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CHANGE IN MECHANICAL PROPERTIES OF TRICEPS SURAE MUSCLE-TENDON UNIT AND RACE PERFORMANCE AFTER 1 YEAR IN WELL TRAINED DISTANCE RUNNERS

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The purpose of this study was to determine change in relationship between stiffness of triceps surae muscle-tendon unit and race performance after one year with continuous training in well trained long distance runners. For 9 long distance runners, official race record and stiffness indexes of both muscle and tendon were investigated in pre and post measurements (after one year). The race performance (1.9%), passive torque of ankle joint (13.2%), and muscle stiffness index (73.6%) increased significantly between pre and post. Although significant correlations were not found between increment of race performance and change in all parameters, 6 of the 9 athletes showed increments of both race performance and stiffness index of muscle tissue. These results suggest that an increment of stiffness of the ankle joint and triceps muscle could be related to improvement of race performance in distance running.

KEYWORDS: stiffness, longitudinal, ankle joint

INTRODUCTION: In distance running, not only cardio-vascular abilities but also mechanical properties of the muscle tendon unit are important. Several previous researchers have reported positive correlations between mechanical properties of the muscle-tendon unit and race performance in long distance running in cross-sectional study designs (Kubo et al., 2010; Oda et al., 2014). These reports suggested the possibility that the difference of stiffness in muscle and tendon could influence increment of usage of elastic energy in tendon and efficient achievement of muscle-tendon interaction (Albracht & Arampatzis, 2013) as well as passive torque generation during stance phase (Oda et al., 2014). However, there is little information so far of these relations in a longitudinal design study. The purpose of this study was to determine the change in relationship between stiffness of triceps surae muscle-tendon unit and race performance after one year with continuous training in well trained long distance runners.

METHODS: Nine well trained long distance runners (Mean ± SD: 167.8 ± 3.9 cm, 52.6 ± 2.8 kg, age 16.4 ± 0.4 years) participated voluntarily in this study. Their best official record was mean ± SD of 15 min 10 ± 31 s in 5000 m race event. The official race record was confirmed from the official data bases of national or local athletics committees.
Stiffness indexes of both muscle and tendon were determined in pre and post measurements (after one year) as the slope of lengthening in tissues measured using B mode ultrasonic images and joint torque. The subjects sat on the bench with left knee fully extended, and the left foot was secured by non-elastic strapping to an adjustable footplate which has an ankle torque measurement system. In this system, the joint angle could be changed every 10° by rotating the footplate, with the fixation of the footplate at every 10° available. To determine the lengthening of muscle tissue, the ultrasonic apparatus (C3CV, Hitachi-Aloka Inc., Tokyo, Japan) with an electronic linear array probe was used to obtain longitudinal ultrasonic B-mode images of medial gastrocnemius (MG) muscle. The probe was put on the surface of central portion of muscle belly of MG muscle. For measurement of tendon stiffness, the left foot was secured to the foot plate at 0° (anatomical position) by non-elastic strapping. Elongation of Achilles tendon was assessed during isometric plantar flexion with B-mode

ultrasonic images. The subject was instructed to develop a gradually increasing force from a relaxed state to maximal voluntary contraction within 5 s. The task was repeated two times per subject with at least 3 min between trials.
The stiffness index was defined as the slope of length of elongation-loaded force relationship for each muscle and tendon tissues. The muscle stiffness index was computed in the range, from 10° plantar flexion to 0° and from 0° to 10° dorsiflexion, respectively. The stiffness index of tendon is generally non-linear in form. In the present study, the linear region was used for calculation. Paired t-test and correlation coefficient were used for statistical analyses.

RESULTS: Figure 1 shows the data with significant differences statistically between pre-post measurements. The race performance (1.9%), passive torque of ankle joint (11.8% at 10° plantar flexion, 7.0% at 0° and 13.2% at 10° dorsi flexion), and muscle stiffness index from 0° to 10° dorsi flexion (73.6%) were increased.

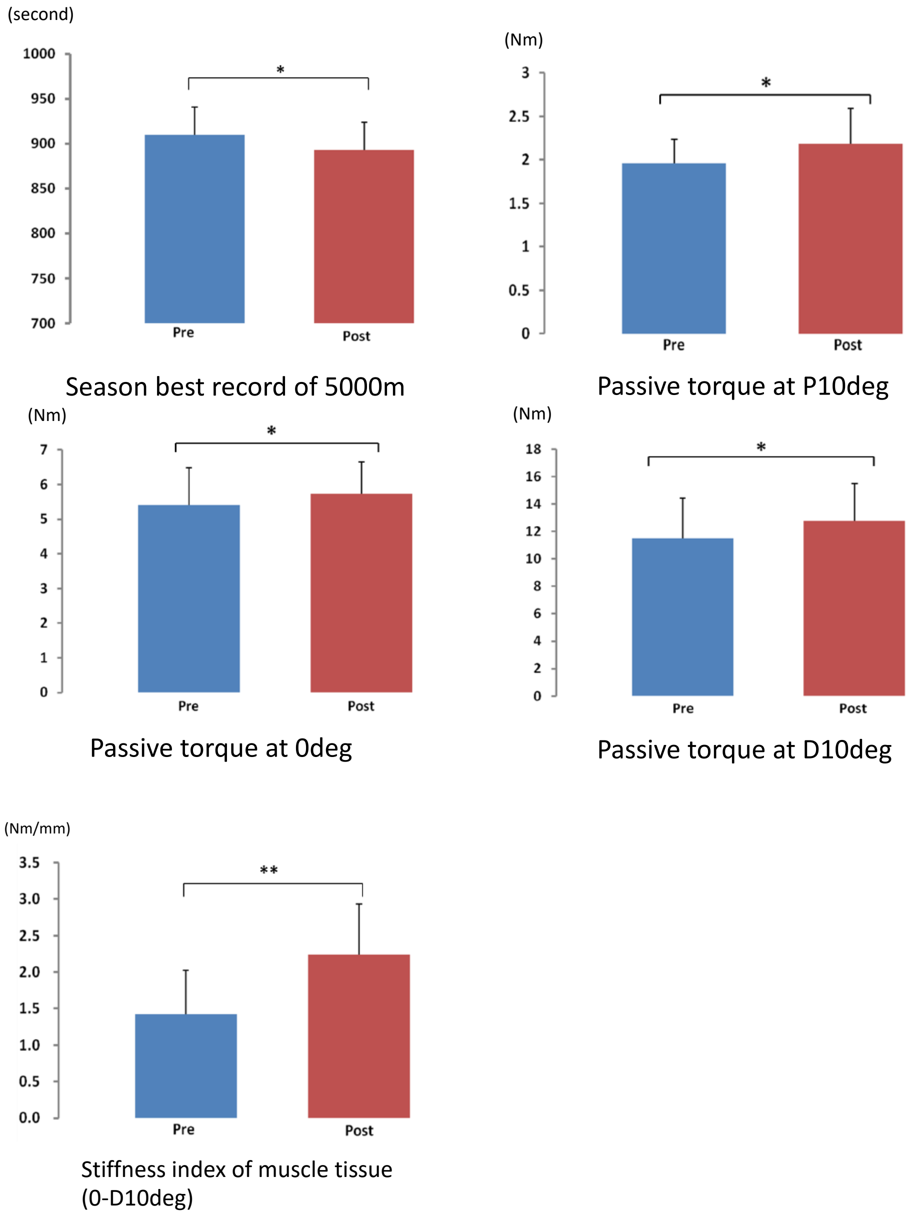

Figure 1: Parameters with significant difference between pre and post
P means plantarflexion, D dorsiflexion (* p<0.05, ** p<0.01)

No statistically significant change was observed in other parameters including the tendon stiffness index. Although significant correlations were not found between increment of official race performance record and change in all parameters, 6 of the 9 athletes showed both increments of race performance and stiffness index of muscle tissue (Figure 2).

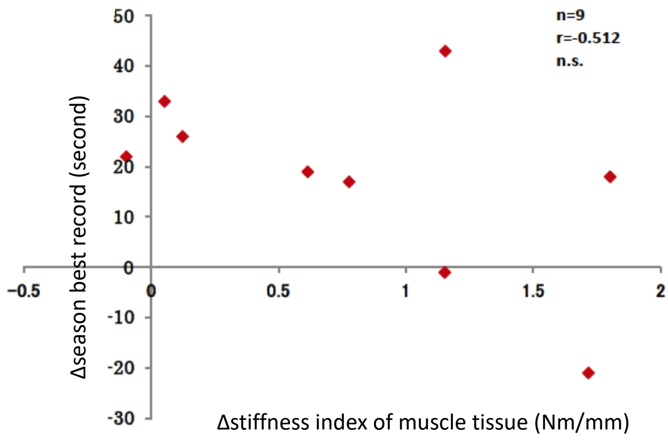

Figure 2: Relation between changes in season best record and stiffness index of muscle tissue.

DISCUSSION: The present study demonstrated the relationship between stiffness of muscle tissues and race performance in a longitudinal design study. After one year with continuous training for well-trained athletes, the ensemble averages of joint passive torque, stiffness index of muscle tissue and official race performance were significantly increased.

Previous reports suggested the possibility that the difference of stiffness in muscle and tendon could influence to improve performance of distance running (Arampatzis et al., 2006). But most studies so far have carried out in cross sectional design. The result in the present study imply that change in stiffness of muscle tissue with training could affect improvement of race performance in well trained long distance runners over a one year period

The mechanical properties of muscle and tendon might increase the usage of elastic energy in tendon and efficient achievement of muscle-tendon interaction (Albracht & Arampatzis, 2013) as well as passive torque generation during stance phase (Oda et al., 2014). In addition, the correlations between mechanical properties of muscle-tendon unit and running economy in distance running were also reported (Arampatzis et al., 2006). In the previous studies, there have been inconsistent results as to which is better for distance runners, stiff or complainant tissue. This study showed stiff muscle tissue might be advantageous for distance running. Moreover, no significant change was shown in tendon stiffness.

In training experiments, it was reported that interventions of jump training such as hurdle jump improved the performance of long distance running (Ramirez-Campillo et al., 2014), interestingly. But this kind of training could modify not only mechanical properties of tissues but also activation timing of muscle in the pre-activation phase before stretch-shortening cycle at stance phase. The measurement of change in mechanical properties of muscle-tendon unit by such kinds of training is required to clarify the mechanisms of physiological change by continuous jump training.

In the present study, we could not measure cardiovascular ability which may be improved by continuous training of distance running for one year. The combined experiments examining mechanical properties, cardiovascular abilities and motion analyses will be needed to clarify the complex effects of continuous endurance training for improvement athletic performances in all endurance sports as well as long distance running.

CONCLUSION: The race performance (1.9%), passive torque of ankle joint (11.8% at 10deg plantarflexion, 7.0% at 0deg and 13.2% at 10deg dorsiflexion), and muscle stiffness index (73.6%) increased significantly after one year of training in 9 well trained long distance runners. Six of the nine athletes showed increments of both race performance and stiffness index of muscle tissue. Increments of stiffness of ankle joint and triceps surae muscle could be related to improvement of race performance in distance running.

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ACKNOWLEDGEMENTS: The authors would like acknowledge Mr. Koei Adachi and Mr. Yuta Kira with help for experiments of athletes. This work was supported by MEXT/JSPS KAK- ENHI Grant Number 23500729, 17H02156, 15KK0261, 26702026.