Static Magnetic Fields Neither Prevent Nor Diminish Symptoms and Signs of Delayed Onset Muscle Soreness

Jonathan C. Reeser, MD, PhD, David T. Smith, MPT, Virginia Fischer, MS, Richard Berg, MS, Kejian Liu, PhD, Charmaine Untiedt, PT, Mayro Kubista, PT

ABSTRACT. Reeser JC, Smith DT, Fischer V, Berg R, Liu K, Untiedt C, Kubista M. Static magnetic fields neither prevent nor diminish symptoms and signs of delayed onset muscle soreness. Arch Phys Med Rehabil 2005;86:565-70.

Objective: To determine whether application of a commercially available static magnetic field would alter the signs and/or symptoms of delayed onset muscle soreness (DOMS) produced by exhaustive eccentric exercise.

Design: A double-blinded, randomized, and placebo-controlled study, with subjects serving as their own controls.

Setting: An outpatient physical therapy and performance center.

Participants: Twenty-three healthy volunteers (18 women; mean age, 30y; range, 18–40y; 5 men; mean age, 29y; range, 19–39y).

Intervention: After exhaustive eccentric exercise of both the right and left elbow flexor muscle groups, subjects received daily treatment with either a 350G magnet or a placebo device for 5 consecutive days.

Main Outcome Measures: Outcome variables, including anthropometric measurements, perceived discomfort, and muscle force production, were compared using linear mixed models.

Results: Arm circumference, relaxed elbow flexion angle, and pain increased, whereas active elbow flexion angle and maximal isometric torque decreased transiently before returning to near baseline. No significant difference in outcome variables existed between the treated and control arms. Participants reported less pain in both treated and control arms after each session, suggesting a placebo effect.

Conclusions: Static magnetic fields were no more effective than placebo in preventing DOMS.

Key Words: Alternative medicine; Exercise; Magnetics; Muscles; Pain; Rehabilitation.

ALTERNATIVE MEDICINE therapies are becoming increasingly popular in the treatment of many painful conditions, including arthritis, back pain, and fibromyalgia. Unfortunately, there is a relative dearth of well-designed experimental studies of the efficacy of these therapies. Consequently, patients and their health care providers are often left to rely on anecdotal reports and intuition when deciding whether to use an alternative intervention.

Since the Middle Ages, magnetic substances have been thought to influence biologic processes. Applying magnetic fields for medicinal purposes has been touted since 1775, when Franz Anton Mesmer published a treatise "On the medicinal uses of the magnet." Mesmer employed magnets to "cure" neuropsychiatric illness among the salon society of Europe,[1] but in 1784 a panel convened by the Royal French Academy of Science concluded that the efficacy of magnetic therapies resided entirely within the mind of the patient. Consequently, "Mesmerism" became synonymous with medicinal quackery throughout Europe.

Magnet therapy subsequently gained a foothold in the New World, and by the early 1800s magnetic insoles and "electric health rings" were available from the Sears Roebuck catalogue. The Chicago Magnetic Company sold magnetic garments advertised to furnish full "protection of the vital organs of the body."[1] Recently, magnet therapy has enjoyed a popular renaissance.[2,3] According to 1 source,[4] 90% of senior Professional Golfers' Association players have worn "therapeutic magnets." Perhaps even more remarkably, the game bench of the National Football League's Miami Dolphins was allegedly once going to be covered with a magnetic pad.[4] "Endorsements" such as these have helped spur the demand for "healing magnets." It has been estimated that $500 million is spent on magnetic devices annually in the United States and Canada, with worldwide sales in excess of $5 billion.[3]

Although anecdotal reports of the benefits of magnet therapy abound, little experimental justification exists for its use. The modern scientific literature dating to 1938[5] is variable in both quality and conclusions. Although a few placebo-controlled investigations have reported that magnetic therapy was effective in relieving pain,[6-10] several other controlled studies have found that magnets lack efficacy in treating pain.[11-17] This includes 1 study[17] that investigated the effect of magnets on exercise-induced delayed onset muscle soreness (DOMS).

People who exercise with unaccustomed intensity typically suffer from subsequent transient (self-limited) muscle pain, or DOMS.[18,19] Weakness, stiffness, and discomfort are quantifiable hallmarks of DOMS. Muscular soreness usually occurs within 24 to 48 hours after the inciting bout of exercise, and is characterized by pain with movement or palpation of the involved muscle group, restricted range of motion (ROM) about the affected joint, and reduced muscle force production. Symptoms of DOMS typically last 5 to 7 days, and improve without specific intervention.[20] Despite this typically benign clinical course, numerous studies[21-24] have explored the efficacy of various therapeutic modalities and pharmaceuticals for the treatment of DOMS, with mixed results. DOMS lends itself to clinical investigations such as this because it represents a well-defined, reproducible model of muscular injury. In view of the resurgent popular interest in magnet therapy, and given the prevalence of overuse musculoskeletal symptoms (includ-

From the Department of Physical Medicine and Rehabilitation, Marshfield Clinic (Reeser); Department of Physical Therapy, Saint Joseph's Hospital (Smith, Untiedt, Kubista); Marshfield Clinic Research Foundation (Fischer, Berg), Marshfield, WI. Liu is currently affiliated with the Department of Biostatistics, Forest Research Institute, Jersey City, NJ.

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Reprint requests to Jonathan C. Reeser, MD, PhD, Dept of Physical Medicine and Rehabilitation, Marshfield Clinic, 1000 N Oak Ave, Marshfield, WI 54449, e-mail: *reeser.jonathan@marshfieldclinic.org*.

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ing DOMS) among active adults, we designed this study to determine if application of a static magnetic field would significantly alter the measurable parameters of DOMS in a clinical setting. Although our study was similar in concept to that of Borsa and Liggett,[17] there were important differences (eg, in the magnetic field strength and the duration of exposure, single- vs double-blinded design), which, in our opinion, warranted repeated investigation using a similar model system.

METHODS

Participants

The study protocol was reviewed and approved by the Marshfield Clinic Institutional Review Board. Healthy volunteers between the ages of 18 and 45 years who were not engaged in regular resistance training were recruited. People with a history of heart disease, hypertension, cancer, diabetes mellitus, cervical radiculopathy, peripheral or upper-limb entrapment neuropathy, or fibromyalgia were excluded. Pregnant women and people with a history of renal impairment were also ineligible. We estimated that from between 20 to 25 participants would be required to detect potentially significant differences in the outcome variables. Preenrollment power calculations were based on published data for recovery of isometric strength after exercise-induced muscle damage.[25] Our estimates showed that 20 subjects would provide more than 90% power (in a 2-sided test with $\alpha=.05$) provided that (1) the true mean difference in strength between magnet and placebo treated arms was at least 2.3kg (equivalent to the recovery of strength at 3 days as reported in Clarkson et al[25]) and (2) there was a moderate correlation between arms within subjects (intraclass correlation=.05). Twenty-four volunteers enrolled; 1 withdrew after the first day because of an unrelated illness. Twenty-three subjects completed the study.

Study Design

The study was double-blinded, randomized, and placebo controlled. Random assignment determined which arm received magnet treatment in a given subject, with the subject's opposite arm receiving sham treatment with a placebo device identical in appearance to the magnet. Subjects understood that 1 limb would receive magnet therapy and the other a sham treatment, but they were blinded (as were the researchers) as to the actual assignment until after the study. Right- and left-handed subjects were randomized separately to balance the assignment of dominant arms between experimental and control groups. Subjects therefore served as their own controls, thereby minimizing potential biases such as 1 person's relative perception of pain and his/her effort during testing.

Measures

Outcome variables assessed included pain, maximal isometric elbow flexor torque, and joint ROM. Pain was assessed via a 100-mm ascending visual analog scale (VAS; 0mm, no pain; 100mm, excruciating pain). Both relaxed and active elbow flexion angles were measured goniometrically, with 0° representing full elbow extension; arm circumference was measured at the midpoint between the acromion and olecranon. These anthropometric measurements were collected to assess the degree of stiffness and soft tissue swelling produced by the eccentric overload protocol. Isometric torque produced by the elbow flexors was quantified using the Biodex System 3.[a] All measurements (except for VAS scoring) were taken in duplicate and the averages calculated.

Protocol

The study was carried out at an outpatient physical therapy and performance center. On day 1, baseline data for all outcome measures were collected from every participant. On that day only, the skinfold thickness over the biceps at the midpoint of both right and left arms was also measured. A 5-second maximal isometric activation of the right elbow flexors was obtained with the subject seated, the shoulder at approximately 90° of flexion, and with the elbow flexed to 90°. After a 10-second rest, a second trial was completed on the same side, and the protocol was then repeated on the left side.

Subjects then engaged in exhaustive eccentric exercise of both their right and left elbow flexor muscle groups, after the method of Nosaka and Clarkson.[18] The calculated exercise weight for each participant was 80% of the force component of the maximum isometric peak torque (torque=force×moment arm), rounded to the nearest .09kg (0.2lb). Barbells and wrist weights were used to achieve exercise weight. The right arm was exercised first. Subjects lowered the weight eccentrically from a fully flexed to a fully extended elbow position, with the examiner helping only to ensure each repetition lasted 10 seconds. The examiner then returned the limb to the fully flexed elbow position. Participants received verbal encouragement from the examiner and visual feedback from a clock placed in front of them. Three sets of 10 repetitions lasting 10 seconds each were completed with a 1-minute rest between sets. Every subject was exercised to failure as a result of the protocol, and when failure occurred, sufficient physical assistance was provided at the weakest joint angles to permit completion of the entire set of 10 eccentric activations.

Discomfort, anthropometric measurements, and isometric torque production were assessed postexercise for both arms, right arm first. Participants subsequently received a 45-minute treatment with a 350G magnet[b] applied over the elbow flexors of 1 arm, while a placebo of identical appearance was applied to the contralateral side. Treatment parameters were selected based on those successfully used by Vallbona et al.[6] The magnet/placebo was positioned at the midpoint of the arm between the olecranon and acromion, and held in place with self-adhesive straps. The magnets and placebos measured 20×12cm, and were placed along the long axis of the limb to cover as much of the elbow flexor musculature as possible (including the distal bicipital myotendinous junction). After the treatment session, participants once again used the VAS to estimate the discomfort felt in both arms.

On days 2 through 5, subjects certified that they had abstained from other analgesics (as required by the study protocol), and used the VAS to quantify their discomfort. Anthropometrics and maximal isometric force production were then measured, followed by a 45-minute magnet/placebo treatment session and a repeat VAS scoring. On the sixth and final day only outcome measures were collected.

Data Analysis

The change in outcome variables after treatment was calculated. Each variable (VAS score, elbow ROM, arm circumference, elbow flexor torque) was compared between control and treatment arms across all evaluation days using linear mixed models (repeated-measures analysis of variance), thereby permitting valid comparisons after adjustment for the correlation between the 2 arms and among the repeated measurements on the same subject. In addition to treatment, the mixed models included time and dominant arm as fixed effects, with the preexercise baseline as a covariate. The interaction between treatment and time was also evaluated.

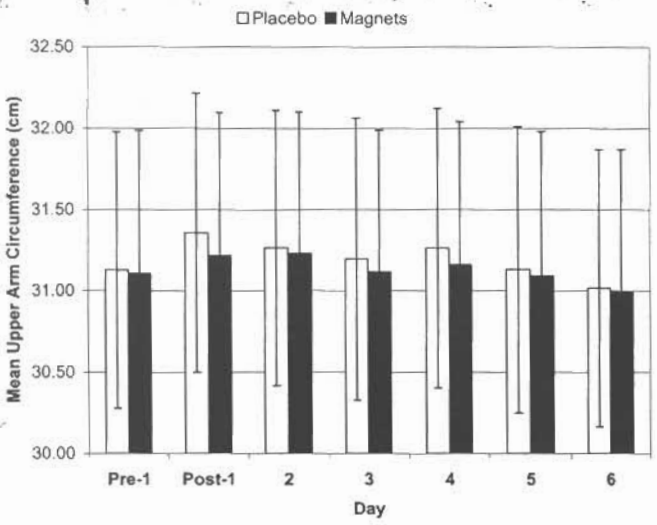

Fig 1. Effect of magnet therapy on arm circumference. Values are means of 23 subjects ± standard error (SE). Abbreviations: Pre-1, baseline determination before undergoing the DOMS induction protocol; Post-1, data collected immediately after the exhaustive eccentric exercise protocol. *P*=.143 for treatment effect across all evaluation days.

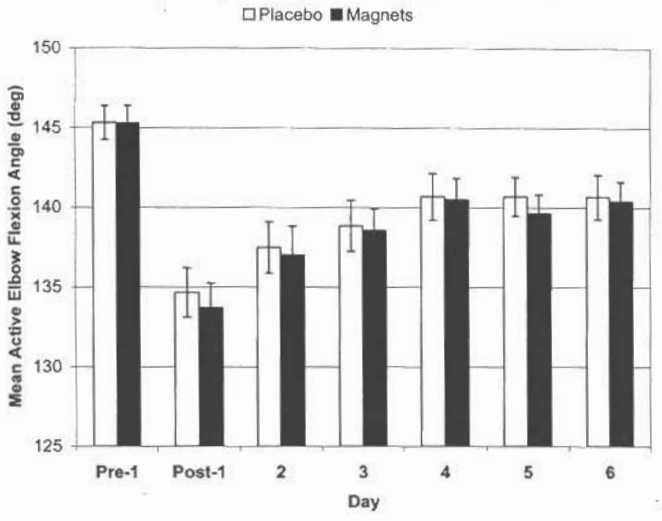

Fig 2. Effect of magnet therapy on active elbow flexion angle. Values are means of 23 subjects ± SE. *P*=.112 for treatment effect across all evaluation days.

RESULTS

Nineteen of the 24 subjects in the study were women (mean age, 30y; range, 18–40y) and 5 were men (mean age, 29y; range, 19–39y). Eighteen women and 5 men completed the 6-day study protocol. Other than the anticipated DOMS as a consequence of the exercise protocol, there were no adverse events associated with the exercise or treatment. As expected, relaxed elbow flexion angle, arm circumference, and pain transiently increased after the induction protocol, reflecting the well-described soft tissue swelling and myofibrillar damage characteristic of DOMS. Similarly, active elbow flexion angle and maximal isometric torque predictably decreased before returning nearly to baseline by the end of the study.

There was no statistically significant difference in any outcome variable between the magnet-treated arms and the control arms. In addition, there was no consistent correlation between skinfold thickness and any of the outcome measures when corrected for the preexercise baseline. When compared across all evaluation days, there was no significant difference between magnet and control arms for arm circumference (fig 1), active elbow flexion angle (fig 2), or average maximum isometric torque (fig 3). On day 1 (postinduction), there was a significant difference in the relaxed elbow flexion angle between magnet and control arms when adjusted for baseline ($P=.006$) (fig 4). However, when adjusted for multiple comparisons using the Bonferroni adjustment, this difference lost its statistical significance. Similarly, on day 4 the relaxed flexion angle appeared to increase (nonsignificantly) in the magnet-treated arms compared with the placebo-treated arms before rapidly declining by day 6. This pattern suggests a significant interaction between treatment and day ($P=.034$). Finally, although no significant differences in VAS scoring were detected between magnet and control arms, a decrease in VAS scoring was noted for both arms after each treatment session (fig 5). The decrease was similar in both arms, and was statistically significant on days 1 ($P<.001$), 2 ($P=.002$), and 3 ($P=.009$).

DISCUSSION

Our study offers no evidence to support a therapeutic role for magnets in treating DOMS resulting from exhaustive eccentric exercise. There was no statistically significant difference in any outcome variable between the magnet-treated arms and the control arms. The lack of significant correlation between skinfold thickness and the outcome variables when corrected for baseline suggests that the absence of a treatment effect cannot be attributed to inadequate penetration of the magnetic field because of variation in body habitus. Although a slight increase in arm circumference was observed after the eccentric overload induction protocol (as expected), we did not observe an increase as great as that previously reported by others using this protocol.[18] The reason for this variation is not clear, but it is conceivable that the DOMS induction protocol as we performed it resulted in less muscle damage than the protocol

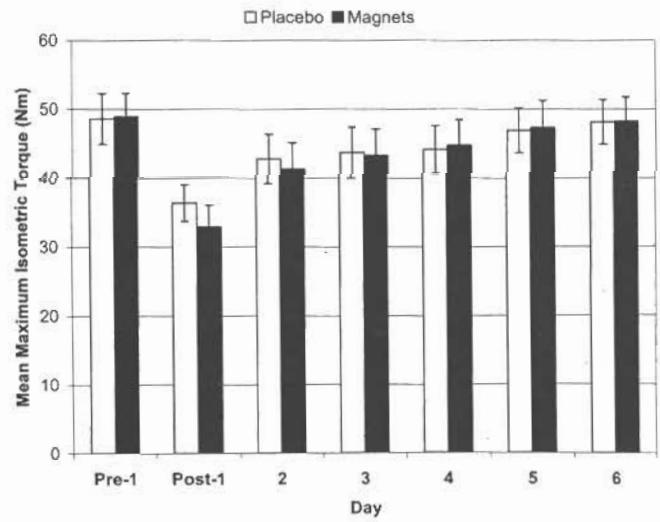

Fig 3. Effect of magnet therapy on average maximum elbow flexor isometric torque production. Values are means of 23 subjects ± SE.

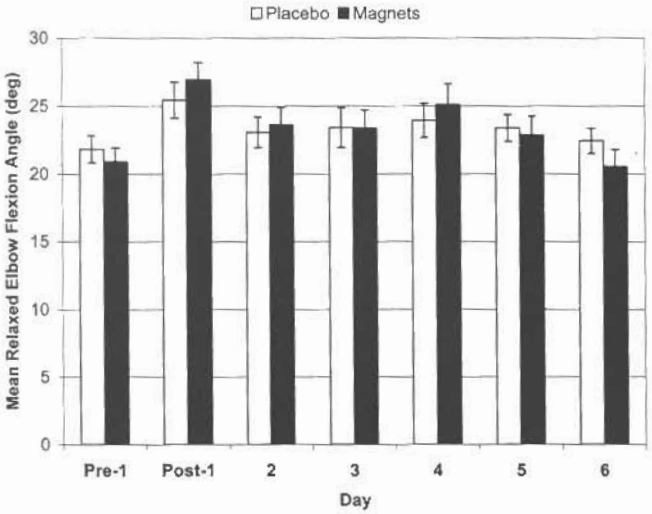

Fig 4. Effect of magnet therapy on relaxed elbow flexion angle. The data suggest an interaction between treatment and day. See text for discussion. Values are means of 23 subjects ± SE.

followed by Nosaka and Clarkson.[18] In this regard, the greatest mean VAS score reported by our subjects was approximately 3 (30mm) (fig 5), compared with maximum VAS scores of 7 to 8 in Clarkson and Hubal's study.[20] The study participants were untrained, which argues against intrinsic resistance to DOMS because of prior eccentric training. However, the observed variation from Nosaka and Clarkson's results[18] for all our outcome variables is a matter of degree rather than direction or trend. We conclude, therefore, that our results are characteristic for experimentally induced DOMS of the elbow flexors.

The arm circumference, active elbow flexion angle, and average maximum isometric torque data were remarkably similar between magnet-treated and control arms, as reflected by the graphs for each of these measures (figs 1–3). The data for the relaxed elbow flexion angle are somewhat inconsistent over time, and the representation of these data (fig 4) suggests a significant interaction between treatment and day. The sham magnet-treated arms actually had a slightly smaller relaxed elbow flexion angle than did the magnet-treated arms on days 1 and 4, suggesting that the control arms were less stiff. However, this difference was not statistically significant and, in our opinion, it seems likely that these results are best explained by chance, particularly in light of the absence of other significant magnet treatment effects.

Notably, there was evidence of a placebo effect, as participants reported less pain in both the magnet-treated arm and the control arm after each treatment session. This was particularly true on days 1 through 3, when the posttreatment VAS scores were significantly lower than pretreatment scores. Although intermittent compression has no effect on the physiologic parameters of DOMS,[21] it is possible that the observed transient reduction in VAS scoring after each treatment session may have been the consequence of the modest compression afforded by the self-adhesive wraps that secured the magnet and the placebo in place. Taken together, these data suggest that static magnetic fields as applied in this study are not more effective than placebo in mitigating the anticipated sequelae of exhaustive eccentric exercise, nor are they an effective treatment for DOMS.

Methodology is, of course, an essential factor in understanding the results of any investigation, and thus it is important to note that we chose the length of treatment sessions and magnet field strength to correspond to that used by Vallbona et al.[6] Their investigation is among the few well-designed studies that have demonstrated a positive effect of magnets in treating muscular pain. In addition, the supplier of our magnets and controls also supplied the devices used in the Vallbona study. Therefore, although it is conceivable that we may have obtained different results by using a different treatment protocol (eg, by varying the length of treatment or magnet field strength), we think it is important that our results were negative despite the fact that we used parameters that effectively reduced soft tissue pain in at least 1 other trial.

It thus becomes readily apparent that *what* is being treated is as important in the therapeutic equation as is *how* the painful condition is being treated. While we investigated experimentally induced muscular soreness, Vallbona[6] investigated pain associated with postpoliomyelitis syndrome (PPS). Unfortunately, the etiology of PPS pain seems less well understood than that for DOMS. Indeed, the areas of pain treated in Vallbona's study were identified as either "predominantly muscular or predominantly arthritic." Vallbona explained that this categorization was "somewhat arbitrary" because "arthritic changes are often accompanied by muscle spasm with clearly distinguishable trigger points."[6(p1201)]

In contrast, DOMS has been thoroughly studied and characterized on several levels. Clinically, its hallmark is a sensation of muscular soreness occurring 24 to 48 hours after exercise of unaccustomed intensity or type. As discussed, Clarkson and Hubal[20] described the typical findings of stiffness and restricted ROM about the affected joint(s) in addition to the reduced muscle force production that rapidly ensues. All these symptoms typically resolve within 5 to 7 days. Eccentric exercise develops more force per actinomyosin crossbridge and more strain per muscle fiber, and thus eccentric overload is particularly apt to produce DOMS. It is believed that fatigued muscle fibers suffer mechanical tissue damage on subsequent stretch or lengthening activation, setting off an inflammatory cascade that may be essential to subsequent myofibrillar regeneration.[26] The pain associated with DOMS is believed to be mediated by type III and IV afferent fibers (located in muscle connective tissue) that respond to mechanical and chemical stimuli such as edema, mast cell degranulation with subsequent histamine release, and local inflammatory mediators, including kinins and prostaglandin E_2. Teleologically, it has been hypothesized that this pain imposes a "voluntary immobilization" of the affected muscle group that facilitates healing. Treatment strategies for DOMS include stretching, warm-up, postexercise massage,

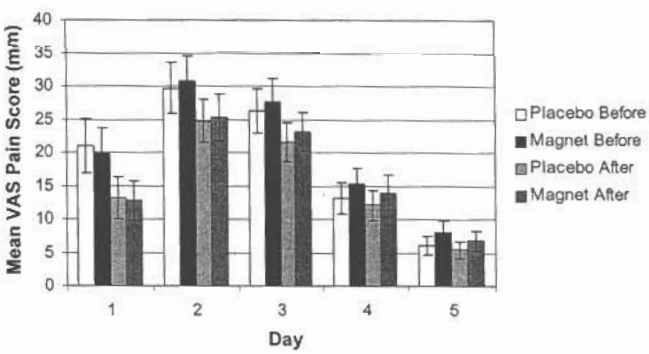

Fig 5. Pain difference before and after magnet and placebo treatment. Values are means of 23 subjects ± SE. *P*=.907 for treatment effect across all evaluation days.

rest, application of ice or heat, and use of nonsteroidal anti-inflammatories,[22] but most studies of the effect of modalities (eg, transcutaneous electric nerve stimulation, ultrasound) suggest no significant acceleration of healing beyond that which occurs spontaneously.[23,24]

To our knowledge, there has been only 1 published peer-reviewed study of the treatment of DOMS with magnets. Borsa and Liggett[17] found no enhanced pain relief or recovery from DOMS treated with a 700G magnet worn continuously over the elbow flexors for 72 hours after exhaustive eccentric exercise. There also have been at least 2 abstracts[27,28] published on the topic. Jing et al[27] reported that magnets had no therapeutic effect on perceived soreness, resting elbow extension, or arm circumference within 48 hours of eccentric overload of the elbow flexors among 13 subjects. However, a study by Zhang et al[29] suggested that protection of eccentrically overloaded human quadriceps from ambient electromagnetic radiation minimized subsequent DOMS over 48 hours. The clinical significance of this latter observation is unclear.

Although there has been scant research on the use of magnets to treat DOMS, there is a small body of literature reporting on their use to treat other painful conditions. In a randomized, double-blinded, placebo-controlled, crossover pilot study of 20 patients with chronic nonradicular lower back pain, Collacott et al[11] found no significant differences in VAS, pain rating index, or lumbar ROM between treatment with a placebo and a 300G magnet. Hong et al[12] found similar results, with no differences in pain intensity or frequency between magnet and nonmagnetic groups in a randomized, double-blinded, placebo-controlled study using a 1300G magnetic necklace for patients with chronic neck and shoulder pain. Caselli et al[13] concluded that magnetic insoles had no effect on heel pain, a finding supported by the recently published double-blind, placebo-controlled study by Winemiller et al.[30] Carter et al[14] conducted a randomized, double-blinded, placebo-controlled pilot study on magnet therapy for treatment of wrist pain attributed to carpal tunnel syndrome and concluded that magnets were no more effective than placebo. In view of our results that suggest a placebo effect, it is interesting that both the placebo and the magnet group in the Carter study reported significant decreases in pain at treatment time as well as at follow-up. Brief reports from Brown et al[15] and Harper and Wright[16] revealed no significant therapeutic effect from magnets on pain threshold and pelvic pain, respectively.

There are even fewer studies that suggest static magnetic fields provide meaningful analgesia. Weintraub[7,8] found that 450 to 475G magnetic insoles reduced pain among patients with diabetic peripheral neuropathy. However, no similar significant effect has been reported for nondiabetic peripheral neuropathy patients. Studies by Alfano[9] and Colbert[10] and colleagues show a significant reduction in pain intensity in fibromyalgia patients using magnetic sleep pads. Alfano[9] reported statistically significant improvement in pain intensity in only 1 of the 2 magnet groups, with the third and fourth groups receiving usual treatment or a placebo. In Colbert's double-blind study,[10] the magnet treatment group reported significant improvement in 7 areas, including pain and level of fatigue on waking, while the sham magnet group only reported less fatigue on waking. Neither group reported improved overall well-being. Hinman et al[31] found significant improvement with static magnet treatment of chronic knee pain resulting from degenerative joint disease. However, the subjectively rated improvements in pain and physical function were greater than the improvement in gait speed. Finally, a few reports[32,33] suggest that static magnetic fields can positively influence wound healing.

The literature (as exemplified by this sampling), therefore, presents a mixed picture, with some studies indicating therapeutic effect and others showing no benefit from static magnets. Study design concerns aside, variables such as magnet field strength and dose, as well as the physical design of the magnet, may also potentially influence treatment outcome. Because there is no consensus on how magnetic fields produce their analgesic effect, it is difficult to predict the conditions for which magnets should be useful a priori. On a first review of the literature, it appears that static magnets may be more likely to be effective in the treatment of chronic (presumably noninflammatory) pain conditions than they are in the treatment of acute inflammatory conditions. This observation, although clearly challenged by Collacott's study[11] on chronic low back pain in particular, may be worthy of further investigation.

Proposed mechanisms by which magnets have been hypothesized to exert their biologic effect(s) include promotion of red cell ingress and blood flow into the area treated, alignment of body meridians, central nervous system effects, realignment of chromosomes, and local effects on intra- and extracellular water.[4] It is known that pulsed magnetic fields can alter the excitability of motor nerves and may even cause them to depolarize, but a similar effect has not been reliably proven for static magnetic devices. In this regard, the electromagnetic literature suggests that magnetic fields generated by a circulating current may have greater biologic effects than static magnetic fields. In particular, pulsed electromagnetic therapy has been shown to be somewhat beneficial in the treatment of osteoarthritis affecting the knee and cervical spine.[34]

CONCLUSIONS

While static magnetic fields may indeed modulate some types of pain, the mechanism is not clearly understood, nor is it known what conditions will respond positively to magnet therapy. Further study is needed before magnets can be proven to merit a spot in the physiatrist's or sports medicine practitioner's arsenal of treatments. Well-designed studies of a sufficiently large sample size to detect small, but possibly clinically significant, effects on specific types of painful conditions are needed to better understand the potential utility of this alternative modality. Such studies must adequately control for variables that might influence treatment outcome, including the strength of the static magnetic field and the duration and number of treatment sessions. In the meantime, we cannot recommend magnets, as used in this study, for the treatment of DOMS.

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Suppliers

a. Biodex Medical Systems, 20 Ramsay Rd, Shirley, NY 11967-4704.
b. BIOflex Medical Magnetics Inc, 3370 NE Fifth Ave, Oakland Park, FL 33334.