Pulsed Signal Therapy Vancouver

Cell Response to Pulsed Electromagnetic Fields (PEMF)

Aaron RK, Ciombor DM, Jolly G (1989). Stimulation of experimental endochondral ossification by low-energy pulsing electromagnetic fields. J Bone Min Res, 4(2):227-233.
Device: coils w/radius 9 cm; 4,5 ms pulse bursts; 12-19 mV; 0-20 G, 15 Hz
Summary: *"Pulsed magnetic fields (PEMFs) of certain configuration have been shown to be equally effective clinically in promoting the healing of fracture nonunions and are believed to enhance calcification of extracellular matrix... The synthesis of cartilage molecules is enhanced by PEMF, and subsequent endochondral calcification is stimulated... 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." (p.227)*

Aaron RK, Ciombor DM (1993). Increase in proteoglycan synthesis in cartilage explant cultures exposed to pulsed fields. Proceedings of the Thirteenth Annual Meeting of the Bioelectrical Repair and Growth Society; October 10-13, 1993; Dana Point, CA. BRAGS, 2.
Device: EBI 15 Hz pulse-burst
Summary: *"This study examines the effects of one PEMF upon proteoglycan synthesis and accumulation within the extracellular matrix in adult bovine cartilage explants. ...Control explants behaved as previously reported, reaching a steady state of PG synthesis by day 5 of culture. Explants exposed to PEMF demonstrated significantly enhanced PG synthesis by day 2 of culture reaching 150% of control by day 12. 95% of the PG synthesized were retained within the matrix and GAG content was increased by greater than 60% compared to controls. No evidence of proliferation, measured by thymidine incorporation, or DNA content was observed. Chromatographic analysis revealed the PG and GAG synthesized to be of normal size distribution and composition. This study indicates that exposure to the PEMF studied increases the synthesis of cartilage proteoglycans of normal size, composition, and function, and suggests that this PEMF may be of use in stimulating cartilage repair." (p 2)*

Aaron RK, Ciombor DM (1992). Stimulation with pulsing electromagnetic fields act synergistically with growth factors to increase cartilage matrix synthesis. Proceedings of The First World Congress for Electricity and Magnetism in Biology and Medicine, June 14-19, 1992. Lake Buena Vista, FL, (N-1)41-42.
Device: Inductively coupled PEMF. 22 pulses/burst and a 5 msec duration. 15 Hz
Summary: *"Increased PG synthesis has been observed in early cartilage injury and arthritis and may be associated with a limited repair process. Increased PG synthesis is of interest both as a measurement of chondrocyte activity and as a component of healing of cartilage injury." (p.41) "This study confirms that either growth factors or PEMF alone can increase the synthesis of PG molecules of typical size and composition and that these two stimuli may have a synergistic effect to increase PG synthesis above the level achieved by either modality alone."(p.42)*

Aaron RK, Ciombor DM (1992). Synergistic effects of growth factors and pulsed fields on proteoglycan synthesis in articular cartilage. Proceedings of the 38th Annual Meeting. Orthopaedic Research Society, Feb 17-20, 1992. Washington, DC, 17(2):527.
Summary: Results demonstrate a synergistic activity of growth factors and electrical stimulation in modulating proteoglycan (PG) synthesis by adult articular cartilage explant cultures maintained in a steady state.

Aaron RK, Plass AHK (1987). Stimulation of proteoglycan synthesis in articular chondorcyte cultures by a pulsed electromagnetic field. Trans Orthop Res Soc, 12:273.
Device: Circular coils. Burst configuration 5 msec & 15 Hz; quasirectangular

Summary: *"The results demonstrate that treatment of confluent articular chondrocytes with PEMF can increase rates of incorporation of 35S-Sulfate into proteoglycans. This effect however appears to be confined to cells grown in the presence of serum with low levels of somatomedin-like stimulatory factors; thus where high control rates were obtained no further increase with PEMF treatment could be measured. Where stimulation was observed (serum B) it appeared to be specific to proteoglycan in that no change in total protein synthesis was evident. Preliminary chromatographic studies indicate that proteoglycan formed in PEMF-treated cultures are of the same size and aggregability as controls suggesting that the cells respond by producing a larger number of normal molecules." (p.273)*

Aaron RK, Ciombor DM, Jolly G (1987). Modulation of chondrogenesis and chondrocyte differentiation by pulsed electromagnetic fields. Trans Orthop Res Soc, 12:272.
Device: Electromagnetic coils; pulse bursts of 5 msec. & 15 Hz.; quasirectangular WF
Summary: *Rats were placed in a PEMF for 8 hours/day. The animals were sacrificed every 2 days from days 4-12. "Our previous studies have suggested that chondrocytes have the ability to change the amount of extracellular matrix molecules produced in response to exposure to PEMFs. This study suggests that not only was the amount of matrix increased but the timing of differentiation and maturation was accelerated as measured by the production of characteristic cartilage-type PG." (p.272)*

Barnes FS (1992). Some engineering models for interactions of electric and magnetic fields with biological systems. Bioelectromagnetics, Suppl 1:67-85.
Summary: *"We begin with a review of the basic equations by which electric or magnetic fields interact with biological fluids..." (p.67) "The important feature of these memory networks in learning is that repetitive sequences of electrical signals in time will modify spatial connections... Thus we have a possible mechanism that allows one to obtain a biological effect from a collection of cells that would not be obtainable from a single cell."(p.82)*

Battini R, Monti MG, Moruzzi MS, Ferrari S, Zaniol P, Barbiroli B (1991). ELF electromagnetic fields affect gene expression of regenerating rat liver following partial hepatectomy. J Bioelectricity, 10(1 & 2):131-138.
Device: 1.2 mV; 50 Hz; triangular WF
Summary: *ELF-PEMFs were shown to influence gene transcription: specifically oncogenes c-myc and c-ras. The magnetic fields used in the experiment had a frequency of 50 Hz and an induced electromotive force of 1.2 mV.*

Blank M, ed. (1993). Electricity and Magnetism in Biology and Medicine. San Francisco: San Francisco Press.
Summary: *Review and research papers, Proceedings of the First World Congress for Electricity and Magnetism in Biology and Medicine, Orlando, FL, 1992.*

Blank M, Goodman R (1992). Changes in the distribution of proteins following electromagnetic stimulation of the sciara salivary glands. Proceedings of The First World Congress for Electricity and Magnetism in Biology and Medicine, June 14-19, 1992. Lake Buena Vista, FL, (P-153)113.

Blank M, Soo L (1991). Ion activation of the Na, K-ATPase in alternating currents. In: Brighton CT, Pollack SR, eds. Electromagnetics in Biology and Medicine. San Francisco, CA: San Francisco Press, Inc, 91-94.
Device: 100 to 200 Hz
Summary: *Window effect at 100 Hz ELF. This experiment demonstrates that an electric current need not penetrate the cell to cause transmembrane signaling. "AC can change the activation of the ion sites on the outer membrane surface, and ion pumping by the enzyme will affect the inner composition of the cell. This could be the way in which induced currents from low-frequency EM signals affect cellular processes even though the currents themselves do not enter the cell." (p. 91)*

Blank M (1988). Recent developments in the theory of ion flow across membranes under imposed electric fields. In: Marino AA, ed. Modern Bioelectricity. New York, NY: Marcel Dekker, Inc., chap 10.

Blank M, Soo L, Henderson AS, Goodman R (1992). Stimulation of transcription in HL-60 cells by alternating currents from electric fields. Proceedings of The First World Congress for Electricity and Magnetism in Biology and Medicine, June 14-19, 1992. Lake Buena Vista, FL, (P-138)109-110.

Braun KA, Lemons JE (1982). Effects of electromagnetic fields on the recovery of circulation in mature rabbit femoral heads. Trans Orthop Res Soc, 7:313.
Device: Bi-Osteogen System 204, Electro-Biology, Inc., Fairfield, NJ; 1.4 mV/cm; 2 G; 72 Hz; 380 usec WF

Summary: *New Zealand white rabbits were used. PEMF were used for 12 hours/day (72 Hz, 380 usec duration, 2 gauss, 1.4 mV/cm bone) "The results of this investigation showed an increase in the rate of revascularization and bone remodeling of the femoral head when exposed to a pulsing electromagnetic field. The similar trend, in both the descriptive and quantitative analyses, showed an increased vasculature associated with PEMF exposure occurring in the early stages of circulatory recovery."(p.313)*

Breger L, Blumenthal NC (1993). Electromagnetic field enhancement of membrane ion transport. Proceedings of the Thirteenth Annual Meeting of the Bioelectrical Repair and Growth Society; October 10-13, 1993; Dana Point, CA. BRAGS, 38.
Summary: *Experiments to test Liboff's hypothesis concerning magnetic fields and calcium diffusion were performed using artificial and biological membranes with no results.*

Brighton CT, Unger AS, Stambough JL (1984). In vitro growth of bovine articular cartilage chondrocytes in various capacitively coupled electrical fields. J Orthop Res, 2(1):15-22.
Device: function generator(Wavetek, Model 148A); 10 to 1000V; 60 Hz; sine WF
Summary: *Window effect. "Thus, articular cartilage chondrocytes grown in pellet form can be stimulated to increase glycosaminoglycan synthesis or to increase cell proliferation by an appropriate capacitively coupled electric field."(15)*

Budinger TF, Wong PDC, Yen C-K (1979). Magnetic field effects on humans: epidemiological study design. In: Phillips RD, Gillis MF, Kaune WT, Mahlum DD. Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium at Richland, WA. Technical Information Center, U.S. Department of Energy, 379-399.

Canaday DJ, Lee RC (1991). Scientific basis for clinical applications of electric fields in soft-tissue repair. In Brighton CT, Pollack SR, eds. Electromagnetics in Biology and Medicine. San Francisco, CA: San Francisco Press, Inc., chap 44.

Cheng N, Van Hoof H, Bockx E, Hoogmartens MJ Mulier JC De Dijcker FJ, et al. (1982). The effects of electric currents on ATP generation, protein synthesis, and membrane transport in rat skin. Clin Orthop, 171:264-272.
Device: 1 to 30,000 uA
Summary: *"Some of the most important electrical changes occurring in living tissues are (1) piezoelectricity, (2) pyroelectricity provoked by heating biopolymers, and (3) streaming potentials caused by the movement of charged liquids... The application of an electric or of an electromagnetic field to various biological systems results in stimulation of growth and tissue repair. In vivo electromagnetic treatment of bone tissue improves osteogenesis." (p.264) "Minimum current intensities of approximately 50 uA are necessary to obtain a maximal stimulatory effect on protein synthesis. When higher currents are applied, the current passing through the skin does not increase significantly. These stimulatory effects are maintained to a level of approximately 1000 uA."(p.269) "DNA metabolism is not affected by electrical stimulation, suggesting that the stimulation and inhibitory effects on protein synthesizing activity occur independently of an effect on transcriptional processes."(p.270)*

Chiabrera A, Nicolini C, Schwan HP(1985). Interactions Between Electromagnetic Fields and Cells. NATO ASI series. Series A, Life Sciences; v. 97. New York, NY: Plenum Press.

Ciombor DM, Aaron RK (1993). Pulsed fields act synergistically with growth factors to increase cartilage matrix synthesis. Proceedings of the Thirteenth Annual Meeting of the Bioelectrical Repair and Growth Society; October 10-13, 1993; Dana Point, CA. BRAGS, 3.
Device:EBI 15 Hz burst
Summary: *"PEMF acted synergistically with most growth factors to increase PG synthesis. ...It suggests that, with optimum combinations, cartilage from older individuals may be stimulated to synthesize matrix to a degree equal to that of younger cartilage and that the decreased matrix synthesis associated with senescence may be reversible." (p 3)*

Cleary SF, Nickless F, Liu L-M, Hoffman R (1980). Studies of exposure of rabbits to electromagnetic pulsed fields. Bioelectromagnetics, 1:345-52.
Device: pulse duration 0.4 us/up to 2 hrs.; 1 to 2 kV/mV; 10-38 Hz
Summary: *"Dutch rabbits were acutely exposed to electromagnetic pulsed (EMP) fields... the dependent variables investigated were pentobarbital-induced sleeping time and serum chemistry (including serum triglycerides, creatine phosphokinase (CPK) isoenzymes, and sodium and potassium)... Over the range of field strengths and pulse durations investigated no consistent, statistical significant alterations were found in the end-points investigated."(p.345)*

De Loecker W, Cheng N, Delport PH (1990). Effects of pulsed electromagnetic fields on membrane transport. In: O'Conner ME, Bentall RH, Monahan JC, eds. Emerging Electromagnetic Medicine. Berlin: Springer-Verlag Publishers, 45-57. Elliott JP, Smith RL, Block CA (1988). Time-varying magnetic fields: effects of orientation on chondrocyte proliferation. J Orthop Res, 6(2):259-264.
Device: Helmholtz coils (19 cm-diameter) Electrobiology (Fairfield NJ USA); 72 Hz
Summary: *The purpose of this study was to determine the effect of orientation of PEMFs on cellular proliferation and extracellular matrix synthesis. Bovine articular chondrocytes were cultured in PEMFs (72 Hz) generated using Helmholtz coils oriented either parallel (horizontal) or perpendicular (vertical) to the plane of cell adhesion. The influence of coil orientation suggests that the relationship of electromagnetic vectors to the plane of cell adhesion plays a role in cell proliferation.*

Farndale RW, Maroudas A, Marsland TP (1987). Effects of low-amplitude pulsed magnetic fields on cellular ion transport. Bioelectromagnetics, 8:119-134.
Device: Helmholtz-aiding coils; Bi-Osteogen Model 204 (Electro-Biology Inc.); 1.6 mT; 15 Hz
Summary: *"The experiments described ... were designed to examine the ability of biologically active PMFs to modify ion transport at the cell membrane."(p.131) "We feel that although there is good evidence to show that PMFs can modify cell behavior in vitro, our study raises the question of whether PMFs' primary action is on ion transport, or whether previous studies showing altered calcium metabolism, for example, describe effects that are secondary to some other change in cell function."(p.132)*

Farndale RW, Murray JC (1985). Pulsed electromagnetic fields promote collagen production in bone marrow fibroblasts via athermal mechanisms. Calcif Tissue Int, 37:178-182.
Device: Bi-Osteogen apparatus
Summary: *Fibroblasts from bone marrow stroma of young rabbits treated with PEMF (Bi-Osteogen apparatus) so that the magnetic field was tangential to the culture surface. Cell proliferation not affected, nor was DNA concentration. Measured temperature using a t-type thermocouple immersed in medium in the culture flask; no increase occurred. Collagen production was not altered until the cultures were post-confluent; elevation of proline to ohproline of about 7% on average occurred with PEMF; p value significant. Exploration of the mechanism of action of PEMFs. The PEMF treatment had no effect on cell proliferation, but did promote collagen production in postconfluent cultures.*

Farndale RW, Murray JC (1985). Low frequency pulsed magnetic fields enhance collagen production in connective tissue. Bioelectrochem Bioenerg, 14:83-91.

Farndale RW, Murray JC (1986). The action of pulsed magnetic fields on cyclic AMP levels in cultured fibroblasts. Biochim Biophys Acta, 881:46-53.

Giaever I, Parce JW, Wightman RM (1992). Electrical measurements of mammalian cells in culture. Science, 258(suppl):28. Grande DA, Magee FP, Weinstein AM, McLeod BR (1991). The effect of low-energy combined AC and DC magnetic fields on articular cartilage metabolism. Ann N Y Acad Sci, 635:404-407.
Device: Vertically oriented copper wire coils; 14.3 to 16 Hz
Summary: *Specifically targeted Ca++ (15 Hz) and K+ (16 Hz) and Mg++ (16 Hz). Increase in thymidine and sulfate uptake. Effects were only observed when cells had grown out to resting phase, were no longer multiplying - personal communication. Magnetic field influence on ion transport across cell membranes is one of the possible mechanisms that has received recent attention. Liboff et al. proposed the cyclotron resonance theory to describe the influence of magnetic fields on ion transport. The theory uses the Lorenz force equations to define magnetic field conditions that will enhance ion transport across cell membranes. The object of this experiment is to expose resting bovine articular cartilage to magnetic fields that satisfy the Liboff hypothesis and evaluate the effect of metabolism. Prevention of osteopenia.*

Kazis LE, Anderson JJ, Meenan RF (1989). Effect sizes for interpreting changes in health status. Med Care, 27(3)(suppl): S178-S189.

- Research Overview
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