Static magnets in Medicine - A Review:

Putative mechanisms of physiological and analgesic effect

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Abstract

There is accumulating evidence for a significant analgesic effect of static magnets against a broad range of different types of pain (neuropathic, inflammatory, musculoskeletal, fibromyalgic, rheumatic and post-surgical). In the light of this evidence of efficacy a literature search was undertaken to look for the putative mechanisms by which static magnets may achieve this and other physiological effects. The possible mechanisms by which static magnetic fields interact with human physiology are discussed. These include the possible alteration of ion fluxes and of membrane potentials, and also evidence for circulatory changes. Issues around magnet design, polarity and safety are also discussed.

Introduction

A recent Systematic review of randomised controlled trials of static magnets for pain relief (Eccles, 2003) showed that overall 9 of the 12 studies reported a significant analgesic effect due to static magnets. Of the 10 better quality studies, 7 were positive and 3 were negative. In 2 of the negative studies there are major concerns over adequacy of magnet power for the type of pain (300 gauss for chronic back pain, Collacott et al, 2000), a query raised by the authors themselves, and of duration of exposure (5 minutes in Harper & Wright, 1977). The latter authors also failed to state the power of the magnet used in their study. Excluding a further 2 studies on grounds of inadequate magnet exposure then 7 out of 8 of the better quality studies demonstrated a positive effect of static magnets in achieving analgesia across a broad range of different types of pain (neuropathic, inflammatory, musculoskeletal, fibromyalgic, rheumatic and post-surgical). In the light of this evidence of efficacy a literature search was undertaken to look for the putative mechanisms by which static magnets may achieve this and other physiological effects.

Methods

A search was performed of scientific journals from 1966 to May 2002 of the following databases: MEDLINE 1966 – 05/2002, EMBASE 1989 – 04/2002, LIFE SCIENCES 1990 – 03/2002, APPLIED & COMPLEMENTARY MEDICINE 1985 – 05/2002, SPORTS DISCUSSIONS 1830 – 04/2002. Search terms used were: *magnets, magnotherapy, pain, analgesia, blood flow and circulation*. In addition Internet searches were performed in *google* using the same terms. The search resulted in over 150 articles and two Proceedings. These were all reviewed in detail and in particular the randomized double blind trials. Original articles were obtained, and all references were scanned for further relevant articles.

Source of Funding

This research was funded by the company Magnopulse, a manufacturer of static magnets, who requested an independent review of the existing scientific evidence for the efficacy of analgesic effect of static magnets. The author was approached on the basis of his previous work and interest in this subject. Otherwise they had no role in the design of the research, nor in collection, analysis or interpretation of the data. They had no role in the write-up of this report or in the decision to submit this study for publication.

Discussion

It has been known for some time that the behaviour of certain types of biological materials are influenced by magnetic fields (Reno & Nutini, 1963). Subtle magnetic fields can produce a physiological effect. For example, pico-tesla range electromagnetic fields have been shown to have significant effects on nerve regeneration (Turing, 1952).

Electrical activity exists in the body at all times e.g. the beating heart. The heart is the biggest electromagnetic field generator in the body (Eyster et al, 1933). Mechanical loading of bones generates electrical currents. The discovery of magnetic material (deposits of magnetite) in the human brain may suggest that we are physiologically designed to respond to magnetic fields (Kirschvink et al, 1992).

It has been postulated that pathological state may result from misalignment of sub-microscopic magnetic fields from their natural state and that applying a magnet allows for a physiological re-orientation of order and coherence in molecules. We now know that wound and hard tissue repair process involves electric currents. Becker & Selden (1985) proposed the existence of an electromagnetic system in the body that controlled tissue healing. When the electrical balance of the body is disturbed by an injury, an injury current is generated, with the resultant shift in the body's current triggering a set of biological repair systems. As healing progresses the injury current diminishes to zero.

It has been noted from Space flight that deprivation of the electromagnetic wave between the earth's surface and the ionosphere leads to abnormal body functioning (Owen, 1986).

The advent of Magnetic Resonance Imaging (MRI) in recent years has given the concept of magnetic interaction with the human body more credibility. MRI exposes the body to magnetic fields of the order of 1-2 Tesla (10 to 20,000 gauss).

The historical evidence highlights the debate over the efficacy of magnetism to achieve positive health effects. However, much of this debate seems to focus on the physiologic basis of the effect rather than of investigating the evidence of a real effect. For an excellent historical review highlighting some of the recorded evidence of the therapeutic use of magnets, see Machlis (1999).

The debate on physiologic influence of biomagnetism has been somewhat re-awakened by more recent epidemiological studies (Jauchem & Merrit,1991; Milham,1982) analyzing cancer deaths in relation to electromagnetic field (EMF) exposure. A small but significant relation between occupational EMF exposure and leukemia was reported by Foster in 1992. Other studies have reported of other health risks such as male breast cancer, chromosomal abnormalities, and several other health hazards. (Michaelson, 1987). A number of important studies have concluded a small but significant relation between childhood domestic EMF and leukemia (Savitz et al, 1988) .The general concordance of these results has led many investigations to revisit the EMF problem.

One of the prices that we pay as technology advances is an increase in electromagnetic pollution. Our environment of power lines, and ever increasing populous of mobile phones and computers has led to controversies over the effect of this electromagnetic pollution on our health.

Geomagnetic storms are associated with an increase in the number of cases of myocardial infarction (Brecus et al, 1995; Andronova et al, 1982). Small mammals and humans deprived of natural geomagnetic oscillations suffer ill-health (Wever, 1973). The dysregulation of these natural fields by technological devices emitting artificial fields and radiations have been reported to have adverse effects on health (Wertheimer & Leeper, 1979; Savitz et al, 1988; Hardell et al, 1995). Electromagnetic fields have been shown to alter EEG signals, alter DNA synthesis, reduce melatonin synthesis, reduce immune response, increase messenger RNA transcription rate, alter enzyme activity and influence the blood brain barrier.

Conversely, positive effects on health have been described of magnetic fields of only a few hundred nanoTesla with frequencies in the range of 7 to 8 Hz.

If indeed high-energy electromagnetic fields can disrupt human physiology it perhaps challenge us to wonder if more subtle magnetic fields could have a health enhancing effect. We should rather than being dismissive, examine more carefully the potential interaction of magnetic fields with the body's biorhythms. The "cure-all" use of magnets by our ancestors should not distract us from a rational look at this simple non-invasive therapeutic modality.

Magnetic devices: some considerations

Strength, source, polarity and size of magnets and duration of exposure should be taken into consideration (Owen, 1986; Barnothy, 1964). The optimum magnetic field strength is unknown and this is complicated by the fact that different cells or cellular components seem to have different thresholds of response to magnetic fields (Pilla, 2000). Nakagawa (1975), from his experience and work with magnets in Japan, concluded that magnets need to exceed 500 gauss strength to be effective on the human body. Magnetic power is expressed in modern units of tesla (T) but the older unit of gauss is still used. 1 telsa is equivalent to 10,000 gauss. The earth's magnetic field is 0.5 Gauss (1/10,000 tesla). Most commercial static magnets have powers of less than 1,000 gauss (0.1 tesla). Moreover, gauss readings are often found to be much lower than manufacturers' claims (less than 20% of the claimed power in some cases) (Blechman et al, 2001). Also, the surface of a magnet usually has non-uniform gauss readings.

One of the limitations of magnet therapy in the past has been the use of relatively low magnetic power for weight ratios of ferrite-based magnets. The advent of neodymium/boron/iron magnets in the 1980s allowed for high magnetic field to weight ratios making therapeutic devices significantly more practical and portable. They also have the advantage of retaining their magnetism for decades.

Field flux density is often greater at the edges compared with the centre of the magnet (Blechman et al, 2001). The field strength is proportional to the square of the distance from the magnetic source. The strength falls off rapidly from the body surface. This makes it difficult to assess penetrability. A non-uniform field results in tissues after application to the skin surface (Pilla, 2000). Devices that utilise a directional plate to focus the magnetic effect in one direction are therefore potentially useful. The degree of sub-dermal decay varies with different magnetic alloys (Blechman et al, 2001)

The optimum treatment duration is also not established and positive results have been obtained from 45 minutes to 24 hours (Grigat et al, 2000).

Some feel that the polarity of the magnet that faces the skin may have a differential effect (Owen, 1986). Most of the double blind studies cited in this review have employed the south pole of the magnet adjacent to the skin. There is still debate over whether application of north or south poles determines the nature of the effect. According to Vallbona (1999) both bipolar (alternating north and south poles in concentric pattern or a grid) and unipolar (one pole at the surface applied to the skin) magnets are effective in pain relief. Some have hypothesised that multi-polar magnets may generate deeper field gradient penetration than either unipolar or bipolar magnets (Weintraub, 2000).

Magnetic fields are not impeded by bone and other structures.

Static magnet safety

The evidence that certain electric and magnetic fields augment DNA synthesis has been met with concern over cancer risk. This concern is largely directed at pulsed electromagnetic fields, and in particular continuous exposure to high voltages e.g. overhead power lines, electric blankets etc (Trock, 2000). No adverse effects on human health have been observed with static magnets up to 2 Tesla or 20,000 Gauss (WHO, 1987). (Vallbona et al, 1997;Jonas, 2000). Magnet therapy practitioners usually recommend that once the magnet has done its job it should be removed, allowing the body to heal itself naturally. Magnetic fields can alter rate of chemical reactions and in some circumstances can enhance conventional drug treatments necessitating a dose reduction in the latter. There is however a paucity of research in this area. Consultation with a Medical practitioner is recommended if regular medication is being taken. Magnetic fields of 2 and 7 Tesla produced no teratogenic effects in pregnant mice (Wagner et al, 2000). However, some studies have reported effects on young animals. It therefore seems prudent to avoid magnets in pregnancy and young children less than 3 months (Coghill, 2000).It is also recommended that magnets should be avoided in pacemaker wearers and those who have metal implants or who wear insulin syringe drivers.

Putative mechanisms of action?

Atoms are spinning magnets and therefore must interact with each other. It is logical to assume that magnetic fields can influence the charged state of biological systems (Adey, 1986). Living systems maintain magnetic profiles in the range of 10^{-7} Gauss to 10^{-12} Gauss. Faraday's law states that a magnetic field will exert a force on a moving ionic current. Ionic currents across cell membranes are fundamental to maintenance of cellular integrity and cell communication. Ionic effects e.g. changes in ion binding have been described with magnetic fields as low as 0.1 to 1 microtesla (Muehsam & Pilla, 2000). Healthy cells seem to have greater electrical charge than unhealthy cells (Owen, 1986). Cellular health and efficient function is to a large degree dependent on the maintenance of correct ionic gradients across the cell membrane. These ionic gradients are maintained by continuous inputs of energy. Most of the chemical energy of our body is used up to re-establish ion gradients, gradients that keep metabolic processes going, including cell signalling mechanisms. Important examples include Na/K transporters, which can either be antiporters, coupling the counter movement of Na and K ions across membranes, or symporters, moving Na^+ and K^+ synchronously and unidirectionally to the same side of the membrane. All electrical currents generate magnetic fields and all magnetic fields cause a change in electrical potential. *Therefore, an interaction of magnetic fields with ion fluxes across the cell membrane is very likely.*That electrical fluxes are important in healing is evident form studies on bone deformation and wound healing. Compression of bone generates a negative electrical potential. Furthermore, the cells are responsive to alteration in externally applied DC electrical fields (Basset & Becker, 1962; Markov, 1995; Jaffe & Vanable, 1984).

Change in ion flux and alteration of membrane potentials

It has been postulated that magnetic fields exert their effects by an action on the ion pumps in the cell membrane; particularly those involved in pumping calcium, sodium and potassium ions such as sodium-potasium-ATPase and calcium-ATPase (Itegin, 1995; Burkhart, 2000; Aceto et al, 1982;Gualtierotti, 1964). The interaction with calcium ions may be important in their proposed circulatory enhancement effects (Horowitz, 2000). Changes in tissue calcium concentration have been described after static magnetic field exposure (Itegin et al, 1995; Flipo et al, 1998).
It has also been postulated that magnets encourage the supply of negative charges to cells thereby restoring cellular resting membrane potentials (Weinberger et al, 1996).

Low amplitude electromagnetic fields alter the threshold for electrical stimulation in nervous tissue (Scherlag & Yamanashi, 2000). There is evidence of pain signal inhibition by this mechanism (Mclean et al, 1995 and Cavopol et al, 1995).
Significant reductions in nerve conduction times have been reported in the ulnar nerves of subjects wearing magnetic necklaces 24 hours a day for 3 weeks (Hong et al, 1982).
Static magnets have been postulated to alter sodium/potassium concentrations leading to an increase in resting membrane potentials. The potential consequence of this would be reduced membrane depolarisation and inhibition in transmission of pain impulses and therefore analgesia (Borsa & Liggett, 1998;Lednev, 1991 and Olney et

al, 1990). Magnets may create a field that alters how pain signals are transmitted (Hawkins, 1998).

Static as well as electromagnetic fields boost ATP production in the test tube (Rosch, 1998). This effect may be mediated by magnets affecting the pH difference across the mitochondrial membrane. This pH difference results from positively charged hydrogen ions being pumped out of the mitochondrial membrane to maintain an electrical potential across the membrane of 220 mV; crucial to driving energy production.

An increase in the synaptic cleft has also been described i.e. the gap between nerve endings and their target tissue, raising the possibility of a biomechanical as well as a bioelectric action of magnetic fields (Itegin et al,1995).

Magnets and circulation

Increased blood perfusion and skin temperature have been observed in human arms exposed to pulsed magnetic fields (Mayrovitz & Larsen, 1992). There are several studies that suggest a similar effect may be elicited by static magnetic fields.
In a microphotoelectric pletysmographic study of rabbit ear circulation in anaesthetised rabbits, static magnets of 0.25-tesla strength were observed to cause an 20% increase of circulation in the face of a 10-15% decrease in circulation in control rabbits (thought to be due to either anaesthetic and/or stress) (Gmitrov et al,2002). Increased rat skin fold circulation has been measured for 5 minutes after exposure to

an 8-tesla static magnet. This was followed by a gradual return to control levels (Ichioka et al 1998).

Static magnet fields of 0.2-0.35 tesla (1,500 gauss) applied to the carotid artery sinus baroreceptor region was found to produce significant macro-circulatory effects in reducing blood pressure and modified micro-circulation (Gmitrov, 2002). There was a time delay of 40 minutes before the effect was observed. In other animal studies it has been suggested that the pain relief due to static magnets may be accounted for by an increase in circulation and there was evidence that this circulatory increase may be elicited by enhanced cholinergic vasodilator neurotransmission or by an anticholinesterase action to prevent breakdown of the vasodilator acetylcholine (Takeshige & Sato, 1996). Serum cholinesterase in rats is inhibited by static magnetic fields (Gorczynika & Wegszynowicz, 1989).

Migration of erythrocytes (red blood cells) has been described along a magnetic field (Saygili et al, 1992). Others have reported a blood viscosity lowering effect of magnets (Cisarik, 1986).

In contrast mini magnets (0.005-0.3 tesla) had no significant effect on buccal mucosal blood flow (Saygili et al, 1992). The aim of this study was to establish whether or not magnets had any untoward effects on blood flow or blood cells. The authors concluded that there were no harmful effects on either blood flow or on blood cells.

No detectable effect of static magnets of 500 gauss on human skin blood perfusion, as assessed by laser Doppler flowmetry or laser Doppler imaging was detected over a period of 36 minutes exposure (Mayrovitz et al, 2001). However, Kanai's double blind study (1998) showed that back pain sufferers had colder areas, as assessed by thermal imaging, in painful areas and that these warmed after 2 to 3 week application of static magnets. The increase in temperature paralleled pain relief. These findings would suggest that static magnets can increase blood flow but that their ability to achieve this may have variable time-dependence.

Blood oxygen changes have been described in both directions in magnetic fields (Kutrumbus & Barnes, 2000).

There is certainly evidence that static magnets can increase blood flow. It is not certain whether this is their primary action or whether this effect is secondary to ionic changes that favour an increase in blood flow.

Other postulated mechanisms of action

Induction of immune and vascular responses (Alfano et al, 2001)

Cyclical changes in the physical state of water (Beall et al, 1976). Sixty percent of the body is water, 2/3 of this being within the cells and 1/3 outside the cells.

A postulated effect on the pineal gland leading to a cascade of effects on several biological outputs such as melatonin, serotonin and various enzymes (Szor & Topp, 1998).

An anti-inflammatory action.Reduced experimental synovitis has been described in rats. Ten rat hind joints were injected with zymosan, a chemical agent that induces synovitis over a 3-week period. Application of a static magnet field to the floor of the rat’s cages (3,800 gauss) significantly

($p<0.002$) reduced the inflammatory score by 50%. This anti-inflammatory effect may explain the benefits of magnets to promote healing in osteoarthritis. A rapid normalization of erythrocyte sedimentation rate (ESR), a non-specific measure of inflammation, was achieved by exposure to a constant magnetic field in an inflammation model in rabbits (Bassett et al, 1982).

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References

Aceto H; Tobias CA; Silver IL (1970). Some studies on biological effects of magnetic fields. IEEEE Trans Magnetics. 6; 368-373

Adey WR. (1986).The sequence and energetics of cell membrane transductive coupling to intracellular enzyme systems. Bioelectrochem Bioenerg. 15: 447-456

Alfano AP; Gill Taylor A; Foresman PA; Dunkl PR; McDonnell GG; Conaway MR; Gilles GT. Static magnetic fields for treatment of fibromyalgia: A randomised Controlled trial. Journal Alternative Compl Med 2001; 7(1); 53-64

Andronova TI; Derapa NR & Solomatin AP (1982). Heloimeteotropicreation of healthy people and patients with cardiovascular diseases. Leningrad "Meditsina",247

Barnothy JM (1964). In Barnothy MF ed: Biological effects of magnetic fields. NY, Plenium Press, pp3-24

Bassett C. A., Becker R. O. (1962). Generation of electric potentials by bone in response to mechanical stress. Science, vol 137,1063-1064.

Bassett CAL; Mitchell SN & Gatson SR (1982). Pulsing electromagnetic field treatment in ununited fractures and failed arthrodeses. JAMA,247:623-628

Beall PT; Hazlewood CF & Rao PN (1976). Nuclear magnetic resonance patterns of intracellular water as afunction of HeLa cell cycle. Science,192:904-907

Becker RO & Selden G (1985). The Body Electric. Electromagnetism and the Fountain of Life. New York, Morrow

Blechman A. M., Mehmet C., Nair V., Ting W. (2001). Discrepancy between claimed field flux density of some commercially available magnets and actual gaussmeter measurements. Alternative Therapies. Vol 7, No. 5, 92-95.

Borsa P. A., Liggett Ch. L. (1998). Flexible magnets are not effective in decreasing pain perception and recovery time after muscle microinjury. Journal of Athletic Training, vol 33, No 2, 150-155.

Brecus TK; Halberg F &Cornelissen G (1995). Solar activity effects on the biosystems. Biophysica,40:54-56

Burkhart C. G. Are magnets effective for pain control? Letters to the Editor JAMA, August 2, 2000; vol 284, No 5

Cavopol AV; Wamil AW; Holcomb RR & McClean MJ (1995). Measurement and analysis of static magnetic fields that block action potentials in cultered neurons. Bioelectromagnetics.16:197-206

Cisarik F (1986). The effect of pulsatile electromagnetic field on the viscosity of human blood in vitro. Biorheology, 23:154

Coghill R (2000). The book of magnetic healing. Gaia Books Ltd, London

Collacott E. A. Are magnets effective for pain control? ? Letters to the Editor JAMA, August 2, 2000; vol 284, No 5

Collacott E. A., Zimmerman J. T., White D. W., Rindone J. P. (2000). Bipolar permanent magnets for the treatment of chronic low back pain. JAMA, vol 283, No 10, 1322-1325

Eyster J. A. E., Maresh F., Krasno M. R. (1993). The nature of the electrical field around the heart. The American Journal of Physiology, vol 106, No 3, 574-588.

Foster KR (1992). Health effects of low level electromagnetic fields: phantom or not so phantom risks? Health Phys, 62: 429-35.

Flipo D; Fournier M; Benquet C; Roux P et al (1998). Increased apoptosis, changes in intracellular calcium, and functional alterations in lymphocytes and macrophages after in vitro exposure to static magnetic field. J. Toxicol Environ Health, 54:63-76

Gmitrov J., Ohkubo C. 0.5T static magnetic field, geomagnetic field and verapamil, a calcium channel blocking agent effect on baroreflex sensitivity. . Bioelectromagnetic Society.22nd Annual Meeting Abstracts. 2000, 188, 273.

Gmitrov J., Ohkubo Ch., Okano H. (2002). Effect of 0.25 T static magnetic field on microcirculation in rabbits. Bioelectromagnetics 23:224-229.

Gorczynika E & Wegszynowicz R (1989). Effects of static magnetic field on some enzymes activity in rats. J Hygiene Epidemiology Microbiology and Immunology, 33: 140-155

Grigat J.P., Stormer B., Trumper T., Schuz J., Brinkmann K., Michaelis J. 16 HZ and 50 HZ-background magnetic fields in residences in Germany. . Bioelectromagnetic Society.22nd Annual Meeting Abstracts. 2000, 132, 221.

Gualtierotti T. (1964). Decrease of sodium pump activity in frog skin on steady magnetic field. (abstract). Physiologist. 7:150

Hardell L; Holmberg B; Malker H &Paulsson LE (1995). Exposure to extremely low electromagnetic fields and risk of malignant diseases – an evaluation of epidemiological and experimental findings. Europ J Cancer Prev, 4(suppl 1): 3-107

Harper D.W., Wright E.F. (1977). Magnets as analgesics. The Lancet, July 2, 1997, 45.

Hawkins D. (1998). Take two magnets and call me later. US News and World Report. December 7, 86.

Hong Chang-Zern, Harmon D., Yu Jen. (1986). Static magnetic field influence on rat tail nerve function. Arch Phys Med Rehab, vol 67, 746-749
.

Hong Chang-Zern, Lin J.C., Bender L.F., Schaeffer J. N., Meltzer R. J., Causin P. (1982). Magnetic necklace: its therapeutic effectiveness on neck and shoulder pain. Arch Phys Med Rehab, vol 63, 462-466.

Horowitz S. (2000). Update on magnet therapy. Alternative and complementary therapies, 325-330.

Ichioka S., Iwasaka M., Shibata M., Harii K., Kamiya A., Ueno S. (1998). Biological effects of static magnetic fields on the microcirculatory blood flow in vivo: a preliminary report. Med. Biol. Eng. Comput, vol 36, 91-95.

Itegin M., Gunay I., Loguglu G., Isbir T. (1995). Effects of static magnetic field on specific adenosine-5-triphosphatase activities and bioelectrical and biomechanical properties in the rat diaphragm muscle. Bioelectromagnetics, 16:147-151.

Jaffe L. F., Vanable J. W. Electric field and wound healing. Clin Dermatol. 1984; 2:34-44.

Jauchem JR & Merritt JH (1991). The Epidemiology of exposure to electromagnetic fields: an overview of the recent literature. J. Clin Epidemiol, 44:895-906

Jonas S. Are magnets effective for pain control? ? Letters to the Editor JAMA, August 2, 2000; vol 284, No 5

Kanai S; Okano H; Susuki R & Hiroko A (1998). Therapeutic effectiveness of static magnetic fields for low back pain monitored with thermography and deep body thermometry. J. of Japanese Soc of Pain Clinicians, 5(1):5-10

Kirschvink JL; Kobayashi-Kirscvink A & Woodfors BJ (1992). Magnetite biomineralization in the human brain. Proc Natl Acad Sci USA, 89:7683-7

Kutrumbos T. D., Barnes F. S. Changes in oxygen saturation level in blood due to exposure to static magnetic fields. Bioelectromagnetic Society.22nd Annual Meeting Abstracts. 2000, 15-2, 88.

Macklis R.M. (1993). Magnetic healing, quackery, and the debate about the health effects of electromagnetic fields. Annals of internal medicine, vol 118, No 5, 376-383. Magnet therapy. Health after 50. June 1999; 8.

Markov M. S. Electric current and electromagnetic field effects on soft tissue: Implication for wound healing. Wounds 1995; 7:94.

Mayrovitz H.N., Groseclose E., Markov M., Pilla A. (2001). Effects of permanent magnets on resting skin blood perfusion in healthy persons assessed by laser Doppler flowmetry and imaging. Bioelectromagnetics 22:494-502.

Mayrovitz HN & Larsen PB (1992). Effects of pulsed electromagnetic fields on skin microvascular blood perfusion. Wounds, 4:197-202.

McLean MJ; Holcomb RR; Wamil AW & Pickett JD (1995). Blockade of sensory neurone actionpotentials by ststic magnetic fields in the 10mT range. Bioelectromagnetics.16:20-32

Michaelson SM (1987). Influence of power frequency electric and magnetic fields on human health. Ann NY Acad Sci, 502:55-75

Milham S (1982). Mortality from leukemia in workers exposed to electrical and magnetic fields (letter). N Eng J Med, 307:249

Muesham D. J., Pilla A. A. Dosimetry for static magnetic field bioeffects and therapeutic applications: saturation with increasing field strength and treatment duration. . Bioelectromagnetic Society.22nd Annual Meeting Abstracts. 2000, 6-2, 36.

Nakagawa K. Study on clinical effects of the magnetic necklace. Plublication series no.1. Beverley Hills, CA, TDK Magnets Corporation, 1975, p 1-12

Olney RK; So YT; Goodin DS et al (1990). A comparison of magnetic and electrical stimulation of peripheral nerves. Muscle Nerve 13:957-963

Owen D. Introduction to magnet therapy. Journal of Alternative Medicine, May 1986; 6-7.

Pilla A.A. Static magnetic fields in biology and medicine: dosimetry, bioeffects and clinical results. . Bioelectromagnetic Society.22nd Annual Meeting Abstracts. 2000, 115, 204.

Reno VR & Nutini LG (1963). Effect of magnetic fields on tissue respiration. Nature, 198:203-204

Rosch P.J. (1998). Stress, pain, fatigue, depression and magnets. Stress medicine; vol 14; 69-74.

Ruibal S (1997). Ironclad cures for pain? Athletes put their faith in power of magnets. USA Today. Aug 20

Saygili G., Aydinlik E., Ercan M. T., Naldoken S., Ulutuncel N. (1992). Investigation of the effect of magnetic retention system used in prostheses on buccal mucosal blood flow. The International Journal of Prosthodontics, vol 5, No 4.

Savitz DA; Wachtel H; Barnes FA, John EM & Tvrdik JG (1988). Case-controlled study of childhood cancer and exposure to 60 Hz magnetic fields. Am J Epidemiol,128:21-38

Scherlag B & Yamanashi WS (2000). Effects of low amplitude ELF electromagnetic fields on the heart rate, conduction, and induction of ectopies via autonomic nerve system in dogs. Ann meeting American Heart Assoc, Nov 11-15.

Szor J. K. (1998). Use of magnet therapy to heal an abdominal wound: A case study, vol 44, No 5; 24-29.

Takeshige C & Sato T,(1996). Comparisons of pain relief mechanisms between needling to the muscles, static magnetic fields, external qi gong and needling to the acupuncture point. Acupunct Electrother Res, 21: 119-131

Trock D. H. (2000). Electromagnetic fields and magnets, vol 26, No 1; 51-63.
Turing AM (1952). The chemical basis of morphogenesis. Philos Trans R Soc London B Biol Sci,237:37-72

Vallbona C., Hazlewood C. F., Jurida G. (1997). Response of pain to static magnetic fields in postpolio patients: A double-blind pilot study. Arch Phys Med Rehabil, vol 78, 1200-1203.

Vallbona C., Richards T. (1999). Evolution of magnetic therapy from alternative to traditional medicine. Complementary therapies in physical medicine and rehabilitation, vol 10, No 3, 729-754.

Wagner H. J. et al Teratological research about the influence of static electromagnetic fields of the prenatal growth of NMRI-mouse. . Bioelectromagnetic Society.22nd Annual Meeting Abstracts. 2000, 206, 289.

Weinberger A., Nyska A., Giler S. (1996). Treatment of experimental inflammatory synovitis with continuous magnetic field. Isr J Med Sci, vol 32; 1197-1201.

Weintraub M. Are magnets effective for pain control? Letters to the Editor JAMA, August 2, 2000; vol 284, No 5

Wever R (1973). Human circadian rhythms under the influence of weak electric fields and the different aspects of these studies. Int J Biometeor,17:227-232

Wertheimer N & Leepr E (1979). Electrical wiring configurations and childhood cancer. Am J Epidemiol 109:273-284

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