



Review on Herbal Transdermal Patches for Effective Pain Relief in Sports Injuries from Ayurvedic and Modern Perspectives

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ABSTRACT: Pain management in remains a critical challenge due to the risk of adverse effects associated with conventional analgesics. Herbal transdermal patches offer a promising, non-invasive, and targeted approach to pain relief, utilizing phytoconstituents with antiinflammatory and analgesic properties. This review explores the potential of herbal transdermal patches in managing musculoskeletal pain in athletes, analyzing their phytochemical composition, mechanism of action, and clinical efficacy through the lens of Ayurveda. Ayurvedic herbs) are known for their *Vedanasthapana* (analgesic) and *Shothahara* (anti-inflammatory) actions. A comprehensive search of scientific literature was conducted using databases such as PubMed, Scopus, and Google Scholar. Studies involving in vitro, in vivo, and clinical evaluations of herbal transdermal patches for pain management in sports-related injuries were analyzed. Ayurvedic literature and classical references were reviewed to validate the traditional use of these herbs. Several Ayurvedic herbs exhibit potent *Vedanasthapana*, *Shothahara*, and *Sandhaneeya* (wound-healing) properties Herbal transdermal patches based on Ayurvedic formulations provide a sustainable and effective alternative for pain management in athletes, minimizing systemic side effects while promoting faster recovery. Further clinical trials and standardization of formulations are essential to establish their widespread application in sports medicine.

KEYWORDS: Ayurveda, Herbal Transdermal Patch, Pain Relief, Sports Medicine, Anti- inflammatory, Analgesic, *Vedanasthapana*, *Shothahara*

INTRODUCTION

Pain from sports injuries can be sudden and intense in acute cases or persistent and dull in chronic conditions. Pain management in athletes poses a significant challenge due to frequent musculoskeletal injuries, leading to inflammation, discomfort, and reduced performance. it is often linked to acute trauma or overuse, but chronic pain is more complex and not solely explained by biomechanical stress. While biomechanical factors may contribute, they are not the primary cause of chronic pain in athletes. Conventional pain management approaches, such as NSAIDs and opioids, often result in gastrointestinal disturbances, renal impairment, and addiction potential. To mitigate these concerns, transdermal patches loaded with herbal extracts are gaining attention for their localized, sustained release of bioactive compounds, offering a safer and effective alternative. Ayurvedic herbs emphasizes the use of *Vedanasthapana* (analgesic) and *Shothahara* (anti-inflammatory) herbs for pain management.

Concept and mechanism of pain in ayurveda

Pain in Ayurveda is described using terms like *Vedana*, *Shoola*, *Dukha*, *Ruja*, and *Pida*. It is a subjective feeling that varies from person to person, depending on time, place, and mental sensitivity. Pain is more intense in individuals with Vata Prakriti or Vata imbalance. Among the Tridoshas, vitiated Vata is the main cause of pain. Pain is influenced by Vata's Rooksha (dry) and Chala (mobile) qualities. The nature of pain changes depending on which Dosha (Kapha or Pitta) is associated with Vata, leading to different types of pain in the body. ¹

Concept of pain in modern medicine

Pain is defined as an unpleasant human experience with various unknown aspects.² The IASP defined pain as an “unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.”³ This definition emphasizes that pain is a complex experience that includes multiple dimensions.

Transdermal patches for pain relief

A transdermal drug delivery system (TDDS) is a non-invasive method of drug delivery through the skin surface that can spread the medication throughout the dermis at a predetermined rate to produce a local or systemic effect. A transdermal analgesic, often known as a pain reliever patch, is an adhesive patch that contains medication to treat mild-to-severe pain.⁴ Transdermal therapeutic systems are defined as self contained, discrete dosage forms which, when applied to the intact skin, deliver the drug, through the skin at controlled rate to the systemic circulation.⁵ Pharmacokinetics of Transdermal Drug Delivery:

Transdermal drug delivery relies on maintaining a high concentration of the drug within the patch, creating a concentration gradient that facilitates diffusion through the skin and ensures a constant plasma drug level. The drug moves by diffusion due to the difference in concentration between the saturated drug solution in the patch and the lower concentration in the skin and bloodstream. For effective transdermal delivery, the drug should ideally have a molecular weight below 500 Da, balanced lipophilic and hydrophilic affinity, a low melting point, non-ionic nature, high potency at low doses, and a short half-life. These properties ensure efficient absorption and sustained drug release through the skin.

Mechanism ⁶

A transdermal patch holds the medication and releases it when applied to the skin. The adhesive helps it stick to the skin, allowing the medicine to enter the bloodstream. The drug travels from the patch through the skin and into the circulatory system. For this process to work, the drug must have specific physicochemical properties that help it pass through the skin and reach the target tissue.

Classification of transdermal patches ⁷- Transdermal patches are mainly of three types:

Transdermal drug delivery systems can be categorized into three types: reservoir, matrix, and microreservoir systems.

In the reservoir system, the drug is placed between an impermeable backing layer and a rate- controlling membrane, allowing drug release only through the membrane. The drug may be in the form of a solution, suspension, gel, or dispersed in a polymer, with an adhesive polymer layer applied between the membrane and the release liner.

In the matrix system, there are two types: the drug-in-adhesive system, where the drug is mixed with an adhesive polymer and spread onto a backing layer, with unmedicated adhesive layers applied for protection, and the matrix-dispersion system, where the drug is evenly dispersed in a hydrophilic or lipophilic polymer matrix, attached to a base plate with an impermeable backing layer, and secured with adhesive along the edges. The microreservoir system combines features of both the reservoir and matrix systems. In this system, the drug is suspended in an aqueous solution of a water-soluble polymer and dispersed in a lipophilic polymer, forming tiny, stable drug reservoirs stabilized by rapid polymer cross- linking Layers of Transdermal patches⁸

- **Backing Layer:** An outer impermeable layer providing support and chemical resistance. It should have optimal elasticity and tensile strength. Examples include polyurethane film, ethylene vinyl acetate, polyethylene, and polypropylene.
- **Drug Reservoir/Polymeric Matrix:** Contains the drug uniformly distributed within a polymer matrix, controlling the drug's release rate. Natural polymers like chitosan and cellulose derivatives, as well as synthetic polymers such as hydroxypropyl methylcellulose (HPMC) and Eudragit, are commonly used.
- **Adhesive:** Ensures the patch adheres to the skin with minimal pressure. Common adhesives include polyacrylates and polyisobutylene (PIB).
- **Release Liner:** A protective layer removed before application, preventing medication loss during storage. Materials like paper fabric and polyester are typically used.
- **Miscellaneous Components:**
 - **Permeation Enhancers:** Substances like menthol, limonene, and lauric acid that increase skin permeability to enhance drug delivery.

Plasticizers (Film-Forming Agents): Compounds such as glycerin and dibutyl phthalate that improve the flexibility and durability of the patch.

Advantages of Transdermal Patches ¹⁸

1. Provides consistent drug permeation, maintaining steady serum levels.
2. Similar to IV infusion, it ensures constant plasma levels.
3. Easy removal in case of toxicity.
4. Convenient and simple application.
5. Bypasses first-pass metabolism.

Application of Transdermal Delivery Systems in Pain Management ¹⁹

1. **Acute Pain** □ **Prevention:** Local anaesthetic patches provide anaesthesia for procedures like venesection or vaccination, especially useful in pediatric practice.
 - **Treatment:** NSAID patches treat musculoskeletal injuries.
 - **Opioid Delivery:** Fentanyl transdermal systems with iontophoretic mechanisms offer patient-controlled analgesia (PCA), but are not typically used in acute pain due to delayed onset and toxicity risks.
2. **Chronic Pain**
 - **Nociceptive Pain:** Fentanyl and buprenorphine patches are used for long-term pain management.
 - **Neuropathic Pain:** Topical capsaicin and lidocaine patches provide localized pain relief.

Ayurveda and sports medicine

Ayurveda, though not explicitly mentioning sports medicine, offers valuable insights applicable to it. Dincharya ensures discipline and stamina, while Rasayana therapy enhances strength and endurance. Mamsa and Asthi Dhatu play a key role in structural and functional integrity, with Snayu and Kandra (Upadhatu) involved in sports injuries. Vulnerable joints include Gulfa, Janu, Aratni, Jatru, and Sthuladanta. Ayurveda recommends Marma therapy, oil massage, Agnikarma, Raktamokshana, and physiotherapy for injury prevention and rehabilitation. Acharya Sushruta also highlighted post-fracture care using natural materials like soil, salt, and stone crystals for faster recovery. Acharya Sushruta referenced physiotherapy for post-fracture rehabilitation using soil, salt crystals, and stony crystals sequentially to strengthen the affected site. This highlights Ayurveda's direct and indirect contribution to managing sports injuries effectively. ⁹

Ayurvedic herbs for managing pain

Herbs such as Draksha, Barbara, Priyala, Parooshaka, Iksu, Yava, Shastika, Dadima, Jeevaka, Phalgu, Rishabhaka, Meda, Mahameda, Kakoli, Ksheerakakoli, Jeevanti, Mashaparni, and Mudgaparna enhance performance, making them valuable in sports medicine.¹⁰ Drugs like Ardraka relieve joint and muscle pain, while Beejapoorra reduces abdominal and muscle cramps. Gangeruki helps heal fresh wounds, and Dronapushpi reduces inflammation. Kanya (Aloe vera) soothes swelling and promotes faster healing. Nimba Patra cleanse and heal wounds and are used externally for Lepana.¹¹ Almost 63 drugs were described in Bhavaprakasha Nighantu in the category of Shoolahara dravyas.¹² Shothahara Mahakashaya, comprising Dashamoola, alleviates Vataj, Pittaj, and Kaphaj Shotha. Its bitter, astringent taste, warm potency, dryness, and lightness impart Tridoshaghna properties, primarily targeting Vata dosha.

MATERIALS AND METHODS

A systematic review of published studies was conducted using databases, including PubMed, Scopus, Google Scholar. The studies evaluating transdermal patches containing herbal extracts, focusing on pain management articles published in peerreviewed journals with relevant data.

Haridra (*Curcuma Longa*)¹⁴

Curcumin-loaded transdermal patches can be effectively used for pain management due to their potent anti-inflammatory and analgesic properties. Curcumin, the active constituent of *Curcuma longa* (Haridra), inhibits pro-inflammatory mediators such as COX-2, TNF- α , and IL-6, thereby reducing inflammation and alleviating pain. It also modulates nociceptive pathways, making it beneficial for managing musculoskeletal pain, arthritis, and sports-related injuries. Since curcumin has poor oral bioavailability due to rapid metabolism in the gastrointestinal tract, transdermal patches enhance its absorption by allowing direct entry into the systemic circulation, bypassing first-pass metabolism. Additionally, these patches ensure sustained and prolonged release of curcumin, maintaining therapeutic concentrations over time, which is crucial for chronic pain management. Consequently, curcumin transdermal patches offer a safe, effective, and non-invasive alternative for pain relief, particularly in conditions such as osteoarthritis, tendonitis, and post-workout muscle soreness.

Shigru (*Moringa Oleifera*)¹⁵

The potential of *Moringa oleifera* in transdermal drug delivery systems (TDDS) due to its rich bioactive profile and diverse pharmacological effects, including antiinflammatory and analgesic properties. Formulating *M. oleifera* in transdermal patches enhances bioavailability by bypassing first-pass metabolism and providing sustained drug release, ensuring better therapeutic outcomes. TDDS improves patient compliance, maintains steady plasma drug levels, and reduces dosing frequency, making it a promising alternative for managing chronic conditions.

Brahmi (*Centella asiatica*) and Aloe vera¹⁶

The results showed that transdermal patches formulated with Aloe vera polysaccharides and *Centella asiatica* extracts had excellent physicochemical properties. The optimized formulation, containing 20% glycerine and 15% sodium alginate, produced films with ideal thickness (0.509 ± 0.015 mm), tensile strength (1.391 ± 0.131 MPa), and elongation at break ($116.2 \pm 13.15\%$). The patches swelled within 20 minutes and degraded by $51.57 \pm 5.96\%$ after 30 minutes, ensuring controlled drug release. About 0.34% of *Centella asiatica* extract, rich in wound-healing triterpenoids, was retained in the patches. Stability studies showed that films stored at 4°C and 25°C maintained good properties, while those stored at 45°C became brittle and unusable. These findings confirm the potential of these herbal transdermal patches for effective pain relief and wound healing in sports injuries.

Ardraka(*Zingiber officinale*) and mentha oil ¹⁷

This study aimed to formulate and characterize a transdermal patch containing ginger extract (*Zingiber officinale*), known for its potent bioactive compounds, particularly gingerols and shogaols, which exhibit anti-inflammatory and analgesic properties. The ginger extract was obtained through the maceration method, while Mentha oil was derived from Mentha leaves using hydro-distillation and incorporated as a permeation enhancer. Various combinations of polymers, plasticizers, and permeation enhancers were evaluated to optimize the patch's mechanical properties, adhesiveness, and drug release profile. In vitro drug release studies confirmed that the optimized formulation exhibited satisfactory tensile strength, uniform drug distribution, and prolonged drug release, making it a promising candidate for transdermal drug delivery systems.

DISCUSSION

The findings of this review underscore the potential of herbal transdermal patches as a safe and effective alternative for pain management in sports medicine. Conventional analgesics, although effective, often pose risks of gastrointestinal disturbances, renal impairment, and addiction, making herbal formulations a desirable option due to their minimal side effects and sustained release. Ayurvedic herbs such as *Haridra*, *Ardraka*, *Kumari* and *Shigru* demonstrated potent *Vedanasthapana* (analgesic) and *Shothahara* (anti-inflammatory) actions, aligning with their traditional use in pain management. Transdermal patches enhanced the bioavailability of these herbs by bypassing first-pass metabolism and providing sustained drug release, ensuring prolonged therapeutic action. The physicochemical properties of the patches, including uniform thickness, tensile strength, and moisture content, further ensured stability and efficacy. Clinical and in vitro studies validated the efficacy of these patches in reducing inflammation, alleviating pain, and accelerating functional recovery in athletes. Additionally, Ayurvedic principles such as *Dincharya*, *Rasayana*, and *Marma Chikitsa* offer valuable insights into enhancing musculoskeletal strength and preventing injuries, further supporting the relevance of these formulations in sports medicine. However, despite promising results, challenges such as standardization, quality control, and the need for large-scale clinical trials remain. Addressing these gaps is essential to establish the widespread clinical application of herbal transdermal patches and validate their role in modern sports medicine.

RESULT

Herbal transdermal patches demonstrated effective pain management and can be used in sports injuries by delivering bioactive compounds with anti-inflammatory and analgesic properties. Key herbs like *Curcuma longa*, *Zingiber officinale*, *Aloe vera*, and *Moringa oleifera* modulated inflammatory pathways, ensuring sustained drug release and improved bioavailability. Physicochemical evaluation confirmed uniform thickness, optimal tensile strength, and stability under appropriate conditions. Ayurvedic validation reinforced the use of *Vedanasthapana* and *Shothahara* herbs, aligning traditional knowledge with modern pharmacological evidence. While transdermal patches proved effective and safe, further standardization and large-scale clinical trials are essential for wider application in sports medicine.

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