New aspects of microcurrent electrical neuromuscular stimulation in sports medicine

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Abstract Sports-associated injuries often involve trauma to soft tissues such as ligaments, tendons, skeletal muscle, and skin. A shortened recovery process for injured tissues is of great interest to athletes, as injury-associated inactivity depresses both sports performance and physical fitness. Recently proposed treatments to accelerate tissue repair include microcurrent electrical neuromuscular stimulation (MENS), low-intensity pulsed ultrasound (LIPUS), hyperbaric oxygen (HBO), and autologous platelet-rich plasma (PRP). Among these treatments, MENS has been applied to alleviate pain and reduce swelling following sports-associated injuries of tendons and ligaments. MENS is reported to stimulate the regeneration of skeletal muscles, a part of the body commonly injured in sports. MENS is expected to soon become a standard therapy for accelerating the repair of injured skeletal muscles and other soft tissues. In this review, we provide an overview of MENS and briefly describe several other proposed treatments for sports-associated injuries.

Keywords : sports injury, microcurrent, soft tissue, muscle injury, healing

Introduction

Sports injuries often involve damage to the musculo-skeletal system such as bruising, bone fractures, dislocations, and injuries of the ligaments, tendons, and skeletal muscles. Mild and severe injuries of the soft tissues are common in sports and are generally treated by clinical therapies to depress pain and edema and facilitate the regeneration of injured tissue¹⁾.

Athletes are eager to find techniques to shorten recovery after injuries, as injury-associated inactivity (rest and rehabilitation) depresses both sports performance and physical fitness²⁾. The RICE approach, namely, rest, ice, compression, and elevation, is generally considered the front line treatment for sports-associated injuries of the soft tissues. Yet RICE is not without drawbacks, as injury-related inactivity can cause both skeletal muscle atrophy and weakness³⁻⁵⁾. Skeletal muscle atrophy is a serious obstacle to a sound and prompt recovery from a sport injury. Several new treatments for the stimulation of injury repair and avoidance of skeletal muscle atrophy have been proposed.

New treatments for sports-associated injuries

Low-intensity pulsed ultrasound (LIPUS) is now widely applied clinically as an established therapy to facilitate the regeneration of fractured bone^{6,7)}. Several other stimulating treatments have been proposed as therapies to promote the regeneration of injured soft tissues such as ligaments, tendons, and skeletal muscles. The most notable among these soft tissue therapies are microcurrent electrical neuromuscular stimulation (MENS)^{2,8,9)}, hyperbaric oxygen (HBO)^{10,11)}, and autologous platelet-rich plasma (PRP)^{12,13)}.

HBO treatment is the administration of 100% oxygen at pressures greater than atmospheric pressure, i.e., more than 1 atmosphere absolute. Results collected over the last decade have supported HBO as a stimulating therapy for the regeneration of sports-related injuries. Yet HBO requires elaborate apparatus and safety measures that hinder its adoption as a standard treatment for tissue injuries.

PRP, which contains growth factors and bioactive proteins, is considered to influence the healing of various sports-associated injuries of tendon, ligament, muscle, and bone¹²⁾. Specifically, it contains platelet derived growth factor (PDGF), vascular endothelial growth factor (VEGF), transforming growth factor beta-1 (TGF-B1), fibroblast growth factor (FGF), and insulin-like growth factor-1 (IGF-1)¹⁴⁾. Yet the experimental data on the effects

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of PRP on humans is still limited, and many open questions regarding the optimal dosage (platelet concentration, concentration fraction ratio, total platelet count, etc.) protocol, etc., remain¹⁴. Additional research to establish a sound clinical protocol for PRP is needed.

What is MENS?

MENS was developed as a physical therapy modality delivering electrical current in the microampere range (μA). The therapy is reported to reduce the signs and symptoms of muscle damage without any known side effects, and can be administered with a compact and portable device^{15,16}. MENS treatment is also largely imperceptible for patients, as it induces no sensation or skeletal muscle contractions. In light of its economical advantage, MENS is now preferred over HBO and PRP as a therapy for sports injuries of soft tissues such as ligament injuries, tendon injuries, bruising, and muscle strain. The published data is limited, but MENS has a confirmable stimulating effect on the recovery of sports-associated injuries.

Molecular mechanisms for MENS

Although MENS is widely used by athletes, the molecular mechanisms of MENS-associated acceleration of the regeneration of injured tissue are still unclear. MENS has been reported to increase the synthesis of adenosine triphosphate (ATP) in rat skin under electrical stimulation with a 500 μA current, but to depress it with a current of 1000 μA or higher¹⁷. Another group suggested that MENS might increase ATP synthesis by stimulating the electron transport system of mitochondria⁸. Overall, however, the molecular mechanisms of MENS remain unclear.

Effects of MENS

Pain healing^{15,19} and facilitated regeneration of injured tissues^{8,9,16,20-22} have been reported as positive effects of MENS.

1. Healing of pain

MENS suppressed delayed onset muscle soreness (DOMS) for 20 min in a study by Curtis et al. on the effects of MENS on DOMS following eccentric exercise in 35 healthy people¹⁵. In another study, MENS administered at a current of less than 1 μA suppressed chronic lower back pain by ~37% immediately after the therapy and by ~75% 2 months later¹⁹.

2. Acceleration of tissue repair

Many reports have described the MENS-associated repair of injured tissues such as skin ulcers, decubitus, wounds, tendon and ligament injuries, and skeletal muscle damage.

A) Skin ulcers, decubitus, and wounds

The healing rate of ischemic skin ulcers treated with MENS (low intensity direct current: LIDC, 200-800 μA) was 2 times faster than that of untreated ulcers²⁰. An LIDC-associated acceleration of painless ulcers (decubitus) was also observed. LIDC administration (200-800 μA for 2 hours twice daily, 5 days per week for 5 weeks) accelerated wound healing 1.5~2.5 times faster than conventional treatment²¹. Carley and Wainapel also reported that wounds treated with LIDC required less debridement and that healed scars were more resilient. Furthermore, no wound infections appeared after LIDC treatment²¹. MENS administered at 50-100 μA decreased the time to wound closure after split-thickness skin grafting for thermal injuries by 36%²².

B) Injuries of tendons and ligaments

MENS accelerated the repair of cultured deep flexor tendons of rabbits using a tendon culture system. Continuous exposure to a 7 μA current by MENS increased the incorporation of (¹⁴C) proline and (¹⁴C) hydroxyproline in injured rabbit deep flexor tendons by 91% and 255%, respectively, compared with the untreated control⁸. MENS administered with a ~40 μA current also facilitated the regeneration of tenotomized rat Achilles tendons⁹. Another study described the effects of MENS treatment administered with a 30 μA current (0.3 Hz and a pulse width of 25 ms) on the healing of knee medial collateral ligament injuries (grade II) in humans. MENS treatment suppressed pain and improved motor function (by the Lysholm Knee Scoring Scale) during immobilization of the knee joint for 3 weeks¹⁸.

C) Skeletal muscle atrophy

As mentioned earlier, injury-associated inactivity is a major cause of skeletal muscle atrophy and weakness³⁻⁵. A treatment to facilitate the recovery of skeletal muscle atrophy is therefore needed. MENS shows promise as such a treatment and is confirmed to facilitate the regrowth of atrophied soleus muscle via the stimulation of protein synthesis²³.

D) Skeletal muscle injuries

Among the reports on the effects of MENS for tissue injuries, relatively few describe the effects on the regeneration of injured skeletal muscle. The MENS-conferred reductions of DOMS and signs and symptoms of muscle damage following eccentric exercise in human subjects strongly suggest that the therapy facilitates the regeneration of injured skeletal muscle^{15,16}. Little is known, however, about the molecular mechanism of the MENS-associated acceleration of skeletal muscle regeneration.

Our group recently investigated the effects of MENS on the regeneration of injured skeletal muscle using a mouse model of cardiotoxin (CTX)-injected injured skeletal muscle. MENS at a 10 μA current (0.3 Hz and a pulse

width of 250 ms) facilitated the early phase of the regenerative process of CTX-induced injured mouse tibialis anterior muscle²⁾. The MENS treatment also increased muscle satellite cells, a key player in muscle regeneration, and accelerated muscle regeneration by stimulating muscle protein synthesis²⁾.

We also investigated the effect of MENS combined with icing, a common first-aid treatment in sports-associated injuries, on the regeneration of injured skeletal muscles²⁴⁾. While icing on injured tissues immediately after an injury is generally believed to suppress pain and swelling, an icing-associated delay of skeletal muscle repair has been reported^{25,26)}. Our experiment on the combined treatment of MENS and icing had no observable effect on the regenerative process of injured skeletal muscle²⁴⁾.

Perspective

The percentage of the population engaged in sports in Japan has increased in recent decades. The need for new strategies to prevent sports-associated injuries and improved therapies to assist the regeneration of injured tissue has grown accordingly. Among the new treatments developed to reduce the recovery period following sports injuries, MENS may be useful for facilitating pain suppression and the regeneration of injured soft tissues such as skeletal muscle, ligament, and tendon. Compared with other treatments, MENS can now be administered with devices that are compact, inexpensive, and easy to operate. Little is known, however, about the molecular mechanisms of MENS. Further investigation to elucidate these mechanisms is needed.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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