

Pharmacological Interventions in the Management of Sports Injuries: A Review of Clinical Use, Dosage Forms, and Anti-Doping Considerations

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Background: Sports injuries are common among active adults and frequently require pharmacological interventions to control pain, reduce inflammation, and support functional recovery. Clear understanding of drug use patterns in clinical trials and their alignment with anti-doping regulations is essential for safe and ethical sports medicine practice.

Objective: To identify and characterize pharmacological interventions investigated in clinical trials for sports injuries in adults, focusing on drug class, dosage form, route of administration, and World Anti-Doping Agency classification.

Methods: A retrospective registry-based analysis was conducted using ClinicalTrials.gov on 13 March 2025. Trials registered under the condition Sport Injury and involving adults aged 18 to 64 years were included, obtaining 426 studies. Pharmacological agents explicitly listed in the Interventions field were extracted and classified by therapeutic category, dosage form, route of administration, and World Anti-Doping Agency status according to the 2024 Prohibited List.

Results: Twenty pharmacological agents were identified across multiple therapeutic classes, including non-steroidal anti-inflammatory drugs, corticosteroids, local anesthetics, biological therapies, and nutritional supplements. Oral, injectable, and topical formulations were most commonly reported. Non-steroidal anti-inflammatory drugs and local anesthetics represented the predominant drug classes. Most identified agents were permitted under World Anti-Doping Agency regulations when used via appropriate routes, whereas systemic corticosteroids were restricted during competition.

Conclusion: Clinical trials evaluating pharmacological management of sports injuries predominantly focus on non-steroidal anti-inflammatory drugs and local anesthetics, reflecting current clinical practice. The findings highlight the importance of route-specific prescribing and regulatory awareness to ensure anti-doping-compliant pharmacotherapy in athletic populations.

Keywords: sports injury, pharmacological intervention, NSAIDs, corticosteroids, WADA, clinical trials, anti-doping

Introduction

Sports injuries are common among youths, athletes, and physically active individuals and represent a significant clinical and public health concern.^{1,2} These injuries range from acute traumas such as dislocation, sprains, strains, and fractures to chronic overuse conditions including tendinopathies and stress fractures.³⁻⁵ Effective management strategies for these injuries are essential not only for pain control and functional recovery but also for preventing long-term disability and ensuring a timely return to sport.^{3,4,6} Among various therapeutic approaches, pharmacological interventions play a central role in the acute and subacute phases of sports injury management.

The pharmacological treatment of sports injuries includes a wide array of drug classes, such as non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroids, local anaesthetics, biological therapies, and nutritional supplements.⁷⁻⁹ These medications are utilized for their analgesic, anti-inflammatory, and tissue repair-promoting properties.^{10,11} In recent years, there has been growing interest in targeted delivery systems such as transdermal patches, injectable suspensions, and liposomal formulations to enhance drug efficacy while minimizing systemic side effects.

NSAIDs, such as etoricoxib, are widely used due to their ability to reduce pain and inflammation through selective inhibition of cyclooxygenase-2.¹² Evidence suggests that NSAID use may delay tissue healing by impairing collagen synthesis and altering the normal inflammatory repair process.^{13,14} Their oral formulations offer ease of use in outpatient settings. Similarly, corticosteroids like methylprednisolone are sometimes used in sports medicine to rapidly reduce inflammation and alleviate pain associated with conditions such as tendinopathies, bursitis, and joint synovitis.^{15–17} They act by suppressing pro-inflammatory mediators and immune activity, providing short-term symptom relief that may help athletes regain mobility.^{18,19} However, repeated or high-dose corticosteroid use can weaken tendons, impair collagen repair, and increase the risk of tendon rupture or cartilage degeneration.^{18,20} However, their use is often limited by regulatory concerns, as systemic administration of glucocorticoids is prohibited during competition under the World Anti-Doping Agency (WADA) guidelines.²¹ Local anaesthetics such as lidocaine and ropivacaine are frequently used in sports medicine for nerve blocks, intra-articular injections, or procedural anaesthesia.^{22–24} These agents are generally permitted under WADA regulations when administered via local routes, emphasizing the importance of route-specific considerations in therapeutic planning. Emerging formulations like Exparel, a liposomal bupivacaine, have provided extended analgesic effects following surgical interventions, thus improving patient comfort and reducing opioid dependence.^{25,26} Biological therapies such as platelet-rich plasma (PRP) injections are gaining traction for their regenerative potential, particularly in the treatment of tendinopathies and ligament injuries.^{27–29} These autologous preparations are considered WADA-compliant as long as they do not include prohibited substances. Similarly, nutritional supplements like omega-3 fatty acids (eg, docosahexaenoic acid, DHA) and antioxidants such as resveratrol are used to modulate inflammation and promote musculoskeletal recovery, although their clinical efficacy continues to be evaluated in large-scale trials.^{30–32}

Previous research on pharmacological management of sports injuries has largely focused on individual drug classes, acute pain control, or rehabilitation outcomes, often without integrated consideration of dosing strategies, routes of administration, or regulatory restrictions in competitive sports.^{33–37} In particular, the implications of anti-doping regulations, such as the World Anti-Doping Agency (WADA) classification, are inconsistently addressed across existing reviews.

The present review addresses these gaps by providing a structured synthesis of commonly used pharmacological agents in sports injury management, with specific emphasis on their therapeutic roles, dosing considerations, routes of administration, and WADA classification.

This review aims to provide a comprehensive overview of the pharmacological agents commonly used in sports injury management, highlighting their therapeutic roles, dosage forms, routes of administration, and WADA categorization. This work supports evidence-based and ethically sound prescribing practices in the field of sports medicine.

Methodology

This study used a retrospective review of registered interventional and observational clinical trials related to sports injuries among adults aged 18 to 64 years. Data were extracted from the publicly available ClinicalTrials.gov database, which is maintained by the US National Library of Medicine and represents one of the largest trial registries globally. The search strategy was designed to identify a comprehensive set of studies investigating pharmacological and other therapeutic interventions for sport-related injuries.

The search was conducted using the following terms: “Sport Injury” within the condition or disease field, limited to adults (18–64 years). The ClinicalTrials.gov database automatically includes synonyms and related terms; thus, the search covered conditions including sport, sports, sports activity, injury, injuries, trauma, and traumatic injury. No restrictions were applied regarding the status of the trials (eg, recruiting, completed, terminated), study design (interventional or observational), or geographical location up to 13th March 2025.

The search identified a total of 426 studies. The metadata from the search output were downloaded in CSV format for analysis. This dataset included variables such as NCT number, study title, study status, brief summary, condition(s), intervention(s), study results availability, enrolment numbers, primary outcome measures, and study design characteristics.

From the full dataset, only specifically reviewed trials that mentioned pharmacological interventions within the “Interventions” field. Interventions were further categorized based on the US FDA classification into:

- A. Drugs (eg, NSAIDs, corticosteroids, anaesthetics),
- B. Dietary Supplements (eg, DHA, resveratrol), and
- C. Biologics or autologous therapies (eg, Platelet-Rich Plasma).

Each identified pharmacological agent was reviewed manually for its therapeutic indication, dosage form, route of administration, drug class, and classification according to the World Anti-Doping Agency (WADA) 2024 Prohibited List. WADA categories were classified as “Prohibited”, “Permitted”, or “Conditionally Permitted” based on route, timing (in-competition vs out-of-competition), and formulation.

Data processing and cleaning were conducted using Microsoft Excel to filter relevant entries and standardize terminology. Duplicate entries and non-drug interventions (eg, devices, procedures, behavioural therapies) were excluded from the final pharmacological dataset.

The final analysis included twenty pharmacological agents used across various studies for the treatment or management of sport-related injuries. These agents were analysed with respect to their pharmacological classification, clinical relevance, and anti-doping considerations to offer a full understanding of current pharmacological strategies in sports medicine.

Results

A total of 426 clinical studies investigating sport-related injuries among adults aged 18–64 years were identified from ClinicalTrials.gov. Of these, a subset of 20 pharmacological interventions across various drug classes was extracted for further analysis based on explicit listing in the “Interventions” field of the study registry.

The pharmacological agents included a diverse range of therapeutic categories. Non-steroidal anti-inflammatory drugs (NSAIDs) were the most frequently investigated class, with etoricoxib being represented in multiple studies, including at two different dosing regimens: 60 mg and 90 mg daily for 14 days. NSAIDs were primarily studied for their analgesic and anti-inflammatory effects in managing acute soft tissue injuries and post-surgical pain.

Corticosteroids, specifically Depo-Medrol (methylprednisolone acetate), were also prominent, used as injectable agents for intra-articular or soft tissue inflammation. While effective, their use remains regulated under WADA guidelines due to potential performance-enhancing effects when used systemically.

Local anaesthetics, including lidocaine, ropivacaine, and the extended-release formulation Exparel (bupivacaine liposomal), were utilized in multiple studies to facilitate regional nerve blocks, post-operative analgesia, or procedural pain relief. These agents are widely used in sports medicine and are permitted under WADA guidelines when administered locally.

Topical analgesics, such as Esflurbiprofen Hydrogel Patch and Esflurbiprofen Topical System (EFTS), were studied for their ability to deliver anti-inflammatory effects directly to the site of injury with reduced systemic absorption.

Biological therapies included Platelet-Rich Plasma (PRP) injections, used for their tissue regeneration and healing potential, particularly in cases of tendinopathies, ligament sprains, and muscle tears. As autologous therapies, PRP was classified as WADA-compliant provided it did not include prohibited substances.

Nutritional and antioxidant supplements, such as Docosahexaenoic Acid (DHA) and Resveratrol, were included in trials aiming to evaluate their anti-inflammatory and recovery-enhancing properties. These agents are not prohibited and are increasingly used as adjuncts in injury recovery protocols.

Additional agents such as Vision Edge Pro (a vision-enhancing supplement) and saline/placebo controls were also documented. Two PET radiotracers, [C-11]6-OH-BTA-1 and [F-18] AV-1451, were used in trials assessing neurological and cognitive impairments following sport-related head injuries; however, these agents were investigational and used for diagnostic rather than therapeutic purposes.

Dosage Forms and Routes of Administration

A wide variety of dosage forms were reported, including oral tablets (eg, etoricoxib, resveratrol), injectable solutions (eg, lidocaine, ropivacaine), topical patches (eg, Esflurbiprofen Hydrogel), and injectable suspensions (eg, Depo-Medrol, PRP). The routes of administration were consistent with standard medical practice in sports injury management: oral, topical, injection (intra-articular, intramuscular, regional nerve block), and inhalation or IV for anaesthesia.

WADA Classification

Of the 20 pharmacological agents reviewed:

16 agents were classified as WADA-permitted, either unconditionally or when administered via local routes.

1 agent (Depo-Medrol) was prohibited in-competition if administered systemically (eg, oral, intramuscular).

3 agents (radiotracers) were diagnostic tools and not classified as therapeutic substances under WADA guidelines.

These results underscore the importance of route-specific and context-specific interpretations of anti-doping regulations, particularly for agents like corticosteroids and local anaesthetics.

The pharmacological interventions identified across the included clinical trials, along with their therapeutic categories, dosage forms, administration routes, and WADA status, are summarized in Table 1. The comparative clinical and safety considerations of major pharmacological classes are summarized in Table 2.

Table 1 Pharmacological Agents Identified From ClinicalTrials.gov Trials Related to Sports Injuries, Including Drug Class, WADA Classification, Dosage Form, and Route of Administration

Medication Name	Drug Class	WADA Category	Dosage Form	Route of Administration
25% Dextrose and 1% Lidocaine	Injectable solution (Prolotherapy + Local Anaesthetic)	Permitted (Lidocaine permitted with local administration)	Injectable solution	Injection (intra-articular, peritendinous)
Arcoxia (etoricoxib 90 mg/tablet)	NSAID (COX-2 inhibitor)	Permitted	Tablet	Oral
Depo medrol	Glucocorticoid (Methylprednisolone acetate)	Prohibited In-Competition (by certain routes – oral, IV, IM, rectal)	Injection (suspension)	Intramuscular, intra-articular
Docosahexaenoic acid (DHA)	Omega-3 fatty acid (nutritional supplement)	Permitted	Softgel capsule	Oral
Esflurbiprofen Hydrogel Patch	Topical NSAID	Permitted	Topical patch	Transdermal
Esflurbiprofen Topical System (EFTS)	Topical NSAID	Permitted	Topical system	Transdermal
Exparel	Local anaesthetic (Bupivacaine liposomal)	Permitted (local use)	Liposomal injectable suspension	Local infiltration
Inhaled Anaesthesia	General anaesthetic	Permitted	Gas	Inhalation
Intragel	Topical analgesic gel	Permitted	Gel	Topical
Lidocaine	Local anaesthetic	Permitted (local use)	Solution or gel	Topical or injection
Platelet-Rich Plasma	Biological therapy (autologous blood product)	Permitted (without prohibited substances)	Injectable preparation	Injection (intra-articular, intratendinous)
Resveratrol	Antioxidant / Nutraceutical	Permitted	Capsule or tablet	Oral
Ropivacaine 0.2% Injectable Solution	Local anaesthetic	Permitted (local use)	Solution	Injection (regional block)
Saline	Isotonic solution / Control	Permitted	Solution	Injection/IV flush
TIVA with Propofol	General anaesthetic (IV)	Permitted	Injectable emulsion	Intravenous
Vision Edge Pro	Nutritional Supplement (eye health)	Permitted	Capsule	Oral
[C-11]6-OH-BTA-1	PET radiotracer (not therapeutic)	Permitted	Radiotracer injection	Intravenous

(Continued)

Table 1 (Continued).

Medication Name	Drug Class	WADA Category	Dosage Form	Route of Administration
[F-18]AV-1451	PET radiotracer (tau imaging agent)	Permitted	Radiotracer injection	Intravenous
Etoricoxib 60mg daily for 14 days	NSAID (COX-2 inhibitor)	Permitted	Tablet	Oral
Etoricoxib 90mg 14 days	NSAID (COX-2 inhibitor)	Permitted	Tablet	Oral

Table 2 Clinical Role, Therapeutic Benefit, and Safety Considerations of Major Pharmacological Classes Used in the Management of Sports-Related Injuries

Drug Class	Primary Indication	Key Benefit	Major Safety Concern	Athlete-Specific Consideration
NSAIDs	Acute musculoskeletal pain	Rapid analgesia	Delayed tissue healing	Short-term use recommended
Corticosteroids	Inflammatory flares	Strong anti-inflammatory effect	Tendon weakening	Avoid repeated or systemic use
Local anesthetics	Procedural pain	Immediate pain relief	Chondrotoxicity (high doses)	Use lowest effective dose
Biologics (PRP)	Tendon/ligament injury	Tissue repair support	Variable efficacy	Protocol standardization needed
Supplements	Recovery modulation	Anti-inflammatory support	Limited clinical evidence	Adjunct only

As depicted in [Figure 1](#), the pharmacological interventions identified from ClinicalTrials.gov were predominantly NSAIDs and local anaesthetics, whereas corticosteroids, biologics, and supplements appeared less frequently.

Discussion

This review provides an analysis of pharmacological agents investigated in clinical trials for the management of sports-related injuries and highlights the therapeutic diversity, mechanistic rationale, and regulatory implications associated with their use. The identification of 20 distinct pharmacological interventions underscores the heterogeneous nature of musculoskeletal injuries and the multifaceted approaches currently employed to control pain, modulate inflammation, and support tissue recovery. Anti-doping considerations are central to pharmacological decision-making in sports injury management, as therapeutic choices must balance clinical effectiveness with regulatory compliance. In this review, pharmacological agents were categorized according to World Anti-Doping Agency (WADA) classifications as prohibited, restricted (permitted under specific conditions or with therapeutic use exemptions), or permitted substances.³⁸ From a clinical perspective, appropriate dosing, route of administration, and duration of therapy are critical determinants of both efficacy and safety, as excessive or inappropriate use of pharmacological agents in sports injury management may increase the risk of adverse events, delayed recovery, or regulatory complications.

NSAIDs constituted the most frequently studied drug class, reaffirming their central role in acute injury management.³⁹⁻⁴¹ Etoricoxib, in particular, was commonly evaluated due to its selective COX-2 inhibition, which provides effective analgesia with reduced gastrointestinal toxicity compared with non-selective NSAIDs.^{42,43} However, mechanistic studies suggest that NSAIDs may impair tendon-to-bone healing and collagen remodelling.^{44,45} Corticosteroids, represented in the dataset by methylprednisolone acetate, remain widely used for rapid suppression of inflammation in conditions such as bursitis, synovitis, and tendinopathies.¹⁹ Precisely, systemic glucocorticoids are prohibited in-competition by the WADA, reflecting concerns regarding potential performance enhancement and the ability to mask symptoms.⁴⁶ Moreover, repeated corticosteroid exposure has been linked to structural effects, including

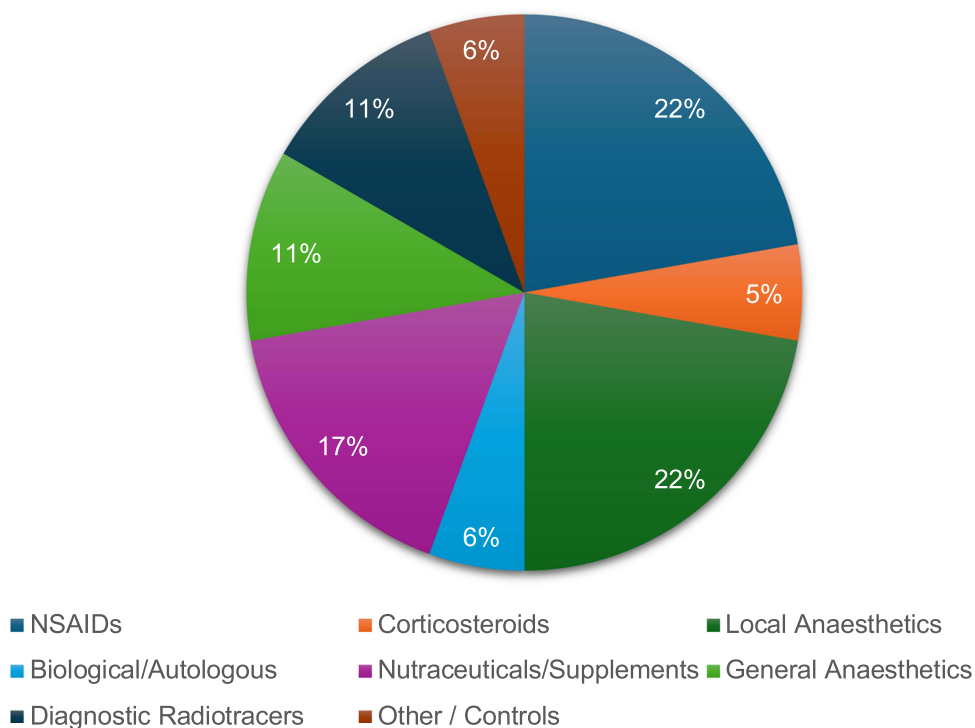


Figure 1 Number of pharmacological agents identified in ClinicalTrials.gov sports injury trials grouped by drug class.

impaired collagen synthesis, tendon weakening, and an increased risk of rupture.^{47–50} These risks highlight the importance of route-specific administration and adherence to evidence-based dosing intervals in athletic populations.

Local anaesthetics, particularly lidocaine, ropivacaine, and extended-release bupivacaine, were frequently incorporated in clinical trials, underscoring their importance in peri-procedural pain control and early mobilization strategies.^{51–53} The development of liposomal formulations such as Exparel represents a significant advancement, enabling prolonged analgesia while reducing reliance on opioids.²⁶ Importantly, local anaesthetics are generally permitted under WADA guidelines when administered through regional or infiltration routes, making them highly relevant for sports medicine practice.

Nutritional and antioxidant agents such as docosahexaenoic acid (DHA) and resveratrol were also represented among the studied interventions. These compounds are of interest due to their anti-inflammatory, cytoprotective, and metabolic modulatory properties.^{54,55} Although they remain permissible under anti-doping regulations and carry favourable safety profiles, current evidence from clinical trials remains insufficient to support definitive therapeutic recommendations.

Finally, the inclusion of PET radiotracers among the reviewed studies illustrates the expanding scope of sports medicine research to include neurocognitive and neurodegenerative consequences of head trauma.^{56,57} These diagnostic agents facilitate advanced imaging of brain pathology and support early identification of sports-related neurological disorders.

Table 2 integrates pharmacological classes used in sports injury management within a risk–benefit framework, emphasizing mechanistic rationale and athlete-specific safety considerations rather than descriptive listing. Analgesic efficacy observed with non-steroidal anti-inflammatory drugs and local anaesthetics reflects their established modulation of nociceptive and inflammatory pathways; however, experimental and clinical evidence suggests that excessive or prolonged exposure may interfere with collagen remodelling and tissue repair. Corticosteroids exert potent anti-inflammatory effects through suppression of cytokine signalling and immune activation, yet their catabolic impact on connective tissue and regulatory restrictions necessitate cautious, time-limited use in competitive athletes. In contrast, biological therapies and nutritional supplements aim to modulate healing environments rather than directly suppress inflammation, offering favourable safety profiles but inconsistent clinical efficacy.

Collectively, the findings of this review indicate that contemporary sports pharmacotherapy is characterized by increasing mechanistic specificity, diversification of delivery systems, and heightened regulatory awareness. The interplay between

therapeutic efficacy, tissue-healing considerations, and WADA compliance necessitates individualized clinical decision-making. The reliance on ClinicalTrials.gov as the sole data source necessarily limits the granularity of available participant-level information, including sex distribution and intervention-specific stratification, as such details are inconsistently reported within the registry. Consequently, this analysis emphasizes intervention-level patterns rather than individual participant characteristics, which should be considered when interpreting applicability to specific subpopulations.

Future investigations should prioritize robust randomized designs, standardized intervention protocols, and long-term follow-up to elucidate optimal pharmacological strategies for diverse athletic populations.

Limitation

This study has limitations related to data completeness and generalizability. It relied solely on ClinicalTrials.gov, which may not include all relevant studies. Many trials lacked detailed information on dosage and administration routes, and several had no published results, limiting the ability to assess clinical outcomes. Additionally, some ambiguity existed in interpreting WADA classifications due to incomplete reporting. The focus on adult populations further limits the applicability of the findings to other age groups.

Conclusion

Pharmacological management of sports-related injuries involves a broad range of therapeutic agents reflecting the diversity of injury types in athletic populations. Non-steroidal anti-inflammatory drugs (NSAIDs) and local anaesthetics were the most frequently investigated agents. These agents remain central to clinical practice due to their established analgesic efficacy and widespread use. Most identified interventions were compliant with World Anti-Doping Agency (WADA) regulations when used via appropriate routes, although systemic corticosteroids were subject to in-competition restrictions, highlighting the importance of route- and context-specific prescribing. By linking drug class, dosage form, route of administration, and WADA status, this review provides a practical framework to support evidence-informed and regulatory-compliant pharmacotherapy in sports injury management.

Data Sharing Statement

All data generated and analyzed during this study are fully included within the manuscript. No additional datasets are available.

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Disclosure

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