Magnets produce energy in the form of magnetic fields. Two main types of magnets exist: static or permanent magnets, in which the magnetic field is generated by the spin of electrons within the material itself, and electromagnets, in which a magnetic field is generated when an electric current is applied. Most magnets that are marketed to consumers for health purposes are static magnets of various strengths, typically between 30 and 500 mT. Magnets have been incorporated into arm and leg wraps, mattress pads, necklaces, shoe inserts and bracelets.  

Static magnets represent a multi-billion-dollar industry. They are marketed with claims of effectiveness for reducing pain of various origins. One survey suggested that about 28% of patients with rheumatoid arthritis, osteoarthritis or fibromyalgia use magnets or copper bracelets for pain relief. However, evidence for the scientific principles or biological mechanisms to support such claims is limited. According to one proposed mechanism, nociceptive C-fibres have a lower threshold potential, and magnetic fields selectively attenuate neuronal depolarization by shifting the membrane resting potential. Another theory suggests that magnetic fields promote an increase in blood flow through the skin and the subcutaneous and muscular tissues, which reduces the pain.

In this systematic review and meta-analysis, we assessed the clinical evidence from randomized controlled trials of static magnets for treating pain.

Methods

Data search

The following databases were searched from inception to March 2007: MEDLINE, EMBASE, AMED (Allied and Complementary Medicine Database), CINAHL, Scopus, the Cochrane Library and the UK National Research Register. The search strategy was designed to retrieve all articles on the topic (using the terms “static,” “permanent,” “magnet” and “pain” and derivatives of these, according to the following strategy: “static” OR “permanent” AND “magnet” AND “pain”). In addition, we hand-searched conference proceedings (published in the journal FACT: Focus on Alternative and Complementary Therapies, 1996–2006), relevant medical journals (specifically, Phy-
tomedicine, 1994–2006; Alternative and Complementary Therapies, 1995–2006; and Forschende Komplementärmedizin Klassische Naturheilkunde (Complementary medicine Research and Classical Naturopathy), 1994–2006) and our own collection of papers. We also searched the bibliographies of all retrieved articles by hand. There were no restrictions on the language of publication. For all relevant trials lacking data, we attempted to contact the corresponding author by email or regular mail for further information.

Data selection
For our analysis, we included only trials that were reported as randomized with a control consisting of nonmagnetic placebo or device with weak magnetic field strength and that had pain as an outcome measure. There were no restrictions on the condition causing the pain. The magnets had to be described as static or permanent, and only trials with human patients were considered. The titles and abstracts of the identified articles were independently assessed, and hard copies of all potentially relevant articles were obtained (by E.M.B. or E.E. or both) for further evaluation.

Validity assessment
Methodological quality was evaluated with the Jadad scoring system. The Jadad score was assessed independently by 2 of us (E.M.B and E.E.). Allocation concealment was assessed with use of the classification of the Cochrane Collaboration.

Data extraction
Data were extracted systematically and independently (by E.M.B. and E.E.). We extracted data on study design, study quality, sample size, magnet strength, exposure, comparator and results. Any differences in extracted data, which were due mostly to reading errors, were resolved by discussion.

Quantitative data synthesis
The mean change in pain, as measured on a 100-mm visual analogue scale relative to baseline, was defined as the primary outcome and was used to assess the difference between static magnets and placebo. In the primary analysis, only randomized placebo-controlled trials were assessed on the basis of data from the end of the treatment period. Means and 95% confidence intervals (CIs) were calculated using standard meta-analysis software (RevMan 4.27, Update Software Ltd., Oxford, UK). Summary estimates of treatment effect were calculated using the more conservative approach of a random-effects model. Differences compared with placebo were considered relevant in the context of this study. The $\chi^2$ test and the Higgins $I^2$ test were used to assess heterogeneity. We attempted to assess publication bias using a funnel plot, whereby effect estimates of the common outcome measure were plotted against sample size. Post hoc sensitivity analyses were performed to test the robustness of the overall effect.

Results
Twenty-nine potentially relevant trials were identified (Table 1 and Table 2). All trials were published in English, and all except 2 randomized controlled trials were double-blinded. Four studies were excluded, 3 because they were reported as abstracts only and could not be fully appraised and 1 because it compared 2 strong magnetic fields (Figure 1). In 2 other cases, additional information was requested but was not received. Four randomized controlled trials assessed patients with peripheral joint osteoarthritis, and 3 were available for each of low-back pain, delayed-onset muscle soreness and foot pain. There was no other condition for which more than 2 randomized trials were available (Table 1 and Table 2). Five trials used weak magnets, most of them below the assumed therapeutic strength (believed to be 30 mT), as the control.

Meta-analysis of the 9 trials that assessed pain on a 100-mm visual analogue scale (Figure 2) indicated no significant difference in pain reduction between the magnet and placebo groups (weighted mean difference 2.1 mm, 95% CI –1.8 to 5.9 mm, $p = 0.29$). The $\chi^2$ test for heterogeneity indicated that the observed differences between trial results were unlikely to have been caused by chance ($\chi^2 = 9.03$, degrees of freedom [df] = 8, $p = 0.34$; $I^2 = 11.4%$). However, the issue of clinical heterogeneity remains. In particular, differences in the conditions causing the pain and differences in the duration of the intervention contributed to this clinical heterogeneity. A post hoc sensitivity analysis, excluding 3 short-term randomized trials with intervention periods between 45 minutes and 18 hours, suggested no significant difference between the magnet and placebo groups (weighted mean difference on a 100-mm visual analogue scale 2.9 mm, 95% CI –2.5 to 8.3 mm, $p = 0.29$; $\chi^2 = 7.92$, df = 5, $p = 0.16$; $I^2 = 36.8%$). Another sensitivity analysis of randomized controlled trials assessing only musculoskeletal pain conditions with intervention periods between 2 and 4 months also suggested no significant difference (weighted mean difference 3.5 mm, 95% CI –5.3 to 12.4 mm, $p = 0.45$; $\chi^2 = 7.67$, df = 3, $p = 0.05$; $I^2 = 60.9%$). Across all trials (Table 1 and Table 2), there was evidence of no effect for intervention periods between 30 minutes and 1 week. Assessment of publication bias using a funnel plot was attempted, but too few studies were available to allow any meaningful judgment. Analysis of the 16 trials that assessed pain using various scales (Table 1) suggested significant statistical heterogeneity among the trials, and pooling these data was therefore considered unreliable (standardized mean difference 0.23 mm, 95% CI 0.04 to 0.42 mm, $p = 0.02$; $\chi^2 = 30.77$, df = 15, $p = 0.009$; $I^2 = 51.2%$).

Osteoarthritis was assessed in 4 double-blind randomized controlled trials (total sample size 275; Table 1 and Table 2). Two small trials ($n = 26$ and 43, respectively) reported some positive effects of static magnets relative to placebo and weak magnets. This finding was confirmed in a larger trial, which reported pain reductions (relative to placebo) on the Western Ontario and McMaster osteoarthritis index and a visual analogue scale. In these 3 trials, treatments lasting 2 to 12 weeks were associated with positive effects, whereas a small study of continuous 24-hour magnet treatment did not report such effects.
Table 1: Characteristics of 16 randomized controlled trials (RCTs) of static magnets for reducing pain that were included in the systematic review (part 1)

| Study                          | Design; quality score; allocation concealment | Condition or syndrome; age; sample size | Intervention; quantification exposure | Control | Pain outcome; quantification method | Comparison | Results               |
|-------------------------------|-----------------------------------------------|----------------------------------------|---------------------------------------|---------|-------------------------------------|------------|-----------------------|
| Winemiller et al (2005)       | Double-blind RCT with 2 parallel groups; quality 5; concealment unclear | Foot pain; 42 and 46 yr (group means); n = 83 | Magnetic insoles (245 mT); at least 4 h/d, 4 d/wk for 8 wk | Placebo | Evening foot pain; visual analogue scale at 4 and 8 wk | Magnet v. placebo | No significant differences at 4 or 8 wk |
| Reeser et al (2005)           | Double-blind RCT with 2 parallel groups; quality 3; concealment unclear | Delayed-onset muscle soreness; 29 and 30 yr (group means); n = 23 | Magnetic band on one of each person’s arms (35 mT); 45 min/d for 5 d | Placebo | Muscle pain; visual analogue scale at day 5 | Magnet v. placebo | No significant differences |
| Mikesky et al (2005)          | Double-blind RCT with 2 parallel groups; quality 2; concealment unclear | Delayed-onset muscle soreness; 19 and 20 yr (group means); n = 20 | Magnetic band on one of each person’s arms (75 mT); 7 d, continuous | Placebo | Muscle pain; visual analogue scale at day 7 | Magnet v. placebo | No significant differences |
| Harlow et al (2004)           | Double-blind RCT with 3 parallel groups; quality 4; concealment unclear | Osteoarthritis; 45-80 yr (min-max); n = 193 | Magnetic wrist bracelet (170-200 mT); worn while awake, for 12 wk | Placebo | Hip or knee pain; 1. WOMAC at 12 wk 2. Visual analogue scale at 12 wk | A. Magnet v. placebo B. Magnet v. weak magnet | 1A, 2A. Significant differences (WOMAC, p < 0.03; visual analogue scale, 95% CI 3.0-19.8) |
| Wolsko et al (2004)           | Double-blind RCT with 2 parallel groups; quality 4; concealment adequate | Osteoarthritis; ≥ 21 yr; n = 26 | Magnetic knee sleeve (4-85 mT); 6 h/d for 6 wk | Weak magnet (0.065 mT) | Knee pain; 1. WOMAC at 6 wk 2. 5-item combined visual analogue scale at 4 h | Magnet v. weak magnet | 1. No significant difference 2. Significant difference (p = 0.03) |
| Winemiller et al (2003)       | Double-blind RCT with 2 parallel groups; quality 5; concealment unclear | Plantar heel pain; ≥ 18 yr; n = 101 | Magnetic insoles (245 mT); 16 h/wk for 8 wk | Placebo | Foot pain; visual analogue scale at 4 and 8 wk | Magnet v. placebo | No significant differences at 4 or 8 wk |
| Weintraub et al (2003)        | Double-blind RCT with 2 parallel groups; quality 5; concealment unclear | Diabetic peripheral neuropathy; 27-85 yr (min-max); n = 259 | Magnetic insoles (45 mT); 4 mo, continuous | Placebo | Foot pain; visual analogue scale at baseline and at 1, 2, 3 and 4 mo | Magnet v. placebo | No significant difference at 4 mo |
| Brown et al (2002)            | Double-blind RCT with 2 parallel groups; quality 4; concealment adequate | Chronic pelvic pain; 18-50 yr (min-max); n = 32 | Magnets secured to pain sites (50 mT); 2 or 4 wk, continuous | Placebo | Pain at trigger points following abdominal palpation; McGill Pain Questionnaire at 2 and 4 wk | Magnet v. placebo | No significant differences |
The strengths of our systematic review pertain to its rigour in terms of searching the literature, the inclusion and exclusion criteria, and the data assessment. Our analyses of data from randomized controlled trials have yielded a relatively robust indication of the effects of magnets on pain outcomes, although further trials are still required. We searched databases with a focus on the US and European literature, as well as specialist data sources, and included hand searches in relevant journals, with no restriction in terms of publication language. However, there remains a possibility that our search was incomplete.†

The limitations of our study pertain to the lack of rigour of the original studies, and (although the forest plot [Figure 2] indicates overlap of confidence intervals for all studies) to the heterogeneity of the trials. Clinical heterogeneity was evident in differences in the conditions causing pain and in the duration of the interventions. Two post hoc sensitivity analyses exploring these issues confirmed the results of the overall analysis. Another reason for clinical heterogeneity was the variation in magnet strength in the original studies, from 4 to 395 mT. Across all trials there was no convincing indication that high-strength magnets performed any better than low-

| Study | Design; quality score; allocation concealment | Condition or syndrome; age; sample size | Intervention; exposure | Control | Pain outcome; quantification method | Comparison | Results |
|-------|---------------------------------------------|---------------------------------------|------------------------|---------|-------------------------------------|------------|---------|
| Carter et al (2002)²⁰ | Double-blind RCT with 2 parallel groups; quality 5; concealment adequate | Carpal tunnel syndrome; 49 and 51 yr (group means); n = 30 | Magnetic pads (100 mT); 45 min in monitored setting | Placebo | Wrist pain; visual analogue scale at 15, 30, 45 min and 2 wk after treatment | Magnet v. placebo† | No significant differences |
| Pope and McNally (2002)²¹ | Double-blind RCT with 3 parallel groups; quality 3; concealment adequate | Repetitive strain injury; 19-22 yr (min-max); n = 45 | Magnetic wrist brace (245 mT); 30 min in monitored setting | 1. Placebo 2. No treatment | Wrist pain; Likert scale at 30 min | Magnet v. placebo* | No significant differences |
| Segal et al (2001)²² | Double-blind RCT with 2 parallel groups; quality 4; concealment adequate | Rheumatoid arthritis; ≥ 18 yr; n = 64 | MagneBloq device (190 mT); 1 wk, continuous | Weak magnet (72 mT) | Knee pain; visual analogue scale at 1 h, 1 d and 1 wk | Magnet v. weak magnet | No significant differences |
| Alfano et al (2001)²³ | Double-blind RCT with 5 parallel groups; quality 5; concealment unclear | Fibromyalgia; 18-65 yr (min-max); n = 119 | 1. Magnetic mattress pad (395 mT) 2. Magnetic mattress pad (75 mT) 6 mo, at night | 1. Placebo 2. Usual care | 18 defined pain sites; dolorimetry and fibromyalgia impact questionnaire at 6 mo | Magnet (395 mT) v. placebo† | Significant differences (p = 0.03) |
| Collacott et al (2000)²⁴ | Double-blind RCT with crossover; quality 5; concealment unclear | Low-back pain; 60 yr (mean); n = 20 | Flexible magnet (30 mT); 6 h/d for 3 d | Placebo | Low-back pain; 1. Visual analogue scale at 18 h 2. McGill Pain Questionnaire at 18 h | Magnet v. placebo | No significant differences |
| Colbert et al (1999)²⁵ | Double-blind RCT with 2 parallel groups; quality 4; concealment unclear | Fibromyalgia syndrome; 25-78 yr (min-max); n = 30 | Magnetic mattress pads (20-60 mT); 16 wk, at night | Placebo | Body pain; visual analogue scale at 16 wk | Within-group comparisons (between-group comparison not reported) | Significant reduction of pain in magnet group (p = 0.04); no significant reduction of pain in placebo group |
| Vallbona et al (1997)²⁶ | Double-blind RCT with 2 parallel groups; quality 4; concealment unclear | Postpolio syndrome; 52-56 yr (min-max); n = 50 | Magnets secured to pain sites (30-50 mT); 45 min in monitored setting | Placebo | Muscular or arthritis-like pain; McGill Pain Questionnaire at 45 min | Magnet v. placebo | Significant differences (p < 0.001) |
| Hong et al (1982)²⁷ | Double-blind RCT with 4 parallel groups; quality 2; concealment unclear | Neck and shoulder pain; 18-62 yr (min-max); n = 101 | Magnetic necklace (130 mT); 3 wk, continuous | Placebo | Intensity and frequency of pain and stiffness; 5-point verbal scale at 3 wk | Magnet v. placebo | No significant differences |

Note: WOMAC = Western Ontario and McMaster University osteoarthritis index, CI = confidence interval.
*The comparison with the no-treatment group was not considered in this systematic review.
†The comparison with the usual-care group was not considered in this systematic review.
strength magnets. Positive and negative studies were spread across magnet strengths, which suggests neither an optimal magnet strength nor a “window of time” when magnet therapy is effective for treating pain.

The success of blinding in magnet and placebo groups was not assessed in 18 of the randomized controlled trials.9,13–19,20–26,28,30–32 Nonspecific effects may have contributed to the observed effects and may even have been the main factor contributing to the findings in some trials. Six trials8,10,11,19,27,29 established that equal proportions of participants in the magnet and placebo groups believed they had been given magnetic devices; the 2 groups could thus be assumed to have similar expectations of pain relief. In 3 of 11 trials indicating a significant beneficial effect,8,10,11 blinding was demonstrated to have

| Study                  | Design; quality score; allocation concealment | Condition or syndrome; age; sample size | Intervention; exposure | Control | Outcome measures | Comparison | Results                        |
|------------------------|-----------------------------------------------|-----------------------------------------|------------------------|---------|------------------|------------|-------------------------------|
| Eccles (2005)31        | Double-blind RCT with 2 parallel groups; quality 5; concealment adequate | Dysmenorrhea; 29 yr (mean); n = 35 | Magnetic underwear device (270 mT); from 2 d before until after menses | Weak magnet (14 mT) | Pain, by McGill Pain Questionnaire | Magnet v. weak magnet | Significant difference (p < 0.02) |
| Kanai et al (2004)26   | Double-blind RCT with 2 parallel groups; quality 2; concealment unclear | Frozen shoulder; 27-83 yr (min–max); n = 40 | Magnets pasted on pain sites (130 mT); 3 wk continuous | Placebo | Composite score from spontaneous pain, range of movement, pain to palpation and night pain at 1, 2, 3 and 4 wk | Magnet v. placebo | Significant differences (p < 0.05) |
| Hinman et al (2002)13  | Double-blind RCT with 2 parallel groups; quality 4; concealment unclear | Osteoarthritis; Magnet group 64 yr, placebo group 63 yr (means); n = 43 | Magnetic discs (40-56 mT); 2 wk, worn when pain felt | Placebo | Knee pain, by sum of visual analogue ratings at 2 wk | Magnet v. placebo | Significant differences (p < 0.002) |
| Holcomb et al (2002)14 | Double-blind RCT with crossover; quality 2; concealment unclear | Low-back pain (n = 41) or knee osteoarthritis (n = 13); 25-86 yr (min-max) | MagnaBloc device (200 mT); 24 h, continuous | Placebo | Back and knee pain, by visual analogue scale at 1, 3 and 24 h | Magnet v. placebo | No significant differences at 24 h for back or knee pain |
| Weintraub (1999)32     | Double-blind RCT with crossover; quality 4; concealment unclear | Diabetic and non-diabetic peripheral neuropathy; 60 and 78 yr (group medians); n = 24 | Magnetic insole (47.5 mT); worn all day for 4 mo | Placebo | Burning or numbness and tingling, by 5-point scale at 4 mo | Diabetic v. non-diabetic peripheral neuropathy | No comparison between magnet and placebo groups |
| Man et al (1999)36     | Double-blind RCT with 2 parallel groups; quality 3; concealment unclear | Suction liposcopy; 18-75 yr (min–max); n = 20 | Magnets secured to suctioned areas (15-40 mT); 14 d, continuous | Placebo | Postoperative pain, by visual analogue scale at 1, 2, 3, 4, 7 and 14 d | Magnet v. placebo | Significant differences (p < 0.05) 1-7; no significant differences at 14 d |
| Kanai et al (1998)17   | Double-blind RCT with 2 parallel groups; quality 3; concealment unclear | Low-back pain; 65 yr (mean); n = 85 | Magnets pasted on painful sites (180 mT); 3 wk, continuous | Weak magnet (10 mT) | Composite score of spontaneous pain, pain in motion, numbness, limitation of range of motion, tenderness and palpable hardening in the muscles at 1, 2, 3 and 4 wk | Magnet v. weak magnet | Significant differences (p < 0.01) |
| Borsa and Liggett (1998)33 | Single-blind RCT with 3 parallel groups; quality 1; concealment unclear | Delayed-onset muscle soreness; 20-32 yr (min-max); n = 45 | Flexible magnets secured to pain sites (70 mT); 72 h, continuous | 1. Placebo 2. No treatment | Muscle pain, by visual analogue scale at 24, 48 and 72 h | Magnet v. placebo v. no treatment | No significant differences |
| Caselli et al (1997)34  | Open RCT with 2 parallel groups; quality 2; concealment unclear | Planter heel pain; 28-59 yr (min-max); n = 40 | Magnetic insoles (50 mT); worn all day for 4 wk | Placebo | Heel pain, by visual analogue scale at 4 wk | Magnet v. placebo | No significant differences |

*Adequate data defined as sufficient data to allow statistical pooling.*
been adequate throughout the study. Among the trials of peripheral joint osteoarthritis, 2 trials\textsuperscript{8,10} reported adequate blinding. Also, the trials had mixed Jadad quality scores and largely suffered from a lack of adequate allocation concealment (Table 1 and Table 2). Most of the samples were small, with 17 of the randomized controlled trials assessing 50 or fewer patients (Table 1 and Table 2). Therefore, the possibility of a type 2 error cannot be excluded. Future studies should be large enough to have an 80% chance of detecting possible effects, should include well-defined patient samples and should pay particular attention to the design of the placebo or sham magnet. From the existing evidence, the ideal magnet strength and treatment duration are unclear.

Static magnets are generally considered safe. Adverse effects are rare, but reddening of the skin on the area of application has been observed.\textsuperscript{1} Pacemakers, insulin pumps and other devices adversely affected by magnetic fields are considered contraindications for the use of static magnets.\textsuperscript{1}

In conclusion, the evidence does not support the use of static magnets for pain relief, and such magnets therefore cannot be recommended as an effective treatment. For osteoarthritis, the evidence is insufficient to exclude a clinically important benefit, which creates an opportunity for further investigation.

This article has been peer reviewed.

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Figure 1: Selection of studies for meta-analysis. In addition to the 9 studies included in the meta-analysis of weighted mean difference, 16 studies were analyzed by standardized mean difference.
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