Morphological and Mechanical Properties of Muscle and Tendon in Highly Trained Sprinters

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The purpose of this study was to investigate muscle and tendon properties in highly trained sprinters and their relations to running performance. Fifteen sprinters and 15 untrained subjects participated in this study. Muscle thickness and tendon stiffness of knee extensors and plantar flexors were measured. Sprinter muscle thickness was significantly greater than that of the untrained subjects for plantar flexors, but not for knee extensors (except for the medial side). Sprinter tendon stiffness was significantly lower than that of the untrained subjects for knee extensors, but not for plantar flexors. The best official record of a 100-m race was significantly correlated to the muscle thickness of the medial side for knee extensors. In conclusion, the tendon structures of highly trained sprinters are more compliant than those of untrained subjects for knee extensors, but not for plantar flexors. Furthermore, a thicker medial side of knee extensors was associated with greater sprinting performance.

Keywords: knee extensor, plantar flexor, tendon elongation, muscle strength

Sprint running induces stretch–shortening cycles in the muscle–tendon complex of the lower limbs. Recent studies have demonstrated using ultrasonography that the tendon properties are related to the performances during stretch–shortening cycle exercises (Bojsen-Møller et al., 2005; Kubo et al., 1999, 2000a, 2007a; Stafilidis & Arampatzis, 2007). In particular, we reported that the tendon properties of knee extensors were more compliant in sprinters compared with untrained subjects (Kubo et al., 2000a). Furthermore, Stafilidis and Arampatzis (2007) also demonstrated that the maximal tendon elongation in knee extensors was greater in excellent sprinters (best official record of a 100-m race; 11.04 ± 0.17 s) than that in inferior sprinters (best official record of a 100-m race; 11.64 ± 0.23 s). However, the average of best official record of a 100-m race in these previous studies (Kubo et al., 2000a; Stafilidis & Arampatzis, 2007) was about 11.0 s. Considering the finding of Stafilidis and Arampatzis (2007), it is likely that the tendon properties of sprinters are dependent on the level of athletic competition. No studies have investigated the tendon properties of faster sprinters compared with the above-quoted previous studies; that is, the average of best official record of a 100-m race was faster than 11.0 s.

It is well known that muscle function and size in knee extensors and plantar flexors play important roles during locomotion, that is, walking and running. Indeed, some previous studies showed that the force-generating capability of knee extensors played a major role in sprint running (Alexander, 1989; Bret et al., 2002). Some previous researchers reported the muscle size (mass, cross-sectional area, thickness) of knee extensors and plantar flexors in sprinters (e.g., Korhonen et al., 2009; Kumagai et al., 2000). However, there were a few studies investigating the muscle size in sprinters compared with untrained subjects (Abe et al., 2000; Maughan et al., 1983). For example, Maughan et al. (1983) reported that the muscle cross-sectional area of knee extensors was greater in the sprinters than in the control subjects but this difference was not significant. In these studies, however, the muscle cross-sectional area and thickness were measured for limited slice of computerized tomography and ultrasonography. This implied that the training-induced changes in muscle size might be overlooked because muscle hypertrophy did not occur equally throughout the entire length of the muscle (Kubo et al., 2008; Narici et al., 1996). In fact, our recent study showed that significant increases of muscle thickness at proximal and medial sites in knee extensors were observed after 6 months of walking training, although the muscle thickness at middle site did not change (Kubo et al., 2008). Therefore, it is possible that the muscle thickness at these sites (at proximal and medial sites in knee extensors) is greater in sprinters than in untrained subjects, since both walking and sprinting are generally classified as “locomotion.”

In the current study, we aimed to investigate the morphological and mechanical properties of muscle and...
tendon in knee extensors and plantar flexors of highly trained sprinters (the average of best official record of a 100-m race was faster than 11.0 s) and their relations to running performance. According to the above-quoted previous studies (Kubo et al., 2000a; Kubo et al., 2008; Stafilidis & Arampatzis, 2007), we hypothesized that the tendon structures in knee extensors were more compliant in highly trained sprinters than in inferior sprinters and untrained subjects, and that peculiar differences in muscle thickness among synergists of knee extensors and/or plantar flexors were observed for highly trained sprinters.

**Methods**

**Subjects**

Fifteen well-trained male 100-m sprinters participated in this study. All the subjects of sprinters had participated in competitive meets at the regional or intercollegiate level within the preceding year, and their best official record of a 100-m race within 1 year of these tests ranged from 10:58 s to 10:98 s (10.79 ± 0.13 s). The duration of training experience in sprint running for sprinters ranged from 4.2 to 9.8 years (6.2 ± 2.8 years). They performed sprint training at least six times per week. In a preliminary study, 15 untrained subjects whose age, body height, and limb length were similar to those of sprinters were selected as a control group. The physical characteristics of the subjects are summarized in Table 1. All untrained subjects were either sedentary or mildly active but none had been involved in any type of regular exercise program for at least 1 year before the test. This study was approved by the office of the Faculty of Physical Education, Kokushikan University, and was consistent with its requirements for human experimentation. The subjects were fully informed of the procedures to be used as well as the purpose of this study. Written informed consent was obtained from all the subjects.

**Muscle Strength and Neural Activation**

Maximal voluntary isometric contraction (MVC) was measured by means of specially designed dynamometers (Applied Office, Tokyo, Japan) for knee extension and plantar flexion, respectively. All measurements were performed on the right lower limb. During each task, subjects exerted isometric torque from zero (relax) to MVC (full extension = 0°). The axis of the knee joint was aligned with the axis of the lever arm of the dynamometer. The right ankle was firmly attached to the lever arm of the dynamometer with a strap and fixed with a knee joint flexed at an angle of 90° (full extension = 0°). During the plantar flexion task, subjects lay prone on a test bench and the waist and shoulders were secured by adjustable lap belts and held in position. The ankle joint was set at 90° with the knee joint at full extension, and the foot was securely strapped to a footplate connected to the lever arm of the dynamometer. Before the test, subjects performed a standardized warm-up and submaximal contractions to become accustomed to the test procedure. Each task was repeated two or three times per subject with at least 3 min between trials. The highest value among these trials was recorded as the muscle strength for each.

When the voluntary torque peaked, evoked twitch contractions were imposed by supramaximal electrical stimulations. The stimulating lead electrodes were placed on the skin over the femoral nerve at the inguinal region and the midbelly of the quadriceps femoris muscle for knee extensors and on the skin of the right popliteal fossa and oriented longitudinal to the estimated path of the tibial nerve with the anode distal for plantar flexors, respectively. A high-voltage stimulator (SEN-3301, having a specially modified isolator SS-1963, Nihon-Koden, Japan) generated rectangular pulses (triple stimuli with a 500-µs duration for one stimulus and an interstimulus interval of 10 ms). Maximal twitch contractions were evoked in the resting muscle by progressively increasing the stimulation intensity until increases failed to elevate twitch torque further. The stimulus intensity that elicited peak twitch torque was used throughout the duration of the measurements. The difference between peak twitch torque and MVC (twitch torque) was measured. Shortly (within 1–2 s) after MVC, the same stimulation was given to the muscle at rest (control twitch torque). The measured values shown below are the means of two trials. The neural activation level (%) of the muscles was calculated as [1 – (twitch torque during MVC / control twitch torque)] × 100, as previously reported (Becker & Awiszus, 2001).

**Elongation and Stiffness of Tendon Structures**

Elongations of the tendon structures in knee extensors and plantar flexors were also assessed during isometric knee extension and plantar flexion. An ultrasonic apparatus

**Table 1  Mean (SD) age and physical characteristics of the subjects**

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>Thigh length (cm)</th>
<th>Lower leg length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprinters</td>
<td>20.8 (1.0)</td>
<td>174.5 (4.3)</td>
<td>67.6 (5.3)</td>
<td>39.8 (1.2)</td>
<td>39.8 (1.5)</td>
</tr>
<tr>
<td>Untrained Subjects</td>
<td>20.7 (1.8)</td>
<td>173.1 (4.2)</td>
<td>70.2 (7.7)</td>
<td>39.7 (1.2)</td>
<td>39.8 (1.4)</td>
</tr>
</tbody>
</table>
Muscle and Tendon Thickness

The muscle thickness for knee extensors (eight anatomical sites) and plantar flexors (six anatomical sites) were measured with an ultrasonic apparatus (SSD-900, Aloka, Japan). The subjects remained in a supine position for the measurements of knee extensors and a prone position for the measurements of plantar flexors with legs straight and the muscles relaxed. The anthropometric locations of the measurement sites were first precisely determined and marked by experienced technicians before the ultrasonic measurement. A transducer with a 7.5-MHz scanning head was coated with water-soluble transmission gel, which provided acoustic contact without depressing the dermal surface. One ultrasonic image of each site was obtained, and the thickness of each muscle was analyzed in the middle side of each image. The thickness of each site was measured to the nearest 0.1 mm. The anatomical sites for the measurements are noted below and presented in Figure 1.

For knee extensors, the mean values of muscle thickness at central (three sites), lateral (three sites), and medial sides (two sites) were adopted as their representative of each part. For plantar flexors, the mean values of muscle thickness of medial gastrocnemius muscle (three sites), lateral gastrocnemius muscle (three sites), and soleus muscle (six sites) were adopted as their representative of each part. The repeatability of the muscle thickness measurements was investigated on seven separate days in one subject. For knee extensors, the coefficient of variance was 2.1% for central side, 2.6% for lateral side, and 2.4% for medial side. For plantar flexors, the coefficient of variance was 1.9% for medial gastrocnemius muscle, 2.2% for lateral gastrocnemius muscle, and 2.5% for soleus muscle. Furthermore, in a preliminary study (n = 20), we found that the mean thickness values of each muscle in knee extensors and plantar flexors were significantly correlated to the muscle volume measured by magnetic resonance imaging (all p < .05): rectus femoris, r = .581; vastus lateralis, r = .666; vastus intermedius, r = .455; vastus medialis, r = .465; medial gastrocnemius, r = .762; lateral gastrocnemius, r = .653; and soleus, r = .558.

Knee extensors were measured at eight sites: on the anterior central (rectus femoris and vastus intermedius), lateral (vastus lateralis and vastus intermedius), and medial (vastus medialis and vastus intermedius) surfaces 30% (proximal; excluded medial site), 50% (middle), and 70% (distal) between the lateral condyle of the femur and the greater trochanter.

Plantar flexors were measured at six sites: on the posterior medial (medial gastrocnemius, soleus, and flexor digitorum) and lateral (lateral gastrocnemius, soleus, and tibialis posterior) surfaces 20% (proximal), 30% (middle), and 40% (distal) between the lateral malleolus of fibula and the lateral condyle of the tibia.

In addition, the thicknesses of the patella and Achilles tendon were measured at 50% of patella tendon length and at 30 mm proximal from the calcaneus, respectively. During the measurement of tendon thickness, the knee and ankle joint angles were at 90°.

Statistics

Descriptive data are represented as the means ± SD. One-way ANOVA was used for the comparison between the
two groups. A linear regression analysis was performed on the relationships among the measured variables of muscles and tendons, and the best official record of a 100-m race for sprinters. The level of significance was set at \( p < .05 \).

### Results

Table 2 shows the measured variables of muscles for the two groups. For knee extensors, the thickness of medial side was significantly greater in sprinters than in untrained subjects (\( p = .020 \)), although there were no differences in the muscle thickness of other parts for knee extensors. For plantar flexors, the thickness values of all measured muscles (medial gastrocnemius, lateral gastrocnemius, and soleus) were significantly greater in sprinters than in controls for plantar flexors (all \( p < .05 \)). The MVC tended to be higher in sprinters than in untrained subjects for plantar flexors (\( p = .073 \)), but not for knee extensors (\( p = .686 \)). For both knee extensors and plantar flexors, there were no differences in neural activation levels between sprinters and untrained subjects.

Table 3 shows the measured variables of tendons for the two groups. For both tendons, there was no difference in tendon thickness between sprinters and untrained subjects. The L values at force production levels beyond 400 N were significantly greater in sprinters than in untrained subjects for knee extensors, but not for plantar flexors (Figure 2). Similarly, the maximal elongation of tendon structures of sprinters was significantly greater than that of untrained subjects for knee extensors (\( p < .001 \)), but not for plantar flexors (\( p = .176 \)). The stiffness of tendon structures of sprinters was significantly lower than that of untrained subjects for knee extensors (\( p = .030 \)), but not for plantar flexors (\( p = .437 \)).

For untrained subjects, the stiffness of tendon structures was significantly correlated to the MVC in both knee extensors (\( r = .613, p < .05 \)) and plantar flexors (\( r = .726, p < .01 \)) (Figure 3). For sprinters, by contrast, the stiffness of tendon structures was not correlated to the MVC in both knee extensors (\( r = .195, p > .05 \)) and plantar flexors (\( r = .244, p > .05 \)) (Figure 4).

For sprinters, the best official record of a 100-m race was significantly correlated to the muscle thickness of the medial side for knee extensors (\( r = -.616, p < .05 \)) (Figure 5). However, no significant correlations were found between the best official record of a 100-m race and the other measured variables of muscles and tendons.

### Discussion

According to the previous findings (Kubo et al., 2000a; Stafilidis & Arampatzis, 2007), the tendon structures in knee extensors were more compliant in excellent sprinters (the best official record of a 100-m race was about 11.0 s) than that in inferior sprinters and untrained subjects. The present result using highly trained sprinters (the best official record in a 100-m race was from 10.58 to...
### Table 2  Mean (SD) measured variables of muscle for sprinters and untrained subjects

<table>
<thead>
<tr>
<th></th>
<th>Sprinters</th>
<th>Untrained Subjects</th>
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<tbody>
<tr>
<td><strong>Knee Extensors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVC (N·m)</td>
<td>231.6 (45.1)</td>
<td>223.8 (55.1)</td>
</tr>
<tr>
<td>Muscle thickness at three central sites (mm)</td>
<td>44.4 (4.5)</td>
<td>42.0 (4.7)</td>
</tr>
<tr>
<td>Muscle thickness at three lateral sites (mm)</td>
<td>43.2 (3.3)</td>
<td>44.2 (5.1)</td>
</tr>
<tr>
<td>Muscle thickness at two medial sites (mm)</td>
<td>42.3 (4.5)*</td>
<td>38.6 (3.8)</td>
</tr>
<tr>
<td>Neural activation level (%)</td>
<td>92.7 (5.1)</td>
<td>92.2 (5.6)</td>
</tr>
<tr>
<td><strong>Plantar Flexors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MVC (N·m)</td>
<td>146.7 (18.3)</td>
<td>130.8 (25.8)</td>
</tr>
<tr>
<td>Muscle thickness of MG at three medial sites (mm)</td>
<td>25.5 (3.1)**</td>
<td>22.4 (2.6)</td>
</tr>
<tr>
<td>Muscle thickness of LG at three lateral sites (mm)</td>
<td>21.6 (2.4)**</td>
<td>18.5 (3.6)</td>
</tr>
<tr>
<td>Muscle thickness of SOL at six sites (mm)</td>
<td>20.5 (2.6)*</td>
<td>18.1 (2.1)</td>
</tr>
<tr>
<td>Neural activation level (%)</td>
<td>92.1 (4.1)</td>
<td>90.3 (10.1)</td>
</tr>
</tbody>
</table>

*Significantly different from untrained subjects (*p < 0.05, **p < 0.01, ***p < 0.001).

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**Figure 2** — The muscle force (Fm): elongation of tendon structures (L) in knee extensors (A) and plantar flexors (B) for sprinter (closed) and untrained subject (open). *Significantly different from untrained subjects at p < .05.

**Figure 3** — The relationships between MVC and stiffness of tendon structures in knee extensors (A) and plantar flexors (B) for the untrained subject group.
Figure 4 — The relationships between MVC and stiffness of tendon structures in knee extensors (A) and plantar flexors (B) for the sprinter group.

Figure 5 — The relationships between the best official record of a 100-m race and maximal elongation (A) and stiffness (B) of tendon structures in knee extensors, muscle thickness at the medial side of knee extensors (C) for the sprinter group.

Table 3  Mean (SD) measured variables of tendon for sprinters and untrained subjects

<table>
<thead>
<tr>
<th></th>
<th>Sprinters</th>
<th>Untrained Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knee Extensors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tendon thickness (mm)</td>
<td>3.15 (0.47)</td>
<td>3.27 (0.50)</td>
</tr>
<tr>
<td>Maximal elongation of tendon structures (mm)</td>
<td>29.3 (4.7) ***</td>
<td>22.7 (3.8)</td>
</tr>
<tr>
<td>Stiffness of tendon structures (N-mm⁻¹)</td>
<td>70.5 (11.7) **</td>
<td>90.0 (21.0)</td>
</tr>
<tr>
<td><strong>Plantar Flexors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tendon thickness (mm)</td>
<td>4.28 (0.54)</td>
<td>4.34 (0.63)</td>
</tr>
<tr>
<td>Maximal elongation of tendon structures (mm)</td>
<td>18.1 (2.9)</td>
<td>16.0 (3.6)</td>
</tr>
<tr>
<td>Stiffness of tendon structures (N-mm⁻¹)</td>
<td>44.0 (12.4)</td>
<td>39.7 (15.9)</td>
</tr>
</tbody>
</table>

*Significantly different from untrained subjects (**p < 0.01, ***p < 0.001).
the stiffness of tendon structures was not related to MVC knee extensors and plantar flexors of sprinter, however, knee extensors and plantar flexors (Figure 3). For both between MVC and stiffness of tendon structures for both the current study, there were significant correlations muscle force of plantar flexors. In untrained subject of ing to the finding of Muraoka et al. (2005), the stiffness stiffness might be related to the muscle strength. Accord- between MVC and stiffness of tendon structures for both plantar flexors between sprinter and untrained subject. As men- plated later, the MVC of plantar flexors was significantly higher in sprinters than in endurance runners and untrained subjects. In the study of Arampatzis et al. (2007), the MVC of plantar flexors was significantly higher in sprinters than in long distance runners and untrained subjects. In the current study, however, there was no significant difference in the MVC of plantar flexors between sprinter and untrained subject. As men- tioned later, the MVC of plantar flexors was significantly correlated to the stiffness of tendon structures. Consid- ering these points, the discrepancy between the present and previous studies could be explained by the difference in MVC between the two groups. This result agreed with the previous findings (Kubo et al., 2000a; Stafilidis & Arampatzis, 2007). However, Arampatzis et al. (2007) reported that the elastic properties of tendon structures in plantar flexors were stiffer in sprinters than in long distance runners and untrained subjects. The discrepancy between the present and previous studies could be explained by the range of the best official record of a 100-m race. For plantar flexors, there were no differences in the maximal elongation and stiffness of tendon structures between the two groups. This result agreed with the previous findings (Kubo et al., 2000a; Stafilidis & Arampatzis, 2007). However, Arampatzis et al. (2007) reported that the elastic properties of tendon structures in plantar flexors were stiffer in sprinters than in long distance runners and untrained subjects. In the study of Arampatzis et al. (2007), the MVC of plantar flexors was significantly higher in sprinters than in endurance runners and untrained subjects. In the current study, however, there was no significant difference in the MVC of plantar flexors between sprinter and untrained subject. As men- tioned later, the MVC of plantar flexors was significantly correlated to the stiffness of tendon structures. Consid- ering these points, the discrepancy between the present and previous studies could be explained by the difference in MVC between the two groups. Similarly, we found that the remarkable difference in the tendon properties between the long-distance runners and untrained subjects was found for knee extensors, but not for plantar flexors (Kubo et al. 2010). Accordingly, it is likely that no dif- ference in the tendon properties for plantar flexors can be attributed to the lower plasticity compared with those for knee extensors. Regardless, further investigations are needed to clarify this point.

The tendon structures in lower limbs are frequently subjected to considerable loads during running. For both knee extensors and plantar flexors, therefore, the tendon stiffness might be related to the muscle strength. According to the finding of Muraoka et al. (2005), the stiffness of human Achilles tendon was correlated to the maximal muscle force of plantar flexors. In untrained subject of the current study, there were significant correlations between MVC and stiffness of tendon structures for both knee extensors and plantar flexors (Figure 3). For both knee extensors and plantar flexors of sprinter, however, the stiffness of tendon structures was not related to MVC (Figure 4). Recent studies indicated that the influences of training on tendon stiffness differ among the exercise protocols used. In particular, we reported that the tendon stiffness did not change after ballistic and plyometric training regimens, although the tendon stiffness increased markedly after isometric training of a longer duration (Kubo et al., 2001, 2007b). Taking the present result into account, we may say that the sprint training of sprinter had a great impact on the muscle properties in lower limbs but not on their tendon properties. To clarify this point, we need to investigate the genetic effects on the tendon properties for sprinters in the future study.

Another interesting finding of this study was that the thickness of the medial side of knee extensors was greater in sprinters than in untrained subjects, and thus that was significantly correlated to the best official record of a 100-m race. Some previous researchers demonstrated that the hamstring and psoas major muscles played an important role during sprint running (Hoshikawa et al., 2006; Mero et al., 1992). However, there were a few stud- ies investigating the muscle size in sprinters compared with untrained subjects (Abe et al., 2000; Maughan et al., 1983). In addition, the muscle size of lower limbs in sprinters might not be evaluated correctly because the muscle size was measured for only one slice of magnetic resonance imaging and ultrasonic image. Maughan et al. (1983) reported that the muscle cross-sectional area of knee extensors was greater in the sprinters than in the control subjects but this difference was not significant. In the current study, the difference in the muscle thickness of only the medial side (mainly, the vastus medialis muscle) of knee extensors was found between sprinter and untrained subject. Toumi et al. (2007) reported that the activation of vastus medialis muscle was higher during landing of “single-leg” squat jump, whereas the vastus medialis and vastus lateralis muscles were activated in a coordinated manner during a squat jump using “both legs.” Therefore, it seems reasonable to support the idea that the vastus medialis muscle among the knee extensor muscles is subjected to considerable loads during sprint running, that is, the repeated landing using a single leg.

To calculate the muscle force, we used the ratio of vastus lateralis muscle to the knee extensors and medial gastrocnemius muscle to the plantar flexors in terms of physiological cross-sectional area from the literature (Fukunaga et al., 1996; Narici et al., 1992) as the contribution of the muscle for force development. For plantar flexors, there were no significant differences in the ratios of muscle thickness of “lateral gastrocnemius / medialis gastrocnemius” and “soleus / medialis gastrocnemius” between the two groups (data not shown), although the thicknesses of each muscle (medial gastrocnemius, lateral gastrocnemius, and soleus) were significantly greater in sprinters than in untrained subjects (Table 2). Therefore, the relative contribution of medial gastrocnemius muscle for force production of plantar flexors was similar between the two groups. On the other hand, the muscle thickness of the medial side of knee extensors was significantly greater in sprinters than in untrained
subjects, although there were no differences in the muscle thickness of other parts for knee extensors (Table 2). Considering this point, it is likely that the actual tendon elongation of vastus lateralis muscle for sprinter would be underestimated, if the contribution of vastus lateralis muscle for force production of knee extensors might be lower in sprinters than in untrained subjects. Hence, we considered that these points did not affect the main result, which was that the tendon structures of sprinters were more compliant than those of untrained subjects for knee extensors.

Furthermore, we calculated the muscle force using the moment arm length from the previous studies (Rugg et al., 1990; Smidt, 1973). Unfortunately, we have no definite information on the difference in moment arm length between sprinters and untrained subjects. As far as we know, there were few reports concerning the differences in moment arm length between the two groups (Arampatzis et al., 2007; Lee & Piazza, 2009). Lee & Piazza (2009) reported that the Achilles tendon moment arm length of sprinters was 25% smaller than that of non-sprinters. However, Arampatzis et al. (2007) showed that there was no difference in the ratio of tendon elongation to joint rotation during passive rotation (corresponding to the moment arm length) among the sprinters, endurance runners, and untrained subjects. Furthermore, some previous studies indicated that the moment arm length changed with changes in joint angle and exerted force level (e.g., Maganaris et al., 1998). Therefore, it would be difficult to measure the accurate moment arm length at present.

In conclusion, the tendon structures of highly trained sprinters are more compliant than those of untrained subjects for knee extensors, but not for plantar flexors. Furthermore, the thickness of medial side of knee extensors (mainly, the vastus medialis) was significantly correlated to the best official record of a 100-m race.

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References


