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CAN MEASURES OF MUSCLE-TENDON INTERACTION REVEAL THE SUPERIORITY OF EAST AFRICAN ENDURANCE RUNNERS?

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SUMMARY

Leg muscle activation profiles and muscle-tendon interaction were studied with internationally high level East African and Japanese runners. Methods of ultrasonography (US) and kinematics were applied together with EMG recordings of lower limb muscles when the subjects ran on treadmill at 9.0, 12.8 km h^{-1}. The kinematic analysis revealed that in contrast to Japanese runners, Africans demonstrated smaller knee and ankle flexion during the braking phase, smaller ankle joint extension during the push-off phase. The US analysis revealed for the Africans smaller amplitudes ($p<0.05$) of stretching and shortening of the tendinous tissue of the gastrocnemius medialis (MG) during contact, but greater tendon contribution to the muscle-tendon unit shortening ($p<0.05$). They presented also shorter values and less shortening of MG fascicle lengths. The Africans were characterized by lower braking/preactivation ratio in both MG and tibialis anterior muscles ($p<0.01$). The finding of a negative relationship ($r = -0.70$ $p<0.05$) in the sole African group between the Achilles tendon moment arm and the MG activation ratio (contact /preactivation) would support the notion that the muscle-tendon structures of the Africans could influence the activation profiles of their muscles with possible, but partial consequence to explain the high running economy of East African endurance runners.

INTRODUCTION

The superior success of east African endurance runners (Africans), especially those coming from Kenya, has stimulated large amount of interest to explore valid reasons for this performance. The approaches used have included attempts to explain their high performance being due to such factors as the superior genetic make-up, early involvement of the young boys and girls in high intensity physical activity, favorable diet, continuous living and training in high altitude, and motivation for athletes to achieve higher economic status in their country. Contrasting the expectations, reliable physiological studies conducted on the Kenyan runners have not shown that they would be markedly different in many basic physiological parameters from their e.g. European counterparts; however, they seem to have high maximal aerobic capacity associated with exceptionally good running economy (Saltin et al. 1995). This finding of high running economy could not be explained by any of the histochemical and/or biochemical parameters measured from the muscle biopsy samples. Consequently, it was a clear conclusion of these reports of Saltin et al. (1995) that one of the possible reasons for the high mechanical efficiency (or running economy) could be the special biomechanical make-up of these runners in their structure and function of the triceps surae muscle-tendon complex, such as the storage and utilization of elastic energy in skeletal muscles.

More concretely, the question could be asked and answered, partially at least, if the Kenyan runners possess a particular type of muscle-tendon complex and especially its Achilles tendon, to store and utilize elastic energy in the stretch–shortening cycle (SSC), which is the basic form of muscle function in running (e.g. Komi, 1990). In order to ask and answer this question objectively, basic information is first needed regarding the specifics of the structure and function of the lower leg among the African superior level middle and long distance runners.

The present study was therefore designed to extend the measures to a testing condition closer to the normal running one. To increase the possibility for better generalization the study included also international competitive level Japanese middle- and long-distance runners as controls. The athletes were also studied for their MG fascicles and tendon characteristics in resting standing position with US. Muscle-tendon interaction was measured by combining the telemetric EMG records with the simultaneous US records during treadmill running at two different submaximal speeds.

METHODS

Subject:

Eleven elite Africans and Japanese middle and long distance male runners volunteered to participate in the study. All of them had previously participated in major national and/or international running competitions and were currently training for the competitions of the coming season. The pair matching of the Japanese subjects to each African subject was performed within error of less than 1 cm in body height. The anthropometric data of the two groups are presented in Table 1.

Protocol:

After several minutes of habituation to treadmill running, the subjects took a standing position for measurements of the anthropometric parameters. The MG fascicle lengths and their pennation angles as well as the Achilles tendon moment arm were measured in the upright position by ultrasonography (linear array probe with scanning frequency of 13 MHz, Hitachi-Aloka Inc., Japan). After these anthropometric measurements and treadmill running practices, the subjects ran on the treadmill for 2 minutes at two different submaximal speeds (slow: 9.0 and medium: 12.8 km h^{-1}, respectively).

Measured parameters:

All the runs on the treadmill were recorded with a high-speed video camera at 240 fps (HDR-CX550V, SONY, Japan) from the left side perpendicularly to the line of motion to calculate knee and ankle joint angles. The obtained joint angles were used to calculate the instantaneous MG muscle-tendon unit length (MG L_{MTU}) with the model of Hawkins and Hull (1990). Ultrasonography was applied to measure the MG fascicle length (L_{Fa}) during running. The instantaneous length of MG tendinous tissues (MG L_{TT}) was calculated by subtracting MG L_{Fa} multiplied by the cosine of its pennation angle from L_{MTU} (e.g. Kubo et al. 2000).

EMG activities were recorded from tibialis anterior (TA), soleus (SOL) and MG muscles of the left leg using bipolar surface active electrodes (NM-512G, Nihon Koden, Japan) with a multi-telemeter AD converter system (WEB-5000, NIHON KODEN, Japan) (sampling frequency 1kHz).

During running, the braking (stretching) and push-off (shortening) phases were determined based on the peak L_{MTU} stretch during the contact phase. The pre-activation (PRE) phase was originally defined as the 100 ms period preceding the ground contact. Average muscle activity (aEMG) was then calculated for the preactivation, braking and push-off phases as well as for the total contact phases.

To synchronize the kinematic, US and EMG data, all recordings were triggered by a foot switch sensor (SEN-08713, FlexiForce, USA) positioned under the ball part of the left foot as none of these runners were heel strikers.

For the Achilles tendon moment arm measurements, the US images of the transverse plane for the tip of medial malleolus and Achilles tendon, and the tip of lateral malleolus and Achilles tendon were measured for both legs.

RESULTS AND DISCUSSION

The anthropometric data of two groups were similar in age, height and body mass, but they differed in shank length and in MG muscle and tendon characteristics (Table 1).

The kinematic analysis did not reveal any significant inter-group difference in either contact time (slow: 265 ± 36 vs. 262 ± 43 ms; medium: 226 ± 23 vs. 220 ± 20 ms) or duration of the respective braking (slow: 129 ± 28 vs. 130 ± 17 ms; medium: 111 ± 25 vs. 113 ± 10 ms) and push-off phases (slow: 136 ± 37 vs. 132 ± 38 ms; medium: 115 ± 23 vs. 108 ± 16 ms) for Africans and Japanese, respectively. Analysis for the contact phase revealed that the Africans had smaller amplitudes of both knee and ankle flexion during the braking phase of both running speeds ($p<0.05$), and smaller ankle extension during the push-off phase of the medium running speed ($p<0.01$).

The US analysis of the treadmill runs demonstrated for both groups during the contact period the classical SSC behavior of the MG L_{MTU} and L_{TT}, but not for the MG L_{Fa}. The MG fascicles of the Africans were operated in shorter relative lengths in both running conditions ($p<0.01$). As compared to the Japanese group, the Africans presented smaller amplitudes of the MG L_{TT} stretching and shortening during contact. However, the shortening ratio of the MG L_{TT} to the L_{MTU} was significantly greater among the Africans.

The Africans showed also lower braking/preactivation EMG ratio in both MG ($p<0.05$) and TA ($p<0.05$) muscles.

Inter-group comparison of the Achilles tendon moment arm length showed that it was significantly longer in the African as compared to the Japanese runners (Table 1). The finding of a negative relationship ($r = -0.70$ $p<0.05$) in the sole African group between the Achilles tendon moment arm and the MG activation ratio (contact /preactivation) would support the notion that the muscle-tendon structures of the Africans could influence the activation profiles of their muscles with possible, but partial consequence to explain the high running economy of East African endurance runners.

Table 1. Anthropocentric data for Africans and Japanese runners

	Africans (n=11)	Japanese (n=11)	
Age (yr)	21.0 ± 6.4	19.5 ± 4.2	
Height (cm)	174.1 ± 8.2	172.5 ± 5.2	
Body mass (kg)	56.1 ± 7.1	58.1 ± 5.1	
Shank length (cm)	39.5 ± 3.0	36.7 ± 2.0	*
MG MTU (cm)	43.4 ± 3.5	40.1 ± 2.1	*
MG fascicle length (cm)	4.8 ± 0.7	5.8 ± 0.6	**
MG pennation angle (degree)	20.0 ± 2.1	15.0 ± 1.5	**
MG tendinous tissue length (cm)	39.4 ± 3.2	34.5 ± 2.2	**
Moment arm (mm)	38.0 ± 3.8	29.5 ± 5.5	**

* and **: significant difference between Kenyan and Japanese groups ($p<0.05$ and $p<0.01$, respectively).

CONCLUSIONS

Our data clearly showed that greater shortening ratio of the MG L_{TT} to the L_{MTU} together with less TA and MG muscle activations during the preactivation, braking and push-off phases observed for Africans give reasons for the new hypothesis that the African runners have a specific type of muscle-tendon structure, with subsequently reduced EMG activity leading then to high running economy.

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REFERENCES

1. Hawkins D & Hull ML, *J Biomech* **23**:487–494, 1990.
2. Komi PV, *J Biomech* **23**:23–34, 1990.
3. Kubo K, et al., *Acta Physiol Scand* **170**:127–135, 2000.
4. Saltin B, et al., *Scand J Med Sci Sports* **5**:209–230, 1995.