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Body dimensions, exercise capacity and physical activity level of adolescent Nandi boys in western Kenya

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Summary. The aim of this study was to characterize untrained Nandi boys (mean age 16.6 years) from a town ($n = 11$) and from a rural area ($n = 19$) in western Kenya (altitude ~2000 m.a.s.l.) in regard to their body dimensions, oxygen uptake and physical activity level. The town boys had a mean maximal oxygen uptake (VO_{2max}) of 50 (range: 45–60) $mL\,kg^{-1}\,min^{-1}$, whereas the village boys reached a value of 55 (37–63) $mL\,kg^{-1}\,min^{-1}$ ($p < 0.01$) in VO_{2max}. The running economy, determined as the oxygen cost at a given running speed, was 221 $mL\,kg^{-1}\,km^{-1}$ (597 $mL\,kg^{-0.75}\,km^{-1}$) for town as well as for village boys. The body mass index (BMI) was very low for town as well as for village boys (18.6 vs 18.4 $kg\,m^{-2}$). The daily mean time spent working in the field during secondary school and doing sports were significantly higher in village boys compared to town boys (working in the field: 44.2 (0–128) vs 1.3 (0–11) min, $p < 0.01$; sports: 32.0 (11–72) vs 12.8 (0–35) min, $p < 0.01$, respectively). A positive correlation between the daily time spent doing sports and VO_{2max} was found when pooling the data from the town and the village boys ($R = 0.55$, $p < 0.01$). It is concluded that the body dimensions of adolescent Nandi town and village boys corresponds well with findings in Kenyan elite runners. They are very slender with relatively long legs. In addition, the VO_{2max} of the village boys was higher than that of the town boys, which is probably due to a higher physical activity level of the village boys during secondary school.

1. Introduction

During the past 35 years, African runners or runners of African ancestry have produced some of the most remarkable results in athletic events at world-class level. While the West Africans have excelled in short distance races (100–400 m), the East Africans, especially Kenyans, have excelled in middle-distance (800–1500 m) and steeplechase, and also, together with the Ethiopians, in long-distance races (5000 m—marathon). In fact, > 55% of the all-time top 20 lists for men in distances from 800 m to the marathon are Kenyans. In addition, the majority of the Kenyan achievements has been produced by a group of eight small tribes called Kalenjin, which today number only ~3.5 million people. Among the Kalenjin tribes, the Nandi tribe has shown the most profound results. Although this tribe constitutes only ~2% of the Kenyan population, it is the most successful single tribe in Kenya to date with respect to performance in running. The reasons for this dominance are still not known, but factors that may play a role are genetic endowment, upbringing and training.

Success in running events depends on several factors. These include both aerobic and anaerobic capacities for energy turnover, muscular strength, running economy as well as biomechanical, psychological and sociological characteristics. So far, only two studies have examined some physiological differences when comparing

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Kenyan athletes with athletes of non-African descent (Saltin *et al.* 1995a,b). These studies revealed that Kenyan elite runners have a very high VO_{2max} (79.9 mL kg^{-1} min^{-1}), but not higher than that observed in Scandinavian elite runners (79.2 mL kg^{-1} min^{-1}). In addition, the studies further demonstrated that untrained Kenyan boys from a town had a VO_{2max} similar to that of untrained Danish boys described by Andersen *et al.* (1987). However, Kenyan elite runners are fostered in small villages and rural areas where physical activity levels are thought to be higher than in towns. Whether this is true and the degree to which this may contribute to the development of physiological properties crucial for performance in middle- and long-distance running is not known. Furthermore, the studies by Saltin *et al.* (1995b) revealed that Kenyan elite runners had a highly proficient running economy compared to Scandinavian elite runners as judged from oxygen uptake at sub-maximal speeds. Moreover, Kenyan elite runners had a lower body mass index (BMI) compared to the Scandinavian runners. Dotan *et al.* (1983) have demonstrated a moderate relationship between the BMI and marathon running performance. However, the underlying physiological reasons for this are not known. Classical studies of human locomotion (Fenn 1930, Cavagna *et al.* 1964) have indicated that the work of moving the limbs comprises a substantial part of the metabolic cost of running, just as load-carrying experiments (e.g. Myers and Steudel 1985) have shown that carrying a few grams of mass on the feet/ankle evokes an increase in the metabolic rate of running. This indicates that a low leg mass is advantageous for the running economy. Therefore, it can be speculated whether the low BMI of the Kenyan elite runners implies that these have more slender limbs than Caucasian elite runners and whether this relates to the observed superior running economy of the Kenyan runners. In addition, to what degree the low BMI of Kenyan elite runners compared to Scandinavian elite runners is due to selection or is a general feature of untrained Kenyans is unknown. Furthermore, no information is available at present about the running economy of untrained Kenyans.

In this light the purpose of the present study was to describe body dimensions, running economy, aerobic power, and related variables and relate them to habitual daily physical activity level of Nandi town and village boys in western Kenya. The hypothesis was that the characteristics of east African elite distance runners can be observed in adolescent Nandi boys regardless of where they live.

2. Methods

2.1. Subjects

Sixty Kenyan boys volunteered for the present study. Before entering the study all subjects filled in questionnaires encompassing questions related to (a) tribe, (b) transportation to and from school during childhood, (c) leisure-time activities and (d) coach-organized training. Based on the questionnaires, 11 town boys and 19 village boys all belonging to the Nandi tribe (verified to the level of grandparents) not previously engaged in any kind of organized endurance training were selected. Three Nandi boys were excluded due to illness, while one was excluded due to insufficient sexual maturation. The remaining 26 boys were excluded due to the fact that they were not Nandies. All subjects were recruited from two secondary day schools. The town boys were recruited from Uasin Gishu High School in the town of Eldoret located in the western part of Kenya, on a plateau at an altitude of ~2000 m.a.s.l. Except for two subjects who were raised in a town or city, they were all born and brought up in the rural area around Eldoret. At the age of ~14 years, nine of the subjects had moved to Eldoret in order to begin their studies at secondary school, while the remaining two subjects continued living in the countryside. The village boys were recruited from Kamobo Secondary School located in the Nandi district about 50 km south-west of Eldoret at the same altitude as this town. All subjects were living in the rural area within a radius of 4 km from the school. Before entering the study, sexual maturation was assessed by one of the investigators who evaluated the development of secondary sex characteristics (pubic hair). The method described by Marshall and Tanner (1970) was employed. The subjects who were in stage 3 (PH3) or lower were excluded from the study. The vast majority of the boys who participated were in stage 5 (PH5), while a few boys were in stage 4 (PH4). The Ethics Committee of the Faculty of Health Sciences at Moi University, Eldoret, Kenya, approved the study. All subjects and their parents were fully informed orally as well as in writing of the experimental procedures and possible risks connected with the study and gave written consent. All subjects were informed that they were free to withdraw from the study at any time. All subjects were studied at altitude (barometric pressure ~595 mmHg). Some physical characteristics, BMI and anthropometric measures (leg length, lower leg length and circumference) of the subjects are given in table 1.

2.2. *Protocol and methods*

The date of birth of each subject was assessed by oral information. All subjects knew in which year they were born. However, one town boy and one village boy were unaware of their exact date of birth, which was then decided to be 1 July. Body mass was assessed by using an electronic scale calibrated with known weights. Height was measured to the nearest millimetre with eye (outer ear orifice being horizontal). Leg circumference was measured by using a string. Other body dimensions were measured by using a folding-rule. Lower and total leg length, defined as the distance from the ground to the middle of the fibula head and the distance from the ground to the anterior superior iliac spine, respectively, were measured in all boys. In addition, the distance from the ground to the middle of the lateral malleolus was measured.

All subjects went through sub-maximal and maximal tests on the treadmill. Prior to these tests, all boys performed two or three (more than 50 min in total) practice sessions at different days at three different speeds each day to accustom them to running on a treadmill as well as with the equipment used to determine the respiratory variables. The exercise protocol on the treadmill consisted of a 10-min warm-up

Table 1. Some physical characteristics, BMI and anthropometric measures (leg length, lower leg length and lower leg circumference) of Nandi town and village boys. Mean values ± SD and ranges are given.

	n	Age (years)	Mass (kg)	Height (cm)	BMI ($kg \cdot m^{-2}$)	Leg length (cm)	Lower leg length (cm)	Lower leg circumference (cm)
Town boys	11	16.6 ± 0.7	53.8 ± 8.1	169.5 ± 7.7	18.6 ± 1.5	101.2 ± 5.3	45.5 ± 2.9	–
		15.7–17.5	41.3–64.7	157–183	15.7–20.5	94–113	41–51	
Village boys	19	16.6 ± 0.8	53.3 ± 5.3	170.4 ± 7.9	18.4 ± 1.6	101.9 ± 4.9†	45.4 ± 3.0†	31.9 ± 1.7‡
		15.2–18.4	45.4–63.2	158–187	15.3–20.5	94–111	43–54	29.8–34.9

† $n = 15$; ‡ $n = 12$.

at speeds from 6.0 to 10.0 km h^{-1}. After 7–10 min of rest, the subjects ran 7 and 6 min, respectively, at two different individual speeds, with 0.5–1.0 min of rest in between. The two speeds were chosen to demand a heart rate of 150−155 (6.0–11.5 km h^{-1}) and 165–175 (8.0–14.0 km h^{-1}) beats per minute (b.p.m.), respectively. In order to be able to calculate exact running economy, body mass including test equipment was measured immediately before and after the test. After 10 min of rest, the maximal test was performed at speeds from 13.0 to 17.5 km h^{-1}. The test started without inclination, and every second minute the inclination was raised by 2% until exhaustion. During the last 1.5 min at each sub-maximal speed, the expired air was collected in Douglas bags, while it was collected continuously during the maximal test. Heart rate was measured continuously during all tests, while a blood sample was taken from a superficial arm vein at rest and during the last 15 s of each sub-maximal run or immediately after this. Furthermore, blood samples were taken at rest shortly before the maximal run and 1 and 3 min, respectively, after this test. The oxygen uptake was calculated after measuring the volume of expired air with a gasmeter (London Gasmeter Co.) calibrated with a Tissot spirometer and the fractions of O_2 and CO_2 using a Servomex S-3 A/I and a Beckman LB-2, respectively. Heart rate was monitored with a telemetric system (Polar Accurex Plus, Polar Electro, Finland). The blood samples were analysed for lactate and ammonia (Kun and Kearney 1974). Haemoglobin was determined spectrophotometrically on blood taken from a fingertip or from a superficial arm vein after the subjects had been resting in supine position for 5–10 min.

2.3. Physical activity level

To obtain information about the boys' physical activity level during childhood, each of them was interviewed by one of the investigators using a standardized formula encompassing questions related to (a) duties at home involving physical activity, (b) transportation to and from school, (c) sport activities during a day in school, and (d) leisure time activities. Furthermore, during secondary school, the boys filled in questionnaires of their habitual physical activity level from hour to hour during 6 days on the average. Two different kinds of questionnaires were employed. In one of these the subjects stated how far they were walking/running each day to and from school and which kind of physical activities they were doing during the day. In the other questionnaire the subjects reported how many minutes they were physically active daily at five different activity levels from lying/sitting to fast running. Using the initial questionnaires, which the subjects filled in before entering the study, checked up the information concerning distance between home and school from the first of these questionnaires. In addition, to obtain more exact measures of the physical activity level of each subject, heart rate was recorded every minute during 24 h using telemetric heart rate monitors.

2.4. Statistics

The statistics included the calculations of means, standard deviation and test for group differences (Siegel 1956). The significance of differences between conditions was tested using the paired *t*-test. Differences between conditions were considered significant at the 95% confidence level.

3. Results

3.1. Physical characteristics, BMI and anthropometric measures (table 1)

Both the town and the village boys were small and light, and their BMIs were 18.6 and 18.4 kg m^{-1}, respectively. Both groups of boys had long and slender legs, with no difference between groups.

3.2. Exercise data and haemoglobin (tables 2 and 3)

The maximal oxygen uptake of the town boys was 50.2 mL kg^{-1} min^{-1}, while the corresponding value for the village boys was ~10% higher (55.1 mL kg^{-1} min^{-1}, $p < 0.01$). Of note is the large range of VO_{2max} observed in the village boys. There were no other differences in the maximal exercise values between the town and village boys. The values of haemoglobin were low (8.8 vs 8.6 mmol L^{-1}, respectively), taking the altitude into consideration. The village boys could run at a slightly higher sub-maximal speed with given sub-maximal heart rate and blood lactate level compared to the town boys.

3.3. Running economy (table 4)

The oxygen cost of running was the same for the town and village boys when expressed per kilogram (220.6 vs 221.1 mL kg^{-1} km^{-1}) as well as per 0.75 kg (597.4 vs 596.4 mL $kg^{-0.75}$ km^{-1}) of body weight.

Table 2. VO_{2max}, maximal heart rate (HR_{max}) and peak blood lactate (Hla_{max}) and ammonia (NH_{3max}) concentration in untrained Nandi town or village boys. Mean values ± SD and ranges are given.

		VO_{2max}					
	n	(L min^{-1})	(mL kg^{-1} min^{-1})	(mL $kg^{-0.75}$ min^{-1})	HR_{max} (b.p.m.)	Hla_{max} (mmol L^{-1})	NH_{3max} (μmol L^{-1})
Town boys	11	2.71 ± 0.51 1.98–3.58	50.2 ± 4.2 45.4–60.2	135.9 ± 13.8 121.7–167.3	196.9 ± 11.0 172–206	9.8 ± 2.5§ 7.1–13.9	226.8 ± 65.9¶ 114–328
Village boys	19	2.94 ± 0.46 1.98–3.87	55.1 ± 5.3† 37.4–62.8	148.9 ± 15.6‡ 100.8–174.9	197.1 ± 6.4 186–209	9.4 ± 1.9** 6.2–12.8	218.7 ± 54.6** 113–281

Significantly different from town boys: † $p < 0.01$; ‡ $p < 0.02$.
§ $n = 9$; ¶ $n = 8$; ** $n = 13$.

Table 3. Sub-maximal test speeds, heart rate, blood lactate and ammonia concentration for Nandi town and village boys. Mean values ± SD and ranges are given.

	n	Test speed (km h^{-1})	Heart rate (b.p.m.)	Blood lactate (mmol L^{-1})	NH_3 (μmol L^{-1})
Town boys	10	8.3 ± 1.5 6.0–10.5	152 ± 7.0 139–167	2.0 ± 0.8† 1.0–3.4	89.6 ± 17.9† 72.0–128.5
	10	10.2 ± 1.4 8.0–12.0	171 ± 10.8 161–179	2.7 ± 1.1† 1.4–4.5	98.0 ± 25.1† 70.0–151.0
Village boys	19	8.7 ± 1.0 7.5–11.5	153 ± 9.0 139–169	1.9 ± 0.4‡ 1.4–2.9	93.4 ± 18.0‡ 58.5–117.5
	19	10.8 ± 1.0 9.5–14.0	170 ± 8.2 152–186	2.5 ± 0.7‡ 1.2–3.3	101.3 ± 22.7‡ 66.0–133.0

† $n = 8$; ‡ $n = 15$.

Table 4. Running economy of Nandi town and village boys measured at 10.15 and 10.79 km h^{-1} on average, respectively. Mean values ± SD and ranges are given.

	n	Test speed (km h^{-1})	VO_2 (mL kg^{-1} min^{-1})	VO_2 (mL kg^{-1} km^{-1})	VO_2 (mL kg$^{-0.75}$ km^{-1})
Town boys	10	10.15 ± 1.4 8.0–12.0	37.0 ± 3.9 32–45	220.6 ± 21.5 179–246	597.4 ± 56.0 509–683
Village boys	14	10.79 ± 1.2 9.5–14.0	39.6 ± 3.5 35–49	221.1 ± 17.9 187–237	596.4 ± 39.2 511–669

Table 5. Major activities before and during the years at primary school in town and village boys. The percentage of boys involved in each activity in varying number of days is given. The data are based on interviews of 11 town boys and 15 village boys.

		Cattle herding		Fieldwork		Sports activities after start at primary school	
		Before start at primary school (%)	After start at primary school (%)	Before start at primary school (%)	After start at primary school (%)	During a day in school (%)	After school time (%)
Almost every day	town boys	64	36	55	27	45	27
	village boys	73	33	27	27	53	20
3–5 days/week	town boys	18	36	36	9	18	18
	village boys	13	27	27	40	27	33
< 2 days/week	town boys	18	27	9	55	27	45
	village boys	13	40	47	33	20	40

3.4. *Habitual physical activity during childhood (table 5)*

Except for two town boys who were born and raised in a town/city, all town boys as well as all village boys reported that they had been living in a village or a rural area during childhood. The mean distance between home and primary school was 2.5 (0.5–3.5) km and 2.1 (1.0–4.0) km, respectively, for town and village boys. One town boy reported that he was running to school daily in the morning, two town boys were running to school if they were late, while two town boys reported that they walked/ran to and from school. Six town boys reported that they were walking to school, while nine town boys were walking back home every day. Four village boys reported that they were walking/running to and from primary school, while 11 village boys reported that they were walking both ways. At the age of 4–12 both town and village boys reported that they had many duties at home. The main duties were cattle herding and field work (table 5). Both groups of boys were most active herding cattle and working in the field before starting primary school. Some of the fieldwork was made using manual power, while some was made using engine power. Other duties included washing clothes, shopping and fetching water and firewood. No differences were observed between the two groups of boys in any physical activity related to duties at home. In addition, both town and village boys were active doing sports while at school as well as after school, but no differences were observed between the two groups (table 5).

3.5. *Habitual physical activity level during secondary school (table 6, figure 1)*

The mean distance between home and secondary school was 2.5 (1.0–4.0) and 3.0 (1.0–4.0) km, respectively, for town and village boys. Both groups of boys were

Table 6. Habitual daily physical activity during six randomly selected days in secondary school for town and village boys. Mean values ± SD and ranges are given.

	n	Walking (km day^{-1})	Running (km day^{-1})	Sports activities (min day^{-1})	Work (field) (min day^{-1})	Cattle herding (min day^{-1})
Town boys	9	3.3 ± 2.4 0.0–5.2	0.3 ± 0.4 0.0–1.1	12.8 ± 11.8 0–35	1.3 ± 3.8 0–11	0.0 ± 0.0 0–0
Village boys	13	2.9 ± 1.7 0.5–6.5	0.9 ± 0.9† 0.0–2.8	32.0 ± 17.3‡ 11–72	44.2 ± 41.6‡ 0–128	9.0 ± 14.9 0–47

Significantly different from town boys: † $p < 0.05$; ‡ $p < 0.01$.

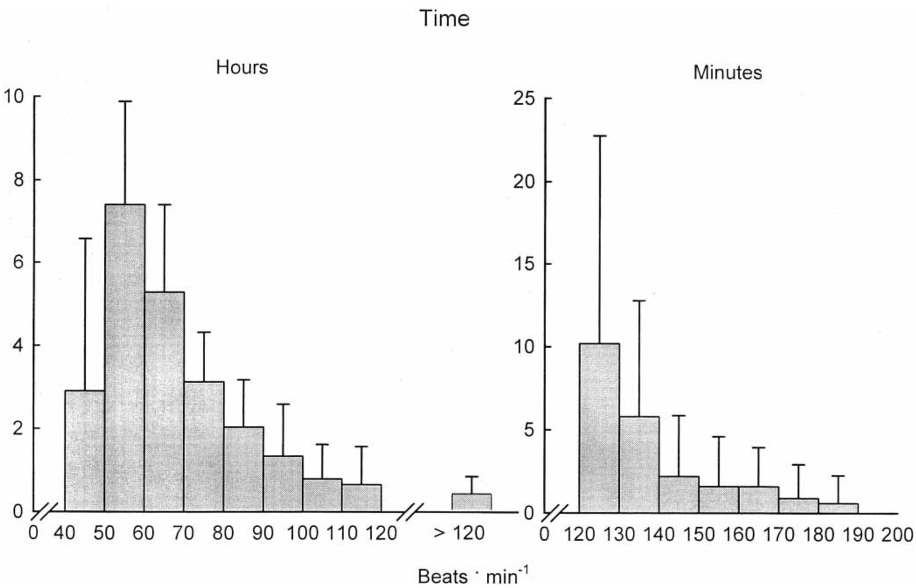

Figure 1. Mean duration (mean ± SD) of heart rates at different frequencies recorded every minute during 24 h in nine Nandi village boys.

walking about 3 km on average per day (table 6). Even though the distance covered daily by running was greater for the village boys compared to the town boys, none of the two groups of boys did much running (0.3 vs 0.9 km day^{-1}, $p < 0.05$). The time spent daily doing sports activities (mainly football and volleyball) was approximately half an hour for the village boys. This was 150% more than for the town boys ($p < 0.02$). The village boys were working for about three-quarters of an hour in the field per day. This was considerably more than the town boys, of whom only one subject was working in the field ($p < 0.01$). Of note is also that the time spent daily herding cattle was very limited for both groups of boys. The 24 h heart-rate recordings in nine village boys demonstrated a rather low physical activity level of these boys. Thus, a heart rate above 120 beats min^{-1} was achieved only during ~23 min day (24 h)$^{-1}$ (figure 1).

4. Discussion

The body proportions of the Nandi boys are indeed much smaller compared to Caucasian boys of almost the same age (Andersen 1994). The height of the Kenyan

Table 7. Summary table of studies examining height, mass and BMI of adolescent boys of different ethnic origin.

Study	Subject population	*n*	Age (years)	Height (cm)	Body mass (kg)	BMI ($kg\,m^{-2}$)
Kobayashi *et al.* 1978	Japanese	43	17.2	168.9	58.2	20.4
Barnett *et al.* 1995	Hong Kong Chinese	22	16.1	165.7	52.7	19.2
Walker *et al.* 1989	South African Indian	77	17	169.9	54.8	19.0
Pathmanathan and Prakash 1994	Indian	20	15.8	164.9	48.8	18.0
Wacharasindhu *et al.* 2002	Thai	53	16.6	170.8		
Andersen 1994	Danish	4511	~17	179.6		
	Danish	4549	~17		66.0	
	Danish	4464	~17			20.4
Becker-Christensen 2002	Greenlanders	16	16.9	169.9	63.9	22.1
da Silva and Malina 2000	Brazilian	125	15.0	166.7	55.1	19.7
Sichieri *et al.* 1995	Brazilian	608	17	167.8	57.4†	20.4
Spurgeon and Meredith 1979	US blacks	219	15	167.2	56.6	20.2
	US whites	186	15	169.4	57.1	19.9
Rosner *et al.* 1998	US blacks	1417	17			22.8
	US whites	1680	17			22.7
	US Hispanic	251	17			23.2
Zavaleta and Malina 1980	Mexican–American	55	16.5	168.2	64.3	22.7
Mukhtar *et al.* 1989	Libyan	44	17	172.4	66.4	22.3
Ibu *et al.* 1986	Nigerian	26	17	165.6	60.8	22.2
Peters *et al.* 1987	Ethiopian	7	16–17	167.9	53.9	19.1
Walker *et al.* 1980	Black South Africans, rural	148	17	167.0	53.5	19.2
	Black South Africans, urban	151	17	168.2	55.9	19.8
Present study	Kenyan Nandi town boys	11	16.6	169.5	53.8	18.6
	Kenyan Nandi village boys	19	16.6	170.4	53.3	18.4

† calculated from BMI and height.

boys is ~9 cm lower, while the body mass is ~12 kg lower. In addition, the BMI is ~2 $kg\,m^{-2}$ lower compared to the Caucasian boys, which shows that the Nandi boys have a much more slender body shape than the Caucasian boys (table 7, figure 2). In addition, except for the Caucasians, the Nandi boys have similar height or tend to be marginally taller compared to the other ethnic groups presented in table 7, whereas the body mass of the Nandi boys, except for the Indians (Pathmanathan and Prakash 1994), is similar to or lower compared to the other groups of boys. However, the fact that the Nandi boys are relatively high, when taking their low mass into consideration, implies that they have a very low BMI compared to almost all the other groups of boys (figure 2). In fact, the only group with a BMI that tends to be lower than that of the Nandis is the Indian boys. However, these boys are 0.8 years younger than the Nandi boys. The BMI of 17-year-old South African Indian boys (Walker *et al.* 1989) actually tends to be higher than the BMI of the Nandi boys. Three other ethnic groups of boys (Ethiopians (Peters *et al.* 1987), black South Africans from the rural area (Walker *et al.* 1980) and Hong Kong Chinese (Barnett *et al.* 1995) (table 7)) tend to have higher BMIs than the Nandi boys. Ethiopians as well as black South Africans are of interest since both peoples have produced some remarkable results in distance running. As the number of Ethiopian boys measured

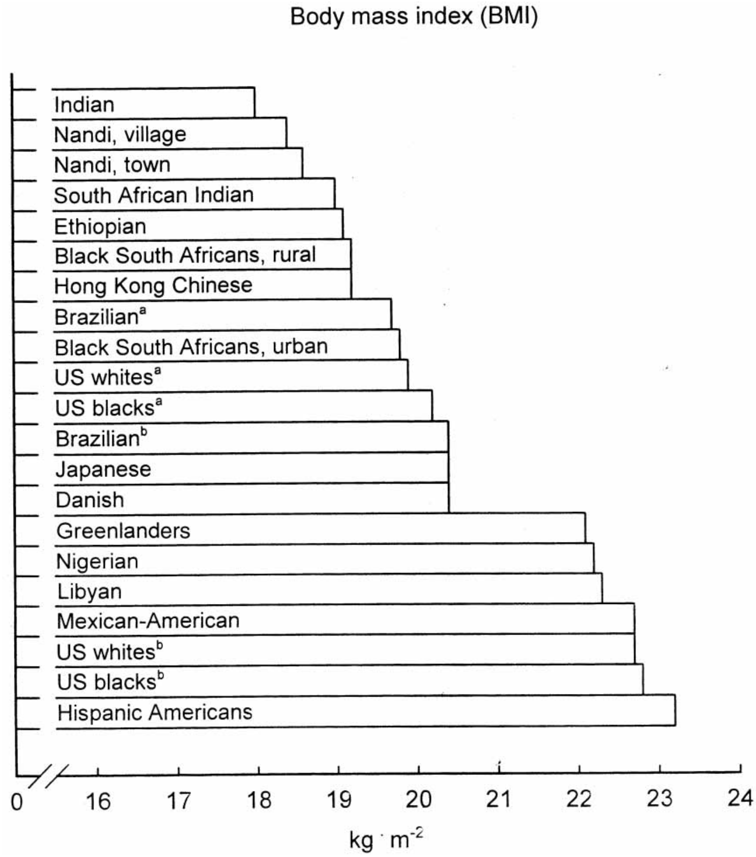

Figure 2. BMIs of Nandi town and village boys and of adolescent boys of different ethnic origin. [a] and [b] refer to two different investigations of the same people presented in table 7.

in the study by Peters *et al.* (1987) is small ($n = 7$), and Ethiopian adults ($n = 156$) investigated in the same study had BMIs of 18.8 kg m^{-2}, while Kenyan elite runners (primarily Nandis) had 19.2 kg m^{-2} (Saltin *et al.* 1995b), this indicates that Ethiopians are at least just as slender as Kenyan Nandis.

The BMIs of several groups of boys of different ethnic origin are in sharp contrast to the BMIs of the Nandi boys. Thus, the BMIs of Nigerians (Ibu *et al.* 1986), Libyans (Mukhtar *et al.* 1989), US blacks, whites and Hispanic (Rosner 1998), Mexican–Americans (Zavaleta and Malina 1980) and Greenlanders (Becker-Christensen 2002) are 4–5 kg m^{-2} ($\sim$20–25%) higher compared to the BMIs of the Nandi boys. It is of note that international results in long-distance running produced by these people today are very scarce.

The fact that the proportion of leg length to total height changes only marginally beyond the age of 16 years (Hertel *et al.* 1995) allows us to compare the percentage of leg length to stature between the Kenyan boys and Caucasian adults. By subtracting the distance from the ground to the middle of the lateral malleolus from the leg length of the Kenyan boys, a direct comparison of leg length between these boys and Caucasian elite runners described by Svedenhag and Sjödin (1994) becomes possible. This comparison reveals that the relative leg length of the Nandi town and village boys is considerably longer compared to the Caucasian elite runners

(55.2 and 55.5 vs 52.8%). In addition, the relative leg length of the Nandi boys is very consistent with findings on Kenyan elite runners (H. B. Larsen *et al.*, unpublished observation). Furthermore, the relatively long legs of the Nandis is in line with earlier findings in a study comparing tibial length between six different ethnic minorities of East African origin and Caucasians (Allbrook 1961). This study revealed that four of these groups had longer tibial length in absolute terms than the Caucasians despite the fact that their stature was smaller. In addition, the relative tibial length was longer in the remaining two African groups compared to Caucasians. Furthermore, the relatively long legs of the Nandi boys is in line with findings in a study of 15-year-old African boys and adults from a large variety of African countries (Meredith 1979) as well as findings in a study comparing 15-year-old black American boys with white American boys (Spurgeon and Meredith 1979). These investigations have shown a longer lower limb length relative to sitting height (skelic index) of blacks compared to Caucasian boys (table 8). Additionally, as the sitting height relative to height seems to be greater in Japanese (Ali *et al.* 2000), Thai (Wacharasindhu *et al.* 2002), and Greenlanders (Becker-Christensen 2002) boys compared to Caucasian boys (Hertel *et al.* 1995, table 8), this implies that the relative leg length of the Nandi boys is considerably longer compared to these groups of boys. In contrast, however, as many studies of adult Australian aborigines have shown a very low sitting height relative to total height (Norgan 1994, table 8),

Table 8. Summary table of studies examining sitting height relative to height, skelic index (leg length relative to sitting height) and leg length (distance from the middle of the lateral malleolus to the anterior superior iliac spine) relative to height in adolescent boys and adults of different ethnic origin.

Study	Subject population	*n*	Age (years)	Sitting height/ height ratio	Skelic index	Leg length/ height ratio
Ali *et al.* 2000	Japanese		17	0.534		
Pathmanathan and Prakash 1994	Indian	20	15.8	0.515		
Wacharasindhu *et al.* 2002	Thai	53	16.6	0.527		
Hertel *et al.* 1995	Danish		16.5	0.520		
Becker-Christensen 2002	Greenlanders	16	16.9	0.531		
Norgan 1994, review based on 17 different investigations (1937–1977)	Australian aborigines	917	adults	0.488		
Spurgeon and Meredith 1979	US whites	186	15	0.524	91.1	
	US blacks	219	15	0.506	97.7	
Meredith 1979, review, three studies	Black Africans	> 75	15		96–105	
Five studies	US blacks	> 290	15		98–101	
Three studies	US blacks	146	17		98–99	
14 studies	Black Africans	3223	adults		94–115	
Two studies	US blacks	987	adults		94–99	
Svedenhag and Sjödin 1994	Swedish elite runners	26	23.4			0.528
Present study	Kenyan Nandi town boys	11	16.6			0.552
	Kenyan Nandi village boys	19	16.6			0.555

this indicates that these people have similar or even longer relative leg length compared to the Nandis.

Finally, as the study by Spurgeon and Meredith (1979) demonstrated that the 15-year-old black American as well as Caucasian boys, who were considerably shorter and lighter than Caucasian boys (Andersen 1994) of almost the same age as the Nandi boys, had calf circumferences of 33.5 and 34.0 cm, respectively, this indicates that the Nandi boys (calf circumference of 31.9 cm, table 1) have more slender limbs in absolute terms compared to black American and Caucasian boys of the same age.

Since the boys in this study volunteered for the investigation it may be speculated whether they constitute a representative sample of Nandi boys. However, when comparing the boys in the present study with an equally large sample of randomly recruited Nandi boys and boys from other Kalenjin tribes (H. B. Larsen *et al.*, unpublished observation) no differences were observed with respect to height, weight, BMI or leg length.

4.1. Running economy (table 4)

The running economy of the two groups of Kenyan boys seems to be better than what has been observed previously in untrained Caucasian boys of the same age, irrespective of whether the oxygen cost is expressed per kilogram or per 0.75 kg of body mass (Åstrand 1952, Sjödin and Svedenhag 1992). This indicates that the superior running economy of the Nandi boys is due to inherent factors. Accordingly, genetic factors may also partially or fully explain the previously observed superior running economy of Kenyan world elite runners compared to Caucasian elite runners (Saltin *et al.* 1995b). In addition, the fact that no difference in running economy was observed between Nandi town and village boys indicates that the higher physical activity level of the village boys during secondary school has limited or no effect on running economy.

4.2. Maximal oxygen uptake and physical activity level (tables 2, 5 and 6, figure 1)

The maximal oxygen consumption of the Nandi town boys is in line with previous findings on untrained Kenyan boys from the same town (Saltin *et al.* 1995b), and also similar to VO_{2max} of untrained Caucasian boys (Andersen *et al.* 1987). However, it can be argued that the maximal oxygen uptake of the town boys is higher compared to untrained Caucasian boys due to the fact that the VO_{2max} of the town boys is reduced because they were tested at altitude. If measured at sea level, the VO_{2max} of these boys would probably have been 3–5% higher (Favier *et al.* 1995). However, if the VO_{2max} of the Kenyan town boys is adjusted to sea level by adding 3–5% and thus tends to be higher than VO_{2max} of untrained Caucasian boys, this difference is equalized when normalizing the data for differences in body mass (by using mass to an exponent of 0.75 instead of 1, since the mass of the Nandi boys is about 12 kg less than the mass of Caucasian boys of the same age (table 7)). 'Scaling' is used in this relationship because it has proven useful in order to compare humans with differences in body mass. Here 0.75 has been chosen, because Svedenhag (1995), who has been studying adolescent runners, their VO_{2max} and their running economy, preferred to use this exponent. The maximal oxygen uptake of the Nandi village boys was about 10% higher than the VO_{2max} of the town boys, which may be due to the higher physical activity level of the village boys. It is difficult to interpret the information concerning the physical activity level during childhood given by the subjects based on interviews, because no information is available about the duration or intensity of the different kinds of physical activity (table 5). However, based on the interviews, there is no indication of a different physical activity pattern between the two groups of boys until they began their secondary school education. After starting secondary school, the habitual physical activity level of the village boys was significantly higher compared to the town boys. The question is therefore whether the difference in physical activity can explain the observed difference in VO_{2max}. It is true that the duration of the physical activity of the village boys is considerably longer compared to the town boys, but the intensity of the main part of this activity may be much too low to stimulate VO_{2max} for subjects consuming 50–55 mL kg^{-1} min^{-1} of oxygen maximally, since the 'training threshold' for these subjects probably is an exercise intensity demanding a heart rate in the range of 135–145 b.p.m (Larsen 2001). The 24-h heart rate recordings support this assumption, even though these data must be interpreted with caution due to the low number of recordings (figure 1). Thus, these recordings indicate that the duration of the period during which the heart rate is above the necessary level needed to stimulate VO_{2max} is only 10–15 min day^{-1}. However, although not generally agreed (Milesis *et al.* 1976), it has been demonstrated previously (Davies and Knibbs 1971) that only a 10-min difference in the duration of short (10 min vs 20 min) daily exercise sessions (5 days per week) can induce a different increase in the VO_{2max} in previously untrained subjects. Therefore, taking both the questionnaires and the heart-rate recordings into consideration, the observed higher VO_{2max} of the village boys compared to the town boys may be due to the higher physical activity level of the village boys. This view gets support when studying the relationship between the time spent daily doing sports and VO_{2max}. While no correlation was found for the town boys, a trend for a relationship was observed for the village boys ($R = 0.52$, $p < 0.07$). When pooling the data from both groups of boys a moderate correlation was found ($R = 0.55$, $p < 0.01$). Somewhat surprisingly, none of the boys in the two groups did much running between home and school, partially because the main distance was short, but also because that those who were running reported that they were only doing so when they wanted to avoid being late for school. The most distinct difference in the activity pattern between the village and the town boys was expressed through the games of football and volleyball as well as working in the field after school time and during the weekends. Even though the maximal oxygen uptake of the village boys was somewhat higher than the VO_{2max} of the town boys, it is much lower than the level reported previously for Kenyan junior runners who had a level of ~64 mL kg^{-1} min^{-1} (Saltin *et al.* 1995b). This means that the daily physical activity of the boys in the rural area does not give sufficient physiological stimulus in order to reach the level needed to become an elite runner. However, some of the observed difference in VO_{2max} between the village boys in the present study and the junior runners studied by Saltin *et al.* (1995b) is probably due to the fact that the junior runners were selected.

The observed values of haemoglobin for both groups of Nandi boys are very low when taking the altitude into consideration. This is probably due to the fact that all village boys ($n = 12$) and half of the town boys ($n = 4$) who were studied with respect to malaria reported that they had suffered from this disease.

This investigation demonstrated that the principal features with respect to body dimensions of adolescent Kenyan Nandi town and village boys compares well with findings in Kenyan elite runners. Thus, the Nandi boys have a very low BMI and thus a slender body shape with relatively long and slender legs. In addition, the study indicated that the oxygen cost when running is lower in untrained Kenyans compared to untrained Caucasians and that this may be due to inherent factors. Furthermore, the study demonstrated that Nandi boys from a rural area have a higher capacity with respect to some physiological properties needed to become an elite runner compared to Nandi town boys. Moreover, the study indicated that the physical activity level of Nandi village boys is higher during secondary school compared to Nandi town boys, which probably explains the observed higher maximal oxygen uptake of the village boys.

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Zusammenfassung. Das Ziel dieser Studie war die Charakterisierung von untrainierten Nandi Knaben aus einer Stadt (n = 11) und einer ländlichen Gegend (n = 19) im Alter von 16,6 Jahren aus Westkenia (Höhe 2000 Meter über Meeresspiegel) hinsichtlich Körpermaße, Sauerstoffaufnahme und sportlicher Aktivität. Die Knaben aus der Stadt hatten eine maximale Sauerstoffaufnahme (Vo_{2max}) von 50 (45–60) $ml \cdot kg \cdot min^{-1}$, während die Dorfknaben einen Wert (Vo_{2max}) von 55 (37–63) $ml \cdot kg \cdot min^{-1}$ ($P <$ 0,01) aufwiesen. Die Laufökonomie, gemessen am Sauerstoffbedarf bei vorgegebener Laufgeschwindigkeit, war für Stadt- und Dorfknaben jeweils 221 $ml \cdot kg^{-1}\ km^{-1}$ (597 $ml \cdot kg^{-0.75} \cdot km^{-1}$).

km^{-1}). Der Körpermasse-Index (body mass index, BMI) war sowohl bei den Stadt- als auch bei den Dorfknaben sehr niedrig (18,6 bzw. 18,4 $kg \cdot m^{-2}$). Während der Schulzeit verbrachten Dorfknaben im Mittel pro Tag signifikant mehr Zeit bei Arbeiten auf dem Feld und beim Sport im Freien als Stadtknaben (44,2 (0-128) gegenüber 1,3 (0-11) min, $P < 0{,}01$ und 32,0 (11-72) gegenüber 12,8 (0-35) min, $P < 0{,}01$). Es wurde eine positive Korrelation zwischen der Zeit, die täglich beim Sport verbracht wurde, und Vo_{2max} gefunden, wenn die Daten von Stadt- und Dorfknaben gemeinsam betrachtet wurden ($R = 0.55$, $P < 0.01$). Zusammenfassend wird festgestellt, dass die Körpermaße jugendlicher Nandi Knaben aus städtischem und ländlichem Umfeld gut mit Befunden übereinstimmen, die bei Kenianischen Elite-Läufern erhoben wurden. Sie sind sehr mager und haben relativ lange Beine. Darüber hinaus ist die Vo_{2max} von Dorfknaben höher als die von Stadtknaben, was vermutlich auf die größere sportliche Betätigung während der Schulzeit zurückzuführen ist.

Résumé. Cette étude a pour but de caractériser des garçons Nandi citadins ($n = 11$) et ruraux ($n = 19$) non entraînés et âgés de 16,6 ans, de l'ouest du Kenya (altitude ~2000m) par rapport à leurs dimensions corporelles, leur consommation d'oxygène et le niveau de leur activité physique. Les garçons citadins ont une moyenne de consommation d'oxygène maximale (Vo_{2max}) de 50 (45-60) $ml \cdot kg \cdot min^{-1}$ alors que les ruraux atteignent une valeur de 55 (37-63) $ml \cdot kg \cdot min^{-1}$ ($P < 0{,}01$). L'économie de course déterminée comme le coût d'oxygène lors d'une course à vitesse donnée, est de 221 $ml \cdot kg^{-1} \cdot km^{-1}$ (597 $ml \cdot kg^{-0,75} \cdot km^{-1}$) aussi bien pour les citadins que pour les ruraux. L'indice de masse corporelle (IMC) est très bas chez les citadins comme chez les ruraux (respectivement 18,6 et 18,4 $kg \cdot m^{-2}$). Le temps passé en moyenne à des travaux à l'extérieur et à des activités sportives dans le cadre de l'école secondaire, est significativement plus élevé chez les ruraux que chez les urbains (respectivement (44,2 (0-128) contre 1.3 (0-11) min, $P < 0.01$ et 32,0 (11-72) contre 12.8 (0-35) min, $P < 0.01$). Après regroupement des données des deux échantillons, on trouve une corrélation positive entre le temps passé quotidiennement en activité sportive et le Vo_{2max} ($R = 0{,}55$ $P < 0.01$). On conclut que les dimensions corporelles des adolescents citadins et ruraux Nandi correspondent bien aux caractéristiques des coureurs d'élite du Kénya. Ils sont très minces avec des jambes relativement longues. De surcroît, le Vo_{2max} des garçons ruraux est plus élevé que celui de leurs homologues citadins, ce qui est probablement l'expression d'un niveau d'activité physique plus élevé chez les ruraux dans le cadre de l'école secondaire.

Resumen. El objetivo de este estudio fue caracterizar a muchachos Nandi no entrenados, de 16,6 años de edad, procedentes de una ciudad ($n = 11$) y de un área rural ($n = 19$) del oeste de Kenya (altitud ~2000 metros sobre el nivel del mar), con respecto a sus dimensiones corporales, consumo de oxígeno y nivel de actividad física. Los chicos de ciudad tuvieron una consumo medio máximo de oxígeno (Vo_{2max}) de 50 (45–60) $ml \cdot kg \cdot min^{-1}$, mientras que los de la aldea alcanzaron un valor de 55 (37–63) $ml \cdot kg \cdot min^{-1}$ ($P < 0{,}01$) en Vo_{2max}. La economía de carrera determinada como el coste de oxígeno a una velocidad de carrera dada fue de 221 $ml \cdot kg^{-1} \cdot km^{-1}$ (597 $ml \cdot kg^{-0,75} \cdot km^{-1}$), tanto para los chicos de ciudad como para los rurales. El índice de masa corporal (IMC) fue muy bajo tanto en los chicos de ciudad como en los de la aldea (18,6 vs. 18,4 $kg \cdot m^{-2}$). El tiempo medio diario dedicado a trabajar en el campo y a hacer deporte durante la educación secundaria fue significativamente mayor en los chicos del área rural que en los de la ciudad (44,2 (0–128) vs. 1,3 (0–11) minutos, $P < 0{,}01$ y 32,0 (11–72) vs. 12,8 (0–35) minutos, $P < 0{,}01$, respectivamente). Se encontró una correlación positiva entre el tiempo empleado diariamente en hacer deporte y el Vo_{2max} cuando se agrupaban los datos de los chicos urbanos y rurales ($R = 0{,}55$, $P < 0{,}01$). Se concluye que las dimensiones corporales de los adolescentes Nandi de ciudad y de aldea se corresponden con los resultados obtenidos en los corredores kenianos de elite, muy delgados y con las piernas relativamente largas. Además, el Vo_{2max} de los chicos rurales es mayor que el de los urbanos, lo que es debido, probablemente, a un mayor nivel de actividad física de los chicos rurales durante la educación secundaria.