recent research highlights the importance of integrating these factors into rehabilitation plans to create a more comprehensive framework (2). The goal is to increase the number of individuals returning to sports and reduce reinjury rates.

Non-traumatic ACL injuries are often associated with complex game situations where athletes need to focus on multiple factors at one time including: the environment, such as opposition players, the ball, and between the goal posts. This leaves fewer neurocognitive resources for neuromuscular control. Athletes with a history of ACL injury may be at a higher risk in these situations, relying on compensatory patterns and increased visual input to maintain joint integrity and motor control. In this neurocognitive model for ACL rehabilitation, the aim is to improve cognitive efficiency and enable athletes to focus on the game while having confidence in their knee's biomechanical performance. This is achieved by limiting visual input during exercises or incorporating different cognitive tasks to enhance proprioceptive control of the knee.

Historically, ACLR (ACL reconstructive surgery) has been the standard post-ACL rupture, as it helps restore mechanical integrity to the knee. Traditional post-surgical rehabilitation has focused on restoring range of motion, normalising gait, improving quadricep strength, and enhancing proprioceptive control. (3,4) However, recent studies have shown that motor control does not always normalise with these approaches. Targeting neurocognitive control factors has the potential to improve post-surgical rehabilitation outcomes (5,6). While biomechanical function in a controlled environment may be restored with these interventions, compensations that allow sensory deficits to persist can be found in the years following ACLR and rehabilitation (7)

More recently, rehabilitation approaches have expanded to include flexibility, agility, plyometrics, and balance exercises (8). While these interventions have helped reduce the rate of reinjury, the risk of second knee reinjury remains high at a ratio of 1:4, with a 40-fold greater risk compared to individuals with no ACL injury history (9). These interventions have primarily addressed function in a controlled environment and may not adequately prepare athletes for the cognitive load and functional requirements of returning to normal play. By integrating neurocognitive training throughout all stages of rehabilitation, the aim is to enhance the transfer of sensorimotor adaptations from the clinic to real-world activities, ultimately improving long-term patient outcomes. By integrating neurocognitive training throughout all stages of rehabilitation, the aim is to enhance the transfer of sensorimotor adaptations from the clinic to real-world activities, ultimately improving long-term patient outcomes.

Case:

A 35-year-old female semi-elite soccer player presented to the clinic following an on-field collision with an opposition player. The collision occurred when the opposition player collided with the athlete's left lateral knee while contesting the ball, causing a valgus load through the knee. The athlete then attempted to step around the opposition, further placing rotational stress on the knee, resulting in the athlete collapsing to the ground.

Immediately after the incident, the athlete reported mild and localised pain around the medial left knee. The athlete was able to bear weight and walk from the field but was unable to continue the match. The team physiotherapist conducted an on-site assessment but did not detect any ligamentous or meniscal injury.

Four days later, the athlete presented to the clinic of the first author. The location and severity of the pain remained unchanged, but intermittent episodes of giving way were noted. There was no observable swelling compared to the uninjured knee. Range of motion (ROM) was slightly limited in flexion, and the athlete experienced pain when attempting terminal extension due to suspected intra-articular swelling. Medial stress tests elicited pain along the medial joint line of the left knee. Lateral stress testing, anterior and posterior drawer tests, pivot shift, McMurray's, and Thessaly's testing were within normal limits (Table 1).

The treatment involved manual therapy, including soft tissue massage and myofascial release techniques (massage long muscle fibres and pin and stretch techniques within knee flexion and extension ROM tolerances) to the thigh and calf, and high-velocity low-amplitude joint manipulation to the right sacroiliac joint, talus, calcaneus, and superior tib/fib joint using a drop-piece technique. The patient was prescribed supine glute activation exercises (3x1 minute holds daily) and squat patterning with door frame support (3x15 squats daily) as home exercises. The next appointment was scheduled for the following week, allowing time for swelling to subside, with a plan to refer for imaging if the giving way had not improved.

During the review appointment one week later, the reported pain had decreased, but ROM and swelling remained unchanged, and the intermittent episodes of giving way persisted. As a result, a referral for MRI imaging was made to assess the extent of the knee injury. The MRI, performed one week later, revealed, a complete ACL tear, impaction injuries to the medial and lateral tibial plateau, fractures of the posteromedial and posterolateral corners of the tibial plateau, bone bruising on the sulcus of the lateral femoral condyle, full ligamentous tears of the meniscofemoral ligament and posterior oblique ligament, and a partial tear of the lateral meniscotibial ligament. ACL reconstructive surgery was scheduled and performed one week after the imaging.

During the surgery, a grade IV laxity of the ACL was observed, with a slightly positive pivot-shift test and minimal joint effusion. The ACL was found to be ruptured proximally, and a graft was taken from the semitendinosus tendon. After fixation, the knee underwent a full range of motion assessment, showing a negative pivot-shift and Lachmans test, with no impingement observed.

Post surgical Treatment Summary:(Table 2)

Week 1-6:

In the first six weeks post-surgery, the athlete's treatment focused on pain reduction, gait normalisation, and improved muscle activation. Range of motion started at 110 degrees of flexion and 160 degrees of extension but gradually improved. Various therapies, including myofascial release (massage long muscle fibres and pin and stretch techniques within knee flexion and extension ROM tolerances) and joint manipulation to the foot, ankle and pelvis, were used where indicated. Numbness was reported in the 2nd week post-surgery on the left lateral shin. To address this pain and numbness, the FNOR protocol was used, applying Prologel (ProloGel: USA) over the anterior femoral cutaneous nerve and lateral sural cutaneous nerve (10).

Exercises were introduced from week one (Table 2), targeting both legs to prevent deconditioning. These exercises introduced the concept of an external focus of control using a metronome. Exercises using an external focus of control have been shown to mimic more closely the sporting environment where the athlete will have to focus their visual attention on the ball or opponent while maintaining joint stability. These exercises train the body to rely on automatic motor control while maintaining joint integrity in a dynamic environment (11,12). Vestibular rehabilitation (Table 2) began, though some nausea was experienced initially. This subsided quickly with home-exercises. By week six, knee range of motion improved to 65 degrees flexion and 165 degrees extension. Athlete's scores on knee-related assessments improved significantly.

Week 6-12:

During weeks 6-12, the focus was on increasing glute activation and progressing squat patterns. Manual therapies continued, and exercises were adapted based on pain levels to ensure that while they challenged the athlete, they remained mainly pain-free. External focus control activities were introduced, aiming to simulate real sports situations. Range of motion improved, reaching 45 degrees of flexion and 176 degrees of extension. Assessment scores improved further, indicating progress.

Week 12-18:

This phase aimed to incorporate dynamic movements like hopping and jumping. Knee pain during exercises required specific therapies, including isometric holds and pain was reduced within a week. Full knee extension was achieved in this block. The athlete also faced a grade-1 ATFL (anterior talofibular ligament) injury, leading to a temporary shift in rehabilitation focus. Exercises advanced, with an external focus of control (Table 2). Balance assessments showed improved vestibular function and questionnaires demonstrated positive psychosocial perspectives. Full knee extension was achieved in this block.

Week 18-24:

Rehabilitation continued with a focus on neurocognitive drills and field-based decision-making exercises. A self-directed plan was created, outlining new and existing neurological and biomechanical exercises, allowing the athlete to take more control over her exercise schedule (Table 3). This empowers the athlete to be more involved in her own rehabilitation and exercise plan.

Balance and cognitive assessments indicated continued progress, including a new cognitive motor test.

Week 24+:

This final stage prepared the athlete for the introduction back to team training and finally match play with neurocognitive drills and decision-making exercises. Return-to-play assessments (Table 6), including strength testing and questionnaires (Table 6 and Table 2), confirmed readiness. Remarkably high scores on assessments highlighted substantial improvement throughout the recovery journey, with the athlete achieving clearance to return to play at 10 months post surgery.

The progress of the athlete was monitored using industry-standard outcome measures, emphasising the importance of outcomes surveillance in tracking rehabilitation progress. The paper also discusses the essential skills and assessments required of sports chiropractors for effective ACL injury management and rehabilitation.

The authors acknowledge the evolving evidence regarding return to play testing and suggest the inclusion of dual tasking and reaction time assessments to consider cognitive loading and readiness for return to play. Additionally, the inclusion of cardio exercises earlier in the program is suggested to better prepare athletes for the physical demands of match play during rehabilitation and return to play programming.

Structured Rehabilitation Phases:
The treatment plan was organised into distinct six-week phases, each with specific objectives and milestones. In the initial phase (Week 1-6), the primary focus was on pain reduction, gait normalisation, and achieving terminal extension. Subsequent phases (Week 6-12, Week 12-18, Week 18-24) gradually advanced to more dynamic movements, including single-leg hopping and jumping. These phases provided a clear roadmap for the athlete's recovery journey, ensuring that her progress was methodical and goal-oriented. The structured approach allowed both the athlete and the healthcare team to track her development, making adjustments as necessary to address her evolving needs. The inclusion of biomechanical and neurological interventions throughout emphasised a holistic approach to rehabilitation, recognising that successful recovery encompasses not only physical aspects but also sensory feedback systems crucial for sports performance.

Assessment and Monitoring:
Regular and comprehensive assessments were integral to the athlete's rehabilitation journey. Standardised questionnaires like Lysholm, Obrero Musculoskeletal Pain Screening Questionnaire (OMPQ), International Knee Documentation Committee Subjective Knee Form (IKDC), and the Knee Injury and Osteoarthritis Outcome Score (KOOS), conducted at specific intervals, quantified her knee function and perception (Table 4). Meanwhile, the BTrackS balance system (Neurotek) objectively assessed her balance, sensory feedback systems, and fall risk. This system consists of a balance plate linked to a computer program to assess and train balance. Assessments performed included balance and fall risk (COP), modified clinical test of sensory integration and balance (mCTSIB), limits of stability and single leg stance symmetry (Table 5). A VOMS (vestibular oculomotor screening) assessment was also included as an additional neurological assessment tool.

These evaluations provided crucial data points to gauge the effectiveness of the rehabilitation process. The insights gained allowed for the fine-tuning of the treatment plan, ensuring that it aligned with the athlete's progress. By incorporating both subjective and objective assessments, the treating sports chiropractor could track the recovery comprehensively, providing a well-rounded view of the readiness for a return to play.

Individualised Progression:
The unique needs and capabilities of the athlete were at the heart of her rehabilitation journey. Unlike a one-size-fits-all approach, this progression through the treatment phases was highly individualised. The decision to advance to the next phase was not solely based on a predetermined timeline but rather on the competence and tolerance levels of the athlete. If specific biomechanical or strength goals were not met or were hindered by pain, the athlete did not progress to the subsequent stage. This

personalised approach ensured that the rehabilitation plan remained adaptable and responsive to the individual recovery trajectory. This progression was crucial in tailoring the treatment plan to the unique needs of the athlete, identified through regular balance testing, ultimately facilitating a more successful rehabilitation journey. Week 18 saw the inclusion of a self-directed exercise program. This aimed to hand autonomy of rehabilitation over to the athlete.

Key Treatment Techniques:
The athlete's treatment plan encompassed a diverse array of therapeutic techniques to address various aspects of her recovery comprehensively. Hands-on therapy included soft tissue massage and myofascial release (massage long muscle fibres and pin and stretch techniques within knee flexion and extension ROM tolerances), targeting essential muscle groups such as the quadriceps, calf, and gluteals. Joint manipulation focused on restoring biomechanical integrity in areas like the sacroiliac joint and tibiofemoral joint. Instrument-assisted soft tissue massage (IASTM) enhanced tissue glide and mobility, aiding in postoperative tissue healing. The introduction of exercises most of which included a cognitive task, ranging from VMO activations to balance and change of direction drills, played a crucial role in strengthening and stabilising the athlete's lower limb. Early vestibular rehabilitation addressed sensory systems. Focusing on multiple aspects of recovery, these techniques collectively aimed to optimise the healing process and support the return to play.

Return to Play and Neurocognitive Training:
Neurocognitive training was included throughout the rehabilitation plan to prepare the athlete for the dynamic demands of competitive play. This type of training aimed to enhance the decision-making abilities, impulse control, and reaction times of the athlete. Field-based exercises, including those with flash cards, replicated real-game scenarios, fostering an intrinsic learning style were used for this purpose.

These exercises aimed not only to rehabilitate the athlete physically but also to increase neural efficiency in preparation for competition. Return-to-play assessments, conducted at the 10-month mark, comprised strength evaluations, balance assessments, and comprehensive hop and jump testing to ensure the athlete's readiness for competitive play (Table 6). The introduction of Cognitive Motor assessments further honed decision-making abilities, enhancing her overall sports performance. This phase represented the culmination of the rehabilitation journey, combining physical prowess but also the cognitive abilities needed to return safely to sport.

Discussion:
Returning to sports after an ACL injury involves not only focusing on the biomechanical control of the injured knee but also managing the cognitive load imposed by dynamic environments and opposition players. The efficiency of the body's three primary afferent pathways—vestibular, visual, and somatosensory—is crucial for neuromuscular control in these situations. Somatosensation, which includes touch, proprioception, and interoception, plays a key role in motor control. (13)

ACL injuries can have a unique impact on motor control that increases the reliance on visual feedback. The interaction between the visual system and somatosensation is essential for maintaining neuromuscular integrity during complex movements, particularly in dynamic environments.

After injury, athletes with ACL ruptures often rely heavily on visual feedback to compensate for reduced proprioception. While basic clinic tasks may show motor function improvement, challenges persist in the athletic environment due to sensory deficits. Current rehabilitative methods may inadvertently reinforce compensatory mechanisms, potentially hindering recovery. Recognising and addressing post-injury neuroplasticity during rehabilitation could help athletes restore both physical and cognitive abilities for returning to sport effectively.

By leveraging the body's ability to undergo neuroplastic changes during the rehabilitation phase after an injury, we can aim to bridge the gap between biomechanical and neurological rehabilitation. This integrated approach has the potential to improve sensorimotor function and, ultimately, enhance patient outcomes and facilitate a successful return to play.

CNS Changes:
ACL injury results in a sudden change in afferent input from the common peroneal nerve, leading to sensory loss (14). Coupled with pain and inflammation post-injury, this loss of sensory input triggers a cascade of biomechanical adaptations and compensations across multiple locations and bodily systems, such as contralateral loading and altered strategies in the hip and ankle.

Gamma motor neurons and perturbation reflex neurons play a crucial role in maintaining neuromuscular support and enabling rapid and precise muscle activation in various environments (15). Following an ACL injury, the central nervous system undergoes adaptations to compensate for the loss of sensory feedback, often relying more heavily on visual systems for load-bearing and stability (16).

Individuals who have undergone ACL reconstruction have been found to exhibit reduced neural efficiency compared to those with intact ACLs. Studies using electroencephalography have shown increased activation in attentional and sensory areas during force and joint sense tasks in the reconstructed ACL group (17,18). Despite this heightened activation, proprioceptive performance remains lower in these individuals compared to those without ACL injury, indicating an ongoing deficit in the neural system. This deficit in neural efficiency has been associated with a higher risk of re-injury, which has been observed in up to 30% of individuals who return to sports after ACL reconstruction (7).

It's important to note that these changes are not rectified by ACL reconstruction and may even become more pronounced or bilateral with time (15) Bilateral presentations can be attributed to ongoing neuromuscular control changes and biomechanical alterations that reduce proprioceptive accuracy. Managing these neuromuscular control changes and addressing proprioceptive deficits are important considerations in ACL injury rehabilitation.

Biomechanical Changes:
Individuals with an ACL injury often exhibit reduced postural control when their vision is obstructed, indicating a greater reliance on the visual system to compensate for decreased input from the vestibuloproprioceptive system (19,20). However, when their eyes are open, there may be no noticeable difference in postural control compared to a control group. This suggests that the ACL injury group is utilising visual feedback to maintain balance and compensate for proprioceptive deficits.

As tasks become more complex, such as cutting and landing with the addition of a target, the risk of injury can increase. This complexity places greater demands on the body's ability to integrate control from multiple systems, which can overwhelm the capacity of the body and lead to mismatches in proprioception. Poor estimation of body parts in space may predispose individuals to injury. In such situations, the reliance on visual feedback and cortical motor planning for control becomes more pronounced.

Interestingly, this mechanism of increased reliance on visual feedback and cortical motor planning may also be relevant to the increased injury potential observed in individuals who have experienced a concussion. Concussions are known to induce deficits in vestibuloproprioceptive systems, which further emphasises the importance of these sensory systems in maintaining balance and preventing injury (21). However, in the case of this individual, this connection between ACL injury and concussion deficits in vestibuloproprioceptive systems did not appear to be a factor in management.

Visuomotor Changes:

Traditional ACL rehabilitation exercises have primarily focused on regaining strength and biomechanical function in the early stages (1). During this phase, the internal focus of control is targeted, by directing attention towards the affected joint. This approach assisted in normalising the gait pattern to improve lower limb mechanics.

However, to progress beyond basic rehabilitation exercises and tackle more complex movements, it becomes crucial to integrate complex sensory inputs to manage motor outputs effectively. This involves incorporating environmental stimuli, visual cues, vestibular input, and proprioceptive acuity while maintaining strength and movement quality.

Disrupting visual input during rehabilitation exercises can simulate the demands on the neurocognitive system experienced during physical activity. By shifting attention to an external focus of control, the goal is to train the body to rely on automatic motor control in dynamic and changing environments, such as those encountered in sports.

Incorporating an external focus of control during all stages of rehabilitation has been shown to increase muscle activity and better simulate the attention demands of the sporting environment (22). This approach aims to help reduce the risk of a second ACL injury.

It is important to consider the nature of the sporting activities, categorising them as open or closed skills based on environmental and task requirements. Closed-skill sports, like gymnastics or shooting, involve relatively consistent environments and skill requirements. Open-skill sports, such as soccer or volleyball, are characterised by rapidly changing environments and skill demands. Open-skill sports have been found to enhance cognitive function to a greater extent than closed-skill sports (11), underscoring the importance of including these types of training drills in the later stages of ACL rehabilitation.

Limitations:

Case reports have inherit limitations. While they provide valuable insights into an individual patient's experience, they lack generalisability due to the lack of a control group for comparison and the fact that only one practitioner provided therapy. The narrow focus of individual case reports may lead to overinterpretation. Despite their value in documenting unique cases, they provide preliminary evidence for feasibility studies, whilst highlighting a need for further research to validate and expand upon these observations noted in this new post-surgical ACL rehabilitation protocol.

Conclusion:

The case report describes the successful management of a semi-elite female soccer player who underwent post-surgical ACL reconstruction and achieved a successful return to play. The multimodal treatment plan considered both biomechanical and neuromuscular control requirements, highlighting the benefits of this comprehensive approach in facilitating a return to high-level sport. By incorporating a range of techniques, modalities, and targeted exercise prescription, sports chiropractors challenge the traditional perception of being solely spine-focused practitioners. They address both the acute and rehabilitation/injury prevention phases of care, employing slow and high-velocity techniques, various soft tissue therapies, and exercises targeting biomechanical and neuromuscular control.

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TABLE 1

Orthopaedic Tests Performed	
Lateral Stress Test	Negative
Medial Stress Test	Positive for pain
Pivot Shift Test	Negative
Anterior Drawer Test	Negative
Posterior Drawer Test	Negative
Thessally's	Negative
McMurray's	Negative
Medial Joint Line Palpation	Positive for pain
Lateral Joint Line Palpation	Negative

TABLE 2:

Week	Goals	Hands On	Exercises	ROM	Swelling
Initial	Pain decrease Normalise gait Glute Activation	STW: Quad Calf Adjustments: Pelvis Fibular Head Ankle Foot	Supine glute activation Door Squats	F 110* E 160*	thigh circ 43/41cm shin circ 33.5/31cm

Week	Goals	Hands On	Exercises	ROM	Swelling
1-6	Pain decrease Normalise gait ROM (Terminal Extension) Glute Activation	Laser STW: Quad Glute Hamstring Tib Post Instrument: Patella Hamstring/ITB with knee extension Adjustments: Pelvis Fib Head (from week 1) Fem/Tib (from week 4) Ankle Foot Other: Prologel around catheter insertion Floss band knee (from week 7)	bent knee calf raises VMO lowers door squats high knee marching with chair support Banded knee extension (seated) Chair Squats	F 65* E 165*	thigh circ 43/41cm shin circ 33.5/31cm By 1 month had equalised 41cm, 32cm

Week	Goals	Hands On	Exercises	ROM	Swelling
6-12	Glute activation Double leg squat patterning Single leg squat patterning	STW: Quad Glute Hamstring Instrument: Patella Adjustments: Pelvis Knee Ankle Foot Patella Mob Knee figure 8 mob Other: Floss band knee Floss band thigh Activate Popliteus	Stronger banded Extension Door squats to metronome ………………………. DONE ON FIELD 1 leg target reaching (to ball) Step ups Step downs 1 leg squat from post (soccer goal) Quadrant jumping (in front of goal)	F 45* E 176*	

Week	Goals	Hands On	Exercises	ROM	Swelling
12-18	Double leg Jumping Single leg hopping Step downs Lateral glides/jumps	STW: Quad Glute Hamstring Instrument: Patella Quad/Patella tendon with squat Adjustments: Pelvis Knee Ankle Foot Patella Mob Knee figure 8 mob Other: Floss band knee Floss band thigh Activate Popliteus	Iso hold knee extension …………………… DONE ON FIELD From Step: - Front Jump - Side Jump - Front single leg landing - Side Single leg landing	F E	

Week	Goals	Hands On	Exercises	ROM	Swelling
18-24	EFoC exercises -metronome, blaze pod and intrinsic learning driven exercises Self directed exercise plans Return to training with controlled/non-opposition drills	STW: Quad Glute Hamstring Instrument: Patella Lateral ankle Adjustments: Pelvis Knee Ankle Foot Patella Mob Knee figure 8 mob Other: Floss band knee Floss band thigh Activate Popliteus	Step/hops around ball. (No metronome) Knee extensions …………………….. DONE ON FIELD Hops -Side to side 45 BPM -Front to back 40 BPM -Quadrant 35 BPM Also to be done with series 7 counting Side shuffle with kick Back/forward shuttle with kick Also to be done with flashcards Heavy calf raises at gym	F E	

Week	Goals	Hands On	Exercises	ROM	Swelling
24-32	Return to Play	STW: Quad Glute Hamstring Instrument: Patella Adjustments: Pelvis Knee Ankle Foot Patella Mob Knee figure 8 mob Other: Floss band knee Floss band thigh Activate Popliteus			

TABLE 3:

Self-Directed Exercise Program Choose one exercise maximum from each column (4 exercises total) Where possible wear soccer boots and perform activity on soccer field Single leg activities are to be performed on both legs				
Banded knee extension (Standing)	Clams	Side-Side hopping w metronome - 45 BPM	Run	Eyes fixed Yes/Yes 60 BPM
Isometric knee extension (seated)	One leg squat	Front-Back hopping w metronome 40 BPM	Bike Ride	Eyes fixed No/No 60 BPM
Supine leg lowers	Glute bridge	Quadrant hopping w metronome - 35 BPM	Skipping	Head fixed Eyes vertical 60 BPM
	Banded donkey kick	Toe Taps around ball with metronome - 45 BPM	Kick Ball	Head fixed Eyes horizontal 60 BPM
	Two-leg jump downs	Side Shuffle x 4 then kick ball		Thumbs out, body twist 45 BPM
	Single-leg jump downs	Front/Back Shuttle then kick ball		

TABLE 4

	KOOS	IKDC	LYSHOLM	OBRERO
1 Week	47	18.5	22	
1 Month	177	22.6	32	84
3 Months	288	45	64	62
6 Months	347	66.7	82	65

TABLE 5:

	COP	Weight Distribution	mCTSIB	Limits of Stability	Single Leg Stance	L/R Targets	F/B Targets	Random Targets
1 week	13cm 98%	L/R - 50/50 F/B - 45/55	S - 10 (92%) P - 11 (98%) Vi - 19 (85%) Ve - 45 (82%)	237cm FL 52 FR 119 BL 14 BR 119	SI - 3% L - 58cm R - 60cm	Total - 92% L - 85% R - 100% Easy - 100% Mod - 88% Hard - 88%	Total - 93% F - 100% B - 86% Easy - 100% Mod - 100% Hard - 75%	
1 month	13cm 98%		S - 12 (78%) P - 12 (96%) Vi - 19 (85%) Ve - 48 (78%)	326cm FL 110 FR 141 BL 24 BR 51	SI - 23% L - 62cm R - 49cm	Total - 100% L - 100% R - 100% Easy - 100% Mod - 100% Hard - 100%	Total - 97% F - 100% B - 94% Easy - 100% Mod - 100% Hard - 90%	Total - 92% Targets - 23/25 Smallest - 2cm

	COP	Weight Distribution	mCTSIB	Limits of Stability	Single Leg Stance	L/R Targets	F/B Targets	Random Targets
3 months	8cm 100%		S - 8 (98%) P - 11 (99%) Vi - 14 (99%) Ve -56 (62%)	386cm FL 126 FR 122 BL 64 BR 74	SI - 22% L - 61cm R - 49cm	Total - 100% L - 100% R - 100% Easy - 100% Mod - 100% Hard - 100%	Total - 100% F - 100% B - 100% Easy - 100% Mod - 100% Hard - 100%	Total - 92% Targets - 22/24 Smallest - 2cm
6 months	10cm 100%		S - 12 (78%) P - 11 (99%) Vi - 21 (79%) Ve -48 (78%)	455cm FL 162 FR 167 BL 64 BR 62	SI% - 20% L - 59cm R - 79cm	Total - 97% L - 94% R - 100% Easy - 100% Mod - 100% Hard - 90%	Total - 100% F - 100% B - 100% Easy - 100% Mod - 100% Hard - 100%	Total - 89% Targets - 24/27 Smallest - 2cm
10 months	8cm 100%		S - 8 (99%) P - 10 (99%) Vi - 13 (99%) Ve -45 (82%)	471cm FL 158 FR 153 BL 82 BR 78	SI% - 13% L - 45cm R - 52cm	Total - 100% L - 100% R - 100% Easy - 100% Mod - 100%	Total - 100% F - 100% B - 100% Easy - 100% Mod - 100%	Total - 93% Targets - 25/27 Smallest - 1cm

	COP	Weight Distribution	mCTSIB	Limits of Stability	Single Leg Stance	L/R Targets	F/B Targets	Random Targets
						Hard - 100%	Hard - 100%	

TABLE 6:

Return to Play Testing			
Test	Involved (L)	Uninvolved (R)	Symmetry (%)
Single Hop for Distance	133cm	133.6cm	99.5%
3 Hop for Distance	418cm	412cm	101.5%
Crossover Hop	374cm	369cm	101.3%
6m Hop for time	2.36sec	2.39sec	98.7%
Cooper-Hughes Vestibular Balance Test	Pass	Pass	-
Max Quad Strength	27.7kg	25.8g	93%
Max Soleus Strength	36kg	38.9kg	93%
Max Gastroc Strength	138.7kg	146.9kg	94%
Max Calf Raises	29	30	97%
Max Single Leg Sit-to-Stand	54	53	102%
ACL-RSI	-	-	93.3% Emotion - 94% Performance - 94% Risk Appraisal - 90%

ACL Rehabilitation Program Protocol*:

TIME	GOAL	EXERCISE
PRE WEEK 1	Pain reduction, normalisation of gait, glute activation.	1. Supine Glute Activation Holds: 3 sets, aiming for holds as close to 1 minute each as possible. 2. Door Squats: 3 sets of 10, slow and controlled.
WEEK 1-6	Pain reduction, normalisation of gait, terminal knee extension ROM, glute activation.	1. Bent Knee Calf Raises: 3 sets of 15 per leg. 2. VMO Lowers (seated leg raises with focus on vastus medialis): 3 sets of 12 per leg. 3. Door Squats: 3 sets of 12, slow descent over 4 seconds. 4. High Knee Marching (Chair Support): 3 sets of 20 steps, alternating legs. 5. Banded Knee Extensions (Seated): 3 sets of 12 per leg. 6. Chair Squats: 3 sets of 12, controlled tempo.

TIME	GOAL	EXERCISE
WEEK 7-12	Glute activation, double-leg squat patterning, single-leg squat patterning Exercises are tailored to progress strength and introduce functional movement patterns. Wherever possible, they were performed on the field in football boots to enhance proprioception.	**Gym-Based Exercises:** 1. Stronger Banded Knee Extensions: 3 sets of 15 per leg. 2. Door Squats to Metronome: 3 sets of 10 (3 seconds down, 2 seconds up). Progress to a variable metronome to incorporate reactive elements. **On-Field Exercises:** 1. 1-Leg Target Reaching (e.g., reaching for a ball): 3 sets of 10 per leg. 2. Step Ups: 3 sets of 8 per leg, slow and controlled. 3. Step Downs: 3 sets of 8 per leg. 4. 1-Leg Squats from Post (e.g., soccer goal): 3 sets of 6 per leg, controlled depth. 5. Quadrant Jumping (on both legs): 3 sets of 10 jumps, controlled landings.

TIME	GOAL	EXERCISE
WEEK 13-18	Double-leg jumping, single-leg hopping, step downs, lateral glides/jumps The focus transitions to developing reactivity and agility, with metronome-based exercises progressing to a variable metronome. Football boots are worn for all on-field work. Introduce self directed exercise program to hand autonomy of rehab to athlete.	**Gym-Based Exercises:** 1. Heavy Calf Raises: 3 sets of 10 per leg. 2. Knee Extensions: 3 sets of 15 per leg. **On-Field Exercises:** 1. Hops: •Side-to-Side (45 BPM): 3 sets of 10 hops per leg. •Front-to-Back (40 BPM): 3 sets of 10 hops per leg. •Quadrant Hopping (35 BPM): 3 sets of 8 sequences per leg. (Incorporate cognitive challenge: Series 7 counting while hopping) (Progress to a variable metronome for reactivity) 2. Step/Hops Around Ball: 3 sets of 10 per leg (no metronome). 3. Side Shuffle with Kick: 3 sets of 10 per side, add flashcards for cognitive load. 4. Back/Forward Shuffle with Kick: 3 sets of 10 per side, add flashcards for cognitive load.

TIME	GOAL	EXERCISE
WEEK 19-24	Prepare for controlled, non-opposition training drills. This phase focuses on external focus of control (EFoC) exercises and preparing for a return to training. Football boots are worn for on-field activities to provide sport-specific sensory input.	**Gym-Based Exercises:** 1. Heavy Calf Raises: 3 sets of 12 per leg. 2. Knee Extensions: 3 sets of 15 per leg. **On-Field Exercises:** 1. Hops (as in Weeks 13–18): Repeat with progression in speed or repetitions . 2. Step/Hops Around Ball: Progress to 4 sets of 10 per leg. 3. Side and Back/Forward Shuffles with Kick: Increase repetitions and integrate faster flashcard responses. **EFoC Exercises:** •Use a variable metronome, BlazePod reaction lights, and intrinsic learning exercises to encourage agility and decision-making.
WEEK 24+	Gradual return to the full training environment with the following considerations	Begin controlled, non-opposition drills. Progress to light opposition drills based on tolerance. Individualised return-to-sport testing and progression criteria.

**This protocol was designed specifically for the needs and weaknesses of this athlete. When creating rehabilitation programs, it is essential to adapt the exercises, volume, and progression to each athlete's unique requirements to ensure optimal recovery and performance. This protocol is adaptable and should be modified based on the athlete's progress, specific deficits, and goals at each stage.*