BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Prospective Clinical Studies

Prevalence, MRI Characteristics, and Rehabilitation Outcomes of Knee Injuries in Adolescent Football Players: An Observational Cohort Study

Nicoleta Anamaria Pascalau [1+], Alexandru Bogdan Ilieș [1], Brigitte Osser [2,3,*], Laura Ioana Bondar [2,4,+], Felicia Liana Andronie Cioara [1,*], Roland Fazakas [4,+], Gheorghe Codruț Bulz [5], Anca Maria Sabău [5], Corina Dalia Toderescu [6] and Gyongyi Osser [3,7]

Citation: Pascalau N.A., Ilieș A.B., Osser B., Bondar L.I., Andronie Cioara F.L., Fazakas R., Bulz G.C., Sabău A.M., Toderescu C.D., Osser G. - Prevalence, MRI Characteristics, and Rehabilitation Outcomes of Knee Injuries in Adolescent Football Players: An Observational Cohort Study
Balneo and PRM Research Journal **2026**, *17(2): 1039*

Academic Editor(s):
Constantin Munteanu

Reviewer Officer:
Viorela Bembea

Production Officer:
Camil Filimon

Received: 24.05.2026
Published: 10.07.2026

Reviewers:
Alin Ciubotaru
Andrei Daniel Iordan

1 Department of Psycho Neuroscience and Recovery, Faculty of Medicine and Pharmacy, University of Oradea, 410087 Oradea, Romania;
2 Doctoral School of Biomedical Sciences, University of Oradea, 410087 Oradea, Romania;
3 Faculty of Physical Education and Sport, "Aurel Vlaicu" University of Arad, 310130 Arad, Romania;
4 Department of Biology and Life Sciences, Faculty of Medicine, "Vasile Goldiș" Western University of Arad, 310025 Arad, Romania;
5 Faculty of Geography, Tourism and Sport, Department of Physical Education, Sports and Physiotherapy, University of Oradea, 410087 Oradea, Romania, (D.M.F.);
6 Faculty of Pharmacy, "Vasile Goldiș" Western University of Arad, 310045 Arad, Romania;
7 Faculty of Medicine and Pharmacy, Master's Programme in Management of Musculoskeletal Disorders, University of Oradea, 410087 Oradea, Romania

* Correspondence: osser.brigitte@student.uoradea.ro; fcioara@uoradea.ro
† These authors equally contributed to this work

Abstract: Knee injuries represent a major source of morbidity in football players, particularly during adolescence when intensive training coincides with ongoing musculoskeletal development. This study investigated the prevalence, distribution, and rehabilitation outcomes of knee injuries in adolescent football players. Thirty male football players aged 13–17 years from two competitive teams were evaluated through clinical examination and magnetic resonance imaging (MRI). Athletes presenting knee pathology participated in individualized rehabilitation programs. Injury characteristics, functional outcomes, and return-to-play status were assessed using pain, mobility, stability, and proprioceptive measures before and after rehabilitation. Seventeen athletes (56.7%) presented clinically relevant knee pathology. A total of 57 injury markers were identified, with meniscal pathology representing the predominant injury category. Team 1 demonstrated a significantly higher injury prevalence than Team 2 (86.7% vs. 26.7%, $p = 0.0025$). Significant improvements were observed following rehabilitation in pain intensity, knee flexion, extension deficit, functional stability, and proprioceptive control (all $p < 0.001$). Pain reduction was observed in 94.1% of athletes, while return-to-play readiness was achieved in 88.2%. Knee injuries were highly prevalent among adolescent football players, with meniscal lesions representing the most common pathology. MRI-based diagnosis combined with individualized rehabilitation was associated with substantial functional improvement and favorable return-to-play outcomes. These findings support the importance of early diagnosis and structured rehabilitation strategies in youth football athletes.

Keywords: adolescent; athletic injuries; football; knee injuries; magnetic resonance imaging; meniscus; rehabilitation; return to sport; sports medicine; youth sports

1. Introduction

Football is one of the most widely practiced sports worldwide and is associated with substantial physical, psychological, and social benefits. However, the high physical demands of football, including sprinting, jumping, rapid changes of direction, pivoting, and repetitive loading, expose athletes to an increased risk of musculoskeletal injury [1-3]. Lower-limb injuries account for the majority of football-related injuries, with the knee joint representing one of the most frequently affected anatomical regions due to its central role in movement control, force transmission, and dynamic stabilization [4-8].

Knee injuries in football players encompass a broad spectrum of traumatic and overuse-related conditions, including meniscal lesions, ligament injuries, tendinopathies, enthesopathies, and growth-related disorders [5,8,9]. Adolescent athletes may be particularly vulnerable because of the combined effects of intensive training, repetitive biomechanical stress, and ongoing musculoskeletal development [10-12]. Recurrent exposure to football-specific movements can contribute to cumulative tissue overload and may increase the risk of both acute injury and progressive degenerative changes affecting knee structures [1,13-15].

Accurate diagnosis and appropriate rehabilitation are essential for optimizing recovery and reducing the risk of reinjury. Magnetic resonance imaging (MRI) is considered one of the most valuable diagnostic tools for the assessment of knee pathology because it enables detailed visualization of intra-articular and periarticular structures [16-20]. In parallel, individualized rehabilitation programs incorporating therapeutic exercise, neuromuscular training, proprioceptive retraining, and sport-specific conditioning have demonstrated beneficial effects on pain reduction, functional recovery, and return-to-play outcomes in injured athletes [21-24].

Despite the growing body of literature on football-related injuries, several gaps remain. Many studies have focused primarily on professional adult athletes, while fewer investigations have examined the prevalence, characteristics, and rehabilitation outcomes of knee injuries in adolescent football players. Furthermore, limited evidence is available regarding the distribution of MRI-confirmed knee pathologies and their functional evolution following individualized rehabilitation programs within youth football populations [4,8,25]. Understanding these injury patterns may contribute to improved prevention strategies, early diagnosis, and more effective rehabilitation planning.

Therefore, the present study aimed to investigate the prevalence and distribution of knee injuries in adolescent football players, to characterize MRI-confirmed pathological findings, and to evaluate functional recovery following individualized rehabilitation programs. It was hypothesized that: (1) meniscal pathology would represent the most frequent category of knee injury; (2) significant differences in injury prevalence would be observed between competitive groups; and (3) significant improvements in pain intensity, joint mobility, functional stability, proprioceptive control, and return-to-play capacity would be observed following rehabilitation.

2. Materials and Methods

2.1. Study Design

This study was designed as an observational cohort study investigating the prevalence, characteristics, and rehabilitation outcomes of knee injuries in adolescent football players. The study was conducted between November 2024 and April 2026.

Participants were recruited from youth football clubs in Arad County, Romania. Athletes presenting symptoms suggestive of knee pathology underwent orthopedic evaluation and MRI at Pelican Clinical Hospital, Oradea, Romania.

Football players diagnosed with clinically relevant knee injuries were subsequently enrolled in individualized rehabilitation programs conducted in collaborating rehabilitation facilities in Arad County, Romania, including Izvorul Sănătății Medical Center and Davima Rehabilitation Center.

Data collection included demographic characteristics, injury profiles, clinical findings, imaging results, rehabilitation outcomes, and return-to-play status. Clinical, imaging, rehabilitation, and follow-up data were collected throughout the study period and analyzed to evaluate changes in pain, joint mobility, functional stability, and proprioceptive control before and after rehabilitation.

Because no control group was included, the study aimed to describe changes observed following rehabilitation rather than establish causal treatment effects. The investigation was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Participants

The study population consisted of 30 male football players recruited from two competitive youth football teams. Fifteen athletes were assigned to Team 1 and fifteen athletes to Team 2. Participants were aged between 13 and 17 years and were actively involved in organized football training and competition. The study included all eligible athletes available during the study period; therefore, no formal a priori sample size calculation was performed.

Inclusion criteria were:

- Active participation in competitive football.
- Age between 13 and 17 years.
- Availability of complete clinical, imaging, and rehabilitation records.
- Participation in the assessment procedures required by the study.

Exclusion criteria included:

- previous knee surgery.
- severe lower-limb trauma unrelated to sports participation.
- Neurological or systemic musculoskeletal disorders affecting movement or balance.
- incomplete clinical follow-up data.

Clinical examinations and MRI assessments were performed at Pelican Clinical Hospital, Oradea, Romania. Athletes diagnosed with knee pathology subsequently completed rehabilitation programs at participating rehabilitation centers in Arad County. Athletes identified with clinically relevant knee pathology were included in the rehabilitation monitoring component of the study. Seventeen athletes met these criteria and were subsequently monitored throughout the rehabilitation process.

Written informed consent was obtained from parents or legal guardians, and assent was obtained from all participating athletes prior to inclusion in the study.

2.3. Ethical Considerations

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki for research involving human participants.

Ethical approval for the study was obtained from the Ethics Committee of Pelican Clinical Hospital, Oradea, Romania (Approval No. 2070/01.10.2024). Administrative authorization to conduct the study was obtained from the participating football clubs in Arad County, Romania, including Voința Macea (Protocol No. 129/09.09.2024), Șoimii Șimand (Protocol No. 113/09.09.2024), and Athletico Vinga (Protocol No. 127/10.09.2024). Additional site-level authorization for clinical assessment and rehabilitation monitoring was granted by the participating rehabilitation facilities, including

Izvorul Sănătății Medical Center (Approval No. 519/14.10.2024) and Davima Rehabilitation Center (Approval No. 1015/06.11.2024).

Written informed consent was obtained from the parents or legal guardians of all participants, while written assent was obtained from the athletes prior to participation in the study.

All clinical evaluations and MRI investigations were performed at Pelican Clinical Hospital, Oradea, Romania, while rehabilitation procedures and functional monitoring were conducted at Izvorul Sănătății Medical Center and Davima Rehabilitation Center, Arad County, Romania, as part of routine clinical management.

2.4. Clinical and MRI Assessment

All participants underwent a standardized clinical and orthopedic evaluation of the knee joint performed by qualified healthcare professionals. The assessment included medical history review, symptom evaluation, pain assessment, range-of-motion measurements, and functional examination of the lower limb.

Pain intensity was assessed using the Visual Analogue Scale (VAS), while knee joint mobility was evaluated through goniometric measurements of active flexion and extension. Clinical examination focused on identifying pain, swelling, joint instability, movement limitations, tenderness on palpation, and functional deficits affecting football participation.

Athletes presenting clinical signs or symptoms suggestive of knee pathology underwent MRI evaluation. MRI examinations were performed at Pelican Clinical Hospital, Oradea, Romania, using a Siemens Magnetom Avanto 1.5-T scanner (Siemens Healthineers, Erlangen, Germany). Standard knee MRI protocols were applied, including proton-density-weighted and T2-weighted sequences with fat suppression acquired in sagittal, coronal, and axial planes. These imaging sequences enabled comprehensive evaluation of intra-articular and periarticular structures, including the menisci, articular cartilage, ligaments, tendons, synovial tissues, and adjacent osseous structures.

MRI examinations were used to identify and characterize meniscal tears, myxoid meniscal degeneration, enthesopathies, inflammatory lesions, Osgood–Schlatter disease, and other associated abnormalities. Particular attention was given to the evaluation of the medial and lateral menisci, extensor mechanism structures, periarticular soft tissues, and growth-related changes affecting the tibial tuberosity.

All MRI examinations were interpreted by experienced radiologists specialized in musculoskeletal imaging. Imaging findings were reviewed in conjunction with clinical examination results to establish the final diagnosis and classify injury type. The identified lesions were subsequently categorized according to their anatomical location and pathological characteristics.

Injury categories included medial meniscal tears, lateral meniscal tears, myxoid meniscal degeneration, patellar enthesopathy, quadriceps enthesopathy, suprapatellar inflammatory involvement, Osgood–Schlatter disease, lateral perimeniscal inflammatory involvement, and other associated periarticular lesions.

Functional stability and proprioceptive performance were evaluated through standardized rehabilitation assessments conducted before and after the rehabilitation program. These evaluations were used to monitor neuromuscular control, postural stability, and functional recovery throughout the rehabilitation process.

Clinical and imaging findings served as the basis for injury classification, rehabilitation planning, monitoring of recovery progression, and outcome evaluation.

2.5. Outcome Measures

Clinical and functional outcomes were assessed before initiation of rehabilitation and after completion of the rehabilitation program. The primary outcome measures included pain intensity, knee joint mobility, functional stability, proprioceptive control, and return-to-play readiness.

Pain intensity was evaluated using the VAS, a validated instrument ranging from 0 (no pain) to 10 (maximum pain intensity). Knee joint mobility was assessed using a universal goniometer, with measurements of active knee flexion and extension performed according to standardized orthopedic procedures.

Functional stability was evaluated through a composite clinical assessment incorporating single-leg stance control, dynamic balance, squat performance, neuromuscular control, and sport-specific movement tasks. Performance across these assessment domains was recorded using a standardized rehabilitation evaluation form and converted into a composite functional stability score ranging from 0 to 100 points, with higher scores indicating superior dynamic knee stability and functional performance.

Proprioceptive control was assessed through neuromuscular and balance evaluations performed during rehabilitation sessions. These assessments included static and dynamic balance tasks, postural control exercises, weight-transfer activities, and lower-limb coordination exercises. Performance was converted into a standardized proprioceptive control score ranging from 0 to 100 points, with higher values reflecting improved balance, neuromuscular coordination, and postural control.

The composite scoring system was developed for clinical monitoring purposes within the participating rehabilitation centers and was applied consistently across all participants to provide a standardized evaluation of functional recovery and rehabilitation progress (Table 11).

Table 11. Components of the composite functional assessment scoring system

Assessment domain	Maximum score
Single-leg stance control	20
Dynamic balance	20
Squat performance	20
Neuromuscular control	20
Sport-specific movement performance	20
Total score	100

Note: Higher scores indicate better functional performance, dynamic stability, and neuromuscular control.

All outcome measures were recorded at baseline and reassessed following completion of the rehabilitation program. Changes in pain intensity, joint mobility, functional stability, and proprioceptive control were used to monitor rehabilitation progress and evaluate functional recovery.

Return-to-play readiness was determined based on the achievement of pain-free movement, restoration of knee range of motion, satisfactory functional stability, adequate proprioceptive control, and the ability to safely perform football-specific activities under clinical supervision.

2.6. Rehabilitation Protocol

Athletes diagnosed with knee pathology participated in individualized rehabilitation programs designed according to injury type, symptom severity, functional limitations, and rehabilitation goals. Although treatment plans were adapted to individual clinical needs, all athletes followed a standardized rehabilitation framework consisting of three progressive phases.

1. **Phase I: Pain and Inflammation Management**

The initial phase focused on pain reduction, control of inflammation, protection of injured structures, and restoration of basic joint mobility. Interventions included cryotherapy, pain-free range-of-motion exercises, soft-tissue mobilization, stretching, and isometric muscle activation exercises, particularly targeting the quadriceps and hamstring muscle groups.

Progression to the next phase was permitted when athletes demonstrated reduced pain intensity, minimal joint swelling, and improved knee mobility.

2. **Phase II: Functional Restoration**

The second phase emphasized restoration of muscular strength, flexibility, neuromuscular control, and dynamic joint stability. Rehabilitation interventions included progressive resistance exercises, closed kinetic chain training, balance exercises, proprioceptive retraining, core stabilization exercises, and functional movement re-education.

Athletes performed exercises designed to improve lower-limb alignment, movement control, and weight-transfer capacity during dynamic activities. Progression criteria included restoration of functional range of motion, improved balance performance, and the ability to perform daily and sport-related movements without significant symptoms.

3. **Phase III: Sport-Specific Rehabilitation and Return-to-Play Preparation**

The final rehabilitation phase focused on football-specific functional recovery and safe return to sports participation. Exercises included agility drills, running progression, change-of-direction activities, plyometric training, dynamic stabilization exercises, and sport-specific movement patterns relevant to football performance.

Athletes were gradually exposed to increasing training loads under professional supervision. Return-to-play progression was individualized according to clinical status, functional performance, pain levels, and neuromuscular control.

Rehabilitation sessions were conducted under the supervision of physiotherapists and Kinesiotherapists. Most athletes participated in two to three supervised sessions per week, complemented by individualized home exercise programs. The duration of rehabilitation varied according to injury type and severity, ranging from approximately 4 to 9 weeks.

Progress was monitored throughout the rehabilitation process using clinical evaluation, functional assessment, pain monitoring, and reassessment of mobility, stability, and proprioceptive performance.

2.7. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages.

The normality of data distribution was assessed using the Shapiro–Wilk test. Descriptive statistical methods were used to summarize demographic characteristics, injury prevalence, injury distribution, rehabilitation outcomes, and recovery duration.

Comparisons between competitive groups were performed using Fisher's exact test for categorical variables and independent-samples t-tests for continuous variables, as appropriate. Differences in injury-marker frequencies between groups were analyzed using the chi-square test.

Pre- and post-rehabilitation comparisons were analyzed using paired-samples t-tests.

The magnitude of rehabilitation-related changes was evaluated using Cohen's d effect size analysis. Effect sizes were interpreted according to conventional thresholds as small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$).

Statistical significance was established at $p < 0.05$.

3. Results

3.1. Characteristics of the study population

A total of 30 male football players were included in the study, with 15 athletes assigned to each competitive group. The baseline demographic and anthropometric characteristics of the participants are presented in Table 1.

The mean age of the study population was 15.3 ± 1.2 years. The overall mean height was 171.4 ± 7.8 cm, mean body weight was 64.0 ± 9.3 kg, and mean body mass index (BMI) was 21.8 ± 2.0 kg/m^2. The participants had a mean football experience of 7.2 ± 2.0 years. No statistically significant differences were observed between Team 1 and Team 2 regarding age, height, weight, BMI, or football experience (all $p > 0.05$).

Table 1. Baseline characteristics of the study population.

Variable	Team 1 (n = 15)	Team 2 (n = 15)	Total (n = 30)	p-value
Age (years)	15.2 ± 1.1	15.4 ± 1.3	15.3 ± 1.2	0.67
Height (cm)	170.5 ± 8.1	172.4 ± 7.5	171.4 ± 7.8	0.52
Weight (kg)	63.2 ± 9.8	64.8 ± 8.9	64.0 ± 9.3	0.71
BMI (kg/m^2)	21.7 ± 2.1	21.8 ± 2.0	21.8 ± 2.0	0.88
Football experience (years)	7.3 ± 2.1	7.1 ± 2.0	7.2 ± 2.0	0.79

3.2. Prevalence and distribution of knee injuries

Among the 30 football players included in the study, 17 athletes (56.7%) presented clinically relevant knee pathology requiring rehabilitation and functional monitoring, whereas 13 athletes (43.3%) showed no evidence of knee injury during the study period (Table 2).

Table 2. Distribution of knee injuries among the study participants.

Variable	n	%
Injured athletes	17	56.7
Non-injured athletes	13	43.3
Total	30	100

3.3. Distribution of injury types

A total of 57 injury markers were identified among the 17 injured athletes. The detailed distribution of injury types is presented in Table 3.

The most frequently identified lesion was medial meniscal tear (35.1%), followed by lateral meniscal tear (17.5%) and myxoid meniscal degeneration (10.5%). Together, meniscal pathologies accounted for the majority of recorded injury markers.

Table 3. Detailed distribution of knee injuries

Injury type	n	%
Medial meniscal tear	20	35.1
Lateral meniscal tear	10	17.5
Myxoid meniscal degeneration	6	10.5
Patellar enthesopathy	4	7.0
Suprapatellar inflammatory involvement	4	7.0

Osgood–Schlatter disease	3	5.3
Quadriceps enthesopathy	2	3.5
Lateral perimeniscal inflammatory involvement	1	1.8
Other associated lesions	7	12.3
Total	57	100

For visualization purposes, injuries were grouped into major clinical categories. Meniscal pathology represented the largest injury category (63.2%), followed by other associated lesions (12.3%), enthesopathies (10.5%), inflammatory lesions (8.8%), and growth-related lesions (5.3%) (Figure 1).

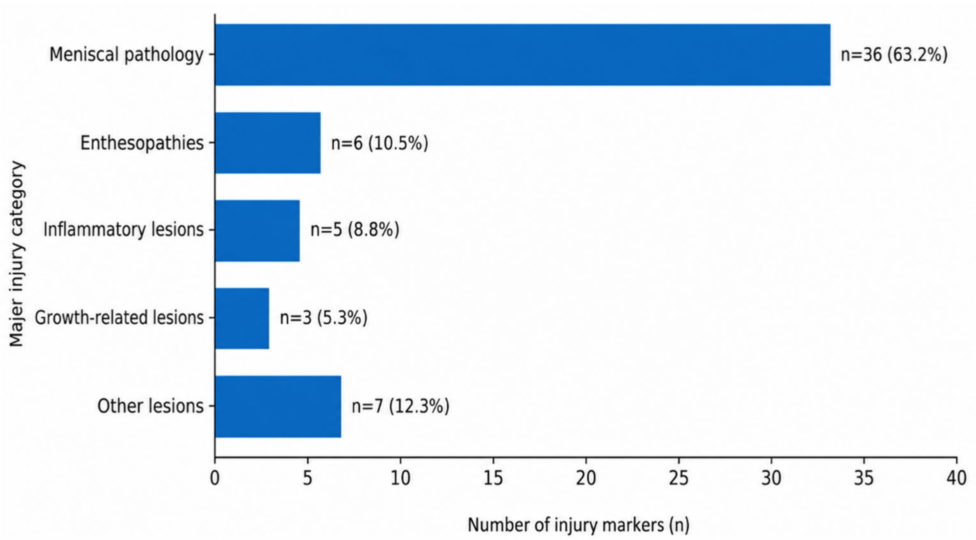

Figure 1. Relative contribution of major knee injury categories.

3.4. Injury laterality and bilateral involvement

Among the 57 recorded injury markers, 33 lesions (57.9%) involved the left knee, whereas 24 lesions (42.1%) involved the right knee. The distribution of injuries according to the affected limb is presented in Table 4.

Table 4. Injury laterality

Affected limb	n	%
Left knee	33	57.9
Right knee	24	42.1
Total	57	100

Analysis of athlete involvement revealed that bilateral pathology was more frequent than unilateral pathology. Bilateral involvement was identified in 11 athletes (64.7%), whereas unilateral involvement was recorded in 6 athletes (35.3%). The distribution of bilateral and unilateral involvement is summarized in Table 5.

Table 5. Bilateral versus unilateral involvement

Injury distribution	n	%
Bilateral	11	64.7
Unilateral	6	35.3
Total injured athletes	17	100

3.5. Comparison between competitive groups

Team 1 demonstrated a significantly higher prevalence of knee injuries than Team 2. A total of 13 out of 15 athletes (86.7%) in Team 1 presented clinically relevant knee pathology, compared with 4 out of 15 athletes (26.7%) in Team 2. In addition, Team 1 accounted for a greater number of injury markers (35 vs. 22). The comparison between the two competitive groups is presented in Table 6.

Table 6. Comparison between teams

Variable	Team 1	Team 2	p-value
Injured athletes	13/15 (86.7%)	4/15 (26.7%)	0.0025
Total injury markers	35	22	<0.05

The differences in injury prevalence between the two competitive groups are illustrated in Figure 2.

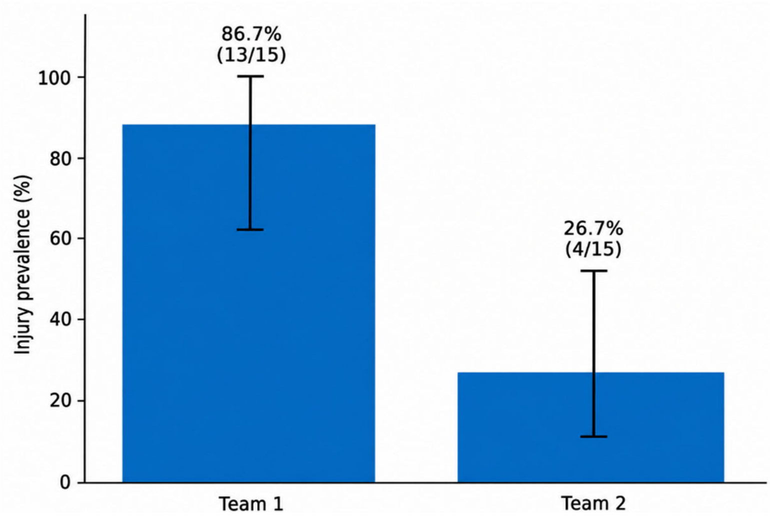

Figure 2. Injury prevalence according to competitive group.

3.6. Functional outcomes following rehabilitation.

Significant improvements were observed in all assessed clinical and functional variables following rehabilitation (Table 7). Pain intensity decreased substantially, while knee range of motion, functional stability, and proprioceptive control improved significantly after completion of the rehabilitation program (all $p < 0.001$).

Table 7. Pre- and post-rehabilitation outcomes

Variable	Pre	Post	Mean difference	p-value
VAS pain	7.1 ± 1.2	2.4 ± 1.1	-4.7	<0.001
Knee flexion (°)	112.5 ± 9.4	132.8 ± 5.7	+20.3	<0.001
Extension deficit (°)	6.8 ± 2.3	1.4 ± 1.1	-5.4	<0.001
Functional stability	61.2 ± 8.6	84.9 ± 6.3	+23.7	<0.001
Proprioceptive control	58.5 ± 7.9	82.1 ± 5.8	+23.6	<0.001

The magnitude of rehabilitation-related changes was evaluated using Cohen's d effect size analysis (Table 8). All outcomes demonstrated very large effect sizes, indicating substantial improvements following rehabilitation.

Table 8. Effect sizes of rehabilitation outcomes.

Variable	Cohen's d
VAS pain score	4.1
Knee flexion (°)	2.6
Extension deficit (°)	2.9
Functional stability score	3.2
Proprioceptive control score	3.4

A graphical representation of rehabilitation effect sizes is presented in Figure 3.

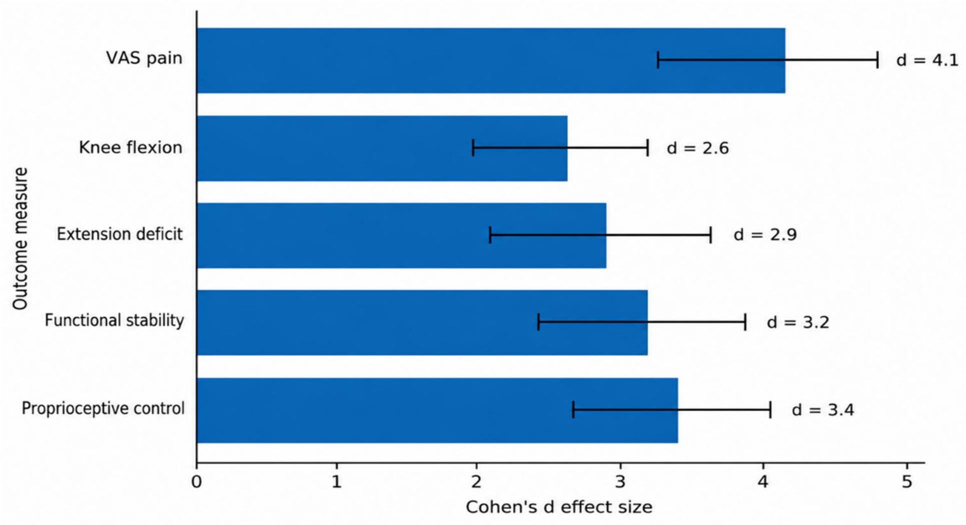

Figure 3. Effect sizes of rehabilitation outcomes.

3.7. Functional recovery and return-to-play outcomes

Functional recovery outcomes following rehabilitation are summarized in Table 9. Pain reduction was observed in 16 of the 17 injured athletes (94.1%), representing the highest improvement rate among the evaluated outcomes. Improvements in joint mobility and return-to-play capacity were achieved in 15 athletes (88.2%), while dynamic stability and proprioceptive control improved in 14 athletes (82.4%). Return-to-play outcomes were calculated at the athlete level rather than the lesion level; therefore, each athlete was counted once regardless of the number of MRI-identified lesions present.

Table 9. Functional recovery outcomes

Outcome	Improved (n)	Unchanged (n)	Improved (%)
Pain reduction	16	1	94.1
Joint mobility	15	2	88.2
Dynamic stability	14	3	82.4
Return-to-play capacity	15	2	88.2
Proprioceptive control	14	3	82.4

3.8. Recovery duration according to injury type

Recovery duration varied according to injury type (Table 10). Athletes presenting meniscal pathology required the longest rehabilitation periods, with mean recovery durations of 8.6 ± 1.9 weeks for medial meniscal lesions and 7.8 ± 1.5 weeks for lateral meniscal lesions. In contrast, athletes with overuse-related conditions, including patellar and quadriceps enthesopathy, demonstrated shorter recovery periods ranging from 4.5 to 4.8 weeks.

Table 10. Recovery duration according to injury type

Injury type	Recovery duration (weeks)	Return-to-play (%)
Medial meniscal lesions	8.6 ± 1.9	90
Lateral meniscal lesions	7.8 ± 1.5	90
Myxoid degeneration	5.4 ± 1.1	100
Patellar enthesopathy	4.8 ± 0.9	100
Quadriceps enthesopathy	4.5 ± 0.7	100
Osgood–Schlatter disease	5.2 ± 1.0	100

Note: Return-to-play rates were calculated at the athlete level rather than the lesion level. Athletes presenting multiple lesions were counted once according to their primary diagnosis.

All athletes presenting overuse-related conditions successfully returned to football participation (100%), whereas athletes with meniscal pathology demonstrated a return-to-play rate of 90%. Among athletes with meniscal pathology, 9 of 10 successfully returned to football participation (90%). The variation in recovery duration among injury categories is illustrated in Figure 4.

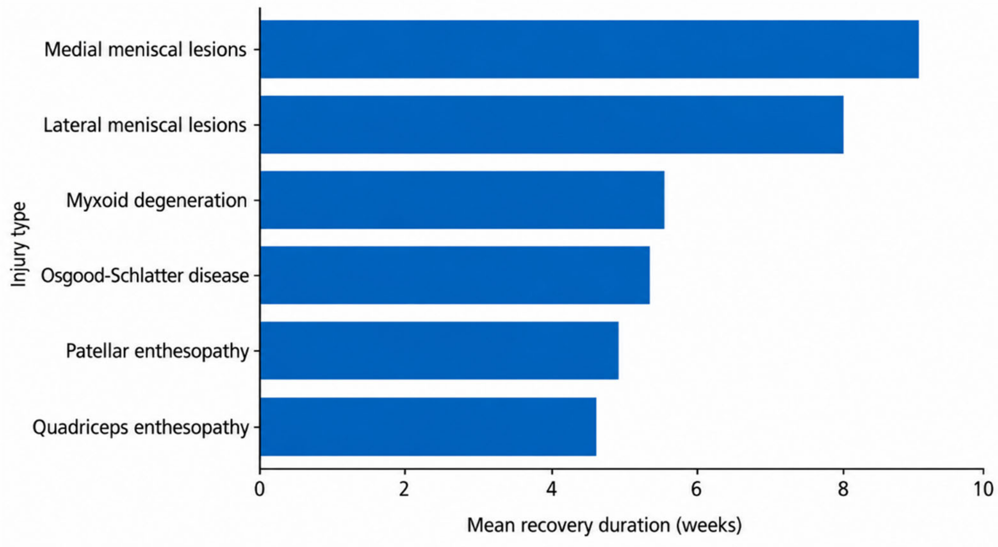

Figure 4. Recovery duration according to injury type.

4. Discussion

4.1. Prevalence of knee injuries in adolescent football players

In the present cohort, 56.7% of athletes presented clinically relevant knee pathology requiring rehabilitation and functional monitoring. This finding highlights the substantial burden of knee injuries among adolescent football players and supports previous epidemiological evidence identifying the knee as one of the most frequently affected anatomical regions in football participation [2,26].

The relatively high injury prevalence observed in the present cohort may be explained by the repetitive biomechanical demands associated with football-specific activities, including sprinting, jumping, pivoting, tackling, and rapid changes of direction. During adolescence, ongoing musculoskeletal development may further increase susceptibility to overload-related pathology and injury occurrence [27-29].

4.2. Distribution of injury types and MRI findings

The first study hypothesis was supported, as meniscal pathology represented the predominant injury category. Medial meniscal tears accounted for the largest proportion of identified lesions, followed by lateral meniscal tears and myxoid meniscal degeneration. Together, meniscal lesions represented more than half of all recorded injury markers.

These findings are consistent with previous sports medicine studies demonstrating that the menisci are particularly vulnerable to rotational loading, compressive forces, and abrupt directional changes characteristic of football activity [30-32]. The predominance of medial meniscal pathology may be associated with the biomechanical role of the medial meniscus in load transmission, shock absorption, and stabilization of the tibiofemoral joint [33-36].

MRI evaluation proved valuable for identifying both traumatic and overuse-related pathology, allowing accurate characterization of meniscal lesions, enthesopathies, inflammatory changes, and growth-related conditions. The use of MRI may therefore facilitate earlier diagnosis and more individualized rehabilitation planning in young athletes [18,37].

4.3. Injury laterality and bilateral involvement

An important finding of the present study was the high frequency of bilateral involvement. Nearly two-thirds of injured athletes demonstrated pathology affecting both lower limbs. Bilateral injury patterns may reflect the cumulative effects of repetitive training loads and symmetrical biomechanical stress imposed by football participation [38-40].

Although left-knee involvement was slightly more frequent than right-knee involvement, the difference was relatively modest. Previous studies have reported inconsistent findings regarding injury laterality, suggesting that limb dominance alone may not fully explain the distribution of football-related knee pathology [41-45].

4.4. Differences between competitive groups

The second study hypothesis was supported by the significant differences observed between the two competitive groups. Team 1 demonstrated substantially higher injury prevalence and a greater number of injury markers than Team 2.

Several factors may contribute to such intergroup differences, including variations in training intensity, cumulative playing time, recovery strategies, physical conditioning, coaching methodology, and injury prevention practices [25,39]. Although the present study was not designed to identify the exact causes of these differences, the findings emphasize the importance of individualized athlete monitoring and workload management in youth football settings.

4.5. Rehabilitation outcomes and functional recovery

The third study hypothesis was supported by the observed changes following rehabilitation. Significant improvements were observed across all evaluated clinical and functional outcomes, including pain intensity, knee mobility, functional stability, and proprioceptive control. Furthermore, all outcome measures demonstrated very large effect sizes, indicating substantial rehabilitation-related improvements.

These findings are consistent with previous research reporting improvements following multimodal rehabilitation programs that combine therapeutic exercise, progressive strengthening, neuromuscular retraining, proprioceptive exercises, and sport-specific functional progression [23,24,46-49]. Improvement in proprioceptive control and functional stability is particularly important because deficits in these domains have been associated with increased reinjury risk and impaired athletic performance [50-52].

4.6. Return-to-play outcomes and clinical implications.

The majority of athletes successfully returned to football participation following rehabilitation. Pain reduction was achieved in more than 90% of participants, while return-to-play readiness was observed in approximately 88% of athletes.

Recovery duration varied according to injury type, with meniscal lesions requiring longer rehabilitation periods than overuse-related conditions. Similar findings have been reported in previous studies, where structural intra-articular injuries generally required prolonged rehabilitation because of the need to restore dynamic stability, neuromuscular control, and movement efficiency before return to sport [31,46,53-56].

From a clinical perspective, these findings suggest that individualized rehabilitation strategies combined with structured progression criteria and functional monitoring may be beneficial for adolescent football players with knee pathology. Early MRI-based diagnosis may facilitate accurate injury characterization and individualized rehabilitation planning, while targeted rehabilitation approaches may be associated with improved clinical outcomes and support safer return-to-play decision-making.

4.7. Strengths and Limitations

The present study possesses several important strengths. First, all identified knee pathologies were confirmed through MRI, which is considered one of the most reliable diagnostic methods for evaluating intra-articular and periarticular knee structures. The use of MRI increased diagnostic accuracy and reduced the possibility of injury misclassification, allowing detailed characterization of meniscal lesions, enthesopathies, inflammatory conditions, and growth-related disorders.

Second, the study integrated clinical assessment, imaging findings, and rehabilitation monitoring within a single investigation. This comprehensive approach allowed evaluation not only of injury prevalence and anatomical characteristics but also of functional recovery following rehabilitation. Such integration provides a broader understanding of knee pathology in adolescent football players and offers clinically relevant information for both diagnosis and treatment planning.

Third, the investigation focused specifically on adolescent football players, a population that remains relatively underrepresented in the sports medicine literature compared with professional adult athletes. Considering that adolescence represents a critical period of musculoskeletal development, the findings contribute valuable information regarding injury patterns, rehabilitation outcomes, and return-to-play considerations in young athletes.

Despite these strengths, several limitations should be acknowledged. The relatively small sample size, particularly the limited number of injured athletes included in the rehabilitation analysis (n = 17), may have reduced the statistical power for subgroup comparisons and limits the generalizability of the findings to other populations, competitive levels, or sporting environments. In addition, participants were recruited from a limited geographical area in western Romania, which may further restrict the external validity of the results. Furthermore, the observational study design and absence of a control group prevented causal conclusions regarding the effectiveness of the rehabilitation interventions.

Another important limitation concerns the functional stability and proprioceptive control scores used during rehabilitation monitoring. Although these assessments were applied consistently across all participants and provided useful information regarding functional progression, they were based on an internally developed clinical monitoring system used within the participating rehabilitation centers and have not undergone formal psychometric validation. Consequently, the reliability, validity, responsiveness, and comparability of these measures with internationally recognized outcome instruments cannot be fully established. The results derived from these scores should therefore be interpreted with caution. Future studies should incorporate validated functional assessment tools and standardized patient-reported outcome measures to facilitate comparison across studies and strengthen methodological rigor.

Additionally, the study evaluated outcomes only during the rehabilitation period and immediate return-to-play process. Long-term follow-up data were not available, preventing assessment of reinjury rates, sustained functional recovery, and the long-term consequences of knee pathology on athletic performance. Finally, potential confounding factors such as training volume, playing position, previous injury history, and biomechanical characteristics were not systematically analyzed and may have influenced injury occurrence and rehabilitation outcomes.

4.8. Clinical Implications

The findings of the present study have several practical implications for sports medicine physicians, physiotherapists, rehabilitation specialists, coaches, and youth football organizations. The relatively high prevalence of knee pathology observed within the investigated cohort highlights the need for regular clinical screening and early identification of injury-related symptoms in adolescent football players. Early recognition of knee dysfunction may facilitate timely intervention and potentially prevent progression toward more severe structural pathology.

The predominance of meniscal lesions identified through MRI emphasizes the importance of accurate diagnostic evaluation in young athletes presenting with persistent knee pain, mechanical symptoms, or functional limitations. MRI assessment may improve diagnostic precision and support individualized treatment planning, particularly in cases where clinical findings alone are insufficient to establish the extent of injury.

The significant functional improvements observed following rehabilitation further support the implementation of structured, individualized rehabilitation programs. The combination of progressive strengthening exercises, neuromuscular retraining, proprioceptive interventions, balance training, and sport-specific functional progression was associated with improvements in pain levels, joint mobility, dynamic stability, and overall functional performance. These findings reinforce current recommendations advocating comprehensive rehabilitation approaches rather than isolated symptom management.

The substantial differences in injury prevalence observed between competitive groups also highlight the potential importance of workload monitoring, training-periodization strategies, and injury-prevention programs. Regular functional assessments may allow practitioners to identify athletes at increased risk of injury and implement corrective interventions before significant pathology develops.

Finally, the findings support the use of objective return-to-play criteria incorporating pain resolution, restoration of joint mobility, neuromuscular control, dynamic stability, and functional performance. Such criteria may contribute to safer reintegration into sport and potentially reduce the risk of recurrent injury following rehabilitation.

4.9. Future Directions

Future research should focus on larger multicenter investigations involving athletes from different geographical regions, competitive levels, and developmental stages. Studies including larger samples would improve statistical power and enhance the generalizability of findings regarding injury prevalence, injury characteristics, and rehabilitation outcomes in youth football populations.

Prospective longitudinal investigations are also needed to better understand the mechanisms underlying the development of knee pathology in adolescent athletes.

Such studies could evaluate the influence of training exposure, playing position, growth and maturation status, biomechanical factors, neuromuscular characteristics, and previous injury history on injury risk.

Future investigations should incorporate validated functional assessment instruments and objective biomechanical measurements to improve methodological rigor and facilitate comparison between studies. The integration of motion analysis systems, force-platform assessments, wearable sensor technologies, and standardized return-to-play testing batteries may provide deeper insight into rehabilitation effectiveness and functional recovery.

Long-term follow-up studies examining reinjury rates, persistent symptoms, athletic performance, and long-term joint health after return-to-play are particularly important. Such investigations may help determine whether short-term rehabilitation gains are maintained over time and whether specific injury patterns are associated with increased risk of future pathology.

Finally, future research should evaluate the effectiveness of targeted injury-prevention programs specifically designed for adolescent football players. Neuromuscular training interventions, proprioceptive exercise programs, workload-management strategies, and individualized risk-factor modification approaches may represent promising avenues for reducing the incidence and severity of knee injuries in this population.

5. Conclusions

The present study identified a high prevalence of knee pathology among adolescent football players, with more than half of the evaluated athletes presenting clinically relevant injuries requiring rehabilitation. Meniscal pathology represented the predominant injury category, with medial meniscal tears constituting the most frequently identified lesion. Significant differences in injury prevalence were observed between the two competitive groups, suggesting that variations in training exposure, workload, and other sport-related factors may influence injury occurrence.

Participants demonstrated substantial improvements following individualized rehabilitation. Athletes presenting overuse-related conditions generally achieved faster recovery than those with meniscal pathology, which required longer rehabilitation periods. These findings highlight the importance of accurate MRI-based diagnosis, structured rehabilitation strategies, and objective functional monitoring in the management of knee injuries among adolescent football players.

Overall, the results suggest that early clinical assessment, MRI-confirmed injury characterization, individualized rehabilitation, and progressive return-to-play criteria may be valuable components of knee injury management in youth football. Further prospective studies involving larger cohorts and long-term follow-up are needed to better understand injury mechanisms, optimize rehabilitation protocols, and improve injury-prevention strategies in this population.

Author Contributions: Conceptualization, N.A.P., B.O., R.F., F.L.A.C. and L.I.B.; methodology, N.A.P., R.F., I.A.B., F.L.A.C. and L.I.B.; software, I.A.B., B.G.C., S.A.M. and C.D.T.; validation, L.I.B., G.O. and C.D.T.; formal analysis, I.A.B., B.G.C., R.F. and C.D.T.; investigation, N.A.P., B.O., G.O. and R.F.; resources, N.A.P., B.O., B.G.C. and S.A.M.; data curation, I.A.B., B.G.C., S.A.M. and C.D.T.; writing—original draft preparation, N.A.P., F.L.A.C., L.I.B., and G.O.; writing—review and editing, B.O., I.A.B., S.A.M. and C.D.T.; visualization, L.I.B., G.O. and S.A.M.; supervision, L.I.B., G.O. and B.G.C.; project administration, B.O., G.O. and R.F. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by the University of Oradea, Romania.

Institutional Review Board Statement: The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Pelican Clinical Hospital, Oradea, Romania (Approval No. 2070/01.10.2024). Administrative authorization to conduct the study was obtained from the participating football clubs in Arad County, Romania, including Voința Macea (Protocol No. 129/09.09.2024), Șoimii Șimand (Protocol No. 113/09.09.2024), and Athletico Vinga (Protocol No. 127/10.09.2024). Additional site-level authorization for clinical assessment and rehabilitation monitoring was granted by the participating rehabilitation facilities, including Izvorul Sănătății Medical Center (Approval No. 519/14.10.2024) and Davima Rehabilitation Center (Approval No. 1015/06.11.2024).

Informed Consent Statement: Informed consent was obtained from the parents or legal guardians of all subjects involved in the study. Written assent was obtained from all participating athletes prior to enrollment. Written informed consent was obtained from the parents or legal guardians to publish this paper.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request**.**

Acknowledgments: The authors would like to thank the University of Oradea, Oradea, Romania, for supporting the APC.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zeng, Y.; Ji, W.; Shi, Y.; Liu, W.; Ji, W. Sports injuries in elite football players: classification, prevention, and treatment strategies update. Front. Sports Act. Living 2025, 7, 1643789. https://doi.org/10.3389/fspor.2025.1643789
2. Andersen, T.R.; Drevsfeldt, A.; Möller, S.; Møller, M. Injuries in male youth football: a one season prospective cohort study of 223 Danish elite players. Front. Sports Act. Living 2023, 5, 1250223. https://doi.org/10.3389/fspor.2023.1250223
3. Ayoub, A.; Ranger, M.; Longmire, M.; Bovid, K. Adolescent soccer overuse injuries: A review of epidemiology, risk factors, and management. Int. J. Environ. Res. Public Health 2025, 22, 1388. https://doi.org/10.3390/ijerph22091388
4. Robles-Palazón, F.J.; López-Valenciano, A.; De Ste Croix, M.; Oliver, J.L.; García-Gómez, A.; Sainz de Baranda, P.; Ayala, F. Epidemiology of injuries in male and female youth football players: A systematic review and meta-analysis. J. Sport Health Sci. 2022, 11, 681–695. https://doi.org/10.1016/j.jshs.2021.10.002
5. Mandorino, M.; Figueiredo, A.J.; Gjaka, M.; Tessitore, A. Injury incidence and risk factors in youth soccer players: a systematic literature review. Part I: epidemiological analysis. Biol. Sport 2023, 40, 3–25. https://doi.org/10.5114/biolsport.2023.109961
6. López-Valenciano, A.; Ruiz-Pérez, I.; Garcia-Gómez, A.; Vera-Garcia, F.J.; De Ste Croix, M.; Myer, G.D.; Ayala, F. Epidemiology of injuries in professional football: a systematic review and meta-analysis. Br. J. Sports Med. 2020, 54, 711–718. https://doi.org/10.1136/bjsports-2018-099577
7. Amirneni, A.; Elahi, J.; Iftikhar, N.; Ganti, L. Mitigating the risks of lower extremity injuries in soccer: A comprehensive analysis of lower extremity injury rates in soccer between 2014 and 2023. Orthop. Rev. 2024, 16, 122315. https://doi.org/10.52965/001c.122315
8. Almansour, L.; Mohammad, W.S.; Elsais, W.; Alonazi, A.; Alyahya, D. Unveiling the knee injury landscape: A comprehensive study of youth male football players in the central region of Saudi Arabia. Appl. Sci. 2024, 14, 3895. https://doi.org/10.3390/app14093895
9. Kuhn, A.W.; Brophy, R.H. Meniscus injuries in soccer. Sports Med. Arthrosc. Rev. 2024, 32, 156–162. https://doi.org/10.1097/JSA.0000000000000389
10. Alcock, R.; Hislop, M.; Vidgen, H.A.; Desbrow, B. Youth and adolescent athlete musculoskeletal health: Dietary and nutritional strategies to optimise injury prevention and support recovery. J. Funct. Morphol. Kinesiol. 2024, 9, 221. https://doi.org/10.3390/jfmk9040221
11. Borkowski, R.; Krzepota, J.; Wróbel, M.; Madej, D.; Błażkiewicz, M. The impact of overtraining on injury rates in school-age athletes—A scoping review. J. Clin. Med. 2025, 14, 4712. https://doi.org/10.3390/jcm14134712
12. Osser, B.; Toth, C.; Nistor-Cseppento, C.D.; Osser, G.; Miuța, C.C.; Ilia, I.; Iovanovici, D.C.; Aur, C.; Bondar, L.I. Evaluating tech neck: A pilot study using a self-developed questionnaire on symptoms, posture, and preventive measures. Children 2025, 12, 102. https://doi.org/10.3390/children12010102
13. Freiberg, A.; Bolm-Audorff, U.; Seidler, A. The risk of knee osteoarthritis in professional soccer players—A systematic review with meta-analyses. Dtsch. Arztebl. Int. 2021, 118, 49–55. https://doi.org/10.3238/arztebl.m2021.0007
14. Smith, R.D.J.; Hanrahan, M.; Gerber, A.; Tanaka, M.J. Patellofemoral disorders in soccer players. Sports Med. Arthrosc. Rev. 2024, 32, 146–155. https://doi.org/10.1097/JSA.0000000000000390
15. Wik, E.H. Growth, maturation and injuries in high-level youth football (soccer): A mini review. Front. Sports Act. Living 2022, 4, 975900. https://doi.org/10.3389/fspor.2022.975900

16. Shetty, N.D.; Dhande, R.P.; Parihar, P.; Bora, N.; Shelar, S.S. The role of magnetic resonance imaging in the evaluation of knee pain. Cureus 2024, 16, e65898. https://doi.org/10.7759/cureus.65898
17. Mead, K.; Cross, T.; Roger, G.; Sabharwal, R.; Singh, S.; Giannotti, N. MRI deep learning models for assisted diagnosis of knee pathologies: A systematic review. Eur. Radiol. 2025, 35, 2457–2469. https://doi.org/10.1007/s00330-024-11105-8
18. Chien, A.; Weaver, J.S.; Kinne, E.; Omar, I. Magnetic resonance imaging of the knee. Pol. J. Radiol. 2020, 85, e509–e531. https://doi.org/10.5114/pjr.2020.99415
19. Bottomley, J.; Al-Dadah, O. Diagnostic accuracy of magnetic resonance imaging in meniscal tears. Cureus 2025, 17, e92155. https://doi.org/10.7759/cureus.92155
20. Lamour, R.J.; Patel, N.N.; Harris, G.B.; England, J.S.; Lesniak, B.P.; Kaplan, L.D.; Jose, J. Comparing MRI and arthroscopic appearances of common knee pathologies: A pictorial review. J. Clin. Imaging Sci. 2024, 14, 15. https://doi.org/10.25259/JCIS_98_2023
21. Takáč, P. Sports injury rehabilitation: A narrative review of emerging technologies and biopsychosocial approaches. Appl. Sci. 2025, 15, 9788. https://doi.org/10.3390/app15179788
22. Defi, I.R. Rehabilitation role in sport injury. Orthop. J. Sports Med. 2023, 11 (Suppl. 2), 2325967121S00833. https://doi.org/10.1177/2325967121S00833
23. Chen, S.; Gu, J.; Shaharudin, S. Effects of proprioceptive training intervention on knee function in patients with anterior cruciate ligament reconstruction: a systematic review and meta-analysis. Ann. Med. 2025, 57, 2542441. https://doi.org/10.1080/07853890.2025.2542441
24. Arumugam, A.; Björklund, M.; Mikko, S.; Häger, C.K. Effects of neuromuscular training on knee proprioception in individuals with anterior cruciate ligament injury: a systematic review and GRADE evidence synthesis. BMJ Open 2021, 11, e049226. https://doi.org/10.1136/bmjopen-2021-049226
25. Mandorino, M.; Figueiredo, A.J.; Gjaka, M.; Tessitore, A. Injury incidence and risk factors in youth soccer players: a systematic literature review. Part II: Intrinsic and extrinsic risk factors. Biol. Sport 2023, 40, 27–49. https://doi.org/10.5114/biolsport.2023.109962
26. Gurau, T.V.; Gurau, G.; Voinescu, D.C.; Anghel, L.; Onose, G.; Iordan, D.A.; Munteanu, C.; Onu, I.; Musat, C.L. Epidemiology of injuries in men's professional and amateur football (Part I). J. Clin. Med. 2023, 12, 5569. https://doi.org/10.3390/jcm12175569
27. Johnson, D.M.; Cumming, S.P.; Bradley, B.; Williams, S. The influence of exposure, growth and maturation on injury risk in male academy football players. J. Sports Sci. 2022, 40, 1127–1136. https://doi.org/10.1080/02640414.2022.2051380
28. Parry, G.N.; Williams, S.; McKay, C.D.; Johnson, D.J.; Bergeron, M.F.; Cumming, S.P. Associations between growth, maturation and injury in youth athletes engaged in elite pathways: a scoping review. Br. J. Sports Med. 2024, 58, 1001–1010. https://doi.org/10.1136/bjsports-2024-108233
29. Osser, B.T.; Toth, C.; Osser, G.; Nistor-Cseppento, C.D.; Niculescu, V.; Bondar, L.I. Student behavior and its association with multi-device addiction and back pain in Western Romania. Balneo PRM Res. J. 2025, 16, 790. https://doi.org/10.12680/balneo.2025.790
30. Marigi, E.M.; Davies, M.R.; Marx, R.G.; Rodeo, S.A.; Williams, R.J. III. Meniscus tears in elite athletes: Treatment considerations, clinical outcomes, and return to play. Curr. Rev. Musculoskelet. Med. 2024, 17, 313–320. https://doi.org/10.1007/s12178-024-09907-w
31. Prill, R.; Ma, C.B.; Wong, S.E.; Beaufils, P.; Monllau, J.C.; Arhos, E.K.; Becker, R.; Villa, F.D.; Goodloe, J.B.; Irrgang, J.J.; Klugarova, J.; Klosterman, E.L.; Królikowska, A.; Krych, A.J.; LaPrade, R.F.; Manske, R.; van Melick, N.; Monson, J.K.; Ostojic, M.; Paterno, M.V.; Piontek, T.; Perelli, S.; Rambaud, A.; Robinson, J.; Schmitt, L.C.; Senorski, E.H.; Snaebjornsson, T.; Tagliero, A.J.; Giordano, A.O.; Pujol, N. The formal EU-US Meniscus Rehabilitation 2024 Consensus: An ESSKA-AOSSM-AASPT initiative. Part II—Prevention, non-operative treatment and return to sport. Knee Surg. Sports Traumatol. Arthrosc. 2025, 33, 3014–3024. https://doi.org/10.1002/ksa.12689
32. Cognetti, D.J.; Bedi, A. Biomechanics of the meniscus and meniscal injury. Oper. Tech. Orthop. 2025, 35, 101180. https://doi.org/10.1016/j.oto.2025.101180
33. Kim, M.S.; In, Y.; Kim, H.; Jeong, J.; Sohn, S. Why hoop tension matters: A biomechanical perspective on medial meniscus posterior root tears—A narrative review. Bioengineering 2025, 12, 638. https://doi.org/10.3390/bioengineering12060638
34. Mameri, E.S.; Dasari, S.P.; Fortier, L.M.; Verdejo, F.G.; Gursoy, S.; Yanke, A.B.; Chahla, J. Review of meniscus anatomy and biomechanics. Curr. Rev. Musculoskelet. Med. 2022, 15, 323–335. https://doi.org/10.1007/s12178-022-09768-1
35. Kuczyński, N.; Boś, J.; Białoskórska, K.; Aleksandrowicz, Z.; Turoń, B.; Zabrzyńska, M.; Bonowicz, K.; Gagat, M. The meniscus: Basic science and therapeutic approaches. J. Clin. Med. 2025, 14, 2020. https://doi.org/10.3390/jcm14062020
36. Sukopp, M.; Schall, F.; Hacker, S.P.; Ignatius, A.; Dürselen, L.; Seitz, A.M. Influence of menisci on tibiofemoral contact mechanics in human knees: A systematic review. Front. Bioeng. Biotechnol. 2021, 9, 765596. https://doi.org/10.3389/fbioe.2021.765596

37. Liew, I.; Low, W.X.; Ikram, A.; McDonnell, S.; Core Kids Knee Steering Committee. Outcomes reported in trials of children and adolescent knee injuries: A systematic review. Bone Jt Open 2025, 6, 971–982. https://doi.org/10.1302/2633-1462.68.BJO-2025-0005.R1
38. Chaari, F.; Boyas, S.; Sahli, S.; Fendri, T.; Harrabi, M.A.; Rebai, H.; Rahmani, A. Postural balance asymmetry and subsequent noncontact lower extremity musculoskeletal injuries among Tunisian soccer players with groin pain: A prospective case control study. Gait Posture 2022, 98, 134–140. https://doi.org/10.1016/j.gaitpost.2022.09.004
39. Nilsson, T.; Börjesson, M.; Lundblad, M.; Ivarsson, A.; Fransson, D. Injury incidence in male elite youth football players is associated with preceding levels and changes in training load. BMJ Open Sport Exerc. Med. 2023, 9, e001638. https://doi.org/10.1136/bmjsem-2023-001638
40. Ayoub, A.; Ranger, M.; Longmire, M.; Bovid, K. Adolescent soccer overuse injuries: A review of epidemiology, risk factors, and management. Int. J. Environ. Res. Public Health 2025, 22, 1388. https://doi.org/10.3390/ijerph22091388
41. Rabal-Pelay, J.; Albalad-Aiguabella, R.; Arjol-Serrano, J.L.; Lozano, D.; Roso-Moliner, A.; Mainer-Pardos, E. Is the dominant leg also the stronger leg in vertical and horizontal jump performance in young male soccer players? Front. Sports Act. Living 2026, 8, 1785376. https://doi.org/10.3389/fspor.2026.1785376
42. DeLang, M.D.; Salamh, P.A.; Farooq, A.; Tabben, M.; Whiteley, R.; van Dyk, N.; Chamari, K. The dominant leg is more likely to get injured in soccer players: Systematic review and meta-analysis. Biol. Sport 2021, 38, 397–435. https://doi.org/10.5114/biolsport.2021.100265
43. Haddad, M.; Abbes, Z.; Zarrouk, N.; Aganovic, Z.; Hulweh, A.; Moussa-Chamari, I.; Behm, D.G. Difference asymmetry between preferred dominant and non-dominant legs in muscular power and balance among sub-elite soccer players in Qatar. Symmetry 2023, 15, 625. https://doi.org/10.3390/sym15030625
44. Lutz, F.D.; Cleary, C.J.; Moffatt, H.M.; Sullivan, V.E.; LaRoche, D.P.; Cook, S.B. Comparison of the H:Q ratio between the dominant and non-dominant legs of soccer players: A meta-analysis. Sports Health 2023, 15, 486–496. https://doi.org/10.1177/19417381221095096
45. Beron-Vera, F.; Lemus, S.A.; Mahmoud, A.O.; Beron-Vera, P.; Ezzy, A.; Chen, C.B.; Mann, B.J.; Travascio, F. Asymmetry in kinematics of dominant/nondominant lower limbs in central and lateral positioned college and sub-elite soccer players. PLoS One 2024, 19, e0304511. https://doi.org/10.1371/journal.pone.0304511
46. Joreitz, R.; Fine, J.; Eshelman, T.; Mock-Grubbs, S.; Witherspoon, Z. Sport-specific training and return to sport after ACL reconstruction in elite athletes: A narrative review. Ann. Jt. 2025, 10, 36. https://doi.org/10.21037/aoj-25-27
47. Thomas, Z.M.; Lupowitz, L.; Ivey, M.; Wilk, K.E. Neurocognitive and neuromuscular rehabilitation techniques after ACL injury – Part 2: Maximizing performance in the advanced return to sport phase. Int. J. Sports Phys. Ther. 2024, 19, 1629–1641. https://doi.org/10.26603/001c.126270
48. Zheng, Q.Y.; Sun, J.N.; Wang, R.S.; Ma, Y.R.; Chen, P. Does proprioceptive training improve joint function and psychological readiness in patients after anterior cruciate ligament reconstruction? A randomized controlled trial. BMC Musculoskelet. Disord. 2025, 26, 364. https://doi.org/10.1186/s12891-025-08621-z
49. Osser, B.; Toth, C.; Nistor-Cseppento, C.D.; Ilia, I.; Osser, G.; Cevei, M.; Aur, C.; Fazakas, R.; Bondar, L.I. Effects of structured physical therapy on spinal alignment in idiopathic scoliosis: A 12-month prospective study. Diagnostics 2025, 15, 2747. https://doi.org/10.3390/diagnostics15212747
50. Inclan, P.M.; Hicks, J.J.; Retzky, J.S.; Janosky, J.J.; Pearle, A.D. Team approach: Neuromuscular training for primary and secondary prevention of anterior cruciate ligament injury. JBJS Rev. 2024, 12, e23.00207. https://doi.org/10.2106/JBJS.RVW.23.00207
51. Huang, L.; You, G.; Li, M.; Xia, Z.; Yang, S.; Zhou, X.; Shi, H.; Wang, D.; Zhang, L. Outcomes of proprioceptive training on recovery after anterior cruciate ligament reconstruction: A systematic review and meta-analysis. Am. J. Phys. Med. Rehabil. 2025, 104, 436–444. https://doi.org/10.1097/PHM.0000000000002639
52. Moiroux-Sahraoui, A.; Mazeas, J.; Gold, M.; Kakavas, G.; Forelli, F. Neuromuscular control deficits after anterior cruciate ligament reconstruction: A pilot study using single-leg functional tests and electromyography. J. Funct. Morphol. Kinesiol. 2025, 10, 98. https://doi.org/10.3390/jfmk10010098
53. Hanna, T.; Smith, N.P.; Sebastianelli, W.J. Treatment, return to play, and performance following meniscus surgery. Curr. Rev. Musculoskelet. Med. 2022, 15, 157–169. https://doi.org/10.1007/s12178-022-09754-7
54. Foley, A.; Confino, J.; Halvorson, R.; Petrie, K.; Torres, A.; Feeley, B. Return to sport following ACL reconstruction. Curr. Rev. Musculoskelet. Med. 2025, 18, 599–610. https://doi.org/10.1007/s12178-025-09989-0
55. van Haren, I.E.P.M.; van der Worp, M.P.; van Rijn, R.; Stubbe, J.H.; van Cingel, R.E.H.; Verbeek, A.L.M.; van der Wees, P.J.; Staal, J.B. Return to sport after anterior cruciate ligament reconstruction—prognostic factors and prognostic models: A systematic review. Ann. Phys. Rehabil. Med. 2025, 68, 101921. https://doi.org/10.1016/j.rehab.2024.101921
56. Fazakas, R.; Tolan, G.A.; Osser, B.; Toth, C.; Ilia, I.; Marcu, F.M.; Pascalau, N.A.; Suciu, R.N.; Gavrila-Ardelean, L.; Bondar, L.I. Hybrid Tightrope–PEEK dual fixation for distal biceps tendon reinsertion in high-performance athletes: A prospective case series. J. Clin. Med. 2025, 14, 8488.