INTRODUCTION: It is known that astronauts experience low back pain during and after space flight [1,2]. During space flight the intervertebral disc experiences low compressive force and this in turn leads to low intra-discal hydrostatic pressure. While disc cells respond (in vitro) to changes in hydrostatic pressure, it is unclear what effect low levels of hydrostatic pressure have in vivo. We decided to assess the total aggrecan, collagen-1, and collagen-2 in the lumbar discs of rats in a tail suspension model (see Figure). This model induces tension across the disc to create decreased hydrostatic pressure in the disc mimicking the “weightless” condition. The rat tail-suspension model has two advantages: 1) it is, to date, an accepted animal model to simulate weightlessness. 2) it is a good model for studying the effects of tensile force on the disc. The disc (especially the anulus) is subjected to tension during various body movements (e.g. bending stretches the posterior anulus, and twisting tensions the whole anulus).

MATERIALS AND METHODS: After Institutional Animal Care and Use Committee approval had been obtained, thirty-two Sprague Dawley rats (~250 g) were tail-suspended for either two weeks (sixteen rats) or four weeks (sixteen rats). Sixteen other rats were left unsuspended four weeks; these were used as controls. At the end of two or four weeks, the rats were killed and their lumbar spines were removed. In each rat the six lumbar discs were removed en bloc (anulus and nucleus together) without the endplates. The discs from two identically treated rats (12 discs) were pooled to give one sample. The pooled discs were then assessed using direct enzyme-linked immunosorbent assays (ELISA) to quantify the total aggrecan, collagen-1, and collagen-2 per pooled disc sample. ANOVA was used to analyze the results and statistical significance was set at p<.05.

RESULTS: The rats tolerated the hindlimb suspension quite well. None broke free. There were no areas of pressure ischemia on the tail. The body weights of the rats were stable over the four-week period.

The three comparative groups were the control group (not suspended), suspended for 2 weeks, and suspended for 4 weeks. The average results are shown in Table 1. For proteoglycan, there was a statistically significant difference between the average values of proteoglycan between the three groups (p-value=0.035). In addition, there was a statistically significant declining trend from the control group, to the two-week group, to the four week group (p-value=0.01). There were statistically significant pairwise differences between the control group and the four-week group (p-value=0.01). One particularly notable result from Table 1 is the 35% statistically significant decrease in proteoglycan content between the control group and the four-week group (c.f. 0.098 for control with 0.064 for four weeks).

There were no statistically significant differences between the three groups for collagen-1 (p-value=0.62), collagen-2 (p-value=0.58), the ratio of proteoglycan to collagen-1 (p-value=0.34), and the ratio of proteoglycan to collagen-2 (p-value=0.27).

DISCUSSION: These findings clearly establish a link between decreased proteoglycan content and tension on the disc, as modeled by the tail-suspended rat. The proteoglycan decrease of approximately 35% (see Table 1) is quite remarkable for an experiment lasting only four weeks. While the mechanism is uncertain, it could be either decreased production or increased catabolism of proteoglycans. It has been shown that proteoglycan synthesis decreases in cells cultured at low values of hydrostatic pressure [3]. MMP-3 production (which could be involved in accelerated proteoglycan degradation) increased at low values of pressure [4]. Other possible mechanisms are changes in disc nutrition due to decreased diurnal fluid exchange or low blood flow. However, irrespective of the mechanism, these results raise concerns about the health of the intervertebral discs of astronauts in space for any extended period of time.

The question rises, in general, for those of us who are earthbound: Do body postures that produce tension in the disc cause long-term changes in proteoglycan content in particular? Bending (a frequently assumed body posture) produces tension in the posterior anulus and it has already been shown that the posterior anulus in degenerated discs is more undersulphated as compared to other parts of the anulus [5]. Do these facts piece together a picture of repeated flexion, producing tension in the posterior anulus, causing a gradual undersulphation of the posterior anulus, resulting in a degenerative cascade leading to radial fissures in the posterior anulus? In a study of the tensile properties of anulus fibrosus it was found that the postero-lateral regions of the anulus failed at much lower values of stress as compared to the anterior regions of the anulus [6].

REFERENCES: