

Arch Oral Biol. 1993 Jan;38(1):67-74.

Autoradiographic study of the effects of pulsed electromagnetic fields on bone and cartilage growth in juvenile rats.

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Application of pulsed electromagnetic fields (PEMF) has been used in growth and repair of non-union bone fractures. The similarities between the fibrocartilage callus in non-union bone fractures and the secondary cartilage in the mandibular condyle, both histologically and functionally, lead naturally to study the effects of PEMFs on growth in the condyle. The purposes of this study were: (1) to describe the effects of PEMFs on the growth of the condyle using autoradiography, [3H]-proline and [3H]-thymidine, and (2) to differentiate between the effects of the magnetic and electrical components of the field. Male pre-adolescent Sprague-Dawley rats (28 days old) were divided into three experimental groups of five animals each: (1) PEMF-magnetic (M), (2) PEMF-electrical (E) and (3) control, and were examined at three different times-3, 7 and 14 days of exposure. Each animal was exposed to the field for 8 h per day. Histological coronal sections were processed for quantitative autoradiography to determine the mitotic activity of the condylar cartilage and the amount of bone deposition. The PEMF (magnetic or electrical) had statistically significant effects only on the thickness of the articular zone, with the thickness in the PEMF-M group being the most reduced. Length of treatment was associated with predictable significant changes in the thickness of the condylar cartilage zones and the amount of bone deposition.(ABSTRACT TRUNCATED AT 250 WORDS)

Int Orthop. 1991;15(4):341-6.

Effects of pulsing electromagnetic fields on cultured cartilage cells.

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In order to evaluate the effects of pulsing electromagnetic fields (PEMFs) on cell proliferation and glycosaminoglycan (GAG) synthesis and to study the action site of PEMF stimulation in the cells, we performed a series of experiments on rabbit costal growth cartilage cells and human articular cartilage cells in culture. A PEMF stimulator was made using a Helmholtz coil. Repetitive pulse burst electric currents with a burst width of 76 ms, a pulse width of 230 microseconds and 6.4 Hz were passed through this coil. The magnetic field strength reached 0.4 mT

(tesla) on the average. The syntheses of DNA and GAG were measured by ³H-thymidine and ³⁵S-sulfuric acid incorporations. The effects on the cells treated with lidocaine, adriamycin and irradiation were also measured using a colony forming assay. The PEMF stimulation for the duration of 5 days promoted both cell proliferation and GAG synthesis in growth cartilage cells and intermittent stimulation on and off alternatively every 12 h increased them most significantly, while, in articular cartilage cells, the stimulation promoted cell proliferation, but did not enhance GAG synthesis. PEMF stimulation promoted cells treated with lidocaine more significantly than with other agents. These results present evidence that intermittent PEMF stimulation is more effective on both cell proliferation and GAG synthesis of cartilage cells than continuous stimulation, and that the stimulation could exert effects not by nucleus directly, but by the cellular membrane-dependent mechanism. This study provides further basic data to encourage the clinical application of PEMF stimulation on bone and cartilage disorders.

J Bone Miner Res. 1989 Apr;4(2):227-33.

Stimulation of experimental endochondral ossification by low-energy pulsing electromagnetic fields.

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Pulsed electromagnetic fields (PEMFs) of certain configuration have been shown to be effective clinically in promoting the healing of fracture nonunions and are believed to enhance calcification of extracellular matrix. In vitro studies have suggested that PEMFs may also have the effect of modifying the extracellular matrix by promoting the synthesis of matrix molecules. This study examines the effect of one PEMF upon the extracellular matrix and calcification of endochondral ossification in vivo. The synthesis of cartilage molecules is enhanced by PEMF, and subsequent endochondral calcification is stimulated. Histomorphometric studies indicate that the maturation of bone trabeculae is also promoted by PEMF stimulation. These results indicate that a specific PEMF can change the composition of cartilage extracellular matrix in vivo and raises the possibility that the effects on other processes of endochondral ossification (e.g., fracture healing and growth plates) may occur through a similar mechanism.

Osteoarthritis Cartilage. 2003 Jun;11(6):455-62.

Modification of osteoarthritis by pulsed electromagnetic field--a morphological study.

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OBJECTIVE: Hartley guinea pigs spontaneously develop arthritis that bears morphological, biochemical, and immunohistochemical similarities to human osteoarthritis. It is characterized by the appearance of superficial fibrillation by 12 months of age and severe cartilage lesions and eburnation by 18 months of age. This study examines the effect of treatment with a pulsed electromagnetic field (PEMF) upon the morphological progression of osteoarthritis in this animal model. **DESIGN:** Hartley guinea pigs were exposed to a specific PEMF for 1h/day for 6 months, beginning at 12 months of age. Control animals were treated identically, but without PEMF exposure. Tibial articular cartilage was examined with histological/histochemical grading of the severity of arthritis, by immunohistochemistry for cartilage neopeptides, 3B3(-) and BC-13, reflecting enzymatic cleavage of aggrecan, and by immunoreactivity to collagenase (MMP-13) and stromelysin (MMP-3). Immunoreactivity to TGFbeta, interleukin (IL)-1beta, and IL receptor antagonist protein (IRAP) antibodies was examined to suggest possible mechanisms of PEMF activity. **RESULTS:** PEMF treatment preserves the morphology of articular cartilage and retards the development of osteoarthritic lesions. This observation is supported by a reduction in the cartilage neopeptides, 3B3(-) and BC-13, and suppression of the matrix-degrading enzymes, collagenase and stromelysin. Cells immunopositive to IL-1 are decreased in number, while IRAP-positive cells are increased in response to treatment. PEMF treatment markedly increases the number of cells immunopositive to TGFbeta. **CONCLUSIONS:** Treatment with PEMF appears to be disease-modifying in this model of osteoarthritis. Since TGFbeta is believed to upregulate gene expression for aggrecan, downregulate matrix metalloprotease and IL-1 activity, and upregulate inhibitors of matrix metalloprotease, the stimulation of TGFbeta may be a mechanism through which PEMF favorably affects cartilage homeostasis.

Electromagnetic fields for the treatment of osteoarthritis.

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BACKGROUND: As the focus for osteoarthritis (OA) treatment shifts away from drug therapy, we consider the effectiveness of pulsed electric stimulation which is proven to stimulate cartilage growth on the cellular level. **OBJECTIVES:** 1) To assess the effectiveness of pulsed electric stimulation for the treatment of osteoarthritis (OA). 2) To assess the most effective and efficient method of applying an electromagnetic field, through pulsed electromagnetic fields (PEMF) or electric stimulation, as well as the consideration of length of treatment, dosage, and the frequency of the applications. **SEARCH STRATEGY:** We searched PREMEDLINE, MEDLINE, HealthSTAR, CINAHL, PEDro, and the Cochrane Controlled Trials Register (CCTR) up to and including 2001. This included searches through the coordinating offices of the trials registries of the Cochrane Field of Physical and Related Therapies and the Cochrane Musculoskeletal Group for further published and unpublished articles. The electronic search was complemented by hand searches and experts in the area. **SELECTION CRITERIA:** Randomized controlled trials and controlled clinical trials that compared PEMF or direct electric stimulation against placebo in patients with OA. **DATA COLLECTION AND ANALYSIS:** Two reviewers determined the studies to be included in the review based on inclusion and exclusion criteria (JH,VR) and extracted the data using pre-developed extraction forms for the Cochrane Musculoskeletal Group. The methodological quality of the trials was assessed by the same reviewers using a validated scale (Jadad 1996). Osteoarthritis outcome measures were extracted from the publications according to OMERACT guidelines (Bellamy 1997) and additional secondary outcomes considered. **MAIN RESULTS:** Only three studies with a total of 259 OA patients were included in the review. Electrical stimulation therapy had a small to moderate effect on outcomes for knee OA, all statistically significant with clinical benefit ranging from 13-23% greater with active treatment than with placebo. Only 2 outcomes for cervical OA were significantly different with PEMF treatment and no clinical benefit can be reported with changes of 12% or less. **REVIEWER'S CONCLUSIONS:** Current evidence suggests that electrical stimulation therapy may provide significant improvements for knee OA, but further studies are required to confirm whether the statistically significant results shown in these trials confer to important benefits.

Pulsed electromagnetic fields preserve proteoglycan composition of extracellular matrix in embryonic chick sternal cartilage.

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The influence of pulsed electromagnetic fields (PEMF) on proteoglycan composition in cartilage extracellular matrix has been investigated. Day 16 embryonic chick sternal cartilage was explanted to culture and exposed for 3 h per day for 2 days to a repetitive single-pulse PEMF with frequency of 15 Hz and peak magnetic field of 1.25 G. PEMF treatment did not affect cell proliferation, as indicated by [3H]thymidine incorporation, but significantly stimulated the retention of glycosaminoglycans in the explants and reduced the release of glycosaminoglycans into the media. Determination of incorporation of [35S]sulfate and [3H]N-acetylglucosamine into proteoglycans in vitro and breakdown of in ovo labelled [35S]sulfated proteoglycans in vitro showed that PEMF treatment significantly suppressed the synthesis of proteoglycans and the degradation of both newly synthesized and pre-existing proteoglycans. Sepharose CL-2B chromatography demonstrated that PEMF did not affect either the size distribution of newly synthesized and pre-existing [35S]sulfated proteoglycans or their ability to aggregate with hyaluronate. Sepharose CL-6B chromatography followed by cellulose acetate electrophoresis revealed that the chain length and degree of sulfation of [35S]sulfated glycosaminoglycans were identical in control and PEMF-treated cultures. It is concluded that PEMF treatment preserved extracellular matrix integrity of cultured cartilage explants by down-regulating proteoglycan synthesis and degradation in a co-ordinated manner without affecting their gross structural nature.

Pulsed electromagnetic field therapy results in healing of full thickness articular cartilage defect

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Abstract

This study aimed to determine the efficacy of PEMF (pulsed electromagnetic field) treatment in experimental osteochondral defect healing in a rabbit model. The study was conducted on 12 New Zealand white rabbits. Six rabbits formed the study group and six rabbits the control group. The right knee joints of all 12 animals were exposed and a 3.5-mm diameter osteochondral defect was created in the trochlear groove. The defect was filled with calcium phosphate scaffold. Six animals from the study group were given PEMF of one hour duration once a day for six weeks with set parameters for frequency of 1 Hz, voltage 20 V, sine wave and current ± 30 mA. At six weeks the animals were sacrificed and histological evaluation was done using H&E, Safranin O, Masson's trichrome staining and immunohistochemistry for type 2 collagen. The quality of the repair tissue was graded and compared between groups with the Wakitani histological grading scale and a statistical analysis was done. The total histological score was significantly better in the study group ($p = 0.002$) with regeneration similar to adjacent normal hyaline cartilage. Immunohistochemistry for collagen type II was positive in the study group. PEMF stimulation of osteochondral defects with calcium phosphate scaffold is effective in hyaline cartilage formation. PEMF is a non-invasive and cost effective adjuvant treatment with salvage procedures such as abrasion chondroplasty and subchondral drilling.