https://doi.org/10.47183/mes.2024-26-4-104-113

PROSPECTS FOR DIAGNOSIS AND TREATMENT OF MINIMAL TRAUMA AND INJURY OF LARGE JOINTS IN UNDERAGE ATHLETES: A REVIEW

Ilya V. Zyabkin[1,2,3], Ivan V. Pankratov[1]✉, Mikhail A. Petrov[1], Murat I. Gabayev[1], Razmik A. Keshishyan[1], Victoria V. Khizhnikova[1], Aleksandra M. Kovalkova[1]

[1] Federal Scientific and Clinical Center for Children and Adolescents of the Federal Medical and Biological Agency, Moscow, Russia

[2] Russian State Research Center — Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency, Moscow, Russia

[3] Russian Medical Academy of Continuous Professional Education

Introduction. The vast majority of modern sports exert a significant load on the musculoskeletal system (MSS). The ever-growing popularity of sports among underage children, their active participation in various competitions and trainings impose an increased risk of sports injuries, particularly minimal trauma and injury of large joints. Although numerous works have addressed the development of clinical diagnostic and therapeutic methods used for MSS injuries, there is a lack of publications on sports injuries in underage athletes.

Objective. Evaluation of current methods for diagnosis and therapy of minimal trauma and injury of large joints in underage athletes with the purpose of selecting the most promising and effective methods.

Findings. The main causes and mechanisms of injuries are considered. Such injuries are generalized depending on the sports type. A review of available methods for clinical and instrumental research and innovative therapeutical methods is carried out. Platelet-rich plasma therapy (PRP) was found to be the most promising minimally-invasive biotherapy for MSS injuries, particularly with respect to children and adolescent athletes. This method restores the anatomical integrity of damaged elements and relieves pain at rest, during physical exertion, and in a stress test with the possibility of preserving the function of the injured joint and rehabilitation in the shortest possible time. PRP therapy is an alternative to conventional treatment methods, offering new prospects in regenerative and sports medicine.

Conclusions. A comprehensive personalized approach combining clinical examination and instrumental studies is key to ensuring the accuracy and objectivity of the health status of young athletes. Such an approach allows diseases to be identified at an early stage, differential diagnosis to be conducted, and treatment efficacy to be evaluated, taking the specifics of pediatric practice into account.

Keywords: sports medicine; pediatric sports injuries; therapy of minimal trauma and injury of large joints; PRP therapy; underage athletes

For citation: Zyabkin I.V., Pankratov I.V., Petrov M.A., Gabayev M.I., Keshishyan R.A., Khizhnikova V.V., Kovalkova A.M. Prospects for diagnosis and treatment of minimal trauma and injury of large joints in underage athletes: A review. *Extreme Medicine*. 2024;26(4):104–113. https://doi.org/10.47183/mes.2024-26-4-104-113

Funding: the research was carried out within the state assignment (theme No. 124022800121-3; code 83.002.24.800).

Acknowledgments: the authors express their gratitude to Valery Mukhortykh, Scientific Secretary of the Federal Scientific and Clinical Center for Children and Adolescents of the FMBA, for assistance in preparing the manuscript for publication.

Potential conflict of interest: the authors declare no conflict of interest.

✉ Ivan V. Pankratov pankratoviv@kidsfmba.ru

Received: 13 Sep. 2024 **Revised:** 18 Nov. 2024 **Accepted:** 19 Nov. 2024

ПЕРСПЕКТИВЫ ДИАГНОСТИКИ И ЛЕЧЕНИЯ МИНИМАЛЬНЫХ ТРАВМ И ПОВРЕЖДЕНИЙ КРУПНЫХ СУСТАВОВ У НЕСОВЕРШЕННОЛЕТНИХ СПОРТСМЕНОВ: СОВРЕМЕННЫЕ ПРЕДСТАВЛЕНИЯ

И.В. Зябкин[1,2,3], И.В. Панкратов[1]✉, М.А. Петров[1], М.И. Габаев[1], Р.А. Кешишян[1], В.В. Хижникова[1], А.М. Ковалькова[1]

[1] Федеральный научно-клинический центр детей и подростков ФМБА России, Москва, Россия

[2] Государственный научный центр Российской Федерации — Федеральный медицинский биофизический центр им. А.И. Бурназяна ФМБА России, Москва, Россия

[3] Российская медицинская академия непрерывного профессионального образования Министерства здравоохранения Российской Федерации, Москва, Россия

Введение. Подавляющее большинство современных видов спорта оказывают значительную нагрузку на опорно-двигательный аппарат (ОДА). Постоянно растущая популярность спорта среди несовершеннолетних детей, их активное участие в различных соревнованиях и тренировках создают повышенный риск получения спортивных травм, особенно минимальных повреждений и травм крупных суставов. Множество работ посвящено клинико-диагностическим и терапевтическим методам, применяющимся при травмах ОДА, однако лишь незначительная их часть касается именно детского спортивного травматизма.

Цель. Оценка существующих методов диагностики и терапии минимальных травм и повреждений крупных суставов у несовершеннолетних спортсменов для выбора наиболее перспективных и эффективных из них.

Обсуждение. Рассмотрены основные причины и механизмы травм, проведена систематизация типов травм в зависимости от вида спорта, выполнен анализ имеющихся современных методов клинико-инструментального исследования и инновационных методов терапии. Выяснено, что наиболее перспективным малоинвазивным методом биотерапии травм и повреждений ОДА, особенно в аспекте применения в детской и подростковой группе спортсменов, является PRP-терапия (терапия богатой тромбоцитами плазмой). Данный метод позволяет существенно восстанавливать анатомическую целостность поврежденных элементов, купировать болевой синдром в покое, при физической нагрузке и в стресс-тесте с возможностью сохранения функции травмированного сустава и реабилитации в кратчайшие сроки. PRP-терапия представляет собой альтернативу традиционным методам лечения, открывая новые горизонты в регенеративной и спортивной медицине.

Выводы. Комплексный персонализированный подход, объединяющий клинический осмотр и инструментальные исследования, является ключевым в обеспечении точности и объективности оценки состояния здоровья юных спортсменов; он позволяет выявить заболевания на ранней стадии, провести дифференциальную диагностику и оценить эффективность лечения с учетом особенностей педиатрической практики.

Ключевые слова: спортивная медицина; детские спортивные травмы; терапия минимальных травм и повреждений крупных суставов; PRP-терапия; несовершеннолетние спортсмены

Для цитирования: Зябкин И.В., Панкратов И.В., Петров М.А., Габаев М.И., Кешишян Р.А., Хижникова В.В., Ковалькова А.М. Перспективы диагностики и лечения минимальных травм и повреждений крупных суставов у несовершеннолетних спортсменов: современные представления. *Медицина экстремальных ситуаций*. 2024;26(4):104–113. https://doi.org/10.47183/mes.2024-26-4-104-113

Финансирование: работа выполнена в рамках государственного задания № 124022800121-3, тема НИР «PRP-терапия при травмах и заболеваниях крупных суставов у юниоров спортивных сборных команд Российской Федерации»; шифр темы «PRP-терапия при травмах»; код — 83.002.24.800.

Благодарности: ученому секретарю ФГБУ «ФНКЦ детей и подростков ФМБА России» Мухортых Валерию Алексеевичу за сопровождение написания и подачи рукописи для публикации.

Потенциальный конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

✉ Панкратов Иван Владимирович pankratoviv@kidsfmba.ru

Статья поступила: 13.09.2024 **После доработки:** 18.11.2024 **Принята к публикации:** 19.11.2024

INTRODUCTION

The vast majority of modern sports exert a significant load on the musculoskeletal system (MSS). At the same time, the frequency of various MSS diseases among athletes is much higher than among the general population. Thus, the prevalence of injuries as a result of sports among children aged 5–17 years reaches about 35.8%.

The ever-growing popularity of sports among minors, their active participation in various competitions and training create an increased risk of sports injuries, especially minimal damage and injuries to large joints [3]. Such injuries, despite their apparent lightness, may have serious consequences for the sports career of a young athlete if timely and adequate diagnosis and therapy of existing changes are not carried out, especially in the early stages.

Accurate diagnosis and rational tactics of managing the patient with injuries of large joints are the key factors in achieving the maximum efficacy of therapeutic measures [4]. Numerous publications have investigated the questions of clinical diagnostic and therapeutic methods for MSS injuries, with only a few of them addressing specifically children's sports injuries. In order to gain a comprehensive understanding of how protocols should be modified when applied to underage athletes in case of injury, it seems relevant to carry out a review of standard and innovative methods of clinical and instrumental examination and treatment of such injuries.

In this work, we review modern methods of diagnosis and therapy of minimal injuries and damage to large joints in underage athletes in order to select the most promising and effective methods.

FINDINGS

General ideas about sports injury

Sports injuries as a result of intense training and competitive stress may involve serious consequences for athletes. Such events not only disrupt the training and competitive processes, but also lead to long-term rehabilitation, frequently accompanied by temporary or permanent restriction of physical activity. In severe cases, sports injuries can cause premature termination of sporting careers and even lead to disability, significantly impairing the quality of life of athletes [5].

Sports-associated injuries are distinguished by a variety of driving mechanisms, the anatomical and physiological characteristics of the child, and the type of sports. The International Olympic Committee Consensus Group on the Epidemiology of Injuries and Diseases defines sports injury as "a tissue damage or other derangement of normal physical function due to participation in sports, resulting from rapid or repetitive transfer of kinetic energy" [6].

Successful treatment of sports injuries depends on accurate diagnosis, which takes into account the following key factors: the onset of occurrence (acute injury or injury caused by excessive exertion), the type of damaged tissue (tendon, muscle, cartilage, bone), and the severity of the injury (fracture without displacement or with displacement) [7].

In acute trauma, the patient clearly remembers the moment, place, cause, and circumstances of its occurrence, unlike injuries associated with excessive overstrain. The most common acute injuries include sprains and ligament damage (rupture), joint dislocations and fractures. Overstrain injuries, conversely, develop gradually as a result of repetitive microtraumas that occur with excessive and repetitive stress. One feature of such injuries is the gradual manifestation of symptoms, when repeated microtrauma overloads the ability of tissues to auto-healing. This is particularly important in children's practice, given the functional immaturity of tissues, organs, and systems of the child's body and less developed resistance to stress [8].

An increase in training loads, a high level of competition in sports, and the requirements imposed on a child — all these circumstances explain why sports injuries occupy a leading place in the morbidity structure of young athletes. Brenner et al. showed that overexertion injuries and emotional burnout of a child are the two main reasons for ending a sporting career. It is important to understand the mechanisms and underlying processes of injury for selecting an optimal examination tactics

and timely determination of treatment criteria (conservative or operative) [10].

Understanding all aspects of sports injury, taking into account gender and age characteristics and the type of sports, as well as the frequency of injuries and the likelihood of acute injury or injury as a result of overexertion, plays an important role in shaping a personalized approach to the management of athletes, including the development of a set of preventive measures. For a systematic assessment of sports injuries, differentiation is necessary by the localization of the anatomical segment and by the type of damaged injury tissue (ligament, muscle, or bone). For example, injuries to the hip or knee area may involve muscle contusion, muscle compartment syndrome, tendinopathy, and tendon rupture. Most childhood injuries associated with excessive exertion affect the lower extremities, especially the knees, ankles, and feet, and also include damage to muscles and tendons [11]. Injuries from excessive loads (in comparison with acute effects) are about twice more common in the knee joint, while acute injuries are about three times more likely to occur in the ankle joint [12].

According to Sheffield, the knee joint is most often injured in sports such as football and rugby [13]. At the same time, the author pays special attention to the assessment, treatment, and rehabilitation of knee instability and the difficulties faced by the attending physician in the management of young and active patients. Other authors noted that the prevalence of patellar tendinopathy (jumper's knee symptoms) in athletes reaches approximately 14%, while the recurrence rate reaches 45% in volleyball players and 32% in basketball players. The study by Bahr M.A. and Bahr R. found that about 29–44% of elite volleyball players who perform more than 500 jumps per week report jumper's knee symptoms [15]. In the structure of sports injuries, ankle injuries reach 10–12% of all injuries to the musculoskeletal system and 20–25% of all sports injuries to the lower extremities.

According to Sobhani et al., the most common injury in football associated with excessive strain is Achilles tendinopathy. This can be explained by the large amount of running and jumping in this kind of sports [16]. The most common MSS injuries as a result of overexertion are presented in Table 1.

Modern methods of diagnosis of minimal injuries and damage to large joints in children

A key factor in the successful recovery of an athlete after injury is a comprehensive and dynamic clinical and instrumental examination [3, 16, 18], which allows not only the degree of damage to be assessed, but also the progress of rehabilitation to be traced in dynamics. The introduction of instrumental research methods into clinical practice has significantly extended the possibilities of early diagnosis [3, 16]. Timely and accurate diagnosis contributes to the speedy return of the athlete to previous physical activity and professional loads [19].

The most common injuries of the MSS in qualified athletes, including minors, are the so-called minor injuries [20], such as bruises, sprains, chronic microtrauma, degenerative-dystrophic processes, etc. Most of these injuries are manifestations of overtraining or minor sports injuries that do not require specialized diagnosis and treatment. However, minor injuries might disguise the initial manifestations of more significant injuries and pathological conditions (spondylolisthesis, protrusion and herniation of discs, dorsalgia, vertebral ring apophyseal fracture, undiagnosed spinal injuries, etc.), which, in the absence of timely treatment, can lead to more serious health problems for an athlete.

The difficulty in diagnosing minor MSS injuries is associated with their meager and non-specific symptoms. Athletes complain of discomfort in the area of injury or mild pain syndrome without a clear localization. As usual, such "complaints" are not given due importance, with their discomfort attributed to a reaction to training loads, overtraining, etc. Such a situation becomes even more complicated in case of underage athletes due to the specifics of collecting and interpreting complaints in pediatric practice, which requires a more thorough approach to interviewing a young patient by the attending physician. Another diagnostic problem is the low sensitivity and specificity of standard traumatic orthopedic tests to a number of minor MSS

Table 1. Injuries of the musculoskeletal system as a result of overstrain

Tissue	Injury type	Examples of manifestation in sports
Muscles/fascia	Chronic compartment syndrome; Delayed Muscle Soreness (DOMS); Fasciitis	Iliotibial syndrome when running
Tendon	Tendinopathy (includes parathenonitis, tenosynovitis, tendinosis and tendinitis)	Tendinopathy of the Achilles tendon in football players; Patellar tendinosis in volleyball (jumper's knee)
Joint	Synovitis; Injuries to the upper lip; Chondropathy; Injuries to the internal structures of the joint	Superior labrum anterior to posterior lesions of the shoulder (SLAP) in athletes engaged in throwing (baseball, cricket); Damage to the internal structures of the knee joint (running, jumping)
Ligamentous apparatus	Chronic degeneration/microfractures	Collateral ulnar ligament injury in baseball
Bone	Stress reaction, stress fracture; Osteitis, periostitis; Apophysitis	Stress fracture of the metatarsal bone during running and ballet; Medial tibial stress syndrome in running and dancing; Osgood-Schlatter disease; Stress fracture

Table prepared by the authors based on [21]

injuries. Such tests are mostly focused on assessing the passive range of motion and the active functioning of the athlete's musculoskeletal system, without association with a particular sports, which limits their clinical significance and application [21]. As a rule, minor injuries occur when performing specific active movements characteristic of certain sports, which are often impossible to reproduce in a standard clinical examination.

The frequency of minor traumas and injuries of the MSS, including in underage athletes, requires a systematic approach to their clinical and diagnostic examination based on a thorough collection of complaints and anamnesis, permitting timely diagnosis of the existing pathology and developing a personalized treatment approach.

Dietvorst et al. described a diagnostic procedure for anterior cruciate ligament injuries in children and adolescents, confirming the diagnostic value of anamnesis collection, physical examination, and arthroscopy [22]. Endele et al. showed sufficient efficacy of standard clinical, radiological, and ultrasound diagnostics for primary detection of fractures and ligament injuries of the ankle joint in children [23].

A thorough history collection is an indispensable tool for diagnosing MSS injuries, which allows not only the mechanism of injury to be identified, but also a conclusion about the intended type of injury to be made, thus suggesting the most appropriate directions for further examination and treatment.

The pain syndrome may be diffuse or local in nature. When determining the intensity of pain, the Visual Analogue Scale (VAS) is most often used, including in traumatology practice [24]. Physical examination includes examination of the joint for swelling and palpation for soreness. Among the assessed factors are local temperature, soreness, fluctuation, sensitivity disorders (hyperesthesia, hyposthesia, anesthesia), tissue turgor, skin and muscle condition, tissue swelling, crepitation of fragments, patellar balloting, and tendon mobility. Palpation is diagnosed with crepitating and stenosing parathenonitis, clicking joint, and snapping scapula syndrome. In addition, the length and circumference of the limb are measured, and the amplitude of its movements is determined.

In modern clinical practice, preference is given to highly informative research methods. X-ray examinations significantly extends diagnostic capabilities, providing data that cannot be detected by conventional clinical methods. Ultrasound examination (ultrasound), magnetic resonance imaging (MRI), and multispiral computed tomography (MSCT) are currently used as the main methods of choice for visualization of bone and cartilage structures [3, 16]. The publications addressing the issues of visualization highlight the importance of radiography, ultrasound, and additional methods (if necessary) for the diagnosis of MSS injuries.

Ultrasound diagnostics of the joints demonstrates a sufficiently high accuracy in the diagnosis of intra-articular injuries. The most frequently detected injuries the knee joint were found to be damage to the inner and outer menisci. A study into latent intraarticular knee joint injuries in children showed the need to use MRI diagnostics to establish a diagnosis in the absence or minimum amount of radiological data [26]. The importance of magnetic resonance imaging in the diagnosis of damage to the ligamentous apparatus of the knee joint in children was noted in [27].

MRI implies a high soft-tissue contrast, allowing examination in any plane and taking into account the anatomical features of the patient (including three-dimensional images). Moreover, MRI is the only noninvasive diagnostic method with high sensitivity and specificity in detecting edema and infiltration of bone tissue. Thus, even minimal damage to the menisci can be detected, including in pediatric practice. MRI diagnostics allows the physician to establish an accurate diagnosis and prescribe appropriate treatment.

Thus, modern diagnostics of sports injuries is based on an integrated approach, including medical history, which determines the nature of the injury, the circumstances of the injury, the duration of injury (acute or chronic), clinical examination (with provocative tests), as well as additional examination methods (CT, MRI, ultrasound, radiography of damaged limb segments, and standard laboratory tests, such as clinical and biochemical blood tests). In case of MSS injuries in children, along with applying standard approaches to patient management, special attention should be paid to collecting complaints and anamnesis. Indeed, the lack of information or its incorrect interpretation can cause an incorrect diagnosis and, as a result, incorrect examination and treatment tactics.

Therapy of minimal injuries and damage to large joints in children

The method and duration of treatment (conservative or operative) are determined by the specifics of injury (which tissue is damaged, the degree of damage), the age of the young athlete, and the kind of sports he or she is engaged in. The most common sports injuries that do not require specialized medical care include superficial injuries, namely: soft tissue bruises, sprains, ruptures of the ligamentous apparatus, joint damage.

The first stage of treatment of sports injuries in children is based on the P.R.I.C.E and/or R.I.C.E protocols: Protection, Rest, Ice, Compression, Elevation (PRICE). Within this framework, Protection is understood as limiting or excluding the load with the help of crutches, a cane, partial immobilization of the injured area with a bandage, splint or bandage. Rest provides for restriction of movements or "relative" rest, when actions that load the injured area to such an extent that pain occurs, or which can slow or prevent healing, are excluded. Ice cryotherapy is applied in acute injuries to reduce swelling and pain. Compression includes the use of a compression bandage, i.e., an elastic bandage for easy support of damaged tissue. Elevation is understood as placing the damaged area above the level of the heart in order to reduce the accumulation of fluid in the damaged limb or joint and, as a result, reduce the level of pain [28].

RICE is the basis for the treatment of acute soft tissue injuries, promoting a conservative approach during the first 24–48 hours after injury. The purpose of this protocol is to minimize bleeding, reduce swelling, and alleviate discomfort at the site of injury, which measures potentially

speed up the recovery process [28]. Scientific discoveries and advances in clinical practice have suggested that RICE cannot be a versatile approach for all injury treatment scenarios [29, 30].

New data confirm the use of more active recovery strategies based on the following principles: Movement, Exercise, Analgesia, Treatment (MEAT); Protection, Optimal Loading, Ice, Compression, Elevation (POLICE), and Protection, Elevation, Avoid anti-inflammatories, Compression, Education and Load, Optimism, Vascularization, and Exercise (PEACE and LOVE) [31, 32]. Thus, the above principles emphasize the importance of early motor activity, individual exercises, and comprehensive care to improve healing and functional recovery. At the same time, the fundamental elements of RICE still retain their value, especially when providing emergency care after injuries [33].

Various treatment methods are aimed at restoring the anatomical integrity and functionality of joints, minimizing pain syndrome, preventing the development of complications and chronic joint diseases, and (most importantly) ensuring a safe and speedy return to sports.

In modern clinical practice, the following methods of treatment of minimal injuries and damage to large joints are distinguished:

1. Conservative treatment

- Immobilization of the joint: fixation of the joint with plaster, orthoses or bandages, which is necessary to stabilize the joint and prevent further damage;
- Pharmacotherapy: the use of painkillers, anti-inflammatory, and other drugs to relieve pain and reduce the inflammatory process. Drug therapy may be effective for mild injuries; however, it may not always completely eliminate the symptoms. In addition, some drugs may have side effects, such as allergic reactions and gastrointestinal disorders [35, 36];
- Comprehensive medical rehabilitation, including rehabilitation programs: physical therapy (a set of exercises aimed at restoring the amplitude of movement in the joints, muscle strength, coordination of movements and balance), massage, physiotherapy (to reduce inflammation, relieve pain, and accelerate the rehabilitation process).

Conservative treatment of minimal injuries and damage to large joints in underage athletes has a number of advantages. Such a treatment approach is non-invasive, requiring no surgical intervention. This reduces the risk of postoperative complications, infections, and scarring of tissues, being associated with minimal risk (compared to surgery, conservative treatment is less risky for young athletes, especially during periods of active growth) and cost-effectiveness. However, conservative treatment has a number of limitations, e.g., it may not be effective enough for severe injuries. In addition, conservative treatment requires a long recovery period and increases the risk of developing chronic instability, which can lead to repeated injuries. Thus, conservative treatment is a promising method of treating minimal injuries and damage to large joints in underage athletes; however, in some cases, surgical intervention may be required.

2. Surgical treatment

Surgical intervention is used for severe injuries requiring restoration of the integrity of ligaments, cartilage, or bones, as well as for stabilizing joints. Indications for surgical intervention include a complete or partial rupture of ligaments, not amenable to conservative treatment, broken bones of the joint that needs fixing fragments, and inflammatory processes that are not amenable to conservative treatment, cartilage defects, causing pain, limited mobility and threatening the destruction of the articular surface, permanent dislocations or subluxations, which are not amenable to conservative therapy [39]. Surgical intervention allows the anatomy of the joint to be restored and its stability to be ensured. It may be necessary for restoring function, preventing repeated injuries, reducing pain, improving joint mobility, and improving the quality of life of an athlete. The disadvantages of this treatment include the risk of complications and a long period of rehabilitation.

Thus, surgery for joint injuries in athletes, including minors, is a serious intervention that requires careful planning and an individual approach.

3. Minimally invasive methods (intra-articular injections)

PRP therapy (Platelet Rich Plasma) is an innovative treatment method that is actively used in various fields of medicine, especially in orthopedics and sports medicine [40, 41]. This method is based on the use of autologous (own) blood plasma of the patient, enriched with platelets [40]. Platelets contain growth factors that stimulate tissue regeneration, accelerate healing, and promote recovery after injury or surgery [41]. One of the main advantages of PRP therapy is rapid recovery after the procedure [40, 41]. Patients can return to sports activities within a few days after this procedure. In addition, PRP can help improve blood circulation and metabolism in the tissues of the joint, which also contributes to their recovery. This method is safe and associated with a minimal risk of allergic diseases. It is important that the composition of PRP can be adapted to the individual needs of the patient. This makes this method versatile for various types of injuries and diseases. In addition, it has become possible to use PRP in professional sports, despite the content of growth factors in the composition. Growth factors are independently considered as doping and, in accordance with the decision of the Anti-Doping Agency, were the reason for deterring the use of PRP until 2011 in sports medicine for muscle damage [42].

Thus, there are several options for the treatment of MSS injuries, while the choice of a specific method depends on the type of damaged tissue, the nature and severity of the damage, the age of the athlete, and the type of sports, as well as the type of injury (acute or related to overstrain/overstrain). In order to alleviate pain, shorten the rehabilitation period, and return to high-performance sports as soon as possible in the absence of indications for surgical treatment, minimally invasive methods,

including PRP therapy, both as monotherapy and in combination with conservative treatment, are undoubtedly a priority in application [43].

PRP therapy as an innovative method of treating minimal injuries and damage to large joints in pediatric practice and sports medicine

Modern knowledge about the anatomy and physiology of child development, taking into account age-related features and growth processes, combined with advanced examination methods (MRI, CT, ultrasound) have brought the diagnosis of injuries and injuries to a qualitatively new level, allowing even minimal damage to be detected and appropriate pathogenetically justified treatment to be prescribed [3, 18].

Conservative treatment, including rest, immobilization, and physiotherapy, has undoubtedly proved its effectiveness over time. However, modern conditions are increasingly requiring faster healing of the damaged part and timely return to athletic fitness, including in high-performance sports [34–36]. This has become an incentive to search for new treatment methods.

In the field of orthopedic medicine, the search for innovative therapies aimed at relieving pain, accelerating recovery, and promoting tissue regeneration has led to the emergence of regenerative therapy as a promising direction. Regenerative therapy is based on the use of innovative cellular technologies and products to repair damaged tissues and organs. As part of the development of regenerative therapy, the use of orthobiologics products, i.e., biological substances that contribute to faster recovery of damaged tissues, is of great importance. These include hyaluronic acid, platelet-rich plasma (PRP), mesenchymal stem cells, bone marrow aspirate concentrate (BMAC), and cultured mesenchymal stem cells [44]. Orthobiological products are naturally found in the body; however, they can help accelerate the healing process in higher concentrations.

PRP therapy is among the most recent methods of biotherapy of MSS injuries. This approach shows positive results in relieving pain syndrome, improving functional state, and shortening the rehabilitation period in patients with injuries of the musculoskeletal system [46–48]. PRP is an orthobiological treatment method based on the use of biologically active platelet molecules. At baseline levels, platelets function as a natural reservoir of growth factors, including platelet-derived growth factor (PDGF), epidermal growth factor (EGF), transforming growth factor beta-1 (TGF-β1), vascular endothelial growth factor (VEGF), basic fibroblast growth factor (FGF), hepatocyte growth factor (HGF), and insulin-like growth factor (IGF-I). PRP is commonly used in orthopedic practice to accelerate tissue healing as a result of injuries, including those related to sports.

According to Russian and foreign literature, PRP is a generalizing term for a group of human autologous blood products. PRP includes products derived from autologous blood, such as platelet-rich plasma and autologous conditioned plasma. Platelet-derived products are classified into pure PRP (Pure Platelet-Rich Plasma/P-PRP), plasma enriched with growth factors (Plasma Rich Growth Factors/PRGF), leukocyte and platelet plasma, pure platelet-rich fibrin (P-PRF), and leukocyte (Leukocyte-Platelet-Rich Fibrin/L-PRF), and platelet fibrin (Advanced/A-PRF). The composition of these products may vary depending on the content of cells and fibrin, as well as on the density of the fibrin network [52].

In 2009, the first classification of platelet concentrates was proposed [53]. This classification is simple and based on the content of certain blood components and their quantity. This classification divides products according to two main parameters: cellular composition (mainly leukocytes) and fibrin architecture. This separation made it possible to identify the four main families for product rearrangement given below.

1. Pure platelet-rich plasma (P-PRP) or leukocyte-poor platelet-rich plasma products are preparations without leukocytes and with a low-density fibrin network after activation. By definition, all products of this family can be used in the form of liquid solutions or in the form of an activated gel. Therefore, it can be injected (in the form of a solution) or applied as a gel to the surface of a wound or suture (similar to the use of fibrin adhesives). This family includes platelet-rich Plasma (PRP) and autologous conditioned plasma (ACP).

2. Plasma products enriched with leukocytes and platelets (L-PRP), which are preparations with leukocytes and a low-density fibrin mesh after activation. By definition, like P-PRP, all products of this family can be used in the form of liquid solutions or in the form of an activated gel [54].

3. Pure platelet-rich fibrin (P-PRF) or leukocyte-poor and platelet-rich fibrin are preparations without leukocytes, but with a high-density fibrin network. By definition, these products exist only in the form of a highly activated gel and cannot be injected or used as traditional fibrin adhesives.

4. Leukocyte- and platelet-rich fibrin (L-PRF) products are preparations with leukocytes and with a high-density fibrin network [55].

The classification described above covers all forms of platelet concentrates. In traumatology and orthopedics, another classification has been proposed, which is based on the use of platelet-enriched plasma (PRP only).

Mishra et al. proposed to classify PRP products taking into account the concentration of platelets and leukocytes specifically for use in therapeutic practice in athletes [49]. This classification divides PRP into four types depending on the presence or absence of white blood cells, as well as whether PRP is activated or not. According to this classification, type 1 PRP is an L-PRP solution, type 2 PRP is an L-PRP gel, type 3 PRP is a PPRP solution, and type 4 PRP is a P-PRP gel. This design classification is similar to the general one published in 2009; however, the division of PRP products is limited by cellular composition and activation, which makes it more understandable for clinical use [49]

The only new parameter in the above classification is the assessment of platelet concentration, and type A PRP

is five times (or more) higher than the concentration of platelets in the blood, and type B PRP is only five times higher than the concentration of platelets in the blood. The latter parameter is controversial, since the concept of accounting for platelet concentrations in an PRP product has been largely rejected in previous years for a logical reason, i.e., platelet concentration depends only on the volume of liquid serum used to maintain platelets in suspension. The amount of serum varies greatly depending on the protocol and the expected use, having no influence on the intended effect. The concept of the absolute platelet count would be more logical, although the effect of this parameter on clinical results has not received confirmation in publications. From this point of view, the fivefold threshold does not have a generally accepted meaning and justification [56].

PRP exhibits a pronounced anti-inflammatory, analgesic, pro-regenerative, and anti-apoptotic effect, stimulates the growth and migration of fibroblasts and osteoblasts. Therefore, it is increasingly used to treat the consequences of MSS injuries. Numerous studies have confirmed the effectiveness of PRP in patellar tendinopathy, lateral epicondylitis, rotator cuff injury, tendon and muscle injuries of various localization [50, 51].

Thus, PRP therapy is a promising method for treating damage to large joints, which can become an alternative to conventional methods of treatment, such as conservative therapy and surgery.

CONCLUSION

Modern medicine pays particular attention to the diagnosis of trauma in young athletes, focusing, among other things, on rehabilitation measures after minimal injuries and damage to large joints. Understanding the circumstances of such injuries (causes, onset, mechanisms), as well as the precise definition of damaged tissue in a specific segment of an athlete's limb, are key for determining an optimal examination tactics, developing an individual treatment plan, and predicting both the recovery process and the possibility of returning to full-fledged athletic activity. Special attention should be paid to young athletes whose musculoskeletal system is only in the formation stage, thus being more vulnerable to damage.

Modern instrumental methods extend the range of tools for preventing the development of complications and selecting an optimal treatment approach. Clinical examination and history analysis offer the primary overview of the patient's condition, allowing the physician to identify the main complaints and symptoms. Instrumental research methods, such as radiography, CT, MRI, and ultrasound, provide a more detailed information about the structure and function of organs and body systems, which complements the overall clinical picture, allowing the physician to gain a systemic view of the pathological process and make an accurate diagnosis.

An integrated approach based on clinical examination and instrumental studies is a key factor in ensuring an accurate and objective assessment of the patient's condition. This, in turn, makes it possible to identify diseases at an early stage, conduct differential diagnosis, and evaluate the treatment efficacy.

Along with standard conservative and surgical approaches to the treatment of minimal trauma and MSS injuries in athletes, including children and adolescents, an increasing attention is currently paid to minimally invasive treatment based on orthobiological products. The latter are capable of accelerating the healing process of damaged cells, tissues and organs, reducing the rehabilitation period, which is especially important for young athletes in their early sporting carriers.

Platelet-rich plasma (PRP) therapy is the most promising minimally-invasive method of biotherapy for MSS injuries, especially as applied to adolescent athletes. This method proves effective in restoring the anatomical integrity of damaged elements and relieving pain at rest, during physical exertion, and in a stress test. PRP provides the possibility of preserving the function of the injured joint and rehabilitation in the shortest possible time. PRP therapy is an alternative to conventional treatment methods, offering new opportunities in the fields of regenerative and sports medicine.

Thus, an integrated approach to diagnosis combining clinical examination and instrumental studies, the use of minimally-invasive innovative cellular technologies in underage professional athletes with MSS injuries, including large joints, is becoming an indispensable tool in modern sports medicine.

References

1. Rjabov VP, Nurullin IF, Kurmaev ZF. Occupational injuries and diseases in athletes: a method. stipend. Kazan'; 2017 (In Russ.).
2. NCAA Injury Surveillance 1997-1998. Overland Park, Kan: National Collegiate Athletic Association;1998.
3. Chang EY, Du J, Chung CB. UTE imaging in the musculoskeletal system. *J Magn Reson Imaging*. 2015;41: 870–83. https://doi.org/10.1002/jmri.24713
4. Yelin E, Weinstein S, King T. The burden of musculoskeletal diseases in the United States. *Semin Arthritis Rheum*. 2016;46:259–60. https://doi.org/10.1016/j.semarthrit.2016.07.013
5. Kujala UM. Acute injuries in soccer, ice hockey, volleyball, basketball, judo and karate: an analysis of national registry data. *BMJ*.1995;311:1465–8. https://doi.org/10.1136/bmj.311.7018.1465
6. Ross AG, Donaldson A, Poulos RG. Nationwide sports injury prevention strategies: A scoping review. *Scand J Med Sci Sports*.2021;31(2):246–64. https://doi.org/10.1111/sms.13858
7. Bray CC, Walker CM, Spence DD. Orthobiologics in Pediatric Sports Medicine. *Orthop Clin North Am.* 2017;48(3):333–42. https://doi.org/10.1016/j.ocl.2017.03.006
8. Clarsen Benjamin. Overuse injuries in sport: development, validation and application of a new surveillance method diss.; 2015.
9. Brenner JS, Watson A. Council on sports medicine and fitness. Overuse Injuries, Overtraining, and Burnout in Young Athletes.

Pediatrics. 2024;153(2):2023065129.
https://doi.org/10.1542/peds.2023-065129

10. Bahr R, Clarsen B, Derman W, Dvorak J, Emery CA, Finch CF, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). Br J Sports *Med*. 2020;54(7):372–89.
https://doi.org/10.1136/bjsports-2019-101969
11. Hamilton B, Pollock N, Reurink G, de Vos RJ, Purdam C, Thorborg K. Muscle Injury Classification and Grading Systems. In: Thorborg, K., Opar, D., Shield, A. (eds) *Prevention and Rehabilitation of Hamstring Injuries. Springer Cham*. 2020.
https://doi.org/10.1007/978-3-030-31638-9_8
12. Owoeye OB, Ghali B, Befus K, Stilling C, Hogg A, Choi J. Palacios-Derflingher L, Pasanen K, Emery CA. Epidemiology of all-complaint injuries in youth basketball. *Scand J Med Sci Sports.* 2020; 30 (12): 2466–76.
https://doi.org/10.1111/sms.13813
13. Webb J, Corry I. Injuries of the sporting knee. *Sports Medicine*. 2000;34:227–8.
https://doi.org/10.1136/bjsm.34.5.395
14. Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. *Am J Sports Med*. 2005;33(4):561–7.
https://doi.org/10.1177/0363546504270454
15. Bahr MA, Bahr R. Jump frequency may contribute to risk of jumper's knee: a study of interindividual and sex differences in a total of 11 943 jumps video recorded during training and matches in young elite volleyball players. *British journal of sports medicine*. 2014;48(17):1322–6.
https://doi.org/10.1136/bjsports-2014-093593
16. Jiménez Díaz F, Gitto S, Sconfienza LM, Draghi FJ. Ultrasound of iliotibial band syndrome. *Ultrasound*. 2020;23(3):379–85.
https://doi.org/10.1007/s40477-020-00478-3
17. Peter Brukner, Ben Clarsen, Jill Cook, Ann Cools, Kay Crossley et al. Clinical Sports Medicine**.** *McGraw-Hill Education*. Australia. 2017;1104.
18. Christensen-Jeffries K, Couture O, Dayton PA, Eldar YC, Hynynen K, Kiessling F, O'Reilly M, Pinton GF, Schmitz G, Tang MX, Tanter M, van Sloun RJG. Super-resolution Ultrasound Imaging. *Ultrasound Med Biol*. 2020;46(4):865–91.
https://doi.org/10.1016/j.ultrasmedbio.2019.11.013
19. Sutter EG, Liu B, Utturkar GM, Widmyer MR, Spritzer CE, Cutcliffe HC et al. Effects of Anterior Cruciate Ligament Deficiency on Tibiofemoral Cartilage Thickness and Strains in Response to Hopping. *Am J Sports Med*. 2019;47:96–103.
https://doi.org/10.1177/0363546518802225
20. Epifanov VA., Epifanov AV. Rehabilitation treatment for injuries of the musculoskeletal system. M.:Author's Academy; 2009 (In Russ.).
21. Samojlov AS, Vasil`ev OS, Lyovushkin SP. Diagnosis of minor injuries of the musculoskeletal system of qualified athletes by the method of level-by-level analysis of the construction of the movement. *Extreme Medicine*. 2018;20(2):197–202 (In Russ.).
22. Dietvorst M, van der Steen MCM, Reijman M, Janssen RPA. Diagnostic values of history taking, physical examination and KT-1000 arthrometer for suspect anterior cruciate ligament injuries in children and adolescents: a prospective diagnostic study. *BMC Musculoskelet Disord*. 2022;23(1):710.
https://doi.org/10.1186/s12891-022-05659-1
23. Jerbana Saeed, Changb Eric Y, Dua Jiang Magnetic resonance imaging (MRI) studies of Knee joint under mechanical loading: review. *Magn Reson Imaging*. 2020;65:27–36.
https://doi.org/10.1016/j.mri.2019.09.007
24. Morozov AM, Zhukov SV, Belyak MA, Minakova YuE, Protchenko IG About the possibilities of evaluating a pain syndrome using the most validized pain scales. Bulletin of new medical technologies. 2020;2:62–8 (In Russ.).
https://doi.org/10.24411/1609-2163-2020-16663
25. Askenberger M, Ekström W, Finnbogason T, Janarv PM. Occult Intra-articular Knee Injuries in Children with Hemarthrosis. *Am J Sports Med*. 2014; 42(7):1600–6.
https://doi.org/10.1177/0363546514529639
26. Endele D, Jung C, Bauer G, Mauch F. Value of MRI in diagnosing injuries after ankle sprains in children. *Foot Ankle Int*. 2012;33(12):1063–8.
https://doi.org/10.3113/FAI.2012.1063
27. Askenberger M, Arendt EA, Ekström W, Voss U, Finnbogason T., Janarv P.M. Medial Patellofemoral Ligament Injuries in Children with First-Time Lateral Patellar Dislocations: A Magnetic Resonance Imaging and Arthroscopic Study. *Am J Sports Med*. 2016;44(1):152–8.
https://doi.org/10.1177/0363546515611661
28. Järvinen TA, Järvinen TL, Kääriäinen M, Kalimo H, Järvinen M. Muscle injuries: biology and treatment. *Am J Sports Med*. 2005;33(5):745–64.
https://doi.org/10.1177/0363546505274714
29. Sun Y, Chen J. Advancements in Sports Medicine. *J Clin Med*. 2023;12(10):3489.
https://doi.org/10.3390/jcm12103489
30. Guillodo Y, Saraux A. Treatment of muscle trauma in sportspeople (from injury on the field to resumption of the sport). *Ann Phys Rehabil Med*. 2009;52(3):246–55.
https://doi.org/10.1016/j.rehab.2008.12.014
31. Campbell Ryan MEAT vs RICE for injury management. Goodmed Direct Primary Care; 2013.
32. Dubois B, Esculier JF. Soft-tissue injuries simply need PEACE and LOVE. *Br J Sports Med*. 2020;54(2):72–3.
https://doi.org/10.1136/bjsports-2019-101253
33. Knight KL. Cryotherapy in Sport Injury Management. Champaign, IL: Human Kinetics; 2015.
34. Schneider F, Sperl M, Steinwender G, Kraus T. Kindliche Kniebinnenverletzungen. *Orthopade*. 2014;43(4):393–401
https://doi.org/10.1007/s00132-014-2290-6
35. Klyuchnikov SO, Kozlov IG, Pushkina TA, i dr. Federal guidelines (formulary) on the medications prescribed to child and adolescent athletes. Extreme Medicine. 2014;(54): 68–74 (In Russ.).
EDN: VBCUPP
36. Drendel AL, Lyon R, Bergholte J, et al. Outpatient pediatric pain management practices for fractures. *Pediatr Emerg Care*. 2006;22(2):94–9.
https://doi.org/10.1097/01.pec.0000199564.64264.f4
37. Cohen E, Sala DA. Rehabilitation of pediatric musculoskel-

etal sport-related injuries: a review of the literature. *Eur J Phys Rehabil Med*. 2010;46(2):133–45.

38. Yurlova Y, Dianov. Anatomo-physiological features of knee injuries and possibilities of conservative treatment. E3S Web of Conferences. TPACEE-2021. 2021;284:1–8. https://doi.org/10.1051/e3sconf/202128402018
39. Gaal BT, Knapik DM, Gilmore A. Patient-Reported Outcome Measures Following Surgical Intervention for Pediatric Sports-Related Injuries to the Knee: a Systematic Review. *Curr Rev Musculoskelet Med.* 2022;15(3):187–93. https://doi.org/10.1007/s12178-022-09756-5
40. Sheth U, Dwyer T, Smith I, Wasserstein D, Theodoropoulos J, Takhar S, Chahal J. Does Platelet-Rich Plasma Lead to Earlier Return to Sport When Compared With Conservative Treatment in Acute Muscle Injuries? A Systematic Review and Meta-analysis. *Arthroscopy*. 2018;34(1):281–8. https://doi.org/10.1016/j.arthro.2017.06.039
41. Zhang JY, Fabricant PD, Ishmael CR, Wang JC, Petrigliano FA, Jones KJ. Utilization of Platelet-Rich Plasma for Musculoskeletal Injuries: An Analysis of Current Treatment Trends in the United States. *Orthop J Sports Med*. 2016;4(12):2325967116676241. https://doi.org/10.1177/2325967116676241
42. Potapnev MP, Zagorodny`j GM, Krivenko SI, i dr. Modern aspects of the use of plasma enriched in soluble platelet factors in the treatment of injuries and diseases of the musculoskeletal system. Sports medicine: science and practice. 2019;9(4):33–45 (In Russ.). https://doi.org/10.17238/ISSN2223-2524.2019.4.33
43. Zagorodny GM, Mukha PG, Yasyukevich AS, Gulevich NP. Domestic and foreign experience of prp-therapy's administration in medicine and sports (literature review). *Applied Sports Science*. 2017;1(5):83–91 (In Russ.). EDN: YUIOTT
44. Eismont OL Orthobiologics in osteoarthritis treatment. *Current problems of Russian traumatology and orthopedics*. 2020;8:45–8 (In Russ.). EDN: ETQNTV
45. Bray CC, Walker CM, Spence DD. Orthobiologics in Pediatric Sports Medicine. *Orthop Clin North Am*. 2017;48(3):333–42. https://doi.org/10.1016/j.ocl.2017.03.006
46. Bansal H, Leon J, Pont JL, Wilson DA, Bansal A, Agarwal D. et al. Platelet-rich plasma (PRP) in osteoarthritis (OA) knee: Correct dose critical for long term clinical efficacy. *Sci Rep*. 2021;11(1):3971. https://doi.org/10.1038/s41598-021-83025-2
47. Chen X, Jones IA, Park C, Vangsness CT Jr. The Efficacy of Platelet-Rich Plasma on Tendon and Ligament Healing: A Systematic Review and Meta-analysis With Bias Assessment. *Am J Sports Med*. 2018;46(8):2020–32. https://doi.org/10.1177/0363546517743746
48. Godek P. High Volume PRP Therapy. *Ortop Traumatol Rehabil*. 2022;24(1):43–60. https://doi.org/10.5604/01.3001.0015.7806
49. Mishra A, Harmon K, Woodall J, Vieira A. Sports medicine applications of platelet rich plasma. *Curr Pharm Biotechnol*. 2012;3(7):1185–95. https://doi.org/10.2174/138920112800624283
50. Fang J, Wang X, Jiang W, Zhu Y, Hu Y. et al. Platelet-Rich Plasma Therapy in the Treatment of Diseases Associated with Orthopedic Injuries. *Tissue Eng Part B Rev*. 2020;26(6):571–85. https://doi.org/10.1089/ten.TEB.2019.0292
51. Milano Giuseppe Platelet-rich plasma in orthopaedic sports medicine: state of the art. *Journal of ISAKOS*. 2019;4:188–95. https://doi.org/10.1136/jisakos-2019-000274
52. Krupina EA Molecular and biological aspects of platelet-rich plasma therapies. *Bulletin of the National Medical and Surgical Center named after N.I. Pirogov*. 2020;15(3):80–5 (In Russ.). https://doi.org/10.25881/BPNMSC.2020.30.34.015
53. Dohan Ehrenfest, Rasmusson L., Albrektsson T. Classification of platelet concentrates: from pure platelet-rich plasma (P-PRP) to leucocyte- and platelet-rich fibrin (L-PRF). *Trends Biotechnol*. 2009;27(3):158–67. https://doi.org/10.1016/j.tibtech.2008.11.009
54. Everts PA, Hoffmann J, Weibrich G, Mahoney CB, Schönberger JP, van Zundert A. et al. Differences in platelet growth factor release and leucocyte kinetics during autologous platelet gel formation. *Transfus Med*. 2006;16(5):363–8. https://doi.org/10.1111/j.1365-3148.2006.00708.x
55. Clark RA. Fibrin and wound healing. *Ann N Y Acad Sci*. 2001;936:355–67. https://doi.org/10.1111/j.1749-6632.2001.tb03522.x
56. Weibrich G, Hansen T, Kleis W, Buch R, Hitzler WE. Effect of platelet concentration in platelet-rich plasma on peri-implant bone regeneration. *Bone*. 2004;34(4):665–71. https://doi.org/10.1016/j.bone.2003.12.010

Authors' contributions. All authors confirm that their authorship meets the ICMJE criteria. The greatest contribution is distributed as follows: Ilya V. Zyabkin — creation of the concept, construction of sections of the work; Ivan V. Pankratov — work with literature sources, analysis and generalization of the data obtained, writing the text of the manuscript; M.A. Petrov — writing the text of the manuscript; Murat I. Gabayev — collection of literature data; Razmik A. Keshishyan — critical revision of the text of the manuscript; Victoria V. Khizhnikova — writing the text of the manuscript regarding instrumental diagnostic methods; Aleksandra M. Kovalkova — collecting literature data.

AUTHORS

Ilya V. Zyabkin, Dr. Sci. (Med.), Professor
https://orcid.org/0000-0002-9717-5872
zyabkin@kidsfmba.ru

Ivan V. Pankratov
https://orcid.org/0009-0007-6665-6394
pankratoviv@kidsfmba.ru

Mikhail A. Petrov, Cand. Sci. (Med)
https://orcid.org/0000-0002-1709-2437
adm@kidsfmba.ru

Murat I. Gabayev, Cand. Sci. (Med)
https://orcid.org/0009-0005-7013-8894
adm@kidsfmba.ru

Razmik A. Keshishyan, Dr. Sci. (Med.)
https://orcid.org/0000-0003-3686-3708
adm@kidsfmba.ru

Victoria V. Khizhnikova
https://orcid.org/0009-0009-6101-7299
adm@kidsfmba.ru

Aleksandra M. Kovalkova
https://orcid.org/0009-0000-6070-0947
gimadeeva.alexandra@yandex.ru