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The evolving role of imaging in sports injury management

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Abstract

Background. Sports injuries constitute a significant health problem in professional and recreational sports. With the growing popularity of physical activity and intensified training, a growing incidence of musculoskeletal injuries has been observed. Imaging diagnostics plays a crucial role in the evaluation of these injuries, enabling assessment of anatomical structures, detection of pathological changes, and monitoring of treatment.

Aim. The aim of this study was to review scientific reports on the role of imaging modalities in improving the quality of medical care for athletes.

Material and methods. Publications available PubMed database published between 2016 and 2026 were analyzed. The article discusses the most important imaging methods used in the diagnosis of sports injuries, including conventional radiography, ultrasonography, magnetic resonance imaging, and computed tomography. Their characteristics, clinical applications, and diagnostic limitations are presented. Particular attention was paid to the importance of magnetic resonance imaging and ultrasonography in the evaluation of soft tissues, as well as the role of computed tomography in the diagnosis of complex bone injuries. The paper also presents current directions in imaging diagnostics, including the application of artificial intelligence.

Results. The analysis of the available literature indicates that the appropriate selection of imaging modalities significantly improves the quality of care for athletes by increasing diagnostic accuracy, shortening the time required to establish a diagnosis, and enabling more precise treatment planning as well as a return to sports activity.

Conclusions. Modern imaging diagnostics plays a fundamental role in sports medicine. Proper use of radiography, ultrasonography, magnetic resonance imaging, and computed tomography supports effective diagnosis and treatment of sports injuries, contributing to safer and faster return to sports activity.

Key words: sport, injuries, MRI, ultrasound, athletes, CT, radiography, AI, X-Ray, US, sport medicine

Content

1. Introduction

Sports injuries are common and therefore represent one of the most frequent clinical challenges in sports medicine and orthopaedics. In recent decades, a systematic increase in the number of individuals engaging in physical activity has been observed, both recreationally and professionally. The highest incidence of injuries is reported in contact sports such as football, basketball, and combat sports, as well as in athletics [1,2,3]. Factors predisposing athletes to injuries include insufficient preparation for physical exertion, lack of adequate warm-up, training overload, inappropriate sports equipment or playing surfaces, and premature return to activity following a previous injury [1,2,3,4,5,6,7]. Accurate identification of the type and extent of injury is a key element of the diagnostic and therapeutic process [3,8]. Early diagnosis allows for the implementation of appropriate treatment, reduction of the risk of complications, and shortening of the time required for the athlete to return to sport [2,3,5,6,7]. In many cases, however, clinical assessment alone is insufficient, particularly in the diagnosis of soft tissue injuries or overuse-related conditions [2]. In this context, imaging diagnostics plays a fundamental role in the diagnostic process. Modern imaging techniques allow for detailed assessment of anatomical structures, identification of post-traumatic changes, and monitoring of the healing process [2,5,8]. Contemporary radiology offers a wide range of diagnostic modalities, including conventional radiography, ultrasonography, magnetic resonance imaging, and computed tomography [9,10,11]. Modern imaging techniques such as ultrasonography (US), magnetic resonance imaging (MRI), computed tomography (CT), and radiography allow for comprehensive assessment of both soft tissues and bone structures [12]. Their appropriate selection directly affects the quality of medical care by increasing diagnostic accuracy and reducing the risk of clinical errors [2,9]. The dynamic development of imaging technologies in recent years has significantly expanded diagnostic capabilities in sports medicine. The introduction of new techniques, such as elastography and image analysis supported by artificial intelligence algorithms, enables even more accurate assessment of pathological changes and more precise treatment planning [2,8]. The aim of this study is to review the current literature on the importance of imaging diagnostics in improving the quality of medical care for athletes.

2. Materials and methods

This study is a literature review. The analysis was conducted based on scientific publications available in the PubMed database published between 2016 and 2026. The literature search was performed using English keywords such as: sports injuries imaging, quality in sports medicine, MRI sports injuries review, ultrasound athletes, computed tomography, ultrasound, sports injuries computed tomography, and radiography. Review articles, clinical studies, and papers concerning the application of imaging modalities in the diagnosis of sports injuries were included. Publications describing the use of conventional radiography, ultrasonography, magnetic resonance imaging, and computed tomography in the diagnosis of musculoskeletal injuries in athletes were included in the analysis. Additionally, studies concerning new technologies in imaging diagnostics, including the use of artificial intelligence and advanced imaging techniques, were considered. Publications not directly related to sports injuries or imaging diagnostics were excluded from the analysis.

3. The importance of diagnostic imaging in sports medicine

Sports injuries encompass a wide range of pathologies affecting various structures of the musculoskeletal system, including muscles, tendons, ligaments, articular cartilage, and bone structures [12,13]. Clinical symptoms of injuries are often nonspecific; therefore, imaging diagnostics represents an important tool supporting the diagnostic process [3,5,8]. The use of appropriately selected imaging modalities enables shortening of diagnostic time, increased diagnostic accuracy, and implementation of appropriate therapeutic management [2,3,8]. In the context of sports medicine, rapid and precise diagnosis is particularly important because it directly influences the time required for an athlete to return to sports activity, commonly referred to in the literature as return to play [2,3,4,5,6,7].

4. Imaging diagnostics in sports medicine

4.1. Radiography (X-ray)

Radiography is one of the oldest and most commonly used diagnostic imaging methods. This technique uses ionizing radiation to obtain images of anatomical structures [1]. Differences in the absorption of radiation by individual tissues enable the assessment of bone structures and anatomical relationships within joints [14]. Radiographic examination is characterized by a short acquisition time, wide availability, and relatively low diagnostic cost. For this reason, it constitutes the primary imaging modality in the diagnosis of acute sports injuries. Radiography is particularly useful in the diagnosis of bone fractures such as stress fractures, traumatic fractures, and avulsion fractures, as well as joint dislocations and subluxations [1]. This method is also used in the evaluation of overuse-related changes such as enthesopathies or calcifications at tendon insertion sites. Despite its widespread use, X-ray imaging has significant diagnostic limitations. It does not allow accurate assessment of muscles, ligaments, tendons, or articular cartilage. In cases where soft tissue injury is suspected, diagnostic evaluation should be supplemented with ultrasonography or magnetic resonance imaging. Additionally, in the early stages some stress fractures may not be visible on radiographic images, which requires the use of more sensitive imaging modalities [15]. Radiography uses ionizing radiation; therefore, the principle of radiation dose minimization (ALARA – As Low As Reasonably Achievable) must be applied [14]. In clinical practice, this means performing the examination only when clinically justified, using protective shielding, and limiting the number of projections to the necessary minimum. In sports medicine, where radiographic examinations are frequently performed in young and physically active individuals, safety considerations are particularly important.

4.2. Ultrasonography (US)

Ultrasonography is one of the fundamental diagnostic methods in musculoskeletal imaging. This technique uses ultrasonic waves to visualize anatomical structures and does not involve exposure to ionizing radiation [16,17]. The main advantages of ultrasonography include high spatial resolution in the assessment of superficial structures and a relatively low diagnostic cost [6,16,17,18]. One of the greatest advantages of this method is the ability to assess structures in real time and perform dynamic tests, which allows for a more accurate assessment of the stability of anatomical structures [2,8,12,16,17]. The examination can also be performed in a bedside setting, increasing its usefulness in clinical practice [9,16,17,18]. Ultrasonography is widely used in the diagnosis of injuries affecting muscles, tendons, and ligaments. This method allows evaluation of hematomas, muscle fiber damage, and inflammatory changes within soft tissues [2,5,9,12,13,16,17]. Additionally, ultrasonography may be used to monitor the healing process and guide image-guided interventional procedures such as injections [1,2,5,6,16,17]. A limitation of ultrasonography is its strong dependence on the operator's experience as well as the limited ability to assess deep anatomical structures [2,8,16, 17,18]. US often represents a first-line imaging modality which, when necessary, is supplemented with MRI examination [2,9,16,19].

4.3. Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is one of the most advanced imaging methods used in the diagnosis of sports injuries [3]. This technique allows for high-contrast images of soft tissue without the use of ionizing radiation [5,8,9,20]. MRI allows detailed assessment of muscles, ligaments, articular cartilage, and bone marrow edema [1,4,5,8,]. Due to its high diagnostic sensitivity, this method is particularly useful in the evaluation of soft tissue injuries such as muscle and ligament damage [2,3,4,5,8,21]. MRI is currently considered the most accurate method for assessing muscle injuries in sports [3,4,8,9,20,22]. MRI enables precise localization of the injury, assessment of its extent, determination of the number of involved musculotendinous structures, and evaluation of the degree of muscle fibre damage [3,4,5,21]. These parameters are crucial for treatment planning and for predicting the time required for an athlete to return to sports activity [1,5,8,10,23,27,28]. The main limitations of this method include the relatively high cost of the examination, limited availability in some centres, longer examination times, and contraindications related to the presence of certain medical implants [17].

4.4. Computed tomography (CT)

Computed tomography is an advanced imaging method that utilizes ionizing radiation and computer-aided reconstruction of cross-sectional images [14]. This technique enables highly accurate assessment of bone structures [8]. In sports medicine, computed tomography is particularly useful in the diagnosis of complex fractures, especially comminuted and intra-articular fractures. The ability to perform multiplanar reconstructions and three-dimensional images allows for precise assessment of fracture fissures and surgical treatment planning. Due to its high spatial resolution, computed tomography allows highly accurate evaluation of bone structures, making it a complementary method to conventional radiography [15]. Key characteristics of computed tomography include very high accuracy in imaging bone structures, the possibility of multiplanar reconstruction (MPR), three-dimensional reconstruction (3D), short examination time, and wide availability in hospital diagnostics. The limitations of computed tomography include the use of ionizing radiation and its limited usefulness in assessing soft tissue compared to magnetic resonance imaging [1,8,15]. Due to the use of ionizing radiation, similarly to radiography, CT examinations should follow the ALARA principle recommended, among others, by the World Health Organization [14].

5. Comparative Summary

Table 1. Comparative Summary – imaging diagnostics in sports medicine.

Modality	**Description**	**Advantages**	**Limitations**	**Typical Clinical Applications**
Radiography (X-ray)	Uses ionizing radiation to visualize bone structures	Rapid, widely available, relatively inexpensive	Limited soft tissue assessment; early stress fractures may be invisible	Acute fractures, stress fractures, joint dislocations, monitoring bone healing
Ultrasonography (US)	Non-invasive imaging of soft tissues using sound waves	No ionizing radiation, dynamic assessment possible, high resolution for superficial structures, low cost, bedside accessibility	Operator-dependent, limited penetration of deep tissues, small field of view, difficulty visualizing intra-articular structures	Muscle strains, tendon/ligament injuries, bursitis, enthesopathies, rehabilitation monitoring, image-guided injections
Magnetic Resonance Imaging (MRI)	Advanced imaging of soft tissues and bone structures using magnetic fields	High sensitivity for soft tissues, no ionizing radiation, detailed evaluation of muscles, ligaments, cartilage	High cost, limited availability, contraindications (implants), longer scan time	Muscle and ligament injuries, cartilage evaluation, injury extent assessment, surgical planning, return-to-play prognosis
Computed Tomography (CT)	Uses ionizing radiation for cross-sectional and 3D reconstruction of anatomical structures	High bone resolution, multiplanar (MPR) and 3D reconstructions, fast, widely available	Ionizing radiation exposure, limited soft tissue assessment, lower soft tissue sensitivity vs MRI	Complex fractures, intra-articular fractures, ankle/knee/shoulder bone injuries, preoperative planning

Source: own elaboration.

6. Diagnostic imaging and improving the quality of medical care

The introduction of advanced imaging methods has significantly improved the quality of care for athletes by shortening diagnostic times, more accurate qualification for conservative or surgical treatment, monitoring tissue regeneration, and reducing the number of complications and recurrences of injuries [2]. Imaging diagnostics also allows a more objective assessment of an athlete's readiness to return to sport (Return to Play), which is one of the most important elements of modern sports medicine [3,4,5,6,7]. According to the principles of preventive healthcare promoted by the World Health Organization, early detection of pathology is key to reducing the long-term consequences of injuries.

7. New technologies in imaging diagnostics in sports medicine

Technological advances in imaging diagnostics have led to the introduction of new imaging methods that may significantly increase diagnostic capabilities in sports medicine in the future. These include elastography, three-dimensional imaging, and the use of artificial intelligence in medical image analysis [2,23]. Artificial intelligence enables the automatic analysis of radiological images, including segmentation of anatomical structures, detection of pathological changes, and quantitative analysis of tissue [24]. The use of machine learning algorithms can improve diagnostic accuracy and shorten the interpretation time. Artificial intelligence also enables automatic image analysis and increased diagnostic accuracy through the detection of subtle changes that may be imperceptible to the human eye.

8. Artificial intelligence (AI) in radiology

The dynamic development of digital technologies has led to the growing application of artificial intelligence (AI) in imaging diagnostics, particularly in sports medicine radiology [25,26]. Machine learning and deep learning algorithms enable automated image analysis, improving diagnostic accuracy, reducing interpretation time, and supporting treatment planning [10,24]. AI is primarily used in the analysis of images obtained from ultrasonography (US), magnetic resonance imaging (MRI), and computed tomography (CT), particularly in the evaluation of the musculoskeletal system. The main functions of these algorithms include automatic segmentation of anatomical structures, detection of pathological changes, quantitative tissue analysis, and automation of reporting [10,24,27]. In magnetic resonance imaging, artificial intelligence supports the evaluation of muscle and tendon injuries, reduction of motion artifacts, and reconstruction of images from accelerated sequences. In computed tomography, it is mainly used to improve image quality, reduce radiation dose, and automatically detect fractures. In ultrasonography, AI reduces operator dependency by enabling automatic identification of structures and analysis of quantitative parameters. The application of AI in interventional radiology includes procedure planning, image-guided navigation, and patient-specific anatomical modelling [10,24,27]. The main benefits of using artificial intelligence include increased diagnostic accuracy, standardization of examination interpretation, and the possibility of monitoring treatment processes and predicting an athlete's return to activity [5,6,7,10,24,27]. Limitations include the need for large training datasets, lack of full model standardization, and legal and ethical issues [25,26,27,28,29]. AI should therefore be considered a supportive tool rather than a replacement for the radiologist [26,27,28,29].

9. Discussion

Imaging diagnostics plays a key role in modern sports medicine by enabling precise diagnosis of injuries and monitoring of the treatment process. Analysis of the literature indicates that appropriate selection of imaging modalities significantly improves the quality of care for athletes and shortens the time required to return to physical activity [3,4,5,6,7]. Radiography remains the primary diagnostic modality in the evaluation of acute bone injuries due to its wide availability, low cost, and short examination time. However, its limited value in assessing soft tissues necessitates the use of additional imaging methods. Ultrasonography represents a valuable tool in the diagnosis of muscle, tendon, and ligament injuries [12]. The possibility of dynamic assessment of anatomical structures and the absence of ionizing radiation make this method particularly useful in everyday clinical practice and bedside diagnostics [2,8,12,16]. However, it should be emphasized that the quality of the examination largely depends on the operator's experience. Magnetic resonance imaging is currently considered the most comprehensive imaging modality in sports medicine, particularly in the diagnosis of soft tissue injuries. Its high contrast resolution allows detailed assessment of muscles, ligaments, articular cartilage, and bone marrow edema. MRI also plays an important role in predicting the time required for an athlete to return to sports activity [3,4,7]. Computed tomography is mainly used in the diagnosis of complex bone injuries and in surgical planning. The possibility of multiplanar reconstruction and three-dimensional imaging enables very precise evaluation of bone structures. In recent years, a dynamic development of new technologies in imaging diagnostics has been observed. A particularly promising direction is the use of artificial intelligence in medical image analysis [26,27]. Machine learning algorithms may support the diagnostic process through automatic detection of pathological changes, quantitative tissue analysis, and standardization of examination interpretation [10,27]. Despite the numerous advantages of artificial intelligence-based technologies, their implementation in clinical practice requires further research, algorithm standardization, and resolution of legal and ethical issues associated with their use [26,27,28,29,30].

10. Conclusions

Imaging diagnostics constitutes a fundamental component of injury diagnosis in sports medicine.

Appropriate selection of imaging modalities such as radiography, ultrasonography, magnetic resonance imaging, and computed tomography allows accurate evaluation of musculoskeletal structures and implementation of appropriate treatment.

Magnetic resonance imaging and ultrasonography play a key role in the diagnosis of soft tissue injuries, whereas computed tomography is particularly useful in the evaluation of complex bone injuries.

Technological advances in imaging diagnostics, including the development of artificial intelligence and new imaging techniques, may significantly increase diagnostic accuracy and improve the quality of care for athletes in the future.

The integration of modern imaging modalities with clinical practice represents an important element in optimizing the diagnostic and therapeutic process and ensuring a safe return of athletes to sports activity.

According to the principles of preventive healthcare promoted by the World Health Organization, early detection of pathology is key to reducing the long-term consequences of injuries.

Disclosure

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In preparing this work, the authors used ChatGPT for the purposes of language editing, translation into English, and improving readability. After using this tool, the authors reviewed and edited the content as necessary and accept full responsibility for the substantive content of the publication.

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