Articular cartilage morphology in the knee joint after spinal cord injury.

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Introduction:
Previous research has shown that muscle, cardiovascular fitness and bone density are altered drastically in spinal cord injured (SCI) subjects (Kocina, 1997). However, the state of the lower extremity joints has not been studied thoroughly, although spinal cord injured subjects suffer from joint problems such as effusion (Buschbacher et al., 1991; Levi et al., 1995), heterotopic ossification (Haassard, 1975), and joint dislocation (Levi et al., 1995). Animal immobilization experiments show that articular cartilage changes can include altered proteoglycan synthesis, fibrofatty proliferation, as well as thinning and softening of the cartilage (Behrens et al., 1989; Jurvelin et al., 1986).

Few studies have analyzed the impact of paralysis on the articular cartilage of lower extremity joints. Pool (Pool, 1974) reviewed 200 cases of flaccid paralysis, and in 25 hip joints the cartilaginous space was found to be narrowed by more than 50%. Richardson evaluated the skeletal changes in neuromuscular disorders and reported apparent overgrowth of the epiphyses, peri-articular osteoporosis and joint-space narrowing to be the most common findings (Richardson et al., 1984). These studies used conventional radiography, which does not visualize cartilage directly and is known to exhibit only limited accuracy and reproducibility. New developments within the magnetic resonance imaging (MRI) research field now permit to quantify changes of articular cartilage with high accuracy and in vivo precision. Hence, the purpose of this study is to estimate changes in articular cartilage in people with a spinal cord injury, and thus to evaluate the effect of immobilization on articular cartilage in humans.

Material and Methods:
The right knee-joints of 7 male spinal cord injury individuals (age 30 years, range 22-45 yrs.) were investigated. Three subjects were 6 months post-injury, 3 were 12 months post-injury and one patient was 24 months post-injury. Volunteers with a history of knee pain, trauma or surgery were not included in the study. The volunteers were examined using a 1,5 T magnet (Magnetom Symphony, Siemens, Switzerland) and a circularly polarized knee-coil. A previously validated fat-suppressed gradient echo sequence (fast low angle shot, FLASH-3D) [repetition time 44 msec, echo time 10 msec, flip angle 30°] (resolution 0.31 x 0.31 x 1.5 mm) was used to acquire one coronal dataset of the tibial cartilage, and one transverse dataset of the patellar cartilage.

All datasets were transferred to a high-end graphics computer (Octane-Duo, Silicon Graphics Inc., California). Segmentation was performed on a section-by-section basis, using a semiautomatic B-spline SNAKE algorithm (Stammberger et al., 1999) that uses a combination of image forces and model forces, to identify the cartilage contours. Each cartilage plate was reconstructed three-dimensionally, and the size of the joint surface area and the cartilage-bone interface area was computed after triangulation. The mean and maximal cartilage thickness values relative to the bone-cartilage interface were computed independent of the original section orientation, using a three-dimensional Euclidian distance transformation algorithm (Stammberger et al., 1999).

The morphological data were compared with previously published data of 49 healthy young man segmented by different observers (aged 25.2 ± 3.2 years) (Eckstein et al., 2001) and with a sub-group out of this database segmented by the same observer who analyzed the patient data.

Data are still being collected and results presented here are preliminary and no statistical tests are done.
Results:
The selected normal dataset showed no significant difference relative to the total database of 49 values. Our first results show no substantial changes in the mean and maximal thickness or volume of patellar cartilage, after an immobilization period of 6 months. There is a small tendency of decrease in patellar mean thickness after 12 months of spinal cord injury (-10%).

![Bar graph showing the average values and standard deviations of the maximal and mean cartilage thickness, cartilage volume and joint surface area of the patella in normal subjects and in SCI individuals 6 (n=3), 12 (n=3) and 24 months (n=1) post-injury. Thick=thickness](image1.png)

Figure 1: Bar graphs showing the average values and standard deviations of the maximal and mean cartilage thickness, cartilage volume and joint surface area of the patella in normal subjects and in SCI individuals 6 (n=3), 12 (n=3) and 24 months (n=1) post-injury. Thick=thickness

In the medial tibia, the decrease appears to occur more rapidly. Six months after the accident, there is already a decrease of 23% in mean thickness. This decrease seems to continue, but somewhat slower during the following months.

![Bar graph showing the average values and standard deviations of the maximal and mean cartilage thickness, cartilage volume and joint surface area of the medial tibia in normal subjects and in SCI individuals 6 (n=3), 12 (n=3) and 24 months (n=1) post-injury. Thick=thickness](image2.png)

Figure 2: Bar graphs showing the average values and standard deviations of the maximal and mean cartilage thickness, cartilage volume and joint surface area of the medial tibia in normal subjects and in SCI individuals 6 (n=3), 12 (n=3) and 24 months (n=1) post-injury. Thick=thickness

Discussion:
In this study we have determined the knee joint cartilage morphology of spinal cord injured patients, and have estimated how fast changes occur. This is the first study to quantify the effect of unloading on articular cartilage in the knee joint of humans. It is speculated that human articular cartilage reacts in a similar way as seen in animal study.
Data are still being collected, but the first results show a clear trend, especially in the medial tibial cartilage. Articular cartilage reacts on the unloading and motion restriction situation by a decrease in mean articular cartilage thickness and volume in the medial tibia after 6 months. However in the patella the changes are much smaller and only visible after a period of 12 months. More data and longitudinal data will be collected to get a better idea of what is happening in the different cartilage plates of the knee joint. The decrease in articular cartilage thickness and volume after a certain period of immobilization emphasize the importance and relevance of correct and well-timed rehabilitation programs.

New developments such as neural regrowth could make it possible for certain spinal cord injury patients to regain parts of their mobility (Chen et al., 2000; Thallmair et al., 1998a; Thallmair et al., 1998b). When this happens it will be crucial that all organs are in good shape. Therefore these results and further research on the effect of different rehabilitation programs are crucial.

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References: