THE STRUCTURE OF HUMAN ACHILLES TENDON AND ITS BIOMECHANICAL SIGNIFICANCE

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INTRODUCTION

The Achilles tendon is one of the strongest tendons in the body. However, it is common to see injuries of the tendon among the athletes. To know more about its structural characteristics, the human Achilles tendons were further investigated with particular attention given to the rotation of tendinous fiber bundles. The biomechanical significance and its relation to sports injury were discussed.

MATERIAL & METHOD

211 human lower limb specimens were divided into groups of adult and children which were subgrouped left and right. The rotation can be divided into three types in line with Cummins et al.'s standard(Fig. 1.). The tendons of male adult specimens were measured.

RESULTS

The morphological characteristics of Achilles tendon

Achilles tendon originates from two wide and thick aponeuroses, one is in front of gastrocncniius and the other behind soleus, which become narrowed, merged and thickened in their way downwards.

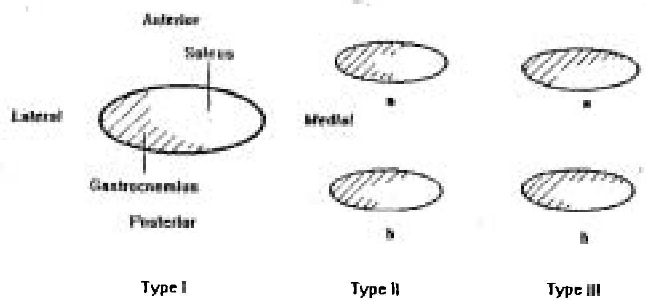

Fig. 1. The cross sectional illustration of Achilles tendon at insertion to show the standard of rotation type classification.

The tendinous fibers of two parts do not go down paralleledly but while merging into Achilles tendon they twist laterally so that most of the fibers of the gastrocnemius part insert on the posterolateral surface of calcancus while those of the soleus part insert on the posteromedial surface. In fact at the insertion some of the fibers of the gastrocnemius part turn even to the front. Twisting in the upper segment is not obvious and 12-15 cm above insertion it starts but becomes most pronounced at approximately 5 cm above the calcaneus.

There is a potential space between the aponeuroses in front of the two bellies of gastrocnemius and that behind soleus, usually in which there is a little loose connective tissue or synovia. Therefore the three bellies of two muscles can contract and pull the tendon separately.

In virtue of the insertion of two heads of gastrocnemius to femoral condyles, while the ankle joint is in dorsiflexion a stretched tendon will develop even greater tension and easily tear when the quadriceps muscle group contracts strongly during knee extension. Even in the situation of plantar flexion of the ankle during the contraction of triceps surae, it has the same effect as above to extend the knee at this moment.

The classil'ication of Achilles tendon rotation

The percentage of 3 rotation types of Achilles tendon of children, adult, left and right in Chinese is shown in Fig. 2.

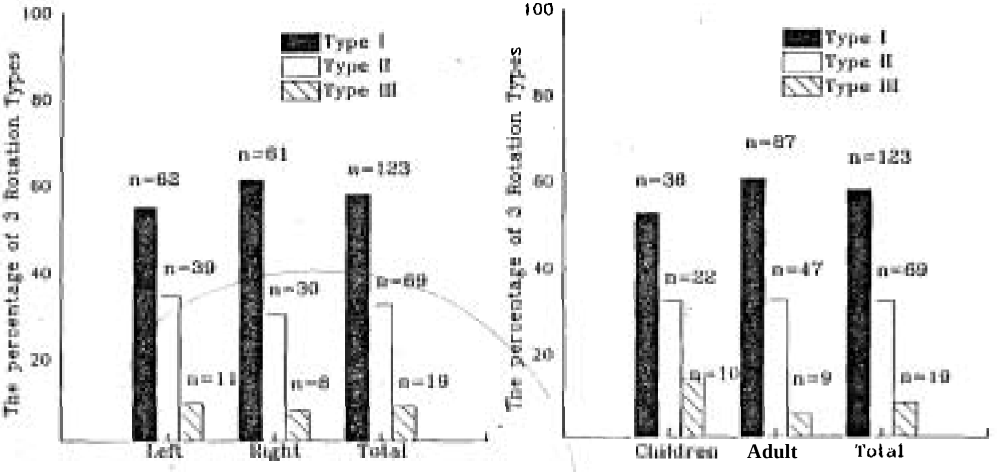

Fig. 2. The percentage of **3** rotation typesof children & adult, left & right Achillestendon in Chinese.

It was found that (1) in both children and adult, both left and right, the percentage of three rotation types is lower in propel order of light, medium and heavy; (2) there are no significant differences between children and adult, left and right in all three types.

The measurement of adult Achilles tendons

One hundred and one (left 54, rigth 47) Achilles tendons of male adult specimens were measured. The statistical data of the five-item measurement are shown in Table 1.:

	Mean +/- S.E.	S.D.	**Max.**	**Min.**
tendon length	19.77+/-0.24	1.75	23.60	15.85
mergence length	19.40+/-0.41	2.94	27.50	11.30
upper-width	6.58+/-0.19	1.30	9.50	4.20
lower-width	1.50+/-0.04	0.24	2.27	1.10
tower-thickness	0.68+/-0.01	0.09	0.95	0.50

Table 1 Measurement of male adult Achilles tendon.

DISCUSSION

The structure and function of Achillcs tendon

The tendon together with triceps surae above and calcaneus below form the typical muscle-tendon-bone triad and control the plantar flexion of the ankle predominantly. Along with the different physical activity situation, the tractive force that the tendon bears has a great range of alteration. It was measured that the maximal tractive force can attain 780 kg when a sportsman is taking off vigorously (Qu et a1.1982). This finding emphasizes the great tension the Achilles tendon has to tolerate.

We believe that the rotation structure of this tendon has certain biomechanical significance in adapting it to the, tremendous tractive force and preventing it from rupture while the body is being in a state of sudden run or violent jump. Just like the rope, with the same number of strands and strings the twisting structure can bear even greater tension than only pulling them together in a parallel way. According to Cummins et al.'s(1946) investigation other mammalian tendo calcaneus also have the twisting property, especially kangaroo.

The rotation we observed using naked eye is the rotation of tendinous fiber bundles. Wang & Wang (1983) found that the collagenous fibers forming these bundles also have a twisting appearance under SEM. If we analyse the tendon from the macroscopic to the microcosmic level it can be found that from the tendinous fiber bundle. collagenous fiber, collagen fibril, collagen microfibril until the tropocollagen molecule which is composed of triple helix of three polypeptide chains, almost all of them have certain twisting architecture, which structure is precisely suitable to its tractional function.

Racial. gender specific and individual diversity of the rotation

The comparison of the percentage of 3 rotation types in U.S. white, Japanese and Chinese is shown in Fig. 3.

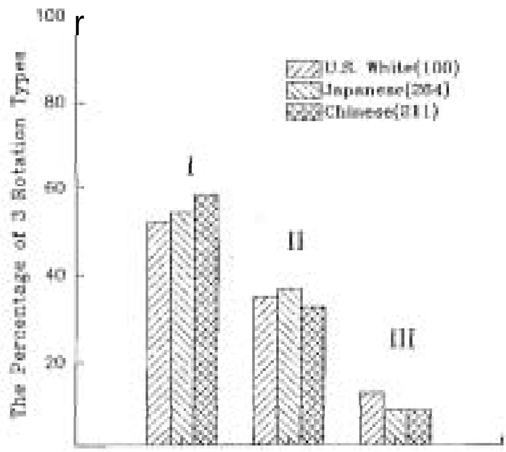

Fig. 3. The comparison of the percentagcof **3** rotation types of Achilles tendon in U.S. White, Japanese and Chinese. The number in parentheses is the amount of samples studied.

It was found that there is no significant differences among races in the distribution of the 3 types of rotation and Morimoto & Kokata asserted that there are no gender differences either. However, among individuals of distinct races, sexes and ages the twisting degree differs greatly, which can be seen even on the infantile and juvenile specimens. Therefore it can be inferred that the degree of rotation is not acquired but rather determined genetically.

The morphological factors of sports injury of the tendon

There are many factors that can cause injury to the tendon and we believe that except for the phathological and biomechanical factors, morphological weakness is also an important factor. Firstly, many statistical data indicate that most of the closed rupture of Achilles tendons caused by indirect violent force occur on a site 4-6 cm above insertion.

According to the observation of Lagergren and Lindholm (1958) this site is the most avascular part of the tcndon, which is just the most obvious region of the tcndon rotation we investigated. Secondly, normal Achilles tendon consists of 85% collagen almost all of all of which is Type I but Helal et al.(1986) found that many torn tendons consist of a mixture of Type III and Type I collagen. Therefore they inferred that the existence of Type III collagen probably reduced the tendon's tension resistance. Thirdly, as shown by the present results, the majority of the tendon rotation belong to the light type. Even though the tendon developmental level is the same, evidently the tendon with light twisting is more easily tom than that with heavy twisting when a violent tractive force acts on it suddenly. Finally, Christensen (1953) held that owing to the crisscross and intersect of two parts of tendinous fibers coming from gastrocnemius and soleus, when the three heads of two muscles contract uncoordinatedly and unsynchronously because of the physiological and psychological factors the damage may occur due to the long-term saw-like action of the two parts of tendon fibers.

CONCLUSIONS

The tendon rotation structure has some biomechanical implications for the tendon's adaptation to the tremendous tractive forces dcvelopcd during special situations. Along with the common factors known to result in tendon injury, the structural weakness is also one ofthe most important factors resulting in the tendon injury.

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