The influence of loading magnitude and loading rate on collagen fibre damage

Orthopaedic Biomechanics

Technische Universiteit Eindhoven University of Technology

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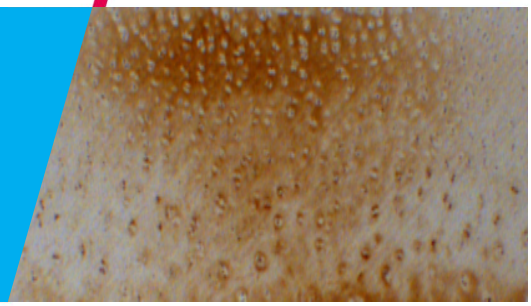

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Background

Articular cartilage is a thin, smooth and bright layer that covers and protects joints. Cartilage allows joints to withstand several times the corporal weight. When cartilage degeneration starts it normally progresses into osteoarthritis (OA). The detection of the very first moment at which cartilage degeneration is starting could be very useful for physicians to apply early treatments, allowing cartilage to regenerate by itself. However, predicting whether damage would progress into OA, requires the understanding of the mechanical and biological mechanisms by which cartilage is getting damaged. The aim of this study was to assess how loading magnitude and/or loading rate are related to the amount of damage in collagen type II fibres.

Methods

72 cartilage plugs were harvested from 1 year old cows. The plugs were mechanically loaded at various magnitudes: 15 (n=18), 25 (n=18), 35 (n=18) and 45 N (n=18); and loading rates: 5, 60 and 120 mm/min. Immediately after loading, cartilage was processed and stained with col2-3/4m antibody for collagen damage. This damage was graded by four observers, and the inter- and intra- observer reliability was evaluated (κ=0.69 and κ =0.9, respectively).

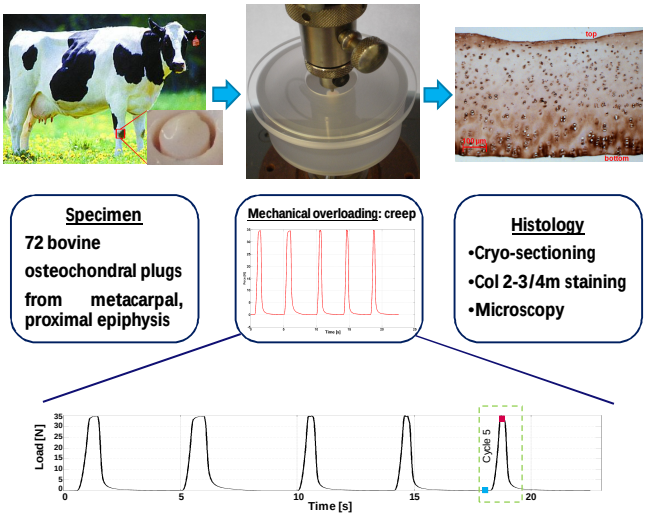

Figure 1. Method overview. Strains at the blue and red points were evaluated to monitor tissue softening (see Fig. 3).

Results

Collagen and structural damage was found in most of the samples, and increased with increasing loading magnitude and loading rate.

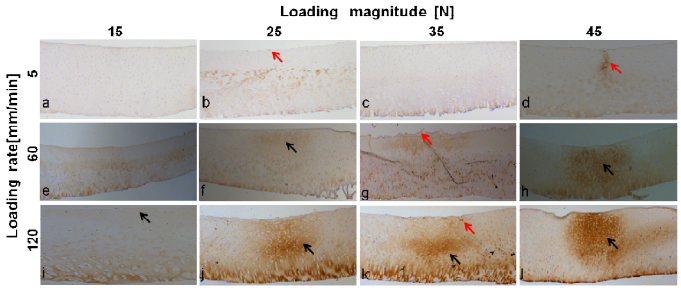

Figure 2. Digitized images of cartilage after col 2-3/4m staining. Brown color indicates collagen fibre damage induced mechanically. The red arrows show structural damage at the surface in (b) and (g) or clefts in (d). The black arrows show collagen fibre damage areas in (d) and (f-l). All images were digitized at 5x magnification, except by (e) (f) 2.5x and (d) (i) 10x.

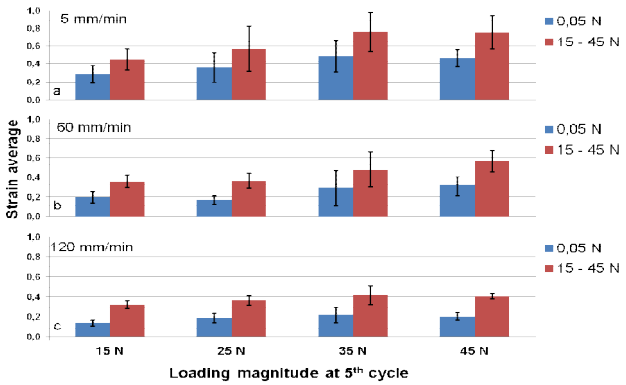

Figure 3. Average strain calculated at 5th cycle of loading for each loading magnitude applied. (a) Loading rate 5 mm/min. (b) Loading rate 60 mm/min. (c) Loading rate 120 mm/min (see Fig. 1).

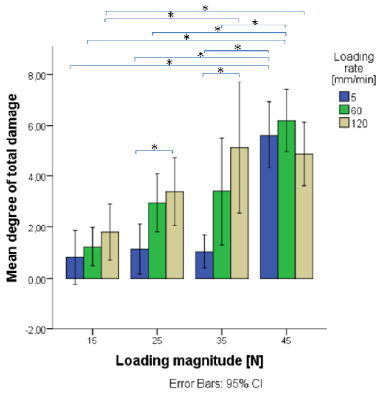

Figure 4. Degree of total damage based on validated scoring system of histological data (see Fig. 2). *p<0.05

Conclusion

Both loading magnitude and loading rate play an important role in the production of cartilage damage. Interestingly, the development of fissures and clefts depends more on loading magnitude, while collagen damage depends more on loading rate.

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This PhD project is possible thanks to the scholarship program for doctoral studies "Francisco José de Caldas Generación del Bicentenario año 2010" awarded by the Administrative Department of Science, Technology and Innovation of the Republic of Colombia, Colciencias.

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