RUNNING ECONOMY AND GASTROCNEMIUS MUSCLE LENGTH DURING RUNNING FOR KENYAN AND JAPANESE ELITE DISTANCE RUNNERS

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The purpose of this study was to compare running economy and gastrocnemius muscle length during running for Kenyan and Japanese elite distance runners. Running economy was measured on the treadmill at 340 m/min while running motion was captured on the inside straight track at their racing speed. Gastrocnemius muscle length was estimated by the equation of Grieve et al. (1978) during the support phase at race speed running on the track. Kenyan runners showed higher running economy and smaller shortening length change of gastrocnemius during support phase than Japanese. These results suggest that shortening gastrocnemius during support phase of the running relates to running economy.

KEY WORDS: distance running, muscle-tendon unit length, two-joint muscle, efficiency.

INTRODUCTION: Many researchers reported that Kenyan runners could run with low oxygen consumption at a sub-maximal running speed, which means Kenyan runners show high running economy. Saltin (2003) suggested that high running economy for Kenyan runners was due to the small circumference of their calf and consequent small moment of inertia. Okada et al. (2009) indicated a difference for running economy between Kenyan and Japanese runners but they made not clear the relationships between running economy and shank inertia properties. Enomoto et al. (2009) showed that there are differences between Kenyan and Japanese running motion but not a clear difference in mechanical work and energy, which suggested that Kenyan runners could run more efficiently at a given level of muscle mechanics. The purpose of this study is to compare running economy and gastrocnemius muscle length during running for Kenyan and Japanese elite distance runners.

METHODS: Five male Kenyan and five male Japanese elite distance runners were participated in the study. The fifth finisher of men's 10000 meter final of the world championships was included for Kenyan and the men's junior 5000 meter record holder was included for Japanese. In the first session, the oxygen consumption of the subjects was measured at 320, 340 and 360 m/min on a treadmill. Each running stage lasted 4 min with 1min rest. The oxygen consumption at 340 m/min was defined as running economy.
In the second session, the subjects were instructed to run at their racing speed for about 80 m in the inside straight track. Running motion and ground reaction force about 60 m apart from the start were captured using twenty VICON cameras at 120 Hz and four force platforms at 1080 Hz synchronized with the camera system. Three dimensional data of the anatomical landmarks of the subjects was converted to the two dimensional data of sagittal plane and then ankle and knee joint angles were calculated.
Gastrocnemius muscle-tendon unit length (dLg) was estimated from ankle and knee joint angles (θ a and θ k, respectively) by equations (1), (2) and (3) (Grieve et al., 1978).

$$dLg = dLga + dLgk \quad (1)$$
$$dLga = -22.18468 + 0.30141(\theta a) - 0.00061(\theta a)^2 \quad (2)$$
$$dLgk = 6.46251 - 0.07987(\theta k) + 0.00011(\theta k)^2 \quad (3)$$

dLg was calculated as a relative value to neutral length of the muscle at 90 degrees of ankle and knee joints.

RESULTS AND DISCUSSION: Running economy for Kenyan and Japanese runners were 58.1 (3.9) ml/kg/min and 65.6 (4.0) ml/kg/min, respectively. There was a significant difference between Kenyan and Japanese ($p<0.01$).
Table 1 shows running parameters for Kenyan and Japanese runners of a cycle running on the track. There were significant differences in step length and support time. These results show that Kenyan runners have longer step length and support time than Japanese although having the same running speed.

Table 1.
Running parameters in a running cycle

Parameters		Kenyan	Japanese	
Running velocity	m/s	6.16 ± 0.12	6.07 ± 0.21	
Step length	m	1.93 ± 0.09	1.77 ± 0.07	$p<0.05$
Step frequency	steps/s	3.20 ± 0.19	3.43 ± 0.20	
Support time	s	0.155 ± 0.004	0.143 ± 0.008	$p<0.05$
Non-support time	s	0.158 ± 0.016	0.149 ± 0.017	

Figure 1 shows typical gastrocnemius (GA) length changes for Kenyan (K) and Japanese runners (J) during the support phase at the race speed when running on the track. GA length for Subject K shows a gradual increase in the first half followed by decrease in the second half. The GA length for Subject J at foot strike, maximum length and toe off were smaller than Subject K and time of maximum length occurs earlier.

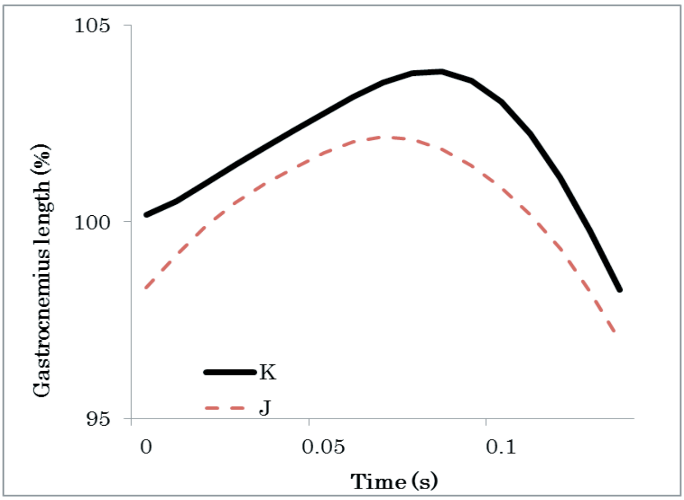

Figure 1: Typical gastrocnemius length changes for Kenyan (K) and Japanese runners (J) during support phase at the race speed. This shows one Kenyan runner and one Japanese runner.

Table 2 shows gastrocnemius length at foot strike, maximum length, and toe-off, and GA length changes and time in the 1st and 2nd halves in the support phase running at their race speeds. GA length for Kenyan runners was greater at maximum length and at toe off and then GA shortening length change for Kenyan was smaller than Japanese. These results indicate that GA for Kenyan does not change greatly in the support phase.

Table 2
Parameters about gastrocnemius muscle length in the support phase of running motion

Parameters		Kenyan			Japanese			
% neutral length								
at foot strike	%	100.8	±	2.3	99.4	±	2.3	
maximum length	%	104.9	±	2.2	102.7	±	1.1	p<0.05
at toe off	%	98.8	±	2.7	96.1	±	1.6	p<0.01
Length change								
in the 1st half	%	4.1	±	1.2	3.3	±	1.3	
in the 2nd half	%	-6.1	±	1.3	-7.1	±	0.5	p<0.05
Time								
in the 1st half	s	0.088	±	0.009	0.072	±	0.010	p<0.01
in the 2nd half	s	0.057	±	0.009	0.065	±	0.007	p<0.05

The correlation coefficients of running economy were 0.151 for lengthening and -0.409 for shortening of GA during the support phase. Fundamental physiology shows that muscle work is greater in concentric than eccentric contraction. And GA work may not influence mechanical work at ankle and knee joint because GA is a two-joint muscle. An important fact is that GA length change is estimated from ankle and knee joint angles. These results also suggest that running kinematics of the lower limb has useful information to evaluate distance running technique.
This work is only the starting one to study the high running economy and high running performance of Kenyan distance runners but muscle mechanics for distance runners offers an important insight to clarify the difference between elite and good runners and offer useful information to improve the running technique and training for distance runners. Furthermore it would imply that circumference length of calf may not be the cause but the effect of Kenyan running technique.

REFERENCES:

Enomoto Y, Yokozawa T, Okada H, Shibutani T, Okazaki K, Morioka Y, Maegawa T, Takamatsu J, Takahashi H, Sugita M (2009) Running economy and running mechanics for Kenyan and Japanese elite runners. *Book of Abstract XXIInd Congress of the International Society of Biomechanics*, Cape Town, South Africa.

Grieve DW, Cavanagh PR, Pheasant S. (1978) Prediction of gastrocnemius length from knee and ankle posture. In: Asmussen E, Jorgensen K, (eds.) *Biomechanics, VI-A.* pp. 405–412.

Okada H, Abe T, Enomoto Y, Shibutani T, Takamatsu J, Yokozawa T (2009) Segment inertial properties of Japanese and Kenyan elite male distance runners determined by three-dimensional body scanner. *Book of Abstract XXIInd Congress of the International Society of Biomechanics*, Cape Town, South Africa.

Saltin B (2003) Kenyan projects: final reports. *New Studies in Athletics* 18. 15-24.