MECHANICAL EFFECTS OF IMMOBILIZATION ON THE ACHILLES TENDON

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The Achilles tendon is one of the most common sites of tendon rupture. It is submitted to large stresses during activities such as running, jumping, and landing. Resistance to these stresses could be decreased by disuse atrophy induced by immobilization of the lower limb for fracture or ligament injury. Full understanding of the effects of immobilization on the Achilles tendon will improve the treatment and rehabilitation of patients after immobilization or suffering from Achilles tendinitis or rupture. Our objectives were to measure the tensile strength of Achilles tendons after immobilization and to locate the site of weakening. We hypothesized that the immobilized Achilles tendon unit would have a lower strength to failure and present evidence of degeneration at the mid-portion of the Achilles tendon, the most common site of rupture clinically.

Methods. The protocol for these experiments was approved by the University of Ottawa Animal Care Committee. One hind limb on each of twenty adult New Zealand white rabbits (average weight 2.6kg) was placed in a cast. A fiberglass cast extended from mid-thigh to the toes spanning the fully flexed knee and ankle held in 45 degrees of plantar flexion. Ten rabbits were euthanized after 4 weeks and ten after 8 weeks and their Achilles tendon-calcaneus units removed. The contralateral leg served as control. Biomechanical testing consisted of applying tensile deformation to the Achilles tendon-calcaneus unit. The calcaneus was fixed with bismuth alloy in a 15 degrees of plantar flexion to Achilles tendon, and the myotendinous end of the Achilles tendon (3 cm proximal to the tendon in sertion) was securely gripped with the cryoclamp (1). The tendon was then submitted to tensile deformation by elongating it at a constant velocity of 10mm/sec until a 75% drop from peak load was detected. The outcome measures of interest included stiffness (N/mm), peak load (N), energy to failure (J), and elongation at peak load (mm) and were calculated. After biomechanical testing, the site of rupture was noted macroscopically as a sagittal parafinn section. The specimens were examined for signs of degeneration at three sites: 1) at the tendon proper, and 2) at the insertion for fiber thinning, fiber tear, histologic disorganization, necrosis or presence of granulation tissue and 3) at the bone for evidence of disuse osteoporosis. Mechanical outcomes were compared between the 4-week immobilized group, the 8-week immobilized group, and the control group using the Kruskal-Wallis Test. Post-hoc analyses of statistically significant comparisons were conducted with multiple Mann-Whitney tests. The Mann-Whitney tests were followed by Bonferroni correction for multiple comparisons.

Results: The specimens failed: 1) at the edge of the cryoclamp (myotendinous junction); 2) at the Achilles tendon; 3) at the calcaneal insertion, or 4) at the calcaneal bone. The mode of failure for each group is shown in figure 1. In controls, failure at the calcaneal insertions and cryoclamp were more frequent. After four weeks of immobility, more failures at the calcaneal insertions occurred. After 8 weeks, a calcaneal fracture was the most frequent mode of failure. The Achilles-tendon cross-sectional area, measured both macroscopically and microscopically, did not change. The tendon was not the weakest point in the Achilles tendon-calcaneus unit. On average, the insertion of the Achilles tendon into the calcaneus after 4 weeks and the calcaneus after 8 weeks failed before the tendon. The mean tendon stiffness of both immobilized groups (4 week: 64.6 ± 24.8 N/mm, 8 week: 53.9 ± 19. 9 N/mm) was significantly lower than that of the control group (125.1 ± 26.5 N/mm, both p < 0.005) (Figure 2). The mean failure loads of both immobilized groups (4 week: 187. 5 ± 45. 7 N, 8 week: 162.6 ± 39.3 N) were significantly smaller than that of the control group (549.2 ± 93.7 N, both p < 0.005). Histologic analysis of Achilles tendons after immobilization revealed no difference among the three groups for fiber thinning, fiber disruption, fiber malalignment, necrosis or granulation tissue.

Discussion: The present study demonstrates that immobility of up to 8 weeks duration caused no tendon atrophy, microscopic degeneration or rupture of the Achilles tendon, therefore suggesting that immobility does not constitute a risk factor for Achilles tendon rupture. The lower stiffness of immobilized Achilles tendons did not lead to mid-substance rupture because mechanical weakening of the insertion and calcaneal predominated. Clinically, graded reloading post-immobilization is required to restore the tendon insertion and calcaneal integrity. Immobility of up to 8 weeks in an above knee cast does not contribute to clinically significant tendon degeneration. Counterintuitively, this duration of immobilization may not constitute a risk factor for Achilles tendon rupture. Despite the decreased Achilles tendon stiffness, it was the severe disuse osteoporosis that was mechanically predominant. Clinically, the management of Achilles tendon repair after rupture and the rehabilitation after lower limb immobilization need to focus more on reversal of immobilization-induced damage at the insertion into bone and disuse osteoporosis than on the tendon proper.

Figure 1. Mode of failure.
In controls, failure at insertion and clamp were more frequent. After 4 weeks of immobility, more avulsions occurred at the calcaneal insertions. After 8 weeks, a calcaneal bone fracture was the most prevalent mode of failure.

Figure 2. Mechanical testing.
The actual stress-strain curves of one representative specimen in each group are displayed. The control and 4 week-immobilized specimens ruptured at the tendon insertion, and the 8 week-immobilized specimen failed at the bone. Notice the lower peak load and lower stiffness with increasing duration of immobilization.

Reference.

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