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The Kenya project - Final report

By Bengt Saltin

ABSTRACT

The author reports on the work and key findings of a twin study project, funded by the International Athletic Foundation, to investigate possible explanations for the success Kenyan middle and long distance runners. The first study, looked at groups of boys from the Kenyan town of Eldoret, a rural village in north-western Kenya, and Denmark. The findings include comparisons of daily physical activity, athropometric measures, maximal oxygen consumption, blood lactate and heart rate, muscle fibre composition and enzyme activity, running economy, fractional utilisation of maximal oxygen consumption, trainability and performance in a 5000 metres competition. The second study was on elite Kenyan and Danish runners. The findings include comparisons of athropometric measures, maximal oxygen consumption, blood lactate, muscle fibre composition and enzyme activity, and running economy. The report concludes with the original articles resulting from the study that will be published in appropriate publications.

AUTHOR

Bengt Saltin is an Adjuct Professor at the August Krogh Institute at the University of Copenhagen. His professional interests cover physiology, exercise physiology and applied physiology and he has published more than 300 original research articles. In addition to a wide variety of academic and administrative posts, he has held a number of important positions in sport including President of the International Orienteering Federation (IOF), Chairman of the International Ski Federation (FIS) Medical Committee and Member of the World Anti-Doping Agency Health and Medical Research Committee.

Introduction

Over the last couple of decades, runners from Kenya have had striking success in middle and long distance events. In fact, more than 50% of the performances on the all-time Top 20 lists for men in distances from 800 metres to the marathon are by Kenyans and during the last decade the number of Kenyan men in the Top 50 lists in these distances has increased more than 150%. Among the Kenyans, the Nandi tribe has shown the most profound results although they constitute less than 2% of the population.

Success in distance running events is determined by a number of factors. Research has shown that maximal oxygen consumption (VO_2 max) and running economy (defined as the energy cost per kilogram of body weight when running at a given distance) are critical for performance in endurance running. In addition, a high fractional utilisation of VO_2 max during competition is also essential. It appears that outstanding performance in distance running requires an optimal combination of the above-mentioned factors.

Our previous investigations indicated that elite Kenyan runners do have a very good combination of these crucial factors. However, these findings have to be further elucidated.

There exists considerable anecdotal evidence suggesting a greater response to training in Kenyan runners compared with Caucasian runners. In fact, this may be true since several studies have indicated a level of greater than 70% heritability of the response to training in endurance performance. Furthermore, it has been speculated that Kenyan runners owe their success to a physically active life style, starting in childhood when they walk/run many kilometres a day to and from school. However, valid information about the habitual daily physical activity level of Kenyans is scarce. Moreover, times have changed and in the last couple of decades Kenya has seen increasing urbanisation, leaving fewer isolated rural areas.

Based on the above, we proposed a study of specific factors lifestyle, physiological and training related believed to contribute to the success of Kenyan distance runners,

Our second proposed study aimed to identify the variables that are critical for good performance in long distance running, based on possible observed differences between elite Kenyan and elite Caucasian runners.

The two studies were started in 1998 and are now complete. They have lead to the original articles listed at the end of this report, which have been prepared as a part of a doctoral thesis by Henrik Larsen and will be published in appropriate journals.

Training study – Summary of key findings

The specific aims of this study were:

1. To evaluate:

a) whether sedentary Kenyan boys of Nandi ancestry living in the town of Eldoret differ from those living in a village in the rural area in the north western part of Kenya, and

b) whether these two groups of Kenyan boys differ from sedentary Caucasian boys with respect to variables essential for good performance in distance running.

2. To investigate:

a) whether a given level of training (appropriate for long distance running) induces the same or different adaptations in the Kenyan and Caucasian Danish boys, and

b) the habitual daily physical activity level of the three groups of boys.

Daily physical activity level

The habitual daily physical activity level was not exceptional in any of the three groups of boys. Thus, the Kenyan subjects from both town and village ran less than one kilometre per day between school and home. In addition, none of the Kenyan boys had a high daily physical activity level of endurance type. However, the duration of the daily sports activities (mainly football and volleyball) was significantly higher in Kenyan village boys compared to Kenyan

town boys. This probably explains why the village boys had a higher initial fitness level (VO_2 max) compared to the town boys. The daily physical activity level of Kenyan village boys was similar to what was observed in Danish boys who were moderately engaged in various sport activities.

Anthropometric measures

Untrained Kenyan boys 16-17 years old were 5cm shorter and 12kg lighter than Danish boys. At the same time, the Kenyan boys had 2cm longer legs and 1cm longer lower legs. This means that the upper body, including neck and head, was 7cm shorter in Kenyan boys compared to Danish boys. Furthermore, the volume and the mean thickness of the lower leg were 15 to 17% less in the Kenyan boys compared to Danish boys.

Maximal oxygen consumption

Untrained Kenyan boys from the town have VO_2 max values that are similar to those of untrained Danish boys. In addition, Kenyan boys from the rural village have about 10% greater VO_2 max compared to Kenyan town boys, but similar VO_2 max compared to physically active but not previously endurance trained Danish boys (Figure 1). Following 12 weeks of standardised moderate training the Kenyan town boys tended to increase the VO_2 max more than the Kenyan boys from the village and the Danish boys. However, this conforms with earlier findings that people with a low initial fitness level improve the most from training. The response of VO_2 max to training was similar for Kenyan village boys and Danish boys, indicating that trainability is equal for Kenyans and Danes.

Blood lactate and heart rate

The levels of blood lactate and heart rate at a given submaximal running speed is a good determinant of performance in endurance running. In our investigation, untrained Kenyan boys from the rural village

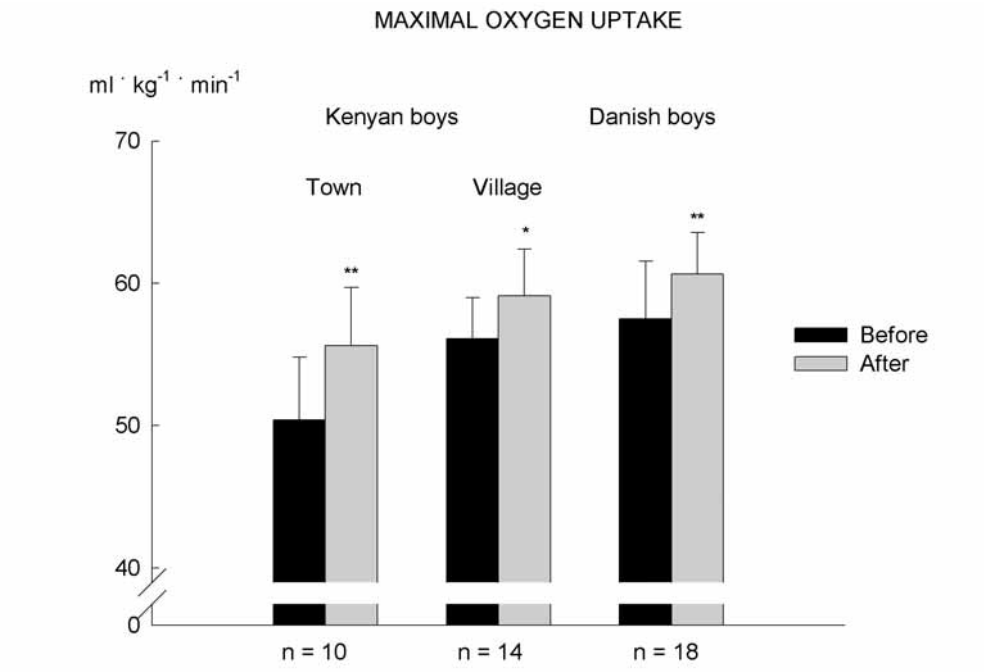

*Figure 1: Maximal oxygen uptake (VO_2 max) in Kenyan town and village boys and in Danish boys before and after 12 weeks of endurance running. Values are means SD. Significantly different from pre training: * P<0.002; ** P<0.001.*

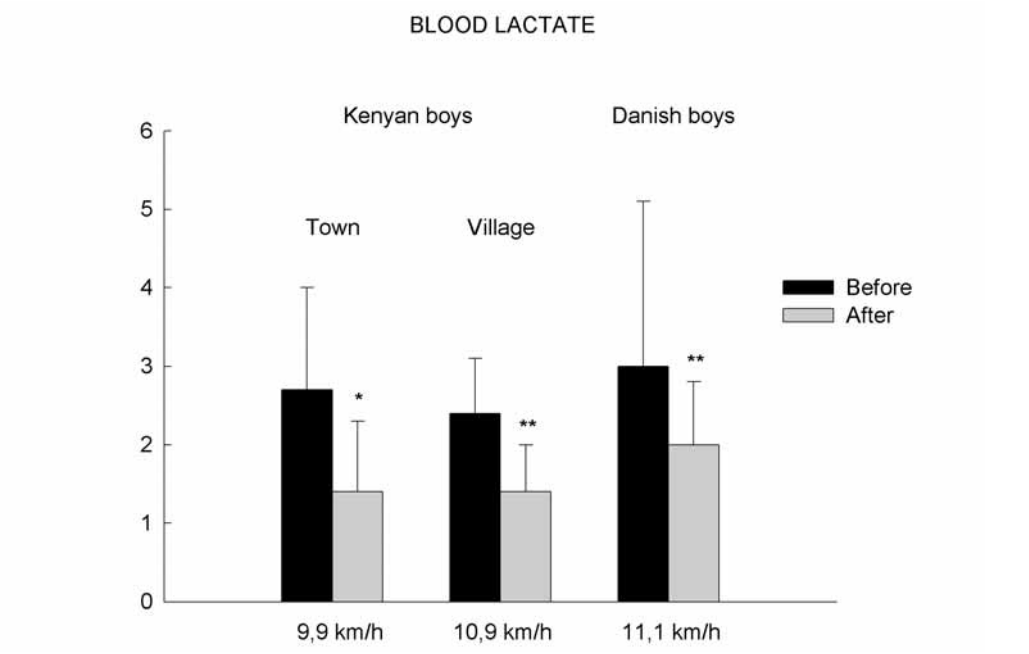

*Figure 2: Blood lactate at submaximal running speeds in Kenyan town and village boys and in Danish boys before and after 12 weeks of endurance running. Values are means SD. Significantly different from pre training: * P<0.005; ** P<0.001.*

had lower initial heart rate and lower concentration of blood lactate (Figure 2) at a given running speed compared to untrained Danish boys. This was not caused by a higher initial aerobic fitness level but was due to the better running economy observed in the Kenyan boys. Both heart rate and blood lactate (Figure 2) at a given running velocity declined to the same extent following 12 weeks of training for Kenyan and Danish boys, which confirms that the trainability of Kenyans and Danes is similar.

Muscle fibre composition and enzyme activity

Muscle fibre composition (relative percentage of slow and fast fibres) is a determinant of maximal contraction speed of the muscle and thus, sprint and endurance capacities. Previous research has shown that long distance runners have a higher proportion of slow (Type 1) muscle fibres in their leg muscles compared to sedentary people. Our study demonstrated that untrained Kenyan town and village boys and Danish boys all had similar percentages of slow and fast (Type 2) muscle fibres (Table 1). However, the percentage of fast muscle fibres (Type 2x) which declines with endurance activities was lower in Danish boys when compared to the Kenyan town boys, indicating a lower physical activity level of the town boys. No difference was found between any of the three groups of boys with respect to cross-sectional area of the various muscle fibre types (Table 2). However, a higher density of capillaries (cap/mm2 and cap/fibre) was observed in Danish boys compared to Kenyan town boys. Moreover, no difference was observed between Kenyan village boys and Danish boys (Table 3). In addition, Kenyan town and village boys at the untrained stage had lower concentration of oxidative enzyme (CS) in the muscle of the thigh compared to the Danish boys. However, a larger response to the training of this enzyme was observed in Kenyan town and village boys. The activity of the HAD enzyme (a measure of the ability to utilize fat while running) was similar in the

three groups of boys before training. Although the Kenyan town boys improved the HAD activity significantly following training, no difference was observed between the three groups of boys after the 12 week training period.

Running economy

Kenyan boys both from the town and the rural village have better running economy compared to untrained Danish boys. When relating the body mass index (body mass divided by height expressed in meters squared; a measure of slenderness) to running economy for Kenyan and Danish boys, we could demonstrate that a close relationship exists between these measures. A low body mass index is advantageous, as the energy cost when running is lower. Therefore, since Kenyan boys are more slender than Danish boys, they run faster at a given energy production per kilogram of body weight. In addition, when the mean lower

Fiber types, %

	n	Type I	Type IIA	Type IIX	Type I/IIA
Town boys	10 26-63	44.9 ± 12.6 18-54	33.8 ± 10.2 7-35	20.1 ± 8.2 0-6	1.3 ± 1.9
Village boys	19 28-64	52.9 ± 10.3 12-53	31.7 ± 9.4 1-37	14.0 ± 9.7 0-10	1.5 ± 2.6
Danish boys	31 23-75	54.2 ± 11.8 18-45	31.6 ± 7.7 0-29	13.4 ± 10.4a 0-4	0.9 ± 1.2

Significantly different from Town boys: [a] P=0.05

Table 1: Muscle fiber types of the quadriceps femoris muscle (vastus lateralis) in Kenyan town and village boys and in Danish boys. Mean values ± SD and range are given.

Mean fiber area (x10³ µm²)

	n	Type I	Type IIA	Type IIX	Type I/IIA
Town boys	8	4.47 ± 0.63 3.68-5.44	4.75 ± 1.19 2.82-6.58	3.68 ± 1.32 2.31-5.51	4.05 ± 0.39b 3.78-4.32
Village boys	15	4.65 ± 1.27 3.12-8.51	4.61 ± 1.06 2.42-6.09	3.34 ± 1.25a 1.66-6.14	5.49 ± 2.98c 2.62-9.49
Danish boys	29	4.14 ± 0.99 2.55-6.90	4.90 ± 1.28 3.25-8.28	4.39 ± 1.66 2.10-7.59	3.67 ± 0.89d 1.74-5.24

[a] n = 12; [b] n = 2; [c] n=4; [d] n=13

Table 2: Muscle fiber type area of the quadriceps muscle (vastus lateralis) in Kenyan town and village boys and in Danish boys. Mean values ± SD and range are given.

	n	Capillaries mm2	per fiber
Town boys	9	471.0 ± 57.0 389-535	2.24 ± 0.27 1.9-2.7
Village boys	16	512.3 ± 57.9 437-612	2.51 ± 0.55 1.8-3.8
Danish boys	31	519.8 ± 72.1[a] 386-724	2.50 ± 0.47[a] 1.79-3.38

	I	IIA	IIX	I/IIA
Town boys	4.0 ± 1.1 2.6-5.6	3.8 ± 1.0 2.2-5.2	2.9 ± 1.0 1.0-4.1	2.5 ± 3.5 0.0-5.0c
Village boys	4.5 ± 1.2 2.1-6.4	4.3 ± 1.0 1.5-5.5	3.1 ± 1.2[b] 0.7-4.9	5.7 ± 1.5[d] 4.0-8.0
Danish boys	4.2 ± 1.4 1.4-6.4	4.1 ± 1.3 1.6-6.6	3.3 ± 1.4 1.1-5.9	4.5 ± 2.2[e] 0.0-8.8

Significantly different from town boys: a $P < 0.05$; b n=14; c n=2; d n=5; e n=13

Table 3: Capillaries in the vastus lateralis of Kenyan town and village boys and Danish boys. The various indices used are cap . $(mm^2)^{-1}$, cap . $fiber^{-1}$ and cap found around the four major fiber types. Mean values ± SD and range are given.

leg thickness (see anthropometric measures above) is related to running economy for both Kenyan and Danish boys, a good relationship can be demonstrated (Figure 3). Thus, subjects with thin legs use less oxygen per kilogram of body weight when running compared to subjects with thick legs. Since the mean lower leg thickness in absolute terms is smaller in Kenyans than Danes, they use less energy when running a given distance compared to Danes. This means that they run faster than Danes do when producing the same amount of energy per kg of body weight. The observation that this relationship seems to be stronger than the relationship between running economy and body mass index indicates, that the lower leg thickness expressed in absolute terms is a crucial factor for running economy.

The optimal body shape of a distance runner with respect to running economy is a combination of small height, slender body shape with the legs representing a large fraction of the body height and thin lower legs. Since untrained Kenyan boys are shorter, lighter and more slender than their Danish counterparts and have the same relative lower leg thickness, it is obvious that they have smaller lower leg thickness in absolute terms. This explains their superior running economy. After performing 12 weeks of standardised training, both Kenyan town and village boys and Danish boys used less energy running a given distance and thus, they improved their running economy. However, this improvement was small and similar in the Danish and Kenyan boys (Figure 4).

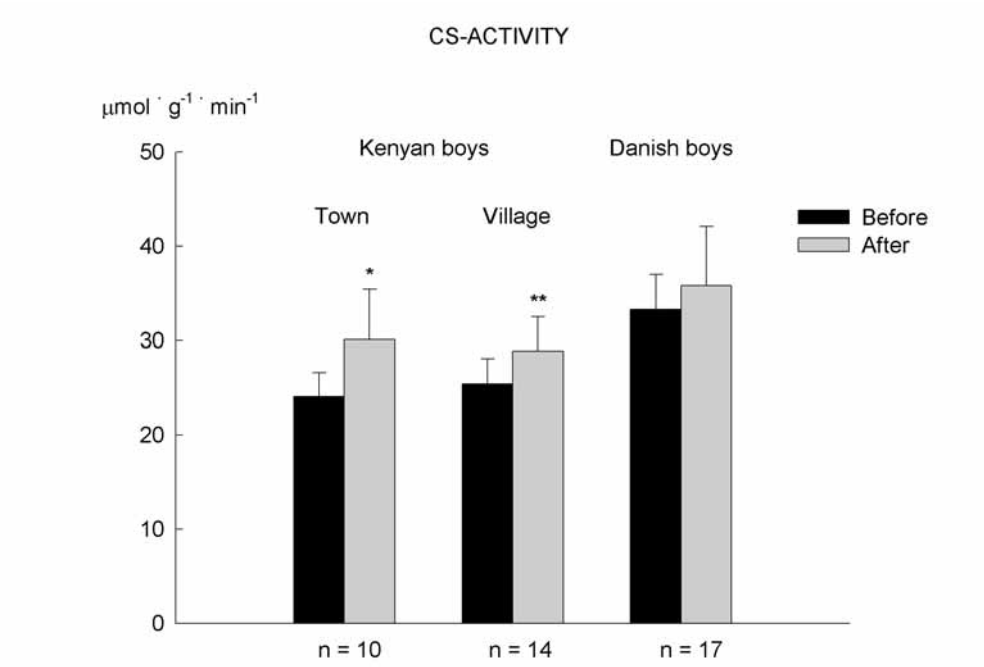

*Figure 3: Citrate cyntaase (CS) activity in Kenyan town and village boys and in Danish boys before and after 12 weeks of endurance runnning. Values are means SD. Significantly different from pre training: P<0.02; ** P<0.005.*

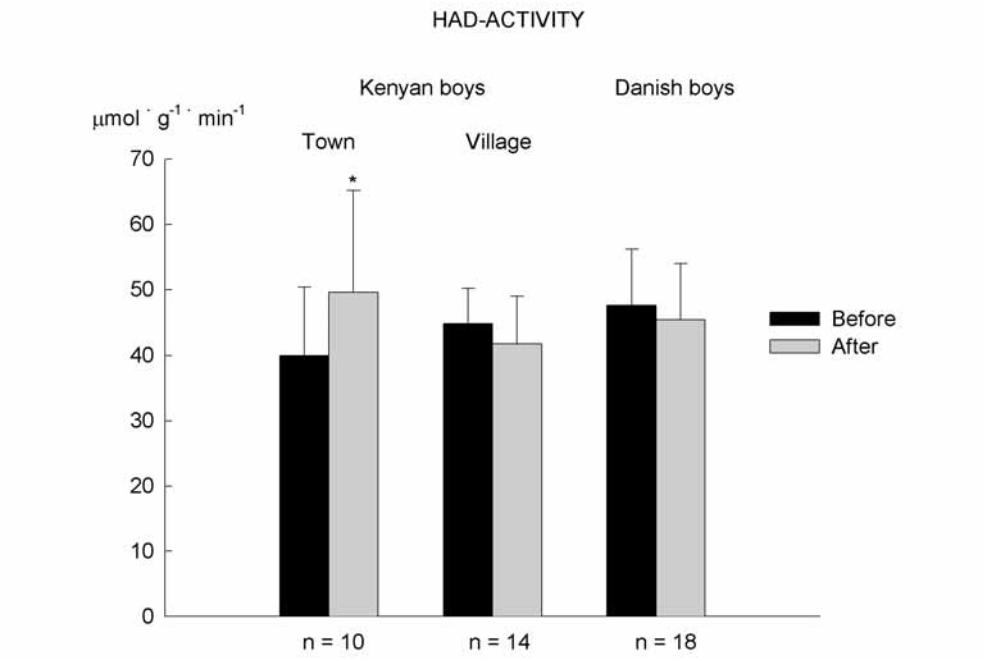

*Figure 4: 3-hydroxyacyl CoA dehydrogenase (HAD) in Kenyan town and village boys and in Danish boys before and after 12 weeks of endurance runnning. Values are means SD. Significantly different from pre training: P<0.02; ** P<0.005.*

Fractional utilisation of maximal oxygen consumption

By using heart rate monitors we were able to estimate and compare the average percentage of maximal oxygen consumption sustained during the 5000 metres competition for Kenyan and Danish boys. Our data revealed that there was no difference between groups.

Trainability

The trainability (response to training) as judged from the average training speed during the 12-week period of standardised training of the Kenyan and Danish boys was very similar. The Danish boys and the Kenyan boys from the town ran at the same training velocity to begin with. However, there was a trend for a larger increase in speed of the Kenyan town boys during the training period but again, this is probably due to a lower initial fitness level of these boys. The Kenyan boys from the rural area showed a higher training velocity compared to Danish boys from the very first day of training and they continued to run faster and to the same extent during all 12 weeks of training.

Performance (for 5000 metres)

Kenyan boys from the rural area having the same initial fitness level (maximal oxygen uptake) as Danish boys ran 10% faster in a 5000 metres competition after performing 12 weeks of standardised training (Figure 5). It is noteworthy, that this is true even though the Kenyans were running at 2000m above sea level. Danish boys and Kenyan boys from the town perform equally well in the competition even though the Danish boys had 10% higher maximal oxygen uptake. Again, the superior running economy of the Kenyan boys is a plausible explanation.

Elite runner study - Summary of key findings

Anthropometric measures

Our investigation revealed that Kenyan elite runners were about 7cm shorter and about 5kg lighter than Danish elite runners. Furthermore, the body mass index of the Kenyan elite runners was substantially lower than that of the Danish elite runners.

Maximal oxygen consumption

Our study showed that Kenyan elite runners have a very high maximal oxygen uptake. However, the VO_2 max of the Kenyans was not higher compared to Danish elite runners.

Blood lactate

Kenyan elite runners had lower plasma lactic acid concentrations than Danish elite runners at submaximal running speeds, also when related to oxygen uptake.

Muscle fibre composition and enzyme activity

No difference in muscle fibre composition was observed when comparing elite Kenyan and Danish runners. There were, however, some distinct differences in the muscle enzyme profile. The activity of the HAD enzyme was markedly higher in the muscles of the elite Kenyan runners indicating that they have a better ability to utilize fat while running compared to Danish runners. No difference was observed in the CS enzyme.

Running economy

Elite Kenyan runners had a better running economy compared to elite Danish runners. When relating the body mass index to the running economy for Kenyan and Danish elite runners we found a similar relationship between these measures as the one observed in Kenyan and Danish

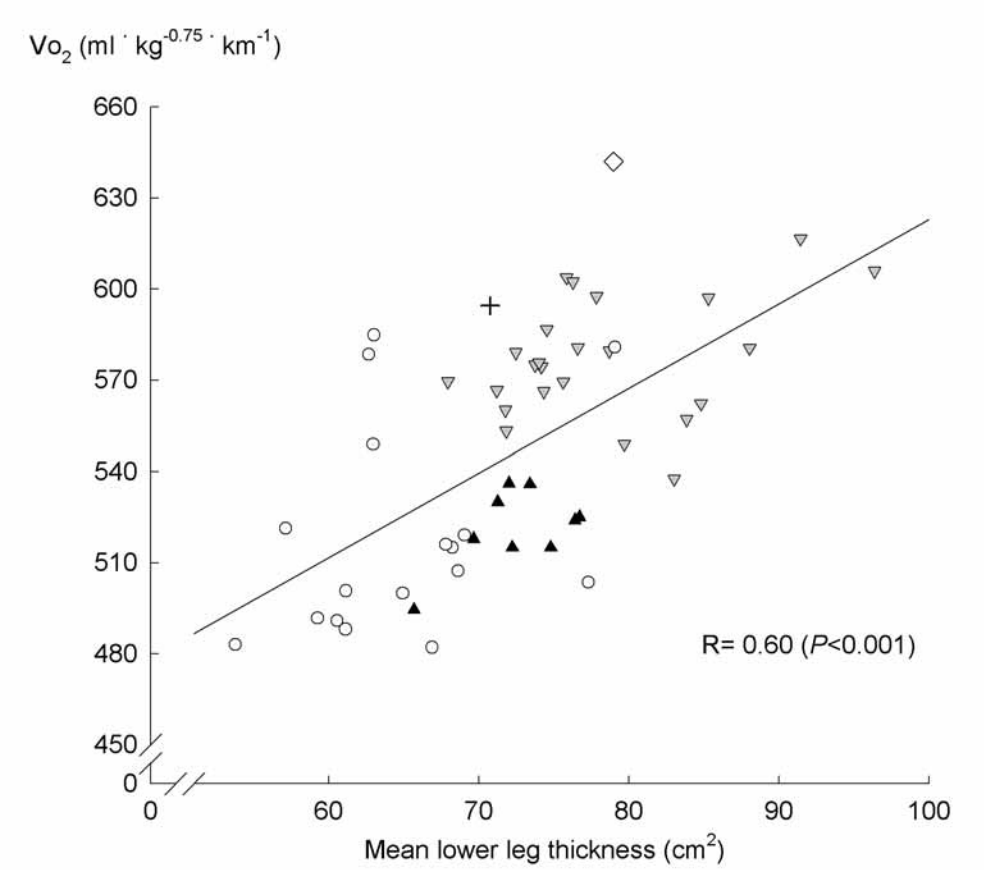

Figure 5: Relationship between mean lower leg thickness and running economy in various groups of runners. Untrained Kenyan and Dansih boys are added for comparison but they are not included in the calculated R-value.

○ *Kenyan elite runners training 70-200km/week $^{-1}$ (n=17)*
▲ *Danish elite runners training 70-180km/week $^{-1}$ (n=9)*
▽ *Danish sub elite runners training 65-135km/week $^{-1}$ (n=24)*
+ *Mean of untrained Kenyan boys (n=12)*
◇ *Mean of untrained Danish boys (n=30)*

boys. Therefore, since elite Kenyan runners are more slender than elite Danish runners they run faster at a given energy production per kg of body weight. In addition, when investigating the relationship between the estimated mean lower leg thickness of elite Danish runners and directly measured mean lower leg thickness of elite Kenyan runners and running economy we could demonstrate a similar relationship between these measures as the one we found in Kenyan and Danish boys (Figure 3). In addition, we found that the relationship between mean lower leg thickness and running economy is also stronger than the relationship between body mass index and running economy. The relationship seems to confirm that the lower leg thickness expressed in absolute terms is a crucial factor for running economy and that the optimal body shape of a distance runner with respect to running economy is a combination of small height, slender body shape and thin lower legs.

Conclusion

Original articles in press or submitted:

Larsen, H.B.; Nolan, T.; Borch, C.; Søndergaard, H.: Training response of adolescent Kenyan town and village boys to endurance running. *Scandinanivan Journal of Medicine and Science in Sports*. In press, 2003.

Larsen, H.B.: Kenyan dominance in distance running. *Comparative Biochemistry and Physiology*. In press, 2003.

Larsen, H.B.; Christensen, D.L.; Nolan, T.; Søndergaard, H.: Body proportions, aerobic exercise capacity and physical activity level of adolescent Nandi boys in western Kenya. *Annals of Human Biology*. Submitted, 2003.

Larsen, H.B.; Andersen, J.L.; Nolan, T.; Søndergaard, H.: Muscle morphology and enzyme activity in adolescent Kenyan Nandi town and village boys. *Annals of Human Biology*. Submitted, 2003.

Original articles to be submitted:

Larsen, H.B.; Søndergaard, H.; Nolan, T.; Saltin, B.: Slender legs in Kenyan Kalenjins causes low energetic cost of running.

Larsen, H.B.; Søndergaard, H.: Training response of adolescent Caucasian boys to endurance running.

Larsen, H.B.; Søndergaard, H.; Asp, S.; Calbet, J.A.L.; Saltin, B.: Skeletal muscle adaptation to endurance running tin adolescent Kenyan town and village boys and in Danish boys.

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