Running economy of African and Caucasian distance runners

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ABSTRACT

WESTON, A. R., Z. MBAMBO, and K. H. MYBURGH. Running economy of African and Caucasian distance runners. Med. Sci. Sports Exerc., Vol. 32, No. 6, pp. 1130–1134, 2000. Purpose: Anecdotal evidence suggests an advantageous physiological endowment of the African endurance athlete. Higher fractional utilization of VO\textsubscript{2max} has been suggested but not measured directly, and investigations of running economy have been inconclusive. The aim of the current study was to measure a) running economy and b) fractional utilization of VO\textsubscript{2max} in African and Caucasian 10-km runners of similar body mass. Methods: Eight African and eight Caucasian runners had no significant difference in mean race time (32.8 ± 2.8, 32.0 ± 2.5 min, respectively), body mass (61.4 ± 7.0, 64.9 ± 3.0 kg), age, body fat, or lean thigh volume. Caucasian runners were 6 cm taller (P < 0.05). Subjects completed a progressive treadmill VO\textsubscript{2peak} test. On a separate day, subjects completed two 6-min workloads (16.1 km·h\textsuperscript{-1} and 10-km race pace) separated by 5 min. Results: Mean VO\textsubscript{2peak} was 13% lower in the Africans (61.9 ± 6.9, 69.9 ± 5.4 mL·kg\textsuperscript{-1}·min\textsuperscript{-1}, P = 0.01). At 16.1 km·h\textsuperscript{-1}, the Africans were 5% more economical (47.3 ± 3.2, 49.9 ± 2.4 mL·kg\textsuperscript{-1}·min\textsuperscript{-1}, P < 0.05). This difference increased to 8% (P < 0.01) when standardized per kg\textsuperscript{0.75}. At race pace, the Africans utilized a higher %VO\textsubscript{2peak} (92.2 ± 3.7, 86.0 ± 4.8%, P < 0.01) and had higher HR (185 ± 9, 174 ± 11 b·min\textsuperscript{-1}, P < 0.05) and plasma [ammonia] (113.2 ± 51, 60.3 ± 16.9 μmol·L\textsuperscript{-1}, P < 0.05). Despite the higher relative workload, the plasma [lactate] was not different (5.2 ± 2.0, 4.2 ± 1.7 mmol·L\textsuperscript{-1}, NS). Conclusions: This study indicates greater running economy and higher fractional utilization of VO\textsubscript{2peak} in African distance runners. Although not elucidating the origin of these differences, the findings may partially explain the success of African runners at the elite level. Key Words: 10-KM RUNNERS, EFFICIENCY, RACE, ENDURANCE PERFORMANCE

African runners dominate international distance running events although the explanation for their disproportionate success is unclear. Limited investigations have confirmed that VO\textsubscript{2max} is not unduly high in these individuals (2,4) and therefore cannot explain their success. It is necessary to consider other contributory parameters such as fractional utilization of VO\textsubscript{2max} and running economy.

Early investigators suggested that African individuals may have greater economy of movement, albeit predominately with regard to stepping tasks (12,13,18). However, investigations of running economy in African and Caucasian runners have proved inconclusive. Coetzer et al. (4) found no difference in oxygen consumption at 17 km·h\textsuperscript{-1} when expressed relative to body weight. However, these subjects were not matched for primary race distance as the Caucasians were predominantly middle-distance runners and the Africans were predominantly long-distance runners. Furthermore, the difference in body mass was large (mean for African = 56 kg vs Caucasian = 70 kg). In contrast, Saltin et al. (14) found that Kenyan runners were more economical than Scandinavian runners. To account for the sizable difference in mean body mass between the two groups, VO\textsubscript{2} was normalized per kg\textsuperscript{0.75} rather than per kg, as suggested by Svedenhag and Sjödin (16). This accentuated the difference in oxygen cost for a given running speed between the Africans and the Caucasians. Furthermore, this difference was more pronounced at faster speeds. Therefore, the running economy data reported to date are conflicting and are confounded by large differences in body mass between groups. At present, it is not clear whether African runners have advantageous running economy when compared with their Caucasian counterparts.

Success in distance running can also be explained by the ability to maintain a high proportion of one’s maximal oxygen consumption throughout the event. Previous studies have indicated that African distance runners race at a higher percentage of VO\textsubscript{2max} (2,4). Bosch et al. (2) investigated physiological characteristics of African and Caucasian distance runners while they ran a simulated marathon on the treadmill. When running at the same percentage (∼87%) of their best marathon time, the African runners ran at a higher percentage of VO\textsubscript{2max} (76% vs 68%, P < 0.05), a higher heart rate and a higher RER. In addition, Coetzer et al. (4) extrapolated race VO\textsubscript{2} from the VO\textsubscript{2} vs treadmill speed relationship obtained during a nonsteady state incremental exercise test. On this basis, the African runners raced 10 km at a higher percentage of their VO\textsubscript{2max}. Weston et al. (17)
reported that African 10-km runners were able to continue running at a high percentage of peak treadmill velocity (92%) for almost twice as long as Caucasian 10-km runners. Although these studies all infer that fractional utilization of $V_O^{2max}$ is greater in African runners, this has not been measured during steady state exercise at actual race pace.

The mechanism for improved fractional utilization may be metabolic in origin. Metabolic investigations indicate that African distance runners accumulate less plasma lactate (4,14,17) and less plasma ammonia (14) than their Caucasian counterparts at comparable workloads. However, no studies to date have directly measured RER and plasma lactate and ammonia concentrations in African and Caucasian distance runners while running at current race pace in a controlled laboratory setting.

Therefore, the aim of this study was to investigate running economy, fractional utilization of maximal oxygen consumption and metabolite concentrations, at a steady state absolute workload (16.1 km·h$^{-1}$) and at 10-km race pace in African and Caucasian groups of runners who are matched for current 10-km performance. In addition, to minimize the potential effects of body mass on running economy, the groups were as closely matched as possible for body mass.

**METHODS**

**Subjects**

Sixteen well-trained distance runners (8 African, 8 Caucasian), with a 10-km race time range of 29.2–37.0 min, were recruited for the study from local running clubs. Mean ages were 28.0 ± 7.0 for Africans and 25.9 ± 5.3 for Caucasians. All reported their primary running distance to be 10 km. The two groups were of the same performance standard with no difference in mean current 10-km race time (African 32.8 ± 2.8 min; Caucasian 32.0 ± 2.5 min). Every effort was made to recruit African and Caucasian athletes of similar body mass. All subjects were seasoned competitors (at least 3 yr of competitive running) and were currently in training for a 10-km race (108 ± 43 km·wk$^{-1}$). All subjects were informed of the possible risks of the experimental procedures, and all gave their written informed consent. The study was approved by the Ethics and Research committee of the Faculty of Medicine at the University of Cape Town.

**Procedures**

**Anthropometry.** Height, weight, thigh length, and mid-thigh circumference were measured. Five skin-fold measurements were made (tricep, bicep, suprailiac, subscapular, mid-thigh) and % body fat calculated using the formula of Durnin and Wolmersley (9). Lean thigh volume was calculated using the assumption of the thigh as a truncated cone and taking into account the thigh skin-fold measurement (11). Lean thigh volume data were unavailable from two of the African subjects.

$V_O^{2peak}/peak$ treadmill velocity test. All subjects had undertaken at least one familiarization session before testing. This included treadmill running at low and high speeds and with and without the face mask. Further familiarization sessions were undertaken by those subjects who were less familiar with treadmill running if deemed necessary in the opinion of the investigator. All subjects then completed a peak treadmill velocity test with concurrent measurement of $V_O^2$, $V_E$, and RER using the same calibrated on-line gas analysis system (Oxycon Alpha, Jaeger Mijnhardt, Wuerzburg, The Netherlands) with HR measured throughout (Polar Sport tester, Kempele, Finland). At exactly 3 min post exercise, a venous blood sample was obtained for determination of plasma lactate concentrations. Samples were immediately centrifuged at 4°C at 3000 rpm and plasma was frozen for later spectrophotometric analysis in duplicate (bioMerieux lactate PAP, Boehringer Mannheim, Germany) using a Beckman DU-62 spectrophotometer (Beckman Industries Inc., Palo Alto, CA).

**Submaximal exercise testing.** On a separate day, subjects returned to the laboratory 3 h after eating. Subjects did not ingest caffeine overnight or before the test. Subjects again warmed up at 14 km·h$^{-1}$ for 5 min. Subjects then completed two submaximal workloads, one at 16.1 km·h$^{-1}$ and the other at current 10-km race pace, with all subjects utilizing the same calibrated treadmill (Powerjog EG30, Birmingham, England). Each workload was undertaken for 6 min separated by a rest period of 5 min. $V_O^2$, $V_E$, RER, and HR were measured continuously and results averaged over 15-s intervals. Mean values of the last 60 s were designated as steady state values for data analysis. A venous blood sample was obtained exactly 1 min after exercise for each workload for determination of plasma ammonia and plasma lactate concentrations. Samples were immediately centrifuged at 4°C at 3000 rpm and plasma was obtained. Plasma ammonia was assayed spectrophotometrically in duplicate within 2 h (NH$_3$ kit, Boehringer Mannheim), and plasma was stored for later spectrophotometric analysis of lactate in duplicate (bioMerieux lactate PAP, Boehringer Mannheim).

Running economy was defined as the steady-state oxygen consumption in mL·kg$^{-1}$·min$^{-1}$ obtained at each workload. $V_O^2$ was also normalized per kg$^{0.66}$(1,10).

**Statistics**

The Student’s unpaired $t$-test was used to compare African and Caucasian runners, and Pearson’s correlation coefficient was used to investigate relationships between variables for all individuals. Correlations were not calculated within groups due to insufficient numbers.

**RESULTS**

Anthropometric results showed no significant difference between the groups in body mass, % body fat or lean thigh volume. However, the Caucasian subjects were 6 cm taller (Table 1).
Maximal treadmill test results are listed in Table 2. All subjects achieved a RER value of higher than 1.0 and a maximal heart rate of above 90% of their age-predicted HRmax (220 – age), VO2peak was considerably higher in the Caucasian athletes, even when corrected for body mass (13%, P = 0.01); however, this was not reflected by a faster mean 10-km race time. Mean peak treadmill velocity (PTV) was also higher in the Caucasian runners than in the African runners, but this did not reach significance.

Results of the exercise test at 16 km·h⁻¹ and at calculated 10-km race pace are listed in Table 3. At 16.1 km·h⁻¹, the African runners had a 5% lower mean oxygen consumption (P < 0.05, Fig. 1), and when this was expressed per kg body mass⁰.⁶⁶, the difference was increased to 8% (P < 0.01). The latter individual data (lower panel) shows only one Caucasian subject with an oxygen consumption below the African group mean and only one African subject with an oxygen consumption greater than the Caucasian group mean. Running economy at 16.1 km·h⁻¹ did not correlate with 10-km performance in this homogeneous group.

The data from the race pace workload indicate that the African runners were able to utilize a considerably higher percentage of their maximal oxygen uptake (Table 3) and to exercise at a higher heart rate. Considerable accumulation of ammonia occurred at race pace. Although highly variable between individuals, the mean was higher in the African runners than in the Caucasian runners. The race pace ammonia results include one African individual who recorded a particularly high plasma ammonia of 217 μmol·L⁻¹ (>2 SD from the mean of the remainder of the group). However, if this individual was removed from the analysis, the mean (95.9 ± 25.0) was still significantly higher than that of the Caucasians (P = 0.01). Accumulation of lactate in the plasma was not higher in the African runners despite the higher relative exercise intensity (Table 4).

**DISCUSSION**

The results indicate that the African athletes in the current study were able to achieve the same performance as the Caucasian group over 10 km, despite having a considerably lower maximal oxygen uptake (13% lower, P = 0.01). Physiological factors that may contribute to such a finding are a) greater running economy or b) the ability to sustain a higher percentage of their VO2max throughout the event, or a combination of both. These two factors have been systematically investigated in the current study.

The oxygen consumption per kilogram body weight of the Caucasian subjects investigated in the current study (mean 49.9 mL·kg⁻¹·min⁻¹ at 16.1 km·h⁻¹, range 45.0–52.6) is comparable to that previously reported in distance runners. Costill et al. (6), Daniels et al. (7), and Conley and...
mean mass between the subject groups (12 kg and 14 kg, with the findings of Saltin et al. (14) in Kenyan runners. The results are accentuated and running economy is 8% better in African athletes had the same carbohydrate flux despite running at 16.1 km h⁻¹.

However, the findings of the current study showed a 5% greater running economy in the African runners when compared with the Caucasian runners (P < 0.05) and a mean (47.4 mL kg⁻¹ min⁻¹) that is lower than the previously reported values above. Only one Caucasian subject had an oxygen consumption below the mean African value (see Fig. 1). The difference in mean body mass between the two groups in the current study was relatively small and statistically insignificant (3.5 kg).

Running economy is regarded as the metabolic power required to run at a particular velocity and metabolic power has been reported to be proportional to mass⁰.⁶⁶ (10). Therefore, when calculating running economy, it is appropriate to scale oxygen consumption per kg⁰.⁶⁶ rather than per kg. In the current study, when VO₂ is normalized per kg⁰.⁶⁶, the results are accentuated and running economy is 8% better in the Africans than the Caucasians (P < 0.05). Our finding of a significant difference in running economy is in agreement with the findings of Saltin et al. (14) in Kenyan runners. The previous studies that do not concur were studies in South African runners (2,4) where there was a sizable difference in mean mass between the subject groups (12 kg and 14 kg, respectively) and results were not scaled relative to mass⁰.⁶⁶.

The results further indicate that the African runners evaluated in this study were able to race 10 km at a significantly higher relative intensity than Caucasian runners. At 10-km race pace, the Africans utilized a considerably higher percentage of their maximal oxygen uptake than the Caucasians (92.2% vs 86.0% respectively, P < 0.01). Running at a higher relative intensity elicited a higher HR and a higher concentration of plasma ammonia. This could potentially be the result of either a physiological or motivational advantage. However, if this was solely the result of a difference in motivation, one would also expect the RER and plasma lactate to be higher, but this was not the case. Despite higher relative intensity at race pace, the African athletes had the same mean RER as the Caucasian group. Therefore, the African athletes had the same carbohydrate flux despite running at an intensity closer to VO₂peak. It is tempting to speculate that race pace is in fact determined by carbohydrate flux. The fact that the African athletes only achieved the same carbohydrate flux and subsequent plasma lactate accumulation at a higher relative intensity of exercise may be due to higher skeletal muscle oxidative enzyme activity as previously reported (17), in data that were inclusive of some of these subjects.

Despite the significant difference in fractional utilization of VO₂peak between the two groups in this study, the range of fractional utilization of VO₂peak reported for both African and Caucasian runners is similar to those previously reported for runners (6,15). The mean value of ~89% for all runners in the current study is only slightly higher than that reported by Costill et al. (6) and Scrimgeour et al. (15). These authors reported the mean %VO₂max sustained during 10-km and 10-mile races, respectively, was 85.8% and 86.1%. The values reported by Davies and Thompson (8), of four ultra-distance world record holders, are more similar to those in the current study (~89%). Therefore, the subelite African runners in the current study are not outside the normal range for well-trained distance runners but rather are representative of the higher end of the range.

At race pace, both plasma lactate and plasma ammonia concentrations were considerably elevated, with mean plasma lactate concentrations above the classically described “onset of blood lactate accumulation” value of 4 mmol L⁻¹. This indicates that exercise lasting as long as 30 min can be maintained despite substantial lactate accumulation. Ammonia accumulation in the plasma was higher in the African runners than the Caucasians. Because there were no significant differences in lactate accumulation, this means that the ammonia accumulation relative to lactate accumulation is higher in the Africans. As it is thought that the accumulation of ammonia and lactate generally occur in parallel (3), this suggests the lactate removal may be enhanced in the African runners.

In summary, the results indicate that the African runners in this study were more economical than the Caucasian runners. Furthermore, the African runners raced 10 km at a higher percentage of their VO₂peak, whereas only accumulating a similar concentration of plasma lactate. These characteristics explain the ability of these African runners to achieve a comparable race performance despite a considerably lower VO₂peak. If these advantageous characteristics are present in elite African distance runners, these findings may assist in the explanation of the disproportionate success of this racial group in distance running events.

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* Indicates N = 5, ** indicates N = 7; results are mean ± SD.
REFERENCES


