CHAPTER V

DISCUSSION

The present study is the first research to measure the individual tendon moment arm length by MRI for calculating tendon force after eccentric training of calf muscles. The intent of this study was to examine the effects of eccentric training on mechanical properties of Achilles tendon. The main findings of this study were that eccentric training of calf muscles increased the maximal plantar flexion strength, tendon force and tendon stiffness whereas tendon displacement decreased.

Information on the effects of eccentric training on tendon force, tendon displacement, and tendon stiffness are inconclusive (16, 17). Our results showed that eccentric training increased in maximal plantar flexion force (change 20.1± 2.4 Nm), tendon force (change 454.6 ± 51.0 N), tendon stiffness (change 198.5 ± 58.1 Nmm^{-1}), and decreased in tendon displacement (change 2.0 ± 0.5 mm). Our results were in agreement with the finding of Duclay et al. (16), they reported that eccentric training increased the MVC (change 17.1 Nm), tendon force (change 350 N), tendon stiffness (change 40 Nmm^{-1}), and decreased in tendon displacement (change 2.4 mm). On the other hand, Mahieu et al. (17) showed tendon stiffness did not change after 6 weeks of eccentric training of Achilles tendon. However, they did not give details of their results i.e. maximal plantar flexion force, tendon force and tendon displacement. A possible explanation for inconsistent results could be the differences in method of progressive training and the differences in calculation methods of tendon stiffness.

This study had a control leg group (no eccentric exercise). However, the control leg unintentionally performed the concentric training because of fact that the control leg was used to return to the starting position. Therefore, maximal plantar flexion force and tendon force were increased whilst tendon displacement was decreased after 6 weeks training. On the other hand, a previous study (16) also had a control group and they reported that maximal plantar flexion force, tendon force, tendon stiffness and tendon displacement did not change after training. However, tendon stiffness in this study did not significantly change after 6 weeks training which agree with previous study (16).

Several previous studies investigated the effect of resistance training on tendon stiffness at different tendons in the body (40, 47, 49, 54, 55). Variation of tendon stiffness depends on the position of human tendon such as patellar tendon or Achilles tendon. For example, Reeves et al. (49) and Couppe et al. (56) showed a wide range of patellar tendon stiffness values (2187- 4766 Nmm^{-1}) whereas previous studies (37, 45, 53, 57) showed a small range of Achilles stiffness values (237- 390 Nmm^{-1}). Similar result was found in our study (179-379 Nmm^{-1}).

The mechanisms to explain why tendon stiffness increased after training remain unknown. However, an increase in tendon stiffness may attribute to hypertrophy and/or to a change in internal structures of tendon. However, the effect of strength training on tendon cross-sectional area is still controversial. One previous study (58) reported that the cross-sectional area of patellar tendon increased after 12 weeks of heavy resistance training. On the other hand, several studies (47, 49, 55) have shown that tendon cross-sectional area did not change after resistance training. However, we did not measure tendon cross-sectional area in the present study, for that reason we cannot exclude the possibility that the increase in tendon stiffness was associated with changes in tendon cross-sectional area. Furthermore, stiffness of a tendon is a direct consequence of the constituent components. Exercises also induce component or biochemical changes in tendon involving increase in tenoblast activity and collagen fiber thickness, cross links and crimp angle, an acceleration in collagen synthesis and an improve in stress orientation of fibers (29, 59). For example, in mice exercised on treadmill for 1 week, the number and size of collagen fibrils increased compared to sedentary mice (59). In addition, Langberg et al. (44) have shown that physical training induces an increased turnover of collagen type I in local connective tissue of the peritendinous Achilles tendon in vivo human.

There are inherent limitations associated with the present study. Firstly, in the measurement of tendon displacement, the myotendinous junction is assumed to shift during contraction in the scanning plane only. However, a mediolateral displacement of a tendon might occur, resulting in an error of tendon displacement. Secondly, the isometric contraction was undertaken at anatomical position which had minimal passive joint moments; this position was assumed to have 0% tendon strain. However, passive joint moment effect on tendon strain will be an underestimate of tendon displacement (60). Next, the control leg in this study cannot avoid concentric exercise because the training program used the control leg to return the body to the starting position. Finally, this study did not measure ankle joint rotation during isometric contraction. Small amounts of ankle joint rotation affect the displacement of tendon measurement. However, this study controlled the ankle joint rotation by visual inspection, if ankle joint rotation was observed the data were rejected, and the test was repeated.

In conclusion, these results suggested that eccentric calf muscle training altered tendon adaptation, i.e. MVC, tendon force, tendon displacement, and tendon stiffness were increased after 6 weeks of training. Thus, eccentric calf muscles training improved strength in Achilles tendon which may help reduce risk of tendon injury and prevent tendon injury in sports.

Clinical implications

The findings of this study were obtained from healthy participants. The results of this study showed that eccentric and concentric training induced muscles adaptation. Only eccentric training induced tendon adaptation. In part of the mechanical properties of tendon, an increase in tendon stiffness indicated that tendon increased in strength, capable of absorbing a large amount of energy before failure, and more resistant to injury. Therefore, our study recommends that eccentric training was suitable for healthy people, athletes, and patients with tendinopathy.

Future study

The control groups (control leg) in this study unintentionally performed the concentric muscle contraction because of fact that the control leg was used to return to starting position. Therefore, future study should be conducted in control groups that did not receive any form of resistance training program. Moreover, the study performed eccentric training program in healthy subjects which the results of this study suggest that eccentric training induced changes in tendon mechanical properties. However, eccentric training has been widely use in the rehabilitation of patients with Achilles tendinopathy. Therefore, eccentric exercise program in the study should be to reproduce in patients with Achilles tendinopathy to provide important information concerning the mechanism behind the good clinical results observed following eccentric training program for Achilles tendinopathy.