The Effect of Pulsed Electromagnetic Field (PEMF) and BMP-2 on Intervertebral Disc Cells

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Introduction: Intervertebral disc degeneration is a process that involves loss of disc matrix, especially loss of aggrecan and collagen type II. Research has focused on methods, such as growth factors and other molecules, for increasing the synthesis of disc matrix. However, as far as we are aware there is no research extant on the anabolic effect of electromagnetic fields on disc cell metabolism. Pulsed electromagnetic field (PEMF) has been previously shown to increase the extracellular matrix synthesis in other cell types(1)(2). Furthermore it has been shown that PEMF can enhance the effect of growth factors. The purpose of the current study was to investigate whether PEMF can increase the production of cartilaginous disc matrix and to determine whether PEMF can enhance the effect of BMP-2, a growth factor that is endogenously expressed in disc tissue. We specifically measured mRNA expression levels of two chondrogenic genes (aggrecan and collagen type II) and one non-chondrogenic gene (collagen type I). The production of glycosaminoglycans was also measured.

Materials and Methods: Cells and culture: Human disc tissues from six patients were harvested during surgical procedures that required excision of disc tissue (ACDF). Intervertebral disc tissue from six New Zealand white rabbits aged 1-2 years of age was also used. The cells from the tissue were grown in monolayer in DMEM/F12 with 1% FBS. When the cells reached 80% confluence, rhBMP-2 was added to attain concentrations of 0, 20 ng/ml, and 40 ng/ml. The cells were incubated for 3 days either with or without PEMF.

PEMF: PEMF was applied via identical Helmholtz coils (Biomet, Parsippany, NJ) specially configured to two matched incubators. The PEMF signal was one that is used clinically for the treatment of fracture nonunions or delayed fracture healing. The applied field consisted of 4.5 ms bursts of 20 pulses repeating at 15 Hz. During each pulse, the magnetic field increased from 0 to 16 gauss in 200 μs and then decayed back to 0 in 25 μs. Coils were activated for 8 hours per day. All experiments were conducted twice.

Analyses: Messenger-RNA was extracted from the cells at the end of the experiment and converted to cDNA for quantitation by real-time polymerase chain reaction. The expression levels of aggrecan, collagen type I and II were measured. Sulfated glycosaminoglycan (sGAG) content in culture media was assayed by using the 1, 9-dimethylmethylen blue (DMMB) staining method.

Statistics: Student’s t-test was used to compare the results. Statistical significance was set at p-value less than 0.05.

Results: The results obtained for the human and rabbit cells were very similar. For brevity only the human data are presented.

Figures 1 and 2. PEMF treatment without rhBMP-2 resulted in nearly doubling of aggrecan and collagen type II mRNA levels. The addition of rhBMP-2 into the media increased the aggrecan and collagen type II mRNA. The combination of rhBMP-2 and PEMF had the highest levels of aggrecan and collagen II mRNA. In contrast the collagen type I mRNA was relatively unchanged with or without PEMF or rhBMP-2 (Figure 3).

PEMF treatment without rhBMP-2 increased sGAG levels by 23±4%. The addition of rhBMP-2 (20 ng/ml or 40 ng/ml) without PEMF increased sGAG levels by 60±5% and 89±9% respectively. The combination of PEMF and rhBMP-2 ( 20 ng/ml or 40 ng/ml) increased sGAG levels by 82±5% and 119±8% respectively.

Discussion: The main findings are the same for the humans as well as the rabbits, and these are as follows: 1) PEMF enhances the effect of BMP-2 in upregulating GAG, aggrecan, and collagen type II; 2) PEMF alone increases GAG production and the expression of chondrogenic genes aggrecan and collagen type II but has no effect on the non-chondrogenic gene collagen type I. This finding is particularly interesting since it represents a biological intervention that is truly non-invasive. This means that PEMF can be used without the worries associated with injecting growth factors into the disc in vivo, and can also be used to enhance the effect of any growth factors that are injected into the disc.