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Case report

INDIRECT CALORIMETRY DURING ULTRADISTANCE RUNNING: A CASE REPORT

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ABSTRACT
The purpose was to determine the energy expenditure during ultradistance trail running. A portable metabolic unit was carried by a male subject for the first 64.5 km portion of the Western States 100 running race. Calibrations were done with known gases and volumes at ambient temperature, humidity and pressure (23-40.5°C and 16-40% respectively). Altitude averaged 1692.8 ± 210 m during data collection. The male subject (36 yrs, 75 kg, VO_2max of 67.0 ml·kg^{-1}·min^{-1}) had an average (mean±SD) heart rate of 132 ± 9 bpm, oxygen consumption of 34.0±6.8 ml·kg^{-1}·min^{-1}, RER of 0.91 ± 0.04, and V_E of 86.0 ± 14.3 L·min^{-1}during the 21.7 km measuring period. This represented an average of 51% VO_2max and 75% heart rate maximum. Energy expenditure was 12.6 ± 2.5 kcals·min^{-1}, or 82.7 ± 16.6 kcals·km^{-1} (134 ± 27 kcals·mile^{-1}) at 68.3 ± 12.5% carbohydrate. Extrapolation of this data would result in an energy expenditure of >13,000 kcals for the 160 km race, and an exogenous carbohydrate requirement of >250 kcal·hr^{-1}. The energy cost of running for this subject on separate, noncompetitive occasions ranged from 64.9 ± 8.5 to 74.4 ± 5.5 kcals·km^{-1} (105 ± 14 to 120 ± 9 kcals·mile^{-1}). Ultradistance trail running increases energy expenditure above that of running on nonundulating terrain, which may result in underestimating energy requirements during these events and subsequent undernourishment and suboptimal performance.

KEY WORDS: Energy expenditure, caloric expenditure, running economy.

INTRODUCTION

Energy expenditure during running is a function of body weight, exercise intensity (speed and grade), duration, and to a smaller extent individual running economy (Saunders et al., 2004a). These assessments however have traditionally been done in controlled laboratory environments. With the advancement of portable metabolic analyzers, the measurement of energy expenditure of running in the field has been made possible.

Ultradistance running is generally assumed to be events greater than a marathon (42.2 km). Previous work on energy expenditure during ultradistance running events in the field is scarce. There have been estimations of caloric expenditure by monitoring caloric intake and changes in body weight (Eden and Abernethy, 1994), intensity (Davies and Thompson, 1979a; 1979b; 1986; Myles, 1979), and the use of doubly labelled water (Hill and Davies, 2001). However oxygen consumption using a portable metabolic system to determine energy expenditure during an ultradistance race event has not been investigated.

Ultradistance running poses a unique stress on the athlete. Environmental conditions, race course, training, and perhaps most importantly fluid and fuel intake all contribute to race performance.

Table 1. Course and intensity data from the four field trials. Data are expressed as means (±SD).

	Distance (km)	Time (min)	Pace ($min \cdot km^{-1}$)	Altitude (m)	HR ($b \cdot min^{-1}$)	%HR max	METS
WS100	21.7	143	6.59	1693 (210)	132 (9)	75.3 (5.2)	9.7 (2.0)
Track	6.45	26.6	4.12	897 (.5)	133 (7)	76.0 (4.1)	13.6 (1.0)
MHC1	4.84	22.0	4.55	1027 (31)	NA	NA	12.7 (.6)
MHC2	9.7	43.4	4.47	1008 (33)	NA	NA	10.9 (1.4)

Abbreviations: WS100 = Western States 100, MHC1 = Moses H. Cone run 1, MHC2 = Moses H. Cone run 2

Participants often make general assumptions about energy expenditure while running in order to match kilocalorie intake. Since relative intensity is undeniably low during ultradistance running (Davies and Thompson, 1979a; 1979b; Myles, 1979), an underestimation of kilocalorie requirement could result in a significant decrement in performance.

It was the purpose of this study to determine the energy expenditure during an ultradistance trail running event (160 km) using indirect calorimetry via a portable metabolic system and compare this to the energy expenditure of running on nonundulating terrain in the same subject.

METHODS

Subject

One subject familiar with the portable metabolic unit (Cosmed K4b^2, Chicago, IL) was recruited for this study. Informed consent approved by the Appalachian State University Internal Review Board, which explained the benefits and risks of the study, was obtained.

Experiment

The subject was an experienced runner with significant training and racing history. The male subject was 36 yr, 180 cm, 75 kg, with a maximum heart rate of 175 bpm and VO_2max of 67.0 $ml \cdot kg^{-1} \cdot min^{-1}$.

The subject did five different tests with the Cosmed K4b^2, a VO_2 max test, an uphill 4.84 km run, a 9.7 km downhill run, 6.45 km on the track, and the first 64.5 km of the Western States 100 (160 km). The Cosmed K4b^2 is a portable metabolic unit that weighs approximately 1 kg with battery pack and contains both an oxygen and carbon dioxide analyzer. It is worn attached to a harness on the chest and back. Following a 30 minute warm up, the portable metabolic unit (PU) was calibrated as specified by the manufacturer. This included room air, reference gas (16% O_2 and 4% CO_2), delay (time for gas to pass through sample lines), and 3 L turbine (flowmeter) calibration. Following each test data was downloaded from the PU to a laptop computer. Data collected included: time, breathing frequency (Rf), tidal volume (Vt), ventilation (V_E), oxygen consumption (VO_2), carbon dioxide production (VCO_2), heart rate (HR), and environmental temperature and pressure. The validity of the Cosmed K4b^2 has been demonstrated previously (McLaughlin et al., 2001; Hausswirth et al., 1997b), and is considered to be less than one percent different from the Douglas bag method while exercising. Substrate use for each data point was calculated from nonprotein respiratory exchange ratio (VCO_2/ VO_2 or RER) using the formula: % of fat burned = 1-RER/0.3.

The VO_2max test was performed in the Human Performance Laboratory at Appalachian State University (897 m). The protocol started at 5 mph and increased 1 mph every 2 minutes up to 9 mph, following which grade was increased by 3% every 2 minutes until volitional exhaustion. Breath by breath data was collected continuously with the Cosmed K4b^2 unit. The remaining tests were performed in the field.

The second test was a 4.84 km gradual uphill run in the mountains of North Carolina (average elevation 1027 m, see Table 2) on the gravel carriage trails of the Moses H Cone Estate Park (MHC1). Subsequently the third test was a gradual 9.7 km downhill (MHC2) at MHC on the same day.

Table 2. Metabolic data from the four field trials. Data are expressed as means (±SD).

	R_F ($b \cdot min^{-1}$)	V_T ($L \cdot b^{-1}$)	V_E ($L \cdot min^{-1}$)	VO_2 ($ml \cdot min^{-1}$)	VCO_2 ($ml \cdot min^{-1}$)	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	%VO_2 max
WS100	41.6±2.9	2.1±0.4	86.0±14	2548±511	2309±470	34.0±6.8	51.0±10.2
Track	41.5±1.1	2.7±0.2	111.0±6.8	3562±270	3640±249	47.5±3.6	71.2±5.4
MHC1	37.8±3.9	2.8±0.2	106.0±7.2	3374±174	NA	44.4±2.3	66.6±3.4
MHC2	41.3±2.6	2.5±0.3	102.1±14	2909±379	2799±378	38.2±5.0	57.4±7.5

Abbreviations: WS100 = Western States 100, MHC1 = Moses H. Cone run 1, MHC2 = Moses H. Cone run 2

Table 3. Energy expenditure (EE) and running economy data from the four field trials. Data are expressed as means (±SD).

	EE (kcal·min^{-1})	EE (kcal·km^{-1})	EE (kcal·min^{-1})	EE (kcal·hr^{-1})	RER	%Fat	%CHO	CHO (kcal·hr^{-1})
WS100	12.6 (2.5)	83.7 (16.6)	134 (27)	753 (151)	.91 (.04)	29.8 (12.0)	68.3 (12.0)	515 (141)
Track	18.1 (1.3)	74.4 (5.5)	120 (9)	1083 (80)	1.0 (.03)	.5 (1.4)	98.3 (1.4)	1065 (81)
MHC1	15.8 (.8)	72.1 (3.6)	116 (6)	951 (47)	NA	NA	NA	NA
MHC2	14.5 (1.9)	64.9 (8.5)	105 (14)	871 (114)	.96 (.04)	12.1 (8.0)	86.3 (8.0)	753 (130)

Abbreviations: WS100 = Western States 100, MHC1 = Moses H. Cone run 1, MHC2 = Moses H. Cone run 2, RER = respiratory exchange ratio, CHO = carbohydrate.

The fourth test was the first 64.5 km of the annual Western States 100 ultra race. The 160-km Western States Endurance Run is a point-to-point trail run in the Sierra Nevada Mountains of northern California, and is regarded as one of the most difficult ultradistance running events in the United States. The race starts at Squaw Valley, California (1,890 m altitude), and finishes at Auburn, California (366 m). The trail race course ascends 777 m to Emigrant Pass (2,668 m, the highest point) within the first 7 km and then passes through remote and rugged territory to Auburn. The race covers single track trail sections with some dirt roads. Distance on the course was determined by rolling with a calibrated wheel. The total altitude gain and loss during the race is 5,500 m and 6,700 m, respectively. Twenty six aid stations line the course, however not all are reachable by the runner's crew. The subject ran to the first aid station where outside help was allowed (39.7 km) before recalibrating the portable metabolic unit. Following calibration, the subject continued on the course for the next 21.7 km. The data for this 21.7 km section of the course is what appears in these results (WS100). The fifth and final test was completed by running for 6.45 km on the Appalachian State University track (Track) in order to assess the energy cost of level running on a hard surface. The subject attempted to match the HR response that was elicited during the WS100 trial during the Track trial. Although in two locales, all four trials were performed in similar ambient, sunny summertime conditions, ~22-28 ˚C, and ~20-50 % humidity.

Breath by breath data from all the tests was downloaded from the PU and converted to a spreadsheet. Data are expressed as means ± SD.

RESULTS

Data from kilometer 39.7 to 61.3 of the WS100 as well as the other three field trials are presented in Tables 1, 2 and 3, and Figures 1 and 2. For this 21.7 km segment of the WS100 there was an elevation gain of 510 m, and a loss of 1015 m, for an overall loss of 505 m. Mean elevation was 1693 ± 210 m. The dry bulb temperature at kilometer 39.7 was 23.1 °C with a humidity of 40%. Data collection ended with an exposed dry bulb temperature of 40.5 °C and 16% humidity. Data from the Cosmed K4b^2 for all the tests were averaged over one minute. Data was discarded during periods of rest, or when the mask had to be removed for significant periods of time. As seen in Figures 1 and 2, there are periods of rest that were not included in the data for the tables. During the WS100 (Figure 1) intermittent removal of the mask was needed for fluid and fuel intake.

Although pace was the slowest, and relative intensity the lowest (%VO_{2max}) during WS100, the energy cost (kcal·km^{-1} and kcal·mile^{-1}) was the greatest for the four different field trials. This is in spite of the overall elevation loss during this trial. There was a total elevation loss of 152 m during MHC2 as well; however the amount of kilocalories per distance during this trial was much less. Intensity as determined by %VO_{2max} or kcal·mile^{-1} was least in WS100, and greatest during the Track trial. However, intensity as determined by HR or % of HRmax were similar (131 bpm vs. 133 bpm and 75.3% vs. 76.0% respectively). Substrate utilization (Table 3) was a function of intensity, duration and exogenous macronutrient intake. During the WS100 *ad libitum* fluid and fuel intake was allowed, which consisted of mostly carbohydrate. During the other field trials only water was ingested. Nevertheless, carbohydrate oxidation is reflective of intensity with the percent carbohydrate being lowest and thus fat oxidation highest during the WS100. This amounted to a carbohydrate requirement of 515 kcals·hr^{-1}, compared to the higher intensity Track trial with nearly twice as much carbohydrate oxidation.

DISCUSSION

The novel results from this investigation is that the energy cost of running during a ultradistance trail running event was substantially greater than the energy cost of running in the same subject under various other running conditions. Even though the intensity of exercise was relatively low during the WS100, the energy expenditure of this individual

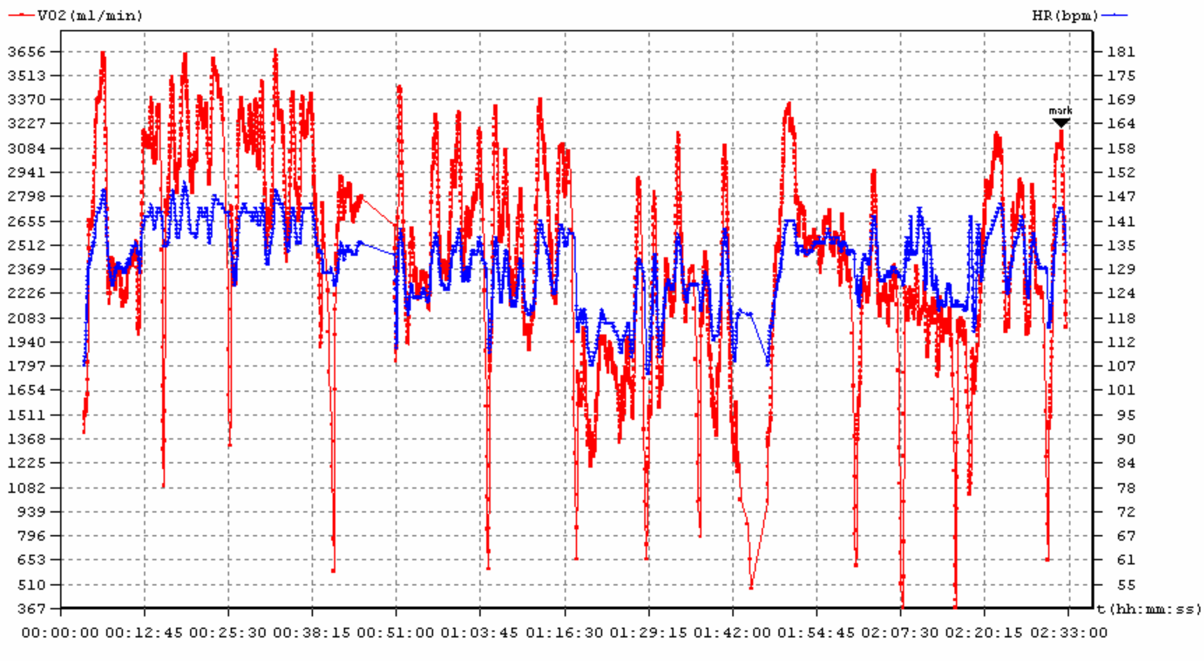

Figure 1. VO_2 (ml·min^{-1}, red trace, left y-axis) and HR (bpm, blue trace, right y-axis) during a 13.4 mile section of the Western States 100 ultradistance running race.

per kilometer of terrain covered was elevated.

DISCUSSION

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Normal horizontal running estimation of kcals·mile^{-1} for an individual of this weight (75 kg) would be ~120 kcals·mile^{-1} (McArdle et al., 2001, Saunders et al., 2004a), which was closely approximated by the track and MHC1 data in the current study. However, even though running intensity was less in the WS100, caloric expenditure was elevated. A number of factors may have contributed to this increase in the energy cost of running; it may be partly due to the single track trail on undulating terrain. Pace and distance covered is reduced under these conditions which would result

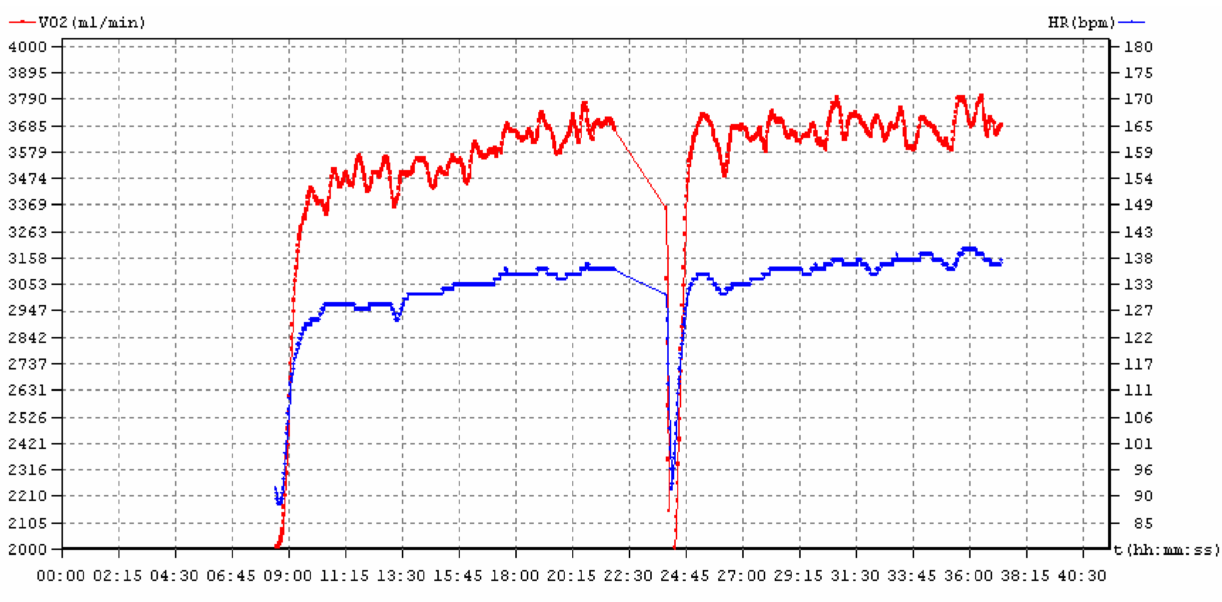

Figure 2. VO_2 (ml·min^{-1}, red trace, left y-axis) and HR (bpm, blue trace, right y-axis) during a 4 mile run on a track.

in an increase in energy expenditure when expressed per given distance or speed at a given intensity. It has been reported that running in sand can result in a 1.6 fold increase in the energy cost of running (Lejeune et al., 1998). Although the WS100 did not include loose sand, this illustrates the range of energy expenditure across different types of running surfaces. In addition, although there was an overall elevation loss for the section of trail in this study, there were multiple uphill and downhill sections. Minetti et al. (2002) reported that uphill treadmill running can increase the energy cost of running by over five fold, and downhill running can reduce the energy cost of running by nearly a half. This is complicated in this field study where the subject would subjectively monitor intensity through perceived exertion and heart rate. Despite the constantly altered low relative intensity and overall elevation loss, the energy expenditure was elevated. Since the WS100 trial was held at moderate altitude (1693 m) there may have been an increased energy cost of respiration which may have elevated the energy cost of running (Morgan and Craib, 1992; Roi et al., 1999). However the subject was altitude acclimatized having lived for over three weeks at over 2400 m prior to the WS100, which has been shown to increase running economy and thus decrease the energy cost of running (Saunders et al., 2004b).

Duration of exercise increases the oxygen cost of running (Davies and Thompson, 1986; Hausswirth and Lehenaff, 2001; Hausswirth et al., 1997a; Sproule, 1998; Xu and Montgomery, 1995). Although cardiovascular drift is thought to contribute to this elevated energy expenditure with prolonged exercise, it is not thought to be the sole factor (Hausswirth et al., 1997a; Sproule, 1998). In the current study, due to the varying terrain and conditions it was difficult to determine any drift in the energy cost over the 21.7 km segment of trail, however the subject had run for ~5 hr over 39.7 km prior to the start of data collection. Therefore the elevation in energy expenditure may have occurred prior to this measuring period. Muscle soreness may have also contributed to the elevated energy cost of running (Braun and Dutto, 2003; Calbet et al., 2001; Palmer and Sleivert, 2001). The intensity of running in the current investigation is similar to that estimated in other studies during ultradistance events. It has been found under conditions of extended running that intensities of 50-60% of VO_2max are possible (Davies and Thompson, 1979a; 1979b; Myles, 1979), which compares favorably to the 51% VO_2max in the current study. Thus, it is not believed that the elevated energy cost of running in the current study is due to increased intensity that is unrealistic during ultradistance running. Therefore the elevated energy expenditure observed during ultradistance running could be due to a number of environmental and physiological factors; however over the course of ultradistance events this would certainly affect energy requirements.

Only one previous study has attempted to measure energy expenditure during prolonged running. Hill and Davies (2001) measured energy expenditure during a two week daily run with the doubly labeled water technique. The sole subject (63 kg) averaged 6321 kcal·day^{-1} while running an average of 76.7 km·day^{-1} (47.6 mile·day^{-1}) on established roadways. Taking into account BMR this would equate to 61.6 kcal·km^{-1} (~100 kcal·mile^{-1}), which is near the estimated energy cost of running for an individual of this body weight (McArdle et al., 2001; Saunders et al., 2004a). These measurements were taken following the first two weeks of a seven month record setting run on roads around Australia. The method of measurement, subject weight and experience, terrain, and running surface may help to explain differences from the current investigation. Even provided the impressive economy of the runner in the Hill and Davies (2001) study, this was not compared to the individual's running economy under normal running conditions to determine any potential elevation in energy expenditure and therefore loss of economy over time.

HR was disproportionately elevated during the WS100 trial given the %VO_2max intensity. Although the heart rate was similar on the Track trial compared to WS100 (76.0 vs. 75.3% respectively), the intensity (%VO2max) was substantially higher (71.2 vs. 51.0% respectively). Anecdotally, many individuals in ultradistance running notice elevated HR at a given perceived exertion, perhaps due to the anxiety of the race environment. Or perhaps, HR under these extreme conditions reflects the elevated energy expenditure disproportionate to relative intensity as determined by oxygen consumption. Again, due to the nature of the course the contribution of cardiovascular drift to the elevated HR seen in the current study is difficult to determine. However, an elevated HR was apparent even during early stages of the race by this subject.

CONCLUSIONS

Since performance in ultradistance running may be largely a function of meeting metabolic costs with exogenous fluid and fuel intake, these data have large implications for the ultradistance community. Participants understand that intensity is low during ultradistance races, therefore it is reasoned that the energy cost would be low as well. In addition, many are familiar with the oversimplified assumption of 100 kcals·mile^{-1} (Krauss et al., 2000), without considering body weight or race conditions. These assumptions may result in low *ad libitum* nutrient intake. In fact, nutrient intake during ultradistance races has been found to be below the estimated energy cost (Dumke, unpublished observations; (Fallon et al., 1998; Kruseman et al., 2005). Suboptimal nutrition certainly would result in decreased performance under these circumstances.

In summary, despite a low relative intensity the energy cost of running is increased in the rough terrain typical of ultradistance trail running races compared to level running. This may result in suboptimal exogenous nutrient intake and consequently hinder performance.

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REFERENCES

Braun, W.A. and Dutto, D.J. (2003) The effects of a single bout of downhill running and ensuing delayed onset of muscle soreness on running economy performed 48 h later. *European Journal of Applied Physiology* **90,** 29-34.

Calbet, J.A., Chavarren, J. and Dorado, C. (2001) Running economy and delayed onset muscle soreness. *Journal of Sports Medicine and Physical Fitness* **41,** 18-26.

Davies, C.T. and Thompson, M.W. (1979a) Aerobic performance of female marathon and male ultramarathon athletes. *European Journal of Applied Physiology and Occupational Physiology,* **41,** 233-245.

Davies, C.T. and Thompson, M.W. (1979b) Estimated aerobic performance and energy cost of severe exercise of 24 h duration. *Ergonomics* **22,** 1249-1255.

Davies, C.T. and Thompson, M.W. (1986) Physiological responses to prolonged exercise in ultramarathon athletes. *Journal of Applied Physiology* **61,** 611-617.

Eden, B.D. and Abernethy, P.J. (1994) Nutritional intake during an ultraendurance running race. *International Journal of Sport Nutrition* **4,** 166-174.

Fallon, K.E., Broad, E., Thompson, M.W. and Reull, P.A. (1998) Nutritional and fluid intake in a 100-km ultramarathon. *International Journal of Sport Nutrition* **8,** 24-35.

Hausswirth, C., Bigard, A.X. and Guezennec, C.Y. (1997a) Relationships between running mechanics and energy cost of running at the end of a triathlon and a marathon. *International Journal of Sports Medicine* **18,** 330-339.

Hausswirth, C., Bigard, A.X. and Le Chevalier, J.M. (1997b) The Cosmed K4 telemetry system as an accurate device for oxygen uptake measurements during exercise. *International Journal of Sports Medicine* **18,** 449-453.

Hausswirth, C. and Lehenaff, D. (2001) Physiological demands of running during long distance runs and triathlons. *Sports Medicine,* **31,** 679-689.

Hill, R.J. and Davies, P.S. (2001) Energy expenditure during 2 wk of an ultra-endurance run around Australia. *Medicine & Science in Sports & Exercise* **33,** 148-151.

Krauss, R.M., Eckel, R.H., Howard, B., Appel, L.J., Daniels, S.R., Deckelbaum, R.J., Erdman, J.W., Kris-Etherton, P.M., Goldberg, I.J., Kotchen, T.A., Lichtenstein, A.H., Mitch, W.E., Mullis, R., Robinson, K., Wylie-Rosett, J., St. Jeor, S., Suttie, J., Tribble, D.L. and Bazzarre, T.L. (2000) AHA Dietary Guidelines: Revision 2000: A statement for Healthcare Professionals from the Nutrition Committee of the American Heart Association. *Circulation* **102,** 2296-2311.

Kruseman, M., Bucher, S., Bovard, M., Kayser, B. and Bovier, P.A. (2005) Nutrient intake and performance during a mountain marathon: an observational study. *European Journal of Applied Physiology* **94,** 151-157.

Lejeune, T.M., Willems, P.A. and Heglund, N.C. (1998) Mechanics and energetics of human locomotion on sand. *Journal of Experimental Biology* **201,** 2071-2080.

McArdle, W.D., Katch, F.I. and Katch, V.L. (2001) *Exercise physiology: Energy, nutrition, and human performance.* Baltimore, Lippincott William & Wilkins.

McLaughlin, J.E., King, G.A., Howley, E.T., Bassett, D.R., JR. and Ainsworth, B.E. (2001) Validation of the COSMED K4 b2 portable metabolic system. *International Journal of Sports Medicine* **22,** 280-284.

Minetti, A.E., Moia, C., Roi, G.S., Susta, D. and Ferretti, G. (2002) Energy cost of walking and running at extreme uphill and downhill slopes. *Journal of Applied Physiology,* **93,** 1039-46.

Morgan, D.W. and Craib, M. (1992) Physiological aspects of running economy. *Medicine & Science in Sports & Exercise* **24,** 456-461.

Myles, W.S. (1979) The energy cost of an 80 km run. *British Journal of Sports Medicine* **13,** 12-14.

Palmer, C.D. and Sleivert, G.G. (2001) Running economy is impaired following a single bout of resistance exercise. *Journal of Science and Medicine in Sport* **4,** 447-459.

Roi, G.S., Giacometti, M. and Von Duvillard, S.P. (1999) Marathons in altitude. *Medicine & Science in Sports & Exercise* **31,** 723-728.

Saunders, P.U., Pyne, D.B., Telford, R.D. and Hawley, J.A. (2004a) Factors affecting running economy in trained distance runners. *Sports Medicine* **34,** 465-485.

Saunders, P.U., Telford, R.D., Pyne, D.B., Cunningham, R.B., Gore, C.J., Hahn, A.G. and Hawley, J.A. (2004b) Improved running economy in elite runners after 20 days of simulated moderate-altitude exposure. *Journal of Applied Physiology* **96,** 931-937.

Sproule, J. (1998) The influence of either no fluid or carbohydrate-electrolyte fluid ingestion and the environment (thermoneutral versus hot and humid) on running economy after prolonged, high-intensity exercise. *European Journal of Applied Physiology and Occupational Physiology* **77,** 536-542.

Xu, F. and Montgomery, D.L. (1995) Effect of prolonged exercise at 65 and 80% of VO_2max on running economy. *International Journal of Sports Medicine,* **16,** 309-313.

KEY POINTS

- The energy cost of running is elevated during ultradistance trail races compared to normal running conditions.
- This elevated energy cost results in a ~12% increase in energy expenditure for a given distance.
- *Ad libitum* energy intake may grossly underestimate the demand of ultradistance running in the conditions investigated in this paper, thus jeopardizing race performance.

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