Finite element analysis to predict the effects of Achilles tendon geometry on rupture or tendinopathy

Enomoto, S.1, Oda, T.2

1: Okayama University, 2: Hyogo University of Teacher Education

INTRODUCTION:

The Achilles tendon (AT) is the largest and plays an important role in the human body's movement. AT is involved in human body movement such as walking, running, or sports activity and is exposed to high loads frequently and continuously. In elite runners, the cumulative incidence during their lifetime of AT rupture and tendinopathy is reported to be 5% and 52%, respectively (1). A previous study on AT rupture has reported that it takes 13.1 weeks to return to full sports activity (2). Achilles tendinopathy can also cause a prolonged absence from sports participation (3). Thus, it is important to identify risk factors for AT rupture and tendinopathy and to prevent them. This study aimed to investigate the effects of the AT geometry on a local strain that would relate to its rupture and tendinopathy using the finite element (FE) method.

METHODS:

We calculated the following eight parameters from the 18 three-dimensional AT models obtained in our previous study (4): the thickness and width of the most distal site; the thickness and width of the minimum cross-sectional area (mCSA); the thickness and width of the most proximal site; and the length and position of the mCSA. We developed a standard three-dimensional AT model that has the aforementioned eight parameters. Furthermore, we developed the model by changing the parameter values every 1 standard deviation (SD) in the range of −2SD to +2SD. To simulate the loading applied to the AT during jumping, the models were only allowed to displace in the long axis direction, and a 4000 N (approximation of peak AT force during hopping: 3786 N, (5)) lengthening force was applied to the proximal surface. The distal surface was fully fixed. V-Biomech was used for FE analysis (6), and the maximum principal strain (MPS) was calculated. The mean and SD of MPS for 96% of the range except for the top and bottom 2% of the length of the model were determined every 3%. The highest mean MPS value in each model was used for analysis.

RESULTS:

The MPS value was 0.071 (SD: 0.016) in the standard model at the 86–89% site (0% is the most distal, and 100% is the most proximal site of the AT). The highest MPS value was observed in the distal thickness −2SD model, and the 2–5% site had a 27.1% higher value than the standard model. The mCSA width −2SD model had the second-highest MPS value, and the 89–92% site had an 18.4% higher value than the standard model.

CONCLUSION:

Our result suggests that ATs with a thin distal site and narrow mCSA have a higher risk of rupture or tendinopathy. Also, our results suggest that the location with the highest risk of rupture or tendinopathy may be different depending on the AT geometry.

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Topic: Biomechanics

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