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Flexible Magnets Are Not Effective in Decreasing Pain Perception and Recovery Time After Muscle Microinjury

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Objective: To assess the therapeutic effects of flexible magnets on pain perception, intramuscular swelling, range of motion, and muscular strength in individuals with a muscle microinjury.

Design and Setting: This experiment was a single-blind, placebo study using a repeated-measures design. Subjects performed an intense exercise protocol to induce a muscle microinjury. After pretreatment measurements were recorded, subjects were randomly assigned to an experimental (magnet), placebo (imitation magnet), or control (no magnet) group. Posttreatment measurements were repeated at 24, 48, and 72 hours.

Subjects: Forty-five healthy subjects participated in the study.

Measurements: Subjects were measured repeatedly for pain perception, upper arm girth, range of motion, and static force production. Four separate univariate analyses of variances were used to reveal statistically significant mean (±SD) differences between variables over time. Interaction effects were analyzed using Scheffe post hoc analysis.

Results: Analysis of variance revealed no statistically significant ($P > .05$) mean differences between conditions for any dependent pretreatment and posttreatment measurements. No significant interaction effects were demonstrated between conditions and times.

Conclusions: No significant therapeutic effects on pain control and muscular dysfunction were observed in subjects wearing flexible magnets.

Key Words: static magnetic field, magnetohydrodynamic effect, Hall voltage

The use of a magnetic field to treat musculoskeletal disorders dates back thousands of years, to when Greek, Persian, and Chinese physicians used the healing powers of magnetic energy to treat conditions such as gout and muscle spasms (E.A. Hacmac, unpublished manuscript, 1991). Since then, clinicians have been using the principles of electromagnetism to treat various musculoskeletal disorders, such as rotator cuff tendinitis,[1] osteoarthritis and rheumatoid arthritis,[2] nonunion fractures and arthrodesis,[3,4] and failed total knee arthroplasties.[5] The energy from an electromagnetic field is used to stimulate mechanisms for tissue growth and repair. Traditional units deliver electromagnetic field energy using either a pulsed or static mode, depending on the type of unit and the prescribed dosage. Sports medicine practitioners and other allied health professionals are currently prescribing commercially available flexible magnets to athletes to reduce the signs and symptoms associated with acute and chronic musculoskeletal injuries. Unpublished written reports and personal testimonies have indicated that flexible magnets promote healing and decrease pain[6–8] (Hacmac, 1991; V. Ardizzone, unpublished data, 1992; T.J. Zablotsky, unpublished data, 1989), although the efficacy of this modality has not been demonstrated experimentally.

The commercially available flexible magnet is a modified and simplified version of the original electromagnetic field unit model. The flexible magnet is constructed of silicon rubber with high-grade steel having ferromagnetic properties capable of inducing low-level, homogeneous, DC static magnetic fields. Most commercially available flexible magnets have field strengths below 0.1 T (1000 G), and the energy transmitted from the magnets is reported to produce both thermal and nonthermal physiologic effects within injured soft tissue[6–8] (Hacmac, 1991; Ardizzone, 1992; Zablotsky, 1989). The flexible magnet is applied directly over the injured area and secured with an elastic bandage or neoprene sleeve (Figure 1). The magnet is worn continuously until the patient is asymptomatic. To date, no research has been published concerning the efficacy of wearing flexible magnets. Since the magnets are being used prior to intensive background research, many questions exist concerning their effectiveness in treating musculoskeletal disorders. The purpose of our investigation was to determine if flexible magnets are effective in decreasing pain perception and recovery time after muscle microinjury.

METHODS

Subjects and Design

This experiment was a single-blind, placebo study using a repeated-measures design. Subjects were required to report to

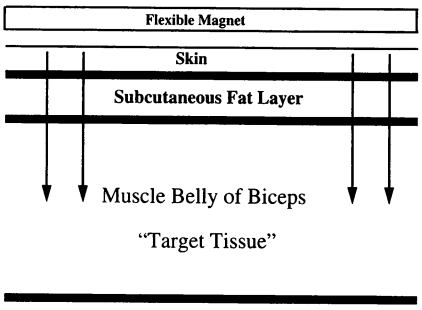

Fig 1. Flexible magnet placed directly over the target tissue.

the laboratory for five testing sessions (Table). Forty-five subjects (20 males, 25 females; mean age, 23.2 ± 2.81 years; range, 20 to 32 years) volunteered to participate in this study. Inclusion criteria consisted of a healthy nondominant arm and abstinence from upper extremity resistance training for at least 6 weeks. All subjects read and signed an informed consent explaining the risks, procedures, measurements, and benefits of participation. The protocol was approved by Oregon State University's Institutional Review Board.

Measurement Procedures

The dependent measures included pain perception, range of motion, upper arm girth, and static force production. At the first session, we took pre-exercise measurements, after which subjects performed the exercise protocol to induce muscle microinjury. We assessed postexercise measurements 24 hours later (session two), after which subjects were randomly assigned to a control (C) (n = 15), placebo (P) (n = 15), or experimental (E) (n = 15) group. We instructed subjects to refrain from analgesic and anti-inflammatory medications, physical therapy, and extensive upper arm activity until the investigation was completed. We repeated posttreatment measurements at sessions three, four, and five (24, 48, and 72 hours). Reliability and precision of measurement were obtained using intraclass correlation coefficients (ICCs) and standard errors of measurement (SEMs), respectively.

The experimental group received a flexible magnet (Nikken, Inc, Los Angeles, CA) with a field strength of 0.07 T (700 G). The placebo group received a sham magnet, which had no field strength (0 T, 0 G). The control group received no treatment. The size of the magnet/placebo was approximately 8 × 5 cm, with a thickness of 3 mm. The modality (magnet or placebo) was worn continually, except when bathing, over the midbelly of the biceps brachii muscle and supported with POWER-Flex, a high-strength, self-adhering elastic tape (Andover Coated Products, Inc, Salisbury, MA) (Figure 2).

Time Line for Study

Session	Activity
1	Completion of informed consent, pre-exercise measures, and exercise-induced muscle soreness protocol.
2	Completion of postexercise/pretreatment measurements, and treatment assignment (experimental, placebo, or control) (24 h postexercise).
3	Completion of postexercise/posttreatment measurements (24 h posttreatment).
4	Completion of postexercise/posttreatment measurements (48 h posttreatment).
5	Completion of postexercise/posttreatment measurements (72 h posttreatment).

Dependent Measures

Pain Perception. We assessed pain perception using a visual analog scale, as in previous investigations.[9] The visual analog scale has been shown to be a reliable and valid method of quantifying pain perception.[10] The visual analog scale consisted of a horizontal line 10 cm in length, with 0 at the extreme left representing "no pain" and 10 cm on the extreme right representing "pain as bad as it possibly could be" for the biceps brachii muscle. Subjects were asked to draw a vertical line at the point that most accurately corresponded to their perceived level of pain with active flexion and extension of the involved arm.

Range of Motion. We measured pain-free range of motion (ROM) for elbow flexion and extension using a standard plastic goniometer. The goniometer approximated the axis of rotation for the ulnohumeral joint and bisected the humerus and forearm.[11] We measured extension with the subject seated and the arm resting pain free at the side.[12] For flexion, subjects

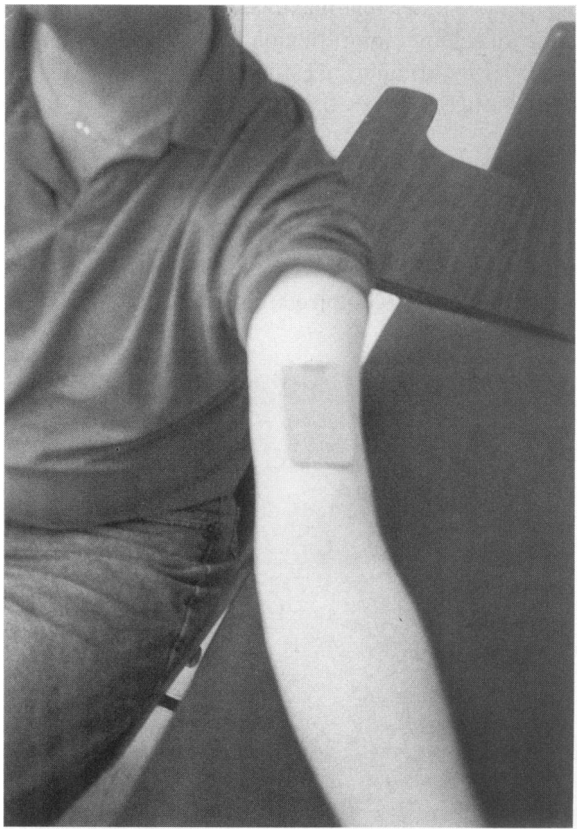

Fig 2. Fixation of the flexible magnet over the biceps brachii muscle.

were asked to flex the elbow to the point just before discomfort. This process was repeated twice for both flexion and extension, and we recorded the average score in degrees. The criterion measure for pain-free ROM was calculated by subtracting the extension score from the flexion score. Test-retest reliability was demonstrated to be ICC (2,1) = 0.92, SEM = 3.3°.

Upper Arm Girth. We measured upper arm girth as a composite score of three sites on the upper arm using a standard measuring tape.[12] The measurement sites for the upper arm included the distal and proximal musculotendinous junctions and the midpoint between the two junctions. We located and marked the sites with a permanent ink marker to ensure consistent tape placement. We also measured the sites from the medial epicondyle of the humerus, which served as the reference bony landmark. We measured girth twice at each site and recorded the average of the six measures as the criterion measure in centimeters. Test-retest reliability was demonstrated to be ICC (2,1) = 0.99, SEM = 1.0 cm.

Static Force Production. We measured static force production using the Kin-Com 500-H isokinetic testing device (Chattecx Corporation, Chattanooga, TN) (Figure 3). Subjects were seated with the nondominant arm placed in a neutral position of elbow flexion (90°). Each subject performed three maximal voluntary isometric contractions held for 2.5 s. The average of the three values was recorded as peak torque in Newtons (N). We used the midrange position as the reference angle because of the length-tension relationship.[13] The length-tension relationship demonstrates that maximal tension is generated at the midrange of elbow joint flexion due to optimal available sarcomere cross-bridging. Test-retest reliability was demonstrated to be ICC (2,1) = 0.99, SEM = 9.4 N.

Exercise-Induced Muscle Soreness Protocol

We used a concentric-eccentric exercise protocol for the biceps brachii muscle to induce muscle microinjury.[1,2,4] As a result of this exercise, subjects display signs and symptoms that are similar to those associated with a sport-related muscle-tendon strain.[5] Exercise was performed on the Kin-Com 500-H isokinetic testing device. The subject was seated and stabilized as for static force production (Figure 3). The angular velocity was set at 30°/s for concentric actions and 60°/s for eccentric actions. The range of motion for the exercise was preset at 45° to 110°. Subjects were seated and the nondominant elbow aligned with the axis of rotation of the dynamometer. Each subject performed near-maximal concentric and eccentric actions consisting of ten sets of five repetitions with 30-second recovery periods between sets.

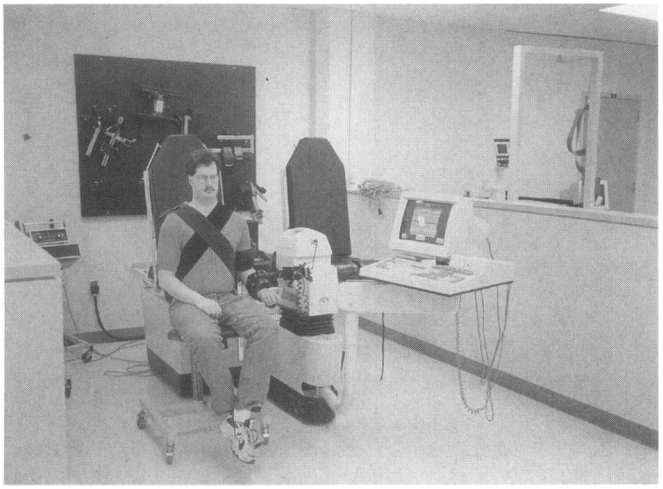

Fig 3. Test and exercise position on the Kin-Com.

Statistical Procedures

We calculated ICCs and SEMs for range of motion, upper arm girth, and static force production using the model proposed by Denegar and Ball.[16] Repeated measures were performed for each dependent variable, and the ICC (2,1) was obtained according to procedures explained by Denegar and Ball.[16]

Using preliminary statistical procedures, we analyzed the pre-exercise and pretreatment measurements. Four separate one-between (group) and one-within (time) univariate ANOVAs with repeated measures for time were performed as an a priori analysis to demonstrate that the exercise-induced muscle soreness protocol was effective in producing significant effects for pain perception, swelling, and dysfunction.

Using a one-between (group) and one-within (time) ANOVA with repeated measures for time, we analyzed pretreatment and posttreatment data. We employed four separate one-between (group) and one-within (time) univariate ANOVAs to reveal statistically significant mean (±SD) differences between variables. Interaction effects were observed using Scheffe post hoc analysis. The level of statistical significance was set at 0.05. We reduced and analyzed all data using Statview 4.1 statistical software for Macintosh (Abascus Concepts, Inc, Berkeley, CA).

RESULTS

Pre-Exercise Versus Postexercise

Preliminary analysis revealed statistically significant mean differences between pre-exercise and postexercise measures for pain perception ($F_{1,44} = 91.9$, $P < .0001$), ROM ($F_{1,44} = 46.4$, $P < .0001$), and static force production ($F_{1,44} = 34.1$, $P < .0001$). No significant pre-exercise/pretreatment differences were demonstrated for upper arm girth ($F_{1,44} = 1.5$, $P > .05$). Consequently, upper arm girth was not included in the pretreatment/posttreatment analysis.

Pretreatment Versus Posttreatment

ANOVA revealed no statistically significant ($P > .05$) mean differences between conditions for all dependent measures: pain perception ($F_{2,42} = 0.50$, $P > .05$), ROM ($F_{2,42} = 0.30$,

$P > .05$), and static force production ($F_{2,42} = 0.002$, $P > .05$) (Figures 4–6). No significant interaction effects were demonstrated between conditions and times: pain perception ($F_{6,126} = 0.65$, $P > .05$), ROM ($F_{6,126} = 1.4$, $P > .05$), and static force production ($F_{6,126} = 0.88$, $P > .05$) .

DISCUSSION

The proposed model promulgating static magnetic therapy implicates the Hall and magnetohydrodynamic effect mechanisms[6–8] (Hacmac, 1991; Ardizzone, 1992; Zablotsky, 1989). Both mechanisms are well-known physical principles that utilize the electrochemical nature of biologic tissue.[17,18] When a magnetic field of sufficient strength passes through a conductive fluid such as blood, an electromotive force, or Hall voltage, is produced (Figure 7).[17] A significant Hall voltage will cause blood ions to vigorously oscillate and collide, producing heat energy and vasodilation.[6,18] Vasodilation combined with an active magnetic field will significantly increase the flow of arterial blood to and away from the target area. The advantages of a magnetohydrodynamic effect are an increased delivery of molecular oxygen for cellular metabolism, a reduction of secondary tissue hypoxia, and local heat production[6] (Hacmac, 1991; Ardizzone, 1992; Zablotsky, 1989). Thermal effects produced by a static magnetic field would mimic those of other superficial and deep heating agents used to promote tissue healing, such as analgesia, increased blood flow, fibroplasia, and viscoelasticity[6–8] (Hacmac, 1991; Ardizzone, 1992; Zablotsky, 1989).

In direct contrast to the proposed model, recent research has demonstrated no significant thermal effects on skin and body tissue from exposure to static magnetic fields ranging from 0.015 to 1.5 T.[18,19] The field strength of most commercially available, flexible magnet models is less than 0.1 T (1000 G). Therefore, we hypothesize that the static magnetic field produced by the flexible magnet is of insufficient strength to produce significant physiologic changes in the target tissue area. Our results support this hypothesis by revealing no statistically significant therapeutic effect of the magnet on pain perception and muscular dysfunction. Additionally, the post-

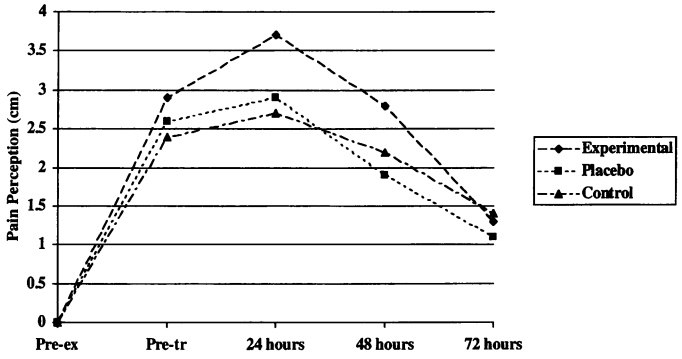

Fig 4. Change in pain perception over time between treatment groups. Repeat measures were taken at pre-exercise (Pre-ex), pretreatment (Pre-tr), and 24, 48, and 72 hours posttreatment.

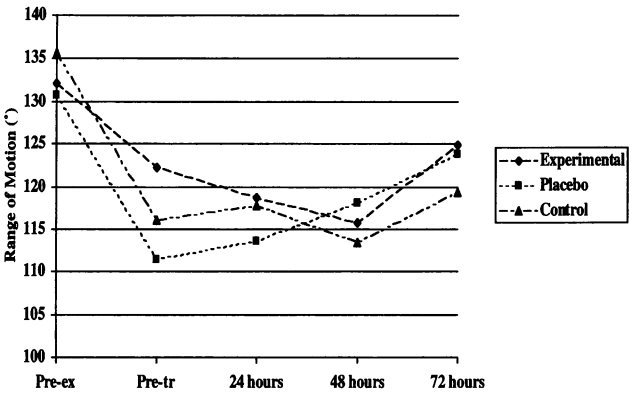

Fig 5. Change in pain-free range of motion over time between treatment groups. Repeat measurements were taken at pre-exercise (Pre-ex), pretreatment (Pre-tr), and 24, 48, and 72 hours posttreatment.

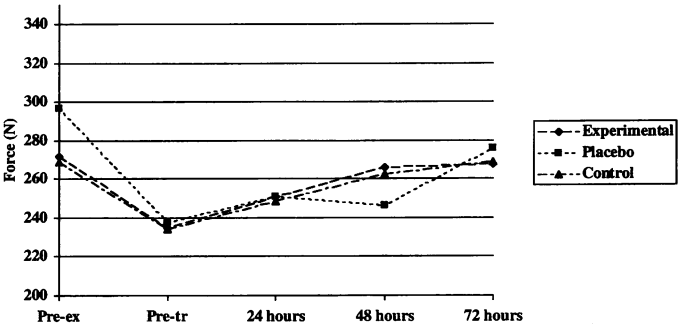

Fig 6. Change in static force production over time between treatment groups. Repeat measurements were taken at pre-exercise (Pre-ex), pretreatment (Pre-tr), and 24, 48, and 72 hours posttreatment.

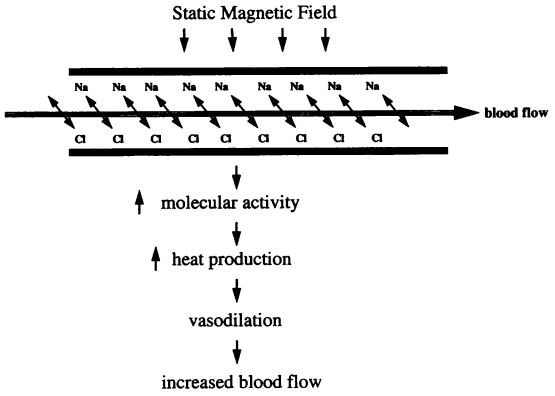

Fig 7. Paradigm depicting the magnetohydrodynamic effect.

treatment recovery curves for pain perception, ROM, and static force production appeared to be similar among all conditions, demonstrating no significant therapeutic effects from wearing the magnet or placebo (Figures 4–6).

Without thermographic or plethysmographic evaluative equipment, it is difficult to demonstrate any direct magnetohydrodynamic effect. However, one manifestation of increased blood flow and local heat is increased tissue viscoelasticity. Increased viscoelasticity has been shown to improve soft tissue

extensibility and muscle performance.[20,21] Appreciable improvements in ROM and static force production should have been observed in our study if the viscoelastic properties of the healing tissues were improved from using the flexible magnet. However, our results did not reveal any significant improvements for ROM and static force production.

Manufacturers' claims and advertisements have indicated that flexible magnets are also effective in relieving muscular pain and soreness as a result of overuse and injury[6–8] (Ardizzone, 1992; Zablotsky, 1989), although research has shown conflicting results with regard to pain control.[22,23] Proponents of static magnetic therapy proclaim that the Hall voltage raises the resting membrane potential of the free nerve ending to a point of inhibition (Ardizzone, 1992). As a result of this shift in resting membrane potential, neural depolarization and conduction velocity is decreased (Figure 8). The proposed therapeutic benefits include analgesia and interruption of the pain-spasm-hypoxia cycle (Hacmac, 1991; Ardizzone, 1992; Zablotsky, 1989).

Flexible magnets are also suggested to provide an analgesic effect via the gate theory of pain control. By producing a superficial warming effect, the magnetic field would act as a counterirritant, thus closing the gate for pain.[24] In a related study, Haynes and Perrin[11] demonstrated that a counterirritant ointment was an effective means of treating pain and dysfunction associated with delayed-onset muscle soreness. In their study, the analgesic effect occurred from the increased warmth of cutaneous tissue by the ointment. Interestingly, we found that, although not statistically significant, the group that wore the flexible magnet in our study had a trend toward greater pain perception than the placebo and control groups. One explanation for this trend may be that the nonthermal effects of the flexible magnets provided additional irritation to damaged free nerve endings, as opposed to stimulating intact superficial nerve endings, thus increasing pain sensitivity.

The theory behind static magnetic therapy appears to be sound in scientific principle, although its practical applications have not been substantiated experimentally. We contend that the commercially available flexible magnets are not a cost-effective means of treating musculoskeletal injuries. The flexible magnet is an expense (the average cost of a magnet is approximately $60), and our results did not reveal any significant therapeutic effects from wearing flexible magnets in treating selected signs and symptoms associated with a muscle microinjury. The Food and Drug Administration places no restrictions on the use of magnetic fields under 1000 G. As a result, flexible magnets have not undergone rigorous controlled testing by reputable agencies such as the Food and Drug Administration. This has led to the unscrupulous advertisement of these products as a panacea for musculoskeletal disorders. The most prudent way of understanding the effect of static magnetic fields on biologic tissue is through controlled experimentation. Until sound evidence is provided concerning the efficacy of flexible magnets, we recommend that consumers be cautious when deciding whether to use them.

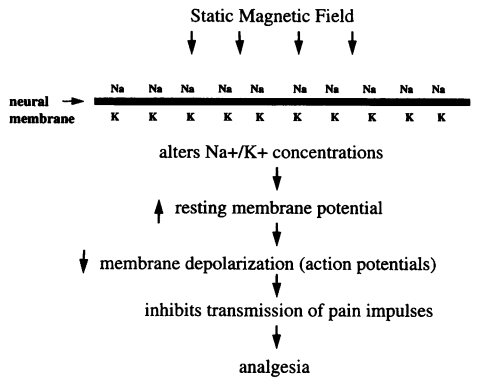

Fig 8. Paradigm depicting inhibition of pain transmission and analgesia.

CONCLUSIONS

The efficacy of flexible magnets has not been demonstrated experimentally, although many clinicians and athletes continue to recommend and use the modality. With respect to pain control and muscular dysfunction, our results reveal no significant therapeutic benefits from wearing flexible magnets. Therefore, without any experimental evidence of efficacy, the use of flexible magnets for athletes who require treatment for pain and dysfunction associated with athletic activity should be scrutinized. In order to legitimize commercially available flexible magnets as a valid therapeutic modality, extensive research and development must be conducted in order to manufacture a product that is safe and cost effective. Until this form of treatment has been substantiated experimentally, we do not recommend using flexible magnets to treat acute or chronic musculoskeletal injuries.

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