Acute exposure to a moderate strength static magnetic field reduces edema formation in rats
Cassandra E. Morris and Thomas C. Skalak
doi:10.1152/ajpheart.00529.2007

You might find this additional info useful...

This article cites 43 articles, 13 of which can be accessed free at:
http://ajpheart.physiology.org/content/294/1/H50.full.html#ref-list-1

Updated information and services including high resolution figures, can be found at:
http://ajpheart.physiology.org/content/294/1/H50.full.html

Additional material and information about AJP - Heart and Circulatory Physiology can be found at:
http://www.the-aps.org/publications/ajpheart

This information is current as of December 22, 2010.
Acute exposure to a moderate strength static magnetic field reduces edema formation in rats

Cassandra E. Morris and Thomas C. Skalak
Department of Biomedical Engineering, University of Virginia Health Sciences Center, Charlottesville, Virginia
Submitted 3 May 2007; accepted in final form 1 November 2007

Morris CE, Skalak TC. Acute exposure to a moderate strength static magnetic field reduces edema formation in rats. Am J Physiol Heart Circ Physiol 294: H50–H57, 2008. First published November 2, 2007; doi:10.1152/ajpheart.00529.2007.—External application of static magnetic fields (SMF), used specifically for the treatment of inflammatory conditions such as soft tissue injuries, has recently become popular as a complementary and/or alternative therapy with minimal investigation into efficacy or mechanism. Localized inflammation was induced via injection of inflammatory agents λ-carrageenan (CA) or histamine into rat hindpaws, alone or in conjunction with pharmacological agents, resulting in a spatially and temporally defined inflammatory reaction. Application of a 10- or 70-mT, but not a 400-mT, SMF for 15 or 30 min immediately following histamine-induced edema resulted in a significant, 20–50% reduction in edema formation. In addition, a 2-h, 70-mT field application to CA-induced edema also resulted in significant (33–37%) edema reduction. Field application before injection or at the time of maximal edema did not influence edema formation or resolution, respectively. Together, these results suggest the existence of a therapeutic threshold of SMF strength (below 400 mT) and a temporal dependence of efficacy. Administration of pharmacological agents directed at nitric oxide signaling and L-type Ca2+ channel dynamics in conjunction with SMF treatment and histamine-induced edema revealed that the potential mechanism of SMF action may be via modulation of vascular tone through effects on L-type Ca2+ channels in vascular smooth muscle cells.

microvascular tone; tissue swelling

EXTERNAL APPLICATION OF static magnetic fields, used specifically for the treatment of inflammatory conditions such as soft tissue injuries, has recently become popular as a complementary and/or alternative therapy with minimal investigation into efficacy or mechanism. Although the literature supports a potential therapeutic benefit of pulsed electromagnetic field (PEMF) application to aid in the treatment of non-union bone fractures (2, 17) and osteoarthritis (5), the acceleration of wound healing (4, 32, 41), and the modulation of angiogenesis (14, 42), direct evidence supporting the therapeutic use of static magnetic fields (SMF) is less established. Static magnetic fields are of particular interest because they are the primary field used in many of the over-the-counter products presently on the market, with ~5 billion dollars worldwide and 500 million dollars in the U.S. per annum being spent on magnetic field therapy (10).

Recent studies have demonstrated that localized SMF application can modulate both blood pressure (29) and flow (21, 46), both suggesting that SMF application may be effective in treating edematous tissue conditions. Clinical investigation of local, chronic SMF treatment on postoperative patients revealed significant reduction of edema and pain when applied immediately after surgery (20). In addition, application of a global, chronic SMF to pharmacologically induced synovitis demonstrated significant reduction in inflammatory infiltrate (44). Investigation of the specific mechanisms governing SMF action has been limited; however, the evidence suggests that the SMF may act via alterations in Ca2+ flux or other enzymatic reactions (23, 28, 29, 36, 40). From these studies, the therapeutic application of magnetic fields for treatment of circulatory problems appears to be promising, but assessment of acute application of SMF in an injured, compromised tissue has not been investigated.

Initiation of acute inflammation, manifested as redness, heat, pain, and swelling, occurs in response to mechanical injury, ionizing radiation, or invading pathogens. Each of these stimuli can independently activate the release/formation of inflammatory mediators such as histamine, bradykinin, platelet-activating factor, TNF-α, and prostaglandins from cells in the tissue. These mediators act on endothelial cells to increase vascular permeability and cause vasodilation and relaxation of smooth muscle cells via production of nitric oxide (NO), and they act on Ca2+ channels through endothelium-dependent and -independent processes (13). Since evidence suggests that SMF application can result in modulation of microvascular tone and flow, we hypothesize that acute application of SMF to an inflammatory injury may limit the formation of edema and therefore accelerate healing.

To test the hypothesis that locally applied acute SMF exposure could significantly reduce edema formation and/or improve resolution, we chose the hindpaw inflammation model. This model allowed for acute, localized application of SMF to an induced injury location, and accurate quantification of the inflammatory response was facilitated by sequestration of inflammation to the paw itself. Two separate but related agents, λ-carrageenan (CA) and histamine, were chosen as severe and minor inflammatory stimuli, respectively, at the selected concentrations.

MATERIALS AND METHODS

All experiments were approved by and conducted in accordance with all rules and regulations set forth by the University of Virginia Animal Care and Use Committee.

Address for reprint requests and other correspondence: T. C. Skalak, Dept. of Biomedical Engineering, Univ. of Virginia Health Sciences Center, PO Box 800759, Health System, Charlottesville, VA 22908 (e-mail: tskalak@virginia.edu).

The costs of publication of this article were defrayed in part by the payment of page charges. The article must therefore be hereby marked “advertisement” in accordance with 18 U.S.C. Section 1734 solely to indicate this fact.
Assessment of the efficacy of acute magnetic field exposure on edema formation and resolution was accomplished by utilizing a well-established inflammatory model that has been used extensively for the detailed investigation of anti-inflammatory therapies. Inflammatory agents CA and histamine were injected locally in the paw of rats, alone or in conjunction with pharmacological agents, resulting in a spatially and temporally defined inflammatory reaction. Magnetic field treatment was then applied locally to the inflamed paws at various strengths and durations in an attempt to elucidate the efficacy and/or mechanism(s) of SMF action on induced edema.

The range of field strengths used in this study (7.5–400 mT) fall into the range generally advertised for magnetic field therapy products (10) and are on the same order of magnitude as those in other investigations into the efficacy of SMF treatment. The duration of exposure for the acute application was chosen based on the generally accepted time scale for application of cryotherapy following injury (15–30 min) (8) together with the mid range of previous studies (1–40 min). Direct comparison of the field strengths used in these studies with the field strength of products on the market is difficult, because most manufacturers report the strength at the core of their magnets and do not know what the “active” strength is at the target site. This may explain the widely varying experiences regarding efficacy reported in the community at large; many devices are designed in such a way that the distance from the core of the magnet to the target site is too great for any effective field strength to remain at the target site. To address this deficiency, we carefully calibrated the magnets used in this study so that the “actual” field strength to which the tissue was exposed was known, rather than estimated based on a stated core strength.

Edema induction. Male Sprague-Dawley rats (Harlan, Indianapolis, IN) weighing 150–210 g were used, and baseline paw volume measurements were taken by sequentially submerging right and left hindpaws up to the tibiotarsal joint in a pressure transducer-driven plethysmometer (Kent Scientific, Torrington, CT), accurate to 0.01 ml (stated by the manufacturer and calibrated by the user before each day of experiments); the changes in volume measured on the order of 0.1–1.0 ml. Left hindpaws were injected subplantar under conscious conditions, to maximize the inflammatory reaction, with 0.1 ml of 1% or 0.5% CA (C-3889; Sigma) or 0.1 ml of histamine (H-1542, Sigma; Aldrich) (3) in deionized water to induce inflammation or 0.1 ml of sterile saline or deionized water as vehicle controls, respectively. Left (treated with SMF, or sham) and right (control) paw volume measurements were taken at regular intervals: every hour for 3 h for CA- treated paws and every 30 min for 3 h following histamine treatment. Right paws were either untreated, to ensure no systemic inflammation, or injected with vehicle control. Percent change in paw volumes from baseline measurements were calculated independently for both the left and right paws. Each animal was only injected in each paw one time; no animals were used for repeated measures, and no data were excluded.

SMF application. After injection, each animal was anesthetized with inhalational isoflurane (Iso-Thesia; Vetus Animal Health, Burns Veterinary Supply, Rockville Center, NY). Anesthesia was induced at a concentration of 2.5% isoflurane delivered in pure oxygen at a flow rate of 1.0 l/min via a VetEquip vaporizer (no. 911103; VetEquip, Pleasanton, CA) and maintained for the duration of magnetic field exposure at a concentration of 1.5% and a flow rate of 1.0 l/min. During anesthesia, the animals were placed prone on a heating pad to maintain physiological temperature of 37°C, and the hindlimbs were loosely taped to a Plexiglas stage to ensure reproducible orientation of the paw for treatment. The magnet treatment was applied within 30 s of injection via a lexan positioning device that placed the magnet directly over the injected paw, 2 mm from the surface. Sham-treated animals were injected with a vehicle control (saline or deionized water) and subjected to identical immobilization and anesthesia treatment, with the only difference being that no magnet was placed over the paw. At the conclusion of exposure, animals were removed from the isoflurane, awoke almost immediately, and were free to roam around their cages for the duration of the experiment.

Pharmacological intervention. Pharmacological agents were used for determination of the mechanism of SMF action. L-Arginine (15 μM, Sigma) was coadministered with 0.1 ml of histamine locally in the paw to minimize systemic action, and (−)-IBAY K 8644 (3 mg/kg; Sigma) was administered intraperitoneally concurrently with the histamine subplantar in 0.1 ml of dimethyl sulfoxide (DMSO; Sigma) because of its insolubility in saline or deionized water.

Magnetic field distribution calibration. A magnetic calibration system developed in our laboratory to generate three-dimensional maps of the magnetic flux density (26) was utilized to assess the strength and uniformity of the magnets used in these experiments (Fig. 1). The magnets used in these experiments (Magnetherapy, Rivera Beach, FL, and Engineered Concepts, Birmingham, AL), each measuring ~3.5 cm in diameter, were scanned with a 2-mm resolution over a 5-cm² area, 2 mm from the surface of the magnet. This separation distance corresponds to the distance between the surface of the magnet and the surface of the paw. During exposure, each magnet was positioned above the plantar surface of the left (treated) paw so that uniform portion of the field encompassed the entirety of paw. Magnetic fields penetrate tissue and bone without distortion; however, the strength decreases as ~1/d², where d is the distance from the core of the magnet (6). The thickness of a rat paw was measured to be 0.5 cm; therefore, the distribution of the magnetic field through the thickness of the paw was a gradient, with each magnet varying in magnitude by ~x·0.25 mT from the plantar to the dorsal surface of the paw, where x represents the strength at the plantar surface. Graphical representation of the two-dimensional projections (a and c) and three-dimensional surfaces (b and d) of the flux distribution on the plantar (a and b) and dorsal (c and d) surfaces of the paw for each of the magnets used are presented in Fig. 1. Figure 1A depicts the 70-mT field used in all but the dose-response experiments, and Fig. 1, B and C, depict the magnets used for dose-response determination.

Statistical analysis. All statistical significance was determined by utilizing a two-way ANOVA and post hoc comparisons with Tukey’s test, assuming a P value <0.05 to be statistically significant (SigmaStat Software; SPSS, Chicago, IL).

RESULTS

SMF application for 15 and 30 min reduces histamine- but not CA-induced edema. Figure 2 shows the average temporal inflammatory response as represented by percent volume increase from the measured preinjection volume for CA- and histamine-treated paws exposed for 15 or 30 min to a 70-mT SMF immediately after injection. These results demonstrate that CA injection resulted in a more complex edema response, with a 70% maximum volume change, fully manifested 4 h after injection, whereas histamine-induced inflammation resulted in a 30% maximal volume change that peaked 30 min postinjection. This deviation in volume and duration is due to the differing inflammatory cascades that are stimulated by CA versus histamine.

Magnet application for 15 or 30 min did not consistently reduce the edema formation resulting from CA injection (Fig. 2, A and B, respectively), whereas histamine-induced edema formation was significantly reduced by the 15- and 30-min magnet applications, but to varying degrees (Fig. 2, C and D, respectively). Fifteen-minute magnetic field exposure significantly reduced histamine-induced edema formation by 40–65% at all but the final time point (Fig. 2C). Thirty-minute exposure also reduced histamine-induced edema formation significantly (20–25%, Fig. 2D) at all but the last two time points, but to a lesser extent than 15-min exposure.
Injection of CA vehicle control (saline) or histamine vehicle control (deionized water) resulted in no measurable change in paw volume (Fig. 2, A–D).

In an effort to address the apparent discrepancy in efficacy between the 15- and 30-min magnet treatment on histamine-induced edema, a protocol was adopted that allowed for investigation of the confounding effects of additional immobilization as well as additional anesthesia on the efficacy of magnet application. The animals were subjected to an additional 15 min of anesthesia immediately following the 15-min magnet treatment, allowing for the comparison of the resulting edema with the 30-min (anesthetized) sham and 30-min magnet-treated paws. Interestingly, the additional 15 min of anesthesia reduced the magnitude of edema reduction (15–30%, Fig. 2E) to that of the 30-min treatment. These results demonstrate that the additional anesthesia and/or immobilization reduces the originally observed additional efficacy of the 15-min treatment over the 30-min treatment.

SMF application for 2 h reduces CA-induced edema. To address the differing efficacy of magnet application in preventing edema formation in CA- and histamine-induced edema, we reduced the CA dose by one-half (0.1 ml of 0.5% CA as opposed to 0.1 ml of 1%), inducing an increase in volume proportional to that of histamine. Application of the 70-mT magnet for 15 min to this reduced-magnitude CA-induced edema was not successful in significantly reducing the edema formation (Fig. 2F). A shortened time line with more frequent volume measurements was then adopted for an additional set of experiments to assess, with greater temporal resolution, the effect of magnet treatment on the edema formation with this reduced CA dose (Fig. 2G). Again, no significant edema reduction was observed between sham and magnet-treated paws. Finally, based on the previously presented data showing that application of the SMF for one-half the time to histamine-induced maximal edema (15 of the 30 min to maximal edema formation) resulted in significant edema reduction, the SMF

---

Fig. 1. Graphical representation of the 2-dimensional projections and 3-dimensional surfaces of the magnetic field densities used. A: 70-mT static magnetic field (SMF) at the plantar (a and b) and dorsal surface (50 mT; c and d) of treated paws. B: 400-mT SMF at the plantar (a and b) and dorsal surface (250 mT; c and d) of treated paws. C: 10-mT SMF at the plantar (a and b) and dorsal surface (7.5 mT; c and d) of treated paws. Units on right axes are in mT.
was applied for a 2-h duration (2 of the 4 h to maximal CA-induced edema formation) to this reduced-dose CA-induced edema. Interestingly, this 2-h application resulted in a significant (33–37%) reduction in edema formation (Fig. 2H).

**SMF application is most effective when applied at the time of injury.** Based on the data showing that a 15-min magnet application was most effective in reducing histamine-induced edema formation, investigation of the influence of magnetic field exposure on edema resolution was completed. Histamine-treated animals were injected as previously described, and the 70-mT SMF was applied for 15 min at the time of maximal edema (30 min postinjection), resulting in no significant enhancement of edema resolution (Fig. 3A). Furthermore, a 15-min magnetic field pretreatment applied just before histamine injection also resulted in no significant reduction in edema formation or resolution (Fig. 3B).

**SMF efficacy is dose dependent.** To address whether the reduction in histamine-induced edema formation was dose dependent, we completed a dose-response experiment via application of a 400- and 10-mT field in addition to the 70-mT...
field used for all previous experiments. Surprisingly, the 400-mT field (Fig. 4, open squares) did not reduce edema formation to any degree, whereas the 10-mT field (open triangles) significantly reduced the edema by 25–55% at all but the last time point, similarly to the 70-mT field (40–65%; open circles). These data support published assertions that there exists a “physiological window” of effective magnetic field strengths (21, 46). In light of these data, the remaining experiments were conducted utilizing the 70-mT magnet.

SMF application may act via L-type Ca\(^{2+}\) channels. After establishing that the magnetic field application can significantly reduce histamine-induced edema formation, we attempted investigation of the mechanism of action via administration of pharmacological agents in conjunction with histamine stimulation and magnetic field exposure. The use of histamine as the injected inflammatory mediator, as opposed to CA, allows for very specific investigation of the early phase of the acute inflammatory response, because the cascade of events is better defined and can be manipulated pharmacologically.

Histamine stimulation results in a transient increase in microvascular permeability and leakage accompanied by vasodilation. The increase in permeability is thought to result from gap formation in intracellular junction complexes (1, 12, 18, 33, 43) initiated by intracellular Ca\(^{2+}\) influx (7, 38), which acts via action of phospholipase C and generation of inositol trisphosphate. This flux can also initiate Ca\(^{2+}\) influx from the extracellular space (38) as well as liberate NO, resulting in the endothelium-mediated vasodilation characteristic of histamine stimulation (47), further exacerbating fluid exudation. Generation of NO and its action on guanylate cyclase to increase cGMP concentrations (22) and administration of L-arginine (19) have also been shown to contribute to histamine-induced increased permeability (15). Although the histamine response is only one of the early phase mediators and therefore only one element of the acute inflammatory response per se, the isolation of this pathway minimizes the number of variables, thus facilitating a more direct investigation of the mechanism(s) involved in magnet treatment.

Studies suggest that electromagnetic field (EMF) exposure may activate NO production via activation of NO synthase (NOS), resulting in modification of the vascular tone through cGMP pathways and influencing the downstream Ca\(^{2+}\) flux (23, 24). Other work has suggested that SMF application may act via influence on Ca\(^{2+}\) dynamics and NOS to regulate blood pressure and local microvascular tone (28, 29). Studies have also recorded an effect of SMF on Ca\(^{2+}\) dynamics in other, nonvascular cell types and systems (30, 31, 36, 37, 39), suggesting that application of a SMF may impact edema formation by influencing the Ca\(^{2+}\) signal directly or indirectly through the NO signaling cascade, resulting in modulated dilation and permeability.

Based on these findings, agonists of both NO synthesis and L-type Ca\(^{2+}\) channel signaling were used in an effort to elucidate the mechanism by which SMF exposure significantly reduces induced edema. L-Arginine, the substrate for NO synthesis, was coadministered subplantar with histamine (0.1 ml) to potentiate edema formation as shown previously (9). The 70-mT magnetic field or sham was applied for 15 min, and volumes were measured every 30 min for 3 h (Fig. 5A). Edema formation was significantly potentiated, 36–87%, by the coadministration of L-arginine plus histamine plus sham treatment (Fig. 5A, filled squares) compared with histamine plus sham treatment alone (filled circles). This potentiation was suppressed 25–35% by application of the magnetic field (open squares), but the total volume level was not reduced to the level of histamine plus magnet alone (open circles). Injection of L-arginine in deionized water did result in a measurable increase in paw volume, and this can possibly be attributed to the potentiation of the small histamine release in response to the injection itself.

Concurrent administration of Ca\(^{2+}\) channel agonist BAY K 8644 (34) intraperitoneally and histamine subplantar (Fig. 5B) resulted in no significant change in the histamine swelling...
DISCUSSION

This study has demonstrated that SMF exposure significantly reduces edema in a time- and dose-dependent manner. Histamine-induced edema was significantly reduced by both a 15- and 30-min SMF, whereas CA-induced edema required a 2-h application to elicit a similar reduction. The effective dose duration appears to be related to the time to maximal edema formation. In the case of histamine-induced edema, the maximally effective tested dose duration was 15 min, and in the case of CA-induced edema, it was 2 h, both corresponding to 50% of the time to maximal edema formation, suggesting that the SMF must be applied for a sufficient fraction of the edema formation period to have a significant effect. This finding is supported by two existing studies evaluating effects of a PEMF to CA-induced edema, which reported a significant decrease in paw volume with an exposure time of 3–4 h (25, 48). In addition, we found that application of the field was required at the time of injury, since exposure before or after maximal edema formation yielded no significant edema reduction.

It was also noted that the slopes of the recovery portion of the volume curves did not differ between sham and SMF-treated groups, and therefore it can be argued that the passive recoil of the tissue, lymphatic uptake, and venous reabsorption were not affected by the SMF application, since this would have been manifested as a change in the rate of recovery. Together, these results suggest that SMF treatment is not beneficial for the resolution of induced edema but is useful in this model solely for the prevention of edema formation.

Whereas other studies have demonstrated physiological effects in tissues exposed to very high field strengths, on the order of 7–8 T (9, 16, 35), we found that a 400-mT field did not have any influence on edema formation, suggesting that there may exist an upper limit of magnetic field strength that results in suppression of edema. The remaining two field strengths investigated, the 70- and 10-mT fields, were successful in reducing edema volume, but to different extents. The 70-mT field reduced the edema formation to a greater degree than the 10-mT field, but it was not seven times more effective, suggesting that the response is nonlinear and that there may exist a saturation point, perhaps related to the available substrate for SMF action. Past studies have suggested that a lower limit of 1 mT exists for eliciting a physiological effect from SMF application (21, 46), but these are the first data suggesting a possible upper limit as well. The lower level may simply reflect the existence of a threshold level of activated substrate necessary to elicit a measurable response. The fact that the response is completely abolished above the yet to be determined upper threshold might also suggest that some other response is activated that masks the desired response. The mechanistic basis for the existence of such a physiological window, however, requires further investigation.

Determination of potential mechanisms involved in the observed physiological responses to magnetic field exposure is ongoing, but no definitive mechanism or pathway has previously been identified. Although studies have reported that magnetic field applications have decreased voltage-sensitive channel activation in GH3 cells (36), increased second messenger levels in human skin fibroblasts (30) and FNC-B4 neuronal cells (31), and increased microvessel dilation mediated by NO signaling (23), the results are mostly confounding, since they are from different cell types in vitro and tissues in vivo with varying magnetic field dosages and durations and have been applied both locally and globally, thus complicating the assessment of therapeutic value. By locally applying the SMF in conjunction with pharmacological alteration of endothelium-dependent production of NO or the Ca^{2+}-induced contractile state in smooth muscle cells, we can begin to assess the mechanism(s) of SMF action and determine the validity of our hypotheses that SMF application might modulate the permeability and/or dilation resulting from histamine-induced edema.

Looking first at the results attained by agonizing NO production in conjunction with local SMF exposure, we found that although the magnitude of edema was elevated by increasing NO production, the degree of the edema reduction (the area...
encompassed between the magnet treated and sham curves, Fig. 5A) was not altered, suggesting that the magnet acts independently of NO production. Conversely, we found that by agonizing L-type Ca\(^{2+}\) channels, we eliminated the edema reduction evoked by application of the SMF. Together, these results suggest that the SMF may act to open/activate L-type Ca\(^{2+}\) channels in vascular smooth muscle cells, increasing the intracellular Ca\(^{2+}\) concentration, and inducing constriction, therefore limiting edema formation. These data do not, however, give any insight into the additional Ca\(^{2+}\) handling mechanisms such as Ca\(^{2+}\) reuptake into the intracellular stores such as the sarcoplasmic reticulum (SR), which also influences the intracellular Ca\(^{2+}\) concentration. Additional studies utilizing pharmacological interventions targeted at intracellular stores need to be completed to solidify the argument that the SMF acts to increase the intracellular Ca\(^{2+}\) concentration. Because active dilation occurs in a transient fashion during edema formation, this conclusion can possibly explain the time-sensitive nature of magnet application. However, in conjunction with the active dilation, permeability is also transiently regulated during edema formation, and therefore further investigation of the direct effect of SMF application on permeability is warranted.

Furthermore, these conclusions provide a possible explanation regarding the observed greater SMF effect when applied to histamine-induced edema for 15 vs. 30 min. We found that 15 min of additional anesthetic immediately following the 15-min application resulted in the same magnitude of edema reduction as a 30-min application, suggesting that the additional time under anesthesia may be influencing the efficacy of the magnet. Since both the 15- and 30-min sham exposures resulted in the same volume curves, we can conclude that the additional anesthetic by itself does not influence the edema formation, and therefore it may be interacting with the action of the SMF. Because isoflurane is a known vasodilator (11), it is possible to conceive that this dilation competes with, in the case of 30-min application, or reverses, in the case of 15-min application followed by 15 min of additional anesthesia, the constriction induced by the magnet, resulting in a smaller magnitude of edema reduction. Ideally, it would be best to conduct the SMF application experiments under conscious conditions, since this eliminates any confounding effect of anesthesia, but immobilization in this case was required to ensure that the magnet application was unvarying for each experiment. Additional experiments could address this possibility by utilizing other techniques for conscious magnet application.

In conclusion, these studies are the first to demonstrate that acute, localized SMF exposure of moderate field strength (5–100 mT), when applied immediately after an inflammatory injury, can result in significant reduction of edema formation. One proposed mechanism of SMF action is through modulation of vascular tone via L-type Ca\(^{2+}\) channels in vascular smooth muscle. These results support the further study of acute application of static magnetic fields for the therapeutic treatment of vascular pathologies related to dysregulation of microvascular tone.

REFERENCES


GRANTS

This work was supported by National Center for Complementary and Alternative Medicine Grant AT-00582.