ORIGINAL ARTICLE

A comparison of estimated maximal oxygen uptake in 9 and 10 year old schoolchildren in Tanzania and Norway

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27 September 2005**Objective:** To compare estimated maximal oxygen uptake ($\dot{V}O_{2max}$) in Tanzanian and Norwegian children, by using the same bicycle protocol in both samples.**Methods:** Maximal oxygen uptake was estimated from an indirect maximal watt cycle ergometer test in 156 rural boys and girls in Tanzania. Similarly aged urban Norwegian boys and girls ($n = 379$) who underwent the same test were used for comparison. The Tanzanian children also participated in a 20 metre shuttle run test and a test of bicycle skill. The Tanzanian children were tested at altitude (~ 1800 metres), while the Norwegian children were tested at sea level.**Results:** In the cycle ergometer test, estimated relative $\dot{V}O_{2max}$ was similar in Tanzanian and Norwegian boys, while Tanzanian girls had 8% lower estimated $\dot{V}O_{2max}$ compared with Norwegian girls ($p < 0.001$). Only one third of the Tanzanian children were able to ride a conventional bicycle. Excluding subjects not able to ride a bicycle, there was no difference in estimated $\dot{V}O_{2max}$ between Norwegian and Tanzanian children. The Tanzanian boys and girls reached significantly higher estimated $\dot{V}O_{2max}$ in the shuttle run test compared with the cycle ergometer test ($p < 0.001$).**Conclusions:** Tanzanian and Norwegian children attained similar relative $\dot{V}O_{2max}$ in the cycle ergometer test. However, the comparison was hampered by differences in altitude and the poor cycle ergometer skills in the Tanzanian children, both of which probably underestimated their $\dot{V}O_{2max}$.

Over the past few decades, East African runners have dominated international middle and long distance running. Kenyans and Ethiopians have been the most successful, but neighbouring countries have also produced good runners. There are many hypotheses for the East African runners' superiority.¹ According to Hamilton and Weston,² a combination of genetics, training, environment, lifestyle, and social factors are involved.

Several research groups have examined the difference in physiological determinants of long distance performance in highly trained white and African runners.^{3–6} Saltin and colleagues^{7–8} showed that major physical characteristics, such as maximal oxygen uptake ($\dot{V}O_{2max}$) and muscle morphology, were similar in elite Kenyan and Scandinavian runners. They also reported that urban Kenyan teenage boys ($n = 6$) had similar relative $\dot{V}O_{2max}$ to untrained teenage Danish boys,⁹ while rural Kenyan boys ($n = 4$) reached 30% higher relative $\dot{V}O_{2max}$. Saltin *et al*⁷ concluded that the physically active childhood, later combined with high intensity training, leads to the high $\dot{V}O_{2max}$ observed in Kenyan runners, and that a high aerobic capacity, together with good running economy, makes Kenyan runners so successful.

If it is true that East African children are more physically active than children in the western world, this might result in a higher $\dot{V}O_{2max}$ among East Africans. Three decades ago, Davies¹⁰ measured $\dot{V}O_{2max}$ directly in urban and rural Tanzanian schoolchildren aged 7–17 years old. This sample was only representative of the healthy population of children, as subjects with signs of malnutrition or anaemia were excluded. Davies reported no difference in absolute $\dot{V}O_{2max}$ (l/min) between rural and urban Tanzanian children, and also noted that these values were similar to studies of European children. Recently, Larsen *et al*¹¹ measured $\dot{V}O_{2max}$ directly from treadmill running in 30 adolescent Kenyan town and village boys. The town boys attained relative $\dot{V}O_{2max}$ values similar to untrained Danish adolescent boys,⁹ while Kenyan village boys reached about 10% higher values. However, the

Danish sample was measured from a maximal bicycle test, which will produce about 7–13% lower $\dot{V}O_{2max}$ than found in treadmill running.^{12–13}

Previous studies comparing aerobic fitness between East African and western children or adolescents have had shortcomings in terms of method differences, small sample sizes, and old reference material. The aim of the present study was to compare aerobic fitness in Tanzanian and Norwegian children by using the same test procedures in both samples and larger sample sizes than in previous studies. The study investigated whether East African nations have an advantage over western nations even in early childhood, through a higher $\dot{V}O_{2max}$ in the childhood population.

MATERIALS AND METHODS

Ethics

Research clearance was obtained from the University of Dar es Salaam. Approval was also given by the local ministry of education and the local authorities in Mbulu district, and headmasters from the five primary schools visited. Consent for participation of the Tanzanian children was provided by the principals of the school acting in loco parentis for the children. All children were given verbal information about the test procedures, and they could withdraw from the study at any time and for any reason.

Subjects

Five primary schools were randomly selected from three wards in Mbulu district, Manyara region, in northern Tanzania. All schoolchildren ($n = 326$) aged 9 and 10 years old (born in 1993) were identified at each of the five schools and invited to participate in the study. Eight tribes were represented in the sample, with a representative 87% of the

Abbreviations: CV, coefficient of variation; HR, heart rate; MWCE, maximal watt cycle ergometer; SRT, shuttle run test

subjects belonging to the Iraqw tribe. The data were collected during a period of 6 weeks in May and June 2003.

The 379 subjects from the Norwegian part of the European Youth Heart Study (EYHS) were used as a basis for comparison with the Tanzanian sample. The Norwegian sample was examined in 2000, and consisted of randomly selected 9 and 10 year old children from nine primary schools in Oslo.¹⁴

Testing methods

The test procedures were standardised to ensure similarity with respect to data gathering in Norway and Tanzania. A flowchart of the test order for the Tanzanian subjects is given in fig 1. The Norwegian subjects underwent anthropometric measurements, the maximal watt cycle ergometer (MWCE) test, and completion of the physical activity questionnaire.

Preliminary cycle ergometer test

All Tanzanian subjects carried out a 10 minute preliminary cycle ergometer test to evaluate the child's ability to cycle on a stationary cycle ergometer with a steady pedal rate of 70–80 rpm. During the preliminary test, 106 (35%) of the subjects were not able to maintain a steady pace, mostly because the foot frequently slipped off the pedal when cycling. Only children able to cycle satisfactorily were invited to participate in the MWCE test. Ultimately, results from 156 Tanzanian MWCE tests were accepted.

Anthropometrics

Body weight was measured to the nearest 0.1 kg, using an electronic scale (Soehnle, Type 7516, Germany). Height was measured to the nearest 5 mm, using a tape measure attached to the wall (table 1).

Figure 1 Flowchart of test order for the Tanzanian subjects. PT, preliminary cycle ergometer test; 20 metre SRT, 20 metre shuttle run test; MWCE test, maximal watt cycle ergometer test.

Maximal watt cycle ergometer test

Maximal power output ($W_{\max}$) was measured from the MWCE test¹⁵ conducted on an electronically braked cycle ergometer (Monark 839 Ergomedic, Sweden). A relative $\dot{V}O_{2\max}$ was calculated from the equation: $\dot{V}O_{2\max} (\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = (12.44 W_{\max} + 250)/\text{body mass}$.¹⁶

Initial and incremental workload were 20 W for children weighing <30 kg and 25 W for children weighing ≥ 30 kg. Every third minute, the load increased, until exhaustion was reached. Heart rate (HR) was registered throughout the test (Polar Pacer, Finland). The criteria for having reached maximal effort were a HR ≥ 185 beats/min and a subjective assessment that the child had reached his or her maximal effort. The cycle ergometer was calibrated electronically twice a day and mechanically once a day or every time after being moved. All bicycle tests in Tanzania were conducted indoor with mean air temperature 22.1°C (confidence intervals (CI) 21.8 to 22.5), relative humidity 60.0% (CI 58.8 to 61.2) and barometric pressure 82.7 kPa (CI 82.6 to 82.8). The Tanzanian children were tested at an altitude between 1750 and 1800 metres above sea level, while the Norwegian children were tested at sea level. Eighteen randomly chosen Tanzanian subjects were retested after 3 weeks to calculate the reproducibility of the MWCE test. The coefficient of variation between the first test and the re-test was 8%, and a 3% higher estimated $\dot{V}O_{2\max}$ was demonstrated in the re-test ($p < 0.001$). The MWCE test has been validated in 21 Scandinavian 9 year old children. The correlation between maximal power output and $\dot{V}O_{2\max}$ was $r = 0.93$ and the standard error of estimation for predicted $\dot{V}O_{2\max}$ was 4.8%.¹⁶

Physical activity

Habitual physical activity was registered using a questionnaire consisting of eight questions pertaining to means of transportation to school, physical activity during school breaks, and participation in after school sports activities. The questions were selected from a validated questionnaire¹⁴ used in the EYHS and translated into Kiswahili. The subjects filled in the questionnaire guided by a Kiswahili and Kiraqwa speaking research assistant.

20 metre shuttle run test

A 20 metre shuttle run test (SRT) was carried out on 276 of the Tanzanian children who participated in the study. The running protocol and calculation of estimated maximal oxygen uptake were according to Léger *et al.*¹⁷ The running took place on a flat area of the schoolyard or on a football field. Correlation coefficients of ≥ 0.7 between $\dot{V}O_{2\max}$ predicted from the 20 metre SRT and direct measurements have been reported for children and adolescents.^{17, 18}

Bicycle skill

Bicycle skill was examined in the Tanzanian sample by observing the subjects riding a regular children's bicycle for about 100 metres. Children able to cycle freely without touching their feet to the ground were characterised as accustomed to bicycling. Children who failed this test were characterised as unaccustomed. Bicycle skill was not examined in the Norwegian sample.

Statistics

SPSS software (version 11.0; SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Differences in height, weight, $HR_{\max}$, $W_{\max}$, and estimated $\dot{V}O_{2\max}$ between groups were tested using the independent samples *t* test. The χ^2 test and the Mann-Whitney *U* test were used when comparing differences in physical activity patterns, while one way analysis of variance with Tukey post hoc test was used to analyse $\dot{V}O_{2\max}$ in relation to physical activity. The one

Table 1 Anthropometrical characteristics of Tanzanian and Norwegian 9 and 10 year old schoolchildren

Country	Sex	n	Weight (kg)	Height (m)	BMI(kg/m ²)
Tanzania	Boys	87	26.7 (26.0 to 27.3)*	1.34. (1.33to 1.35)*	14.8 (14.6 to 15.0)*
	Girls	69	27.2 (26.3 to 28.0)*	1.35 (1.33 to 1.36)*	15.0 (14.6 to 15.3)*
	Total	156	26.9 (26.3 to 27.4)*	1.34 (1.33 to 1.35)*	14.9 (14.7 to 15.1)*
Norway	Boys	195	33.5 (32.8 to 34.3)	1.40 (1.39 to 1.41)	17.0 (16.7 to 17.3)
	Girls	184	33.1 (32.2 to 34.0)	1.39 (1.38 to 1.39)	17.2 (16.8 to 17.5)
	Total	379	33.3 (32.7 to 33.9)	1.39 (1.39 to 1.40)	17.1 (16.9 to 17.3)

Values are reported as means (95% CI). *p<0.001 from the corresponding Norwegian value.

sample *t* test, calculation of coefficient of variation (CV) and Pearson's product moment correlation coefficient was used to calculate reproducibility of the MWCE test. All data are reported as mean values with 95% confidence intervals (95% CI). The level of significance was set at p<0.05.

RESULTS

Estimated maximal oxygen uptake

When bicycle skill was not taken into consideration, Tanzanian girls attained 8% lower relative $\dot{V}O_{2\max}$ in the MWCE test compared with Norwegian girls, while there was no significant difference between Tanzanian and Norwegian boys (table 2). However, experience and skill in bicycling influenced the result of the MWCE test. Tanzanian boys and girls who were accustomed to bicycling achieved a 12% higher estimated $\dot{V}O_{2\max}$ in the MWCE test compared with boys and girls unaccustomed to bicycling (table 3), whereas there was no difference in estimated $\dot{V}O_{2\max}$ between the Tanzanian accustomed and unaccustomed children in the 20 metre SRT (table 3). Thus, the Tanzanian $\dot{V}O_{2\max}$ values in the MWCE test (table 2) are probably an underestimate.

Of 174 Tanzanian subjects, 54 (31%) were considered to be accustomed to conventional bicycling, while the rest were characterised as unaccustomed. When comparing the Tanzanian children accustomed to bicycling with the Norwegian children, no significant difference in relative $\dot{V}O_{2\max}$ estimated from the MWCE test was revealed for either sex (fig 2).

Tanzanian boys and girls attained 21.6% and 36.0%, respectively, higher estimated $\dot{V}O_{2\max}$ in the 20 metre SRT (table 4) compared with the MWCE test (table 3; AB subjects) (p<0.001).

Physical activity

The majority of both Tanzanian and Norwegian children walked to school, but the Tanzanian children had to travel a significantly longer distance (table 5). There was no significant difference in $\dot{V}O_{2\max}$ measured from the MWCE test or the 20 metre SRT between Tanzanian children who walked short *versus* long distances to school. Tanzanian boys were less active in playing outdoor games after school compared with Norwegian boys, while no significant

Figure 2 Estimated maximal oxygen uptake ($\dot{V}O_{2\max}$) in Norwegian and Tanzanian 9 and 10 year old schoolchildren. AB, only subjects accustomed to conventional bicycling are included. All, all children, both accustomed and unaccustomed to conventional bicycling are included. Values are reported as means (95% CI). Significance: *p<0.001; ns=not significant.

difference was found between Norwegian and Tanzanian girls.

DISCUSSION

The study demonstrates that estimated relative $\dot{V}O_{2\max}$ from the MWCE test does not differ between Norwegian and Tanzanian 9–10 year old schoolchildren when only children accustomed to conventional bicycling are included in the analysis. The study also revealed that the Tanzanian children attained significantly higher estimated $\dot{V}O_{2\max}$ in the 20 metre SRT compared with the MWCE test.

Estimated $\dot{V}O_{2\max}$ from the maximal watt cycle ergometer test

In the MWCE test, a 12% higher $\dot{V}O_{2\max}$ was reported for Tanzanian boys and girls accustomed to bicycling compared with their unaccustomed counterparts. In the 20 metre SRT there was no significant difference in $\dot{V}O_{2\max}$ between accustomed and unaccustomed Tanzanian children. The most likely explanation for this discrepancy is that the

Table 2 Maximal heart rate ($HR_{\max}$), maximal watt ($W_{\max}$), and estimated relative maximal oxygen uptake ($\dot{V}O_{2\max}$) from the maximal watt cycle ergometer test in Tanzanian and Norwegian 9 and 10 year old schoolchildren

Country	Sex	n	$HR_{\max}$ (beats/min)	$W_{\max}$ (W)	$\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)
Tanzania	Boys	87	195.6 (194.0 to 197.2)	75.3 (71.8 to 78.9)*	44.6 (43.3 to 45.8)
	Girls	69	196.1 (194.3 to 197.8)	60.7 (57.6 to 63.9)*	37.2 (36.1 to 38.3)*
Norway	Boys	195	193.5 (192.1 to 194.8)	102.1 (99.4 to 104.9)	45.9 (44.9 to 46.9)
	Girls	184	193.8 (192.4 to 195.2)	85.5 (83.2 to 87.8)	40.5 (39.5 to 41.5)

Values are reported as means (95% CI). *p<0.001 from the corresponding Norwegian value. All other differences were not significant.

Table 3 Estimated maximal oxygen uptake ($\dot{V}O_{2\max}$) from the maximal watt cycle ergometer test (MWCE test) and the 20 metre shuttle run test (20 metre SRT) in Tanzanian schoolchildren, who were accustomed (AB) or unaccustomed (UB) to conventional bicycling.

Country	Sex	MWCE test $\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)		20 metre SRT $\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)	
		AB	UB	AB	UB
Tanzania	Boys	47.3 (45.5 to 49.0)* (n=38)	42.1 (40.6 to 43.7) (n=43)	58.6 (57.3 to 60.0) (n=31)	57.3 (56.6 to 58.0) (n=51)
	Girls	40.3 (37.2 to 43.4)** (n=13)	36.1 (35.0 to 37.2) (n=49)	54.7 (52.9 to 56.5) (n=14)	55.2 (54.4 to 55.9) (n=62)

Values are reported as means (95% CI) (n). *p<0.001; **p<0.01 from the corresponding UB value. All other differences were not significant.

MWCE test underestimated $\dot{V}O_{2\max}$ in children unable to cycle on a conventional bicycle, due to their poorer cycle ergometer skill. Estimation of $\dot{V}O_{2\max}$ from indirect performance tests is exposed to bias if work efficiency of the tested subjects differs from the work efficiency of the subjects used to produce the test equation.¹⁹ The equation we used to estimate $\dot{V}O_{2\max}$ from the MWCE test is based on measurements taken from Scandinavian children, who were probably accustomed to conventional bicycling.¹⁶ Hence, $\dot{V}O_{2\max}$ is probably underestimated among the unaccustomed Tanzanian children. Thus, including only accustomed Tanzanian children gives the most valid comparison of $\dot{V}O_{2\max}$ between the Tanzanian and Norwegian children. Even though one third of the Tanzanian children managed to cycle on a conventional bicycle, most were, in our visual judgement, less accustomed to bicycling than Norwegian children of the same age. This might indicate that even $\dot{V}O_{2\max}$ values in the accustomed Tanzanian children were underestimated compared with the Norwegian subjects. However, Davies¹⁰ examined the $\dot{V}O_2$ /watt relationship in Tanzanian and western children working on a cycle ergometer. No differences were found, despite the fact that many of the Tanzanians had never pedalled any type of cycle, except for the familiarisation prior to the study.

Larsen *et al*¹¹ measured $\dot{V}O_{2\max}$ in Kenyan boys at an altitude of ~2000 metres, and suggested a 3–5% increase in $\dot{V}O_{2\max}$ if measured at sea level, referring to Favier *et al*.²⁰ Other studies have demonstrated greater increases in $\dot{V}O_{2\max}$ when subjects native to moderate or high altitude were tested at sea level.^{21, 22} Altitude should be kept in mind when analysing the $\dot{V}O_{2\max}$ values in the Tanzanian children, but inconsistencies in the literature make it difficult to quantify how much higher the estimated $\dot{V}O_{2\max}$ would have been if the Tanzanian children had been tested at sea level.

It is suggested that allometric scaling of $\dot{V}O_{2\max}$ has less bias than $\dot{V}O_{2\max}$ expressed relative to body weight, when comparing individuals of different size.^{23–24} There was a great difference in body size between the Norwegian and Tanzanian children, thus analysis with allometric scaling was carried out. Expressing $\dot{V}O_{2\max}$ as ml/kg^{0.75}/min favoured the Norwegian children compared with the Tanzanian. For example, Norwegian girls reached 14% higher $\dot{V}O_{2\max}$ compared with Tanzanian girls using allometric scaling (96.4 and 84.6 ml/kg^{0.75}/min, respectively), while the conventional ratio method only revealed a 9% higher $\dot{V}O_{2\max}$ in Norwegian girls compared with Tanzanian girls. However, as

$\dot{V}O_{2\max}$ is most typically expressed per kilogram of body mass, the results have been presented in the conventional way.

Estimated $\dot{V}O_{2\max}$ from the 20 metre shuttle run test

The 20 metre SRT was carried out for three reasons. Firstly, we wanted to detect if relative $\dot{V}O_{2\max}$, estimated from the 20 metre SRT, differed between the children who passed the preliminary cycle ergometer test and those who failed. For the boys, a 2.4% higher $\dot{V}O_{2\max}$ was found among the successful group (p<0.05). There was no significant difference in $\dot{V}O_{2\max}$ between girls who passed and girls who failed the preliminary test. Secondly, the 20 metre SRT, combined with the cycling skill test, should give us an idea of whether the MWCE test underestimates Tanzanian children who were unaccustomed to conventional bicycling. As previously discussed, this seemed to be the case. Finally, the 20 metre SRT is one of the most widely used tests to assess aerobic fitness in children and adolescents.²⁵ The results can be compared with a large number of studies worldwide, but the different existing protocols and equations often complicate direct comparison. Tanzanian boys and girls performed well in the 20 metre SRT, compared with what is previously reported in other international studies of children.^{17, 26–28} On average, the Tanzanian boys (n=121) and girls (n=152) continued running until level 8 (57.5 ml·kg⁻¹·min⁻¹) and level 7 (54.8 ml·kg⁻¹·min⁻¹), respectively. Leger *et al*¹⁷ have presented normal values for the 20 metre SRT in a large number of Canadian children. Canadian boys aged 9 years old were able to run to level 5 (51.5 ml·kg⁻¹·min⁻¹), while Canadian girls of the same age continued until level 4 (49.2 ml·kg⁻¹·min⁻¹). Similar or slightly lower results have been demonstrated in 9 year old children from Portugal²⁸ and Switzerland,²⁷ while no such data have yet been gathered in Norway. Comparing the Tanzanian 20 metre SRT results with the aforementioned studies on western children, the Tanzanians achieved an 11–17% higher estimated $\dot{V}O_{2\max}$.

While the Tanzanian 20 metre SRT results were significantly better compared with western values, Tanzanian and Norwegian children reached similar estimated $\dot{V}O_{2\max}$ in the MWCE test. This discrepancy might be explained by a better running efficiency in the East African population compared with the western children, as reported in studies on adult East African runners.^{7, 29–30} Another explanation is that the Tanzanian children actually have a higher relative $\dot{V}O_{2\max}$ compared with Norwegian and other western children, but

Table 4 20 metre shuttle run results in Tanzanian 9 and 10 year old schoolchildren: number of levels completed, final speed, and estimated maximal oxygen uptake ($\dot{V}O_{2\max}$)

Sex	n	Levels (no.)	Final speed (km/h)	$\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)
Boys	121	8.4 (8.2 to 8.6)	12.2 (12.1 to 12.3)	57.5 (56.9 to 58.0)
Girls	152	7.3 (7.1 to 7.5)	11.6 (11.5 to 11.7)	54.8 (54.3 to 55.3)
Total	273	7.8 (7.6 to 7.9)	11.9 (11.8 to 12.0)	56.0 (55.6 to 56.4)

Table 5 Physical activity patterns in Norwegian and Tanzanian 9 and 10 year old schoolchildren

	Norway				Tanzania			
	Boys		Girls		Boys		Girls	
	n	%	n	%	n	%	n	%
Means of transportation to school								
Foot	194	94	183	94	87	90	75	88
Other	11	6	12	6	10	10	10	12
Total	205	100	195	100	97	100	85	100
Travelling time to school, boys* and girls*								
<5 min	56	27	60	31	6	6	9	10
5–15 min	114	55	92	47	21	22	16	19
15–30 min	28	14	34	17	33	35	28	32
30–60 min	6	3	7	4	23	24	23	27
>1 hour	1	1	2	1	12	13	10	12
Total	205	100	195	100	95	100	86	100
Participation in outdoor games after school, boys*								
Hardly ever or never	38	18	70	36	47	48	34	40
1–2 days/week	67	33	63	32	16	17	18	21
Most days	61	30	49	25	16	17	7	8
Every day	39	19	13	7	18	18	27	31
Total	205	100	195	100	97	100	86	100

*p<0.001 between the Norwegian and Tanzanian values. All other differences were not significant.

that the general low efficiency in the cycle test underestimated the MWCE test results, as previously hypothesised.

The study demonstrated a 21.6% and 36.0% higher estimated $\dot{V}O_{2max}$ in the 20 metre SRT compared with the MWCE test in Tanzanian boys and girls, respectively. This difference is partly explained by the fact that children and adults yield about 7–13% higher $\dot{V}O_{2max}$ in running compared with cycling.^{12–13} Another explanation for the difference is the possible underestimation in the MWCE test. It should also be mentioned that different equations exist for predicting $\dot{V}O_{2max}$ from the MWCE test^{15–31} and the 20 metre SRT.³² Using other equations could produce different estimated values for $\dot{V}O_{2max}$, but we used the equations we felt were the most reliable and applicable in regard to our samples.

Irrespective of discussions regarding $\dot{V}O_{2max}$, the shuttle run results clearly demonstrated that the Tanzanian children were good runners.

Physical activity

It has been claimed that one of the reasons why East African runners perform so well in international running is because of high levels of physical activity during childhood.⁷ The present study showed that the majority of both Tanzanian and the Norwegian children travelled to school by foot, but the Tanzanian children had to walk longer distances than the Norwegian children. Urban Norwegian children typically walk short distances from home to school. Almost 40% of the Tanzanian children walked for more than 30 minutes to get to school, compared with 5% of Norwegian children. The intensity of the movement was not evaluated, but from our experience, the Tanzanian children walked rather than ran. Improvement in $\dot{V}O_{2max}$ during childhood is probably only achieved when the training intensity is high.³³ This might contribute to why we did not find any differences in $\dot{V}O_{2max}$ between Tanzanian children covering long or short distances by foot for transportation to school.

CONCLUSIONS

No difference in estimated $\dot{V}O_{2max}$ was found between Norwegian and Tanzanian 9–10 year old children, as long as subjects unaccustomed to bicycling were excluded from the analysis. However, the study has some limits. The Tanzanians were tested at moderate altitude while the

Norwegians were tested at sea level. In addition, an indirect test such as the MWCE test has sources of error when estimating $\dot{V}O_{2max}$, compared with direct measurements. Finally, we would recommend that future studies of populations not accustomed to bicycling should consider using test methods other than the MWCE test, as this test probably underestimates $\dot{V}O_{2max}$ in subjects unaccustomed to bicycling.

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What is already known on this topic

- The success of East African runners is not fully understood.
- Few studies have examined differences in $\dot{V}O_{2max}$ between western and African children.
- However, it has been shown that rural East African boys attain 10–30% higher relative $\dot{V}O_{2max}$ compared with Scandinavian boys.
- Previous studies have had small sample sizes and different test methods.

What this study adds

- This study showed that Tanzanian and Norwegian children attained similar relative $\dot{V}O_{2max}$ estimated from the maximal watt cycle ergometer test.
- However, the Tanzanian children reached a significantly higher estimated $\dot{V}O_{2max}$ in the 20 metre shuttle run test, and it is likely that the Tanzanian cycle ergometer results are underestimated.

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