Mechanical properties of Achilles tendon complex with overuse tendon injuries

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Introduction: Tendon overuse injury usually occurs as a result of sports-induced repetitive overloading to the muscle-tendon unit. Reports on the surgical management of chronic Achilles tendonitis often include macroscopic descriptions of the tissues. Tendons showed diffuse degenerative changes including tendon sheath thickening, areas of fibrinoid and myxomatous degeneration, fibrosis and metaplastic calcification. Several in-vivo human studies have attempted to investigate the tendon mechanical properties related to the loading pattern of the muscle-tendon complex induced by exercise, disuse, aging [1]. Accordingly, we hypothesized that the mechanical properties of Achilles tendon complex with chronic tendon injuries would change by the quantitative or qualitative composition and content of collagen fiber type and extracellular matrix with the situation of pathogenic process, progressive symptoms, recovery process. The objective of this study was to investigate the form and mechanical properties of Achilles tendon complex with chronic tendon injuries in athletes.

Materials and Methods: Subjects were 5 athletes (24.6±3.3 years, 174.0±5.1 cm, 69.2±8.3 kg) who had the diagnosis of chronic Achilles tendinosis with a long duration of symptoms on light side. All the subjects had participated in competitive meets at the regional or national level within the preceding year. The thickness, length at resting, and elongation of the Achilles tendon during isometric ankle plantar flexion were determined from ultrasonograms (ALOKA SSD-1000, JAPAN). The elongation of the tendon and aponeurosis of medial gastrocnemius muscle (MG) during isometric plantar flexion, respectively, were determined using a real-time ultrasonic apparatus in vivo, while the subjects exerted a gradually increasing torque from zero to maximal effort within 5 s. Mechanical properties of Achilles tendon complex were calculated from tendon elongation and force of MG. The relationship between the estimated muscle force and tendon elongation was fitted to a linear regression, the slope of which was defined as stiffness of the tendon structures. The precision and linearity of the image have been confirmed by Kawakami et al. [2]. Similarly, Young's modulus of the Achilles tendon was estimated by dividing the stress by the strain obtained at the level of MG in the 50-100% of stress. Descriptive date include means±SD. One-way ANOVA was used to analyze the data. The F ratio for main effects and interactions were considered significant at P≤0.05 were detected using post hoc test.

Results: There were no statistically significant differences in tendon length, but most subjects had more than 5 mm and up to a maximum of 16 mm differences between affected and unaffected leg. There was no significant relationship between duration of symptom and tendon length. Achilles tendon thickness was greater in affected leg. Thickening of the Achilles tendon was uniformly-varying near the attachment of Soleus (Figure 1). We find no significant changes for the relationship between muscle force (Fm) and tendon elongation (L) at affected and unaffected side. For the affected and unaffected leg, there were no significant differences in the stiffness of the Achilles tendon complex. On the other hand, the strain values above 80% of stress levels of affected leg were greater than that above 30% of stress levels of unaffected side. Young's modulus of affected side was significantly smaller than the unaffected side (Figure 2).

Discussion: The mechanism of the chronic response to tendon injury has not been fully explained. In addition, the mechanical characteristics of the adapted (thickened) tendon have not been investigated both in vivo and in animal studies. So, this study is the first report about the mechanics of the tendon with chronic tendinopathy.

Our result suggests that tendinopathic tendon become longer and thicker than the healthy tendon, and that these changes compensate the weakened Young's modulus. As the duration required for reorganization of the tendinopathic tendon is unknown, the limitation of this study is that our subjects might be on the long way of reorganization. If reorganization of the tendinopathic tendon results in dense and strong tendon tissue, the thickness of the tendon may decrease at the time of the completion of reorganization. Longer follow-up measurements are necessary to know the entire course of the chronic response to tendon injury.