Static or dynamic low-frequency magnetic field? A review of literature

Statyczne czy zmienne pole magnetyczne niskiej częstotliwości? Przegląd piśmiennictwa

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Key words
low-frequency magnetic field, static magnetic field, magnetic field therapy

Abstract
The therapeutic application of magnetic fields has experienced significant growth in recent years. A small number of contraindications, as well as the lack of side effects makes both permanent magnets and alternating magnetic fields frequently used in physical therapy practice. In a significant number of clinical studies the efficacy of this physical factor as both an independent method, as well as supporting treatment programs has been confirmed. In the last few years, a lot of emphasis is put on the fact that all therapeutic methods should have a scientific basis and their usage should meet the evidence based medicine criteria (EBM). Therefore, this work will focus on comparison of the use of permanent magnets and alternating low-frequency magnetic field on the basis of the available literature, including mainly, a randomized double-blind trial. Analysis of the available literature on permanent magnet usage has shown clinical efficacy in many diseases, however, placebo-controlled studies confirm mainly the analgesic effect in patients after liposuction surgery, with diabetic neuropathy and with chronic pelvic pain. The use of the alternating low-frequency magnetic field also leaves many questions to which scientists have still not found the answer. Randomized double-blind trial proved its therapeutic efficacy in patients after knee arthroscopy, fractures and delayed bone unions, knee and cervical spine osteoarthritis as well as in case of leg ulceration. Alternating magnetic field application has a wider therapeutic range in comparison to permanent magnets and its effectiveness is much better documented, both in clinical studies as well as randomized double-blind trials.

Słowa kluczowe
pole magnetyczne niskiej częstotliwości, stałe pole magnetyczne, magnetoterapia

Streszczenie
Terapeutyczne zastosowanie pól magnetycznych wykazuje w ostatnich latach znaczący rozwój. Niewielka liczba przeciwwskazań, jak również brak działań ubocznych przyczyniają się do częstego stosowania tych zabiegów w praktyce fizykoterapeutycznej. W znacznej liczbie prac klinicznych potwierdzono skuteczność tego czynnika fizykalnego zarówno jako samodzielnej metody, jak i wspomagającej w programach terapeutycznych. W terapii stosuje się zarówno magnesy stałe, jak i zmienne pola magnetyczne. W ostatnich latach kładzie się coraz większy nacisk na to, aby wszelkiego rodzaju metody lecznicze miały podstawy naukowe,

The individual division on this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

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a ich zastosowanie spełniało kryteria medycyny opartej na faktach (*evidence based medicine*). Autorzy niniejszej pracy skupią się zatem na omówieniu zastosowania magnesów stałych i zmiennego pola magnetycznego niskiej częstotliwości na podstawie dostępnej literatury obejmującej randomizowane badania na podwójnie ślepej próbie. Analiza dostępnej literatury dotyczącej stosowania magnesów stałych wykazała ich skuteczność kliniczną w wielu schorzeniach, badania z grupą placebo potwierdziły natomiast działanie głównie przeciwbólowe u pacjentów po zabiegach liposukcji, u osób z neuropatią cukrzycową oraz u pacjentek z przewlekłym bólem miednicznym. Zastosowanie zmiennych pól elektromagnetycznych niskiej częstotliwości również pozostawia wiele pytań, na które jak do tej pory naukowcy nie znaleźli odpowiedzi. W badaniach na podwójnie ślepej próbie udowodniono skuteczność terapeutyczną u pacjentów po artroskopii stawu kolanowego, złamaniach i opóźnionym zrostem kostnym, u osób ze zmianami zwyrodnieniowymi stawów kolanowych i kręgosłupa szyjnego, a także w przypadku owrzodzeń podudzi. Działanie pól zmiennych ma w porównaniu z magnesami stałymi znacznie większy zakres terapeutyczny, a skuteczność ich działania jest o wiele lepiej udokumentowana zarówno w badaniach klinicznych, jak i randomizowanych na podwójnie ślepej próbie.

An electromagnetic field is one of the elementary forms of energy, on which life on Earth is dependent. An electromagnetic wave is energy transmitted through the material system in the form of electric and magnetic fields, wherein, the vector force of the electric and magnetic fields are perpendicular to each other and to the propagation direction of the wave at each point. The remaining stationary electric charge produces an electric field, whereas the current flowing through a conductor creates a magnetic field. Changes in electric fields generate changes in the magnetic field and vice versa. They cause induction of so-called eddy currents, mainly in highly-hydrated tissues containing ions which at higher frequencies, may result in heat generation. Low frequencies do not produce thermal effects and, above all, allow deeper penetration and percolate uniformly through all structures and therefore, can be used in spite of metal anastomosis or immobilization using bandages. There are two ways to produce a magnetic field - by varying the electric field or through the flow of an alternating current. The therapeutic apparatus uses the latter method. A magnetic field is also generated by permanent magnets, which are bodies of ferromagnetic properties, i.e. generate magnetic fields. They may be natural, e.g. magnetite or obtained as a result of magnetization of hard steel, which are used for therapeutic purposes, such as samarium-cobalt or neodymium or plastic - alloys containing nickel. The permanent magnets may have various shapes and sizes. In therapy, both two- and four-field magnets are used.

The unit of magnetic induction in the SI system is Tesla (T). Earth's magnetic field strength is less than 0.05 mT, while during an MRI exam, dosages of about 1.5-3 T are used. In therapy, however, if we do not create a division into magnetic-therapy and magnetic-stimulation, magnetic fields ranging from 1 μT to 10-20 mT are used, while in transcranial stimulation, e.g. in the treatment of depression, up to 8T [2] is used.

The use of this agent in the treatment goes back as far as over a hundred years, but the biggest development of methods in treatment of this type occurred in the second half of the twentieth century. Despite much research, the exact mechanisms of action are not exactly known.

Treatments incorporating magnetic fields are widely used due to their spectrum of biological activity. From the magnetic point of view, the human body is neutral, which means that the ratio of diamagnetics to para- and ferromagnetics is balanced. The fact that the structures of paramagnetic and ferromagnetic properties may change their energy state influenced by the magnetic field is used in therapy.

Under the influence of alternating magnetic fields, so-called Lorentz forces are produced, which cause ions to oscillate around their position in time to field changes. This can result in their increased transport across cell membranes. The induced electric currents in the tissues may affect piezoelectric systems present in the body, causing their mechanical deformation. These include collagen, dentin, keratin and other proteins. Under the influence of treatment, water may change their chemical properties. This leads to an increase in the concentration of gases, primarily oxygen, sedimentation and coagulation of the suspension in them, thereby obtaining bactericidal properties. Also demonstrated was the influence of magnetic fields on the liquid crystal included in, inter alia, the spinal cord, adrenal cortex, sex hormones, DNA and internal layers of cell membranes[3,4]. This affects the permeability of biological barriers. The magnetic field exerts an analgesic effect[5,6], moreover, stimulating the immunological processes due to an increase in the number of leukocytes in the blood[7-10].

Through its extensive biological effects, pulsating low-frequency magnetic fields are widely used in many clinical cases, among others:

- complications in bone healing;
- disturbances in bone mineralization;
- degenerative diseases of the joints;
- reduced muscle tension;
- nerve regeneration;
- pain syndromes of different origin;
- regeneration of soft tissues and others[2].

In recent years, there has been a growing interest in the therapeutic application of electromagnetic fields, and hence, there is a large number of scientific papers in this field. Due to the multitude of works on the subject, as well as the created ambiguous nomenclature, informative chaos occurs and hence, the rather skeptical attitude of the world of science towards this type of therapy. In the literature, especially English, one may very often encounter collective usage of electromagnetic fields of low and high frequency, and even electrical stimulation. The reviews often do not differentiate between the effects of electromagnetic fields of different frequencies[11-15].

On the other hand, comparison of the effects of magnetotherapy is difficult due to different doses and devices described in the research.

Electromagnetic fields used in physical therapy can be divided into the following 5 categories: 1) permanent magnetic fields generated by the permanent magnets or the constant flow of currents in the coils; 2) sinusoidal electromagnetic field (called low-frequency sine waves) at frequencies of 50 Hz and 60 Hz; 3) pulsed electromagnetic fields (PEMFA) of different frequencies (usually 1-100Hz), shapes of the field line (triangular, sinusoidal, trapezoidal, rectangular) and different values of induction (1 μT - 10-20 mT); 4) pulsed radiofrequency fields (PRF); 5) transcranial magnetic stimulation with a short-duration pulse and induction up to 8 T [2].

In recent years, increasing emphasis has been placed on the fact that all kinds of treatment methods should have a scientific basis, and their usage should meet the criteria of evidence-based medicine (EBM)[16,17]. The authors of this study, therefore, focus on discussing the use of permanent magnets and alternating magnetic fields of low frequency on the basis of available literature including a randomized double-blind trial.

Interest in the therapeutic usage of permanent magnets is increasing due to their "miraculous" effects propagated in the media. Most authors, however, found no difference in the use of permanent magnets in comparison to placebos. Chen et al.[18] found no significant effect on knee joint proprioception during the 12-week use of the recently popular magnetic bands. Similarly, no differences between groups in patients with carpal tunnel syndrome[19], fibromyalgia[20], urinary incontinence in elderly women[21] or in healthy individuals experiencing delayed muscle soreness[22].

However, there are studies which confirm the analgesic and antioedematous effect of permanent magnets in liposuction patients[23] as well as patients with diabetic neuropathy for reducing pain and paresthesia, but in this case only after 3-4 months of usage[24]. In a study by Brown et al.[25], the analgesic effect in female-patients with chronic pelvic pain was proven. They reduced pain compared to the control group, but also after 4 weeks of application, 24 hours a day. Meta-analysis carried out by Eccles[26] confirmed the analgesic effect of permanent magnets in 13 out of 21 studies. In all the analyzed works, there are very large discrepancies, both with regard to the type of magnets and therapeutic parameters, which is also confirmed by Colbert et al.[27] in analysis on therapeutic parameters using permanent magnets.

The use of varying low-frequency electromagnetic fields also leaves many questions unanswered. Many studies have confirmed the effectiveness of the application of magnetic fields, but in this case, there are even greater discrepancies regarding their dosage.

The studies carried out by Brown et al.[25] have confirmed the effectiveness of low-frequency magnetic fields in patients after knee arthroscopy, who underwent chondro-abrasion and/or perforation of the cartilage. The results showed significant improvement in knee function in the researched group, both after 90 days, and 3 years following the arthroscopy. The authors concluded that this effect was most likely the result of better control of inflammation and thus, chondro-protective action.

Whereas, Cheing et al.[28] compared the effectiveness of treatment programs including exercise combined with the usage of ice-packs and/or magnetic field and/or the placebo effect in patients after 6 weeks of immobilization of a fracture in the distal radius. The patients were divided into 4 groups. The first group used ice-packs and magnetic fields, the second ice-packs and placebos, the third only magnetic fields, and the fourth only placebos. The best analgesic and anti-swelling effects, and increased range of motion were observed in the first group, which used an exercise program, ice-packs and low-frequency magnetic fields. A slightly weaker effect was obtained in the second and third groups, and a significantly smaller effect was noted in the group that used only placebos.

Satisfactory results were also obtained in patients with osteoarthritis of the cervical spine. Significantly greater effects of magnetic field usage were noted as compared to the control group in reduction of pain and muscle tension[29].

After a 3-week treatment program in patients with impingement syndrome, no differences were found between groups (in the study group or the control group with the placebo effect)[30].

In patients with osteoarthritis of the knee joints undergoing treatment programs using magnetic fields, no differences were found between the study and control groups with the placebo effect[31-33]. On the other hand, Ganesan et al.[14], who carried out a meta-analysis of different types of publications, stated that magnetic fields have not only analgesic effects but are also chondro-protective and reduce inflammation.

In the meta-analysis by Vavken et al.[34], it is suggested that the use of pulsed electromagnetic fields of low frequency is of great clinical relevance as a supplement to the complex therapy of knee osteoarthritis, and not as independent treatment. The beneficial effect on the improvement of ADL without significant effects on pain were confirmed. However, there was a higher reduction of pain in patients undergoing therapy with pulsed electromagnetic fields of low frequency than in patients taking paracetamol or placebos.

Numerous studies, however, confirm the efficacy of magnetotherapy in the treatment of many diseases. Meta-analysis of 49 research works, including 3 double-blind trials, demonstrated the significant efficacy of low-frequency magnetic field usage in patients experiencing delayed fracture healing of the long bones[13]. Vavken et al.[32] also confirm the effectiveness of electromagnetic fields in the treatment of degenerative changes in the knee, above all in terms of functionality, but pay attention to the lack of differences compared to the control groups with the placebo effect in analgesic functions. These results were also confirmed in the work by McCarthy et al.[11].

The authors of meta-analyzes also confirmed the effectiveness of magnetic fields in the treatment of leg ulcers, however, often paying attention to the unsatisfactory methodological level of analyzed studiem [35-37].

The therapeutic use of low-frequency magnetic fields has significantly developed in recent years. The small number of contraindications, as well as the lack of side effects contribute to the frequent use of this procedure in the practice of physiotherapy. In a significant number of clinical studies, the efficacy of this physical factor has been confirmed as both a standalone therapeutic method, e.g. in the case of difficult bone healing, and as a supplement to treatment programs. Treatments using low-frequency magnetic fields can be successfully combined with other forms of physical therapy[38]. This allows to optimize treatment at a later time.

Unfortunately, there are no clear guidelines regarding dosages, and studies on the unification of therapeutic procedures on the use of the type of field, the induction value and frequency, the shape of the field, treatment time, etc. are still being conducted.

CONCLUSIONS

The research conducted so far on the use of permanent magnets generating a constant magnetic field confirmed the analgesic effect of using this method, but only after a long treatment period. Most authors, however, found no significant differences compared to placebo groups in the treatment of other symptoms.

The effects of varying fields has a much greater therapeutic range and their effectiveness is much better documented both in clinical and randomized double-blind trials.

Conflict of interest: none declared

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