

# Three-dimensional constitutive finite element modelling of the Achilles tendon

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The Achilles tendon is the largest tendon in the human body and it is commonly injured. However, the efficiency of today's treatments is not well established, because the biomechanical behaviour of tendons is not entirely understood. Computational modelling can provide useful information about tendon mechanics.

The Achilles tendon is located in the lower leg connecting the calf muscle to the heel bone. Its function is to transmit the force created by the muscle to generate locomotion. The Achilles tendon is used in common activities such as walking, running and jumping.

Tendons consist of a complex structure of highly organized collagen fibers oriented along the longitudinal axis and embedded in a hydrated matrix. The main component is water making approximately 70% of the total weight. Collagen makes up for 65-80% of the dry weight and the rest is accounted as ground substances composing the matrix.

Material models can be developed to represent the mechanical behaviours of tendons in terms of stresses and strains. This study further develops a 2D model of the Achilles tendon that accounts for all the main components: water, collagen fibers and matrix.

To simulate the mechanical behaviour of a realistic geometry of the Achilles tendon, it is necessary to have a model with a 3D geometry. Moreover, the existing model was predicting an inward non-physiological direction of the fluid flow. Therefore, the model was reformulated for 3D analyses and a model, that describes direction dependent properties, was used for the matrix.

Experimental data were used to validate the model. These consisted of measured reaction forces over time of 9 rat Achilles tendons under cyclic tensile loading. The calculated average behaviour was used in this study.

The experiment was simulated using the material model on ABAQUS, a computer software. The difference between simulated and measured reaction forces was minimized to obtain the optimal set of material parameters describing the model.

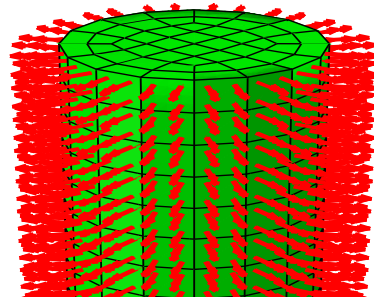


Figure 1: Outward movement of water (red arrows) in the upper part of the tendon predicted by the 3D transversely isotropic model simulating tensile loading.

The results showed that the reformulation of the model for 3D analysis did not change the prediction of tendon behaviour compared to the previous 2D model. Also modelling the matrix as a directional dependent material yielded an outward physiological fluid flow (Fig.1). The ability to represent the experimental data remained very good (Fig.2).

Further developments could validate the fluid behaviour with experimental measurements describing the amount of water extruded and its dynamics. Moreover, the model's capacity to predict viscous behaviour, characteristic of soft biological tissues, could be investigated.

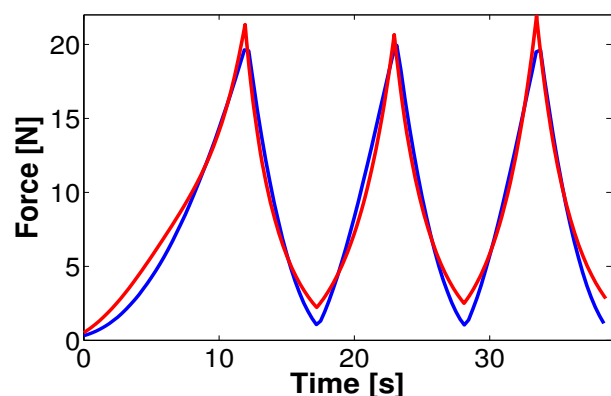


Figure 2: Reaction forces over time of the average tendon (blue) and the 3D transversely isotropic model (red).