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THE EFFECTS OF RUNNING 1,200 KM WITHIN 17 DAYS ON BODY COMPOSITION IN A FEMALE ULTRARUNNER—DEUTSCHLANDLAUF 2007

Beat Knechtle

Gesundheitszentrum St. Gallen, St. Gallen, Switzerland
Department of General Practice, University of Zurich, Switzerland

Brida Duff

Gesundheitszentrum St. Gallen, St. Gallen, Switzerland

Ingo Schulze

Deutschlandlauf, Horb—Nordstetten, Germany

Götz Kohler

Division of Biophysical Chemistry, Biozentrum, University of Basel, Basel, Switzerland

We describe the changes of body composition in the female overall winner of the Deutschlandlauf *2007 over 17 stages from the northeast to the southwest of Germany with average daily running stages of 70.9 km to cover the*

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Address correspondence to Dr. Med. Beat Knechtle, Facharzt FMH für Allgemeinmedizin, Gesundheitszentrum, Vadianstrasse 26, CH-9001 St. Gallen, Switzerland. E-mail: beat.knechtle@hispeed.ch

total distance of 1,200 km. Determined by bioelectrical impedance analysis, body mass (BM) increased, percent body fat (% BF) decreased, and percent body water as well as lean body mass (LBM) increased. Skeletal muscle mass and % BF as determined by an anthropometric method showed no changes. This data show, that this female runner achieved an excellent performance and that it is possible for a woman to beat all the men. This type of analysis provides a unique opportunity to gain insight into the physiological changes during multiday running in ultraendurance athletes.

Keywords: ultraendurance, gender, percent body fat, body water

INTRODUCTION

Competing in ultraendurance races becomes more and more popular. Races such as cycling or running across America have a long tradition. In the beginning of ultraendurance races, mainly men participated and finished these extremely long races. Only a few case studies have been published about female athletes. In scientific literature, case reports and field studies of ultraendurance performance primarily are reserved for men. In a few cases, ultraendurance performances of women are reported in case reports such as swimming across the English Channel (Frisch et al. 1984), an ultrarun covering 7,250 km across Canada (Mertens et al. 1996), or at the Race across America (RAAM; Clark et al. 1992).

The assumption that women's endurance capacity gets closer and closer to that of men is a superficial interpretation of phenomena from the extreme sport where side factors such as lack of sleep, mental strength, or motivation affect performance. In comparable groups, the performance of female ultraendurance athletes is 10% less when compared with men (Neumann and Berbalk 2000, Yoshiga and Higuchi 2003). In runs over 100 and 200 km, men are, on average, 12% faster than women (Coast et al. 2004), and comparing the times in marathons, age-matched difference is 10% in the age group from 20 to 49 years (Leyk et al. 2007). The main reason for these differences seems to be the higher percentage of body fat in women and the lower proportion of skeletal muscle mass (Cheuvront et al. 2005). Women, unlike men, have a higher proportion of fat and a lower proportion of skeletal muscles (Tarnopolsky 2000). Women also have thinner muscles and thicker fat tissue (Kanehisa et al. 2004). Unlike men, women have 6% to 9% more body fat (Phillips et al. 1993; Tarnopolsky et al. 1990), which under certain circumstances could have a positive affect on ultraendurance performances. In addition, men are about 7% taller and 19% heavier when compared with women (Jaworowski et al. 2002) and have a roughly 10% higher VO_2max with respect to body mass (Helgerud 1994).

In this present case study we present the anthropometric characteristics and change of body composition in a female ultraendurance runner who finished the *Deutschlandlauf*, running 1,200 km within 17 days, in 2007 and achieving first place, over all the men. Taking advantage of this unique event of an ultraendurance run across a country, we aimed at analysing the changes in several anthropometrical factors.

ATHLETE AND METHODS

Athlete

Our athlete is a female nonprofessional ultrarunner from Japan (45 years, 48.8 kg, 158 cm, BMI 19.5 kg/m^2). Her training volume is about 400 to 500 km per month and she has been running for 15 years. She has a regular menstrual cycle of 28 days. During this actual race, she had her period from stage 13 to 16. Up to this actual race she had finished about 50 marathons, including ultramarathons. Her personal best time in a marathon is 3 h 05 min 47 s, which she completed, aged 45 years, in 2007. In 2003 she ran 40 out of 64 stages during the Trans-Europe-Footrace from Lisbon to Moscow over a distance of 3,200 km. At that point she dropped out of the race as leading woman and achieved sixth place overall. Her first finished multiday ultrarun was Trans Gaule (a run across France) in 2005, which she finished in fifth place. In 2006 she started for the first time at the *Deutschlandlauf* and finished the race in second position overall.

The Race

The third occasion of the *Deutschlandlauf* was held from September 10 to September 27, 2007. It is a multistage ultraendurance run across Germany, Europe, from the northeast (Kap Arkona on the island of Rügen) to the southwest (Lörrach). The average daily distances were 70.9 km. Forty-two athletes (36 men and 6 women) started in the race. Most of the competitors were experienced ultrarunners. Some of them already had finished races such as running across America, Europe, or Germany. Seventeen men and 4 women finished all stages of the run successfully. The race director with his staff organised the accommodation in halls, and also the food before, during, and after a stage. The runners were allowed to take personal luggage of not more than 20 kg with them.

Methods

Body mass (BM), % body fat (% BF), as well as lean body mass (LBM) and percent total body water (% TBW) were determined by bioelectrical impedance analysis (BIA). In addition, skeletal muscle mass (SM) and % BF were calculated from anthropometric measurements by calipermetry. The day before the *Deutschlandlauf* started and after every stage, the measurements were performed in the same manner by the same person. In addition, urine samples were taken to determine urinary specific gravity (USG) in order to determine hydration status.

Anthropometrical Measurements

Body mass (BM) was measured with the bioelectrical impedance balance Tanita BC-545 (Tanita Corporation of America Inc., Arlington Heights, IL, USA) to the nearest 0.1 kg. Circumference of the upper arm, thigh, and calf were measured at the largest circumference of the limb to the nearest 0.1 cm. At the thigh, circumference was determined 20 cm above the upper pole of the patella.

Every anthropometric measurement was taken by the same person three times, and then the mean value was used for calculation. Skinfold thicknesses of chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh, and calf were measured with a skinfold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm at the right side, according to Lee et al. (2000). Skeletal muscle mass (SM) was calculated using the formula of Lee et al. (2000). Percent body fat (% BF) was calculated using the formula of Ball et al. (2004). Total body water (BW), and BF were calculated for direct comparisons from the percentage values and BM.

Bioelectrical Impedance Analysis

Lean body mass (LBM), % TBW, and % BF were measured with the BIA-balance Tanita BC-545 (Tanita Corporation of America Inc., Arlington Heights, IL 60005, USA). Impedance measurements were performed with the athlete standing in an upright position, barefoot in runningwear, on footelectrodes on the platform of the instrument, with the legs and thighs not touching, and the arms not touching the torso. The runner stood on the four footelectrodes, two oval-shaped electrodes, and two heel-shaped electrodes, and gripped the two palm-and-thumb electrodes in order to yield two thumb electrodes and two palm electrodes. The skin and the electrodes were precleaned and dried.

Determination of Specific Gravity of Urine (USG)

A sample of urine was collected upon arrival at the end of each stage. Urinary specific gravity (USG) was determined with the Combur^{10} Test® (Roche Diagnostics, GmbH, Mannheim, Germany). The test detects the ion concentration of urine. In the presence of cations, protons are released by a complexing agent and produce a colour change in the indicator bromthymol blue from blue via blue-green to yellow.

RESULTS

Table 1 presents the stages of the race, the weather, the temperature at the start and at finish, as well as the average speed of our athlete during a stage. Our athlete had no blisters and no problems with toenails but suffered sometimes from low back pain. During stages 4 to 8, she suffered from shin splints, which spontaneously disappeared after stage 8. Except at stage 1 she always arrived within the first 3 runners (Table 1). In nine stages she was the fastest of all competitors. She finished the *Deutschlandlauf* in a total of 124 h 40 min 33 s, whereas the first man finished in 132 h 44 min 15 s, about 8 h behind her. Figure 1 shows the body composition determined by BIA, Figures 2 and 3 show limb circumferences and skinfold thicknesses in order to calculate SM, and Figure 4 shows SM and % BF determined by the anthropometric method. Body mass (BM) increased from 48.8 kg prerace to 50.3 kg (stage 16) to reach 49.7 kg at the end of the race (Figure 1). Percent Body fat (% BF) [BIA] decreased from 9.7% prerace to 5.0% at stage 5, to remain at this value until the end of the race. Visceral fat mass and bone mass showed no changes (Table 2). Percent body water (% TBW) increased from 67.7% prerace to 83.6% at stage 12 to reach 75.5% at the end of the race (Figure 1). Parallel to % TBW, LBM increased from 41.9 kg prerace to 44.9 kg at stage 12, to reach 44.8 kg at the end of the run. Skeletal muscle mass (SM) and % BF as determined by the anthropometric method (Figure 4) showed no obvious change compared with the results of the BIA.

DISCUSSION

We describe here the occasion where a female ultrarunner was faster than all the men in an international multistage ultrarun across a country in Europe. As far as we are aware of, this is a very exclusive fact. In addition we found that BM as well as LBM increased throughout the race, whereas according to the general opinion BM should decrease during an ultraendurance performance. Parallel to LBM, % TBW also increased. And when we compared the change of % BF, BIA showed a continuous decrease, whereas anthropometry shows no change of % BF.

Why is a Female Ultrarunner Faster Than All the Men?

It has been suggested that gender differences in running should disappear as distances increase, particularly past the marathon. This suggestion

Table 1. The Stages of the Race, the Position After the Stage, the Weather, and the Speed of Our Athlete

Stage	Start	Finish	Stage rank	Distance (km)	Ascent (m)	Speed (km/h)	Weather	Temperature at the start (° Celsius)	Temperature at the finish (° Celsius)
1	Kap Arkona	Stralsund	3	64.9	180	10.46	rain	12	15
2	Stralsund	Stavenhagen	3	85.4	250	10.85	clouds	8	16
3	Stavenhagen	Pritzwalk	2	93.4	450	10.04	clouds	12	12
4	Pritzwalk	Jerichow	2	81.6	215	9.85	clouds	13	19
5	Jerichow	Schönebeck	1	73.3	240	9.70	sunny	11	22
6	Schönebeck	Eisleben	4	66.9	605	9.42	sunny	12	21
7	Eisleben	Sömmerda	1	70.5	580	9.83	sunny	7	24
8	Sömmerda	Ilmenau	2	80.6	1,030	9.28	clouds, rain	12	23
9	Ilmenau	Trappstadt	1	64.8	720	9.39	rain	9	15
10	Trappstadt	Prosselsheim	1	74.4	605	9.81	sunny	2.5	12
11	Prosselsheim	Assamstadt	1	85.9	1,000	8.42	sunny	3	15
12	Assamstadt	Biberach	1	72.7	680	9.95	sunny	7	24
13	Biberach	Malmsheim	3	63.0	900	9.26	sunny	9	25
14	Malmsheim	Horb	1	62.2	450	10.08	sunny	7	25
15	Horb	St. Georgen	1	57.5	730	9.12	sunny	8	25
16	St. Georgen	Feldberg	1	51.7	760	9.48	clouds, rain	7	15
17	Feldberg	Lörrach	3	59.9	400	10.03	sunny	8	19

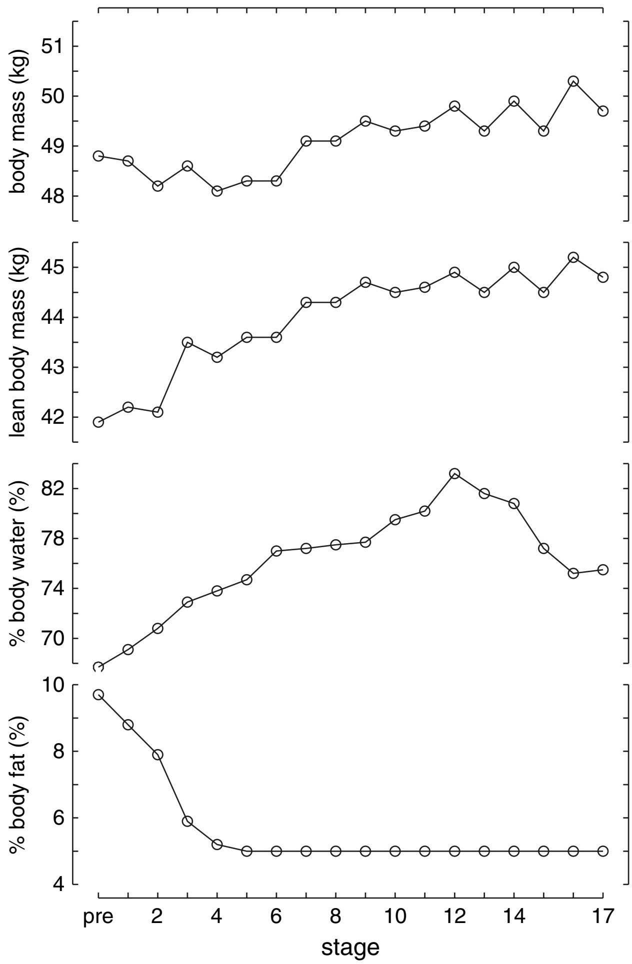

Figure 1. Body composition determined with bioelectrical impedance analysis (BIA).

primarily is based on differences in fuel utilisation, muscle damage following exercise, relative improvements in performance over the past decades, and on the analysis of marathon versus ultramarathon performances of men and women (Coast et al. 2004). One explanation for the victory of a female runner over all the men in an ultraendurance run could be the greater fatigue resistance of female ultrarunners. Based on worldwide indices of competitive distance running over 1,500 m and marathon, the gender difference in distance running performance has plateaued in

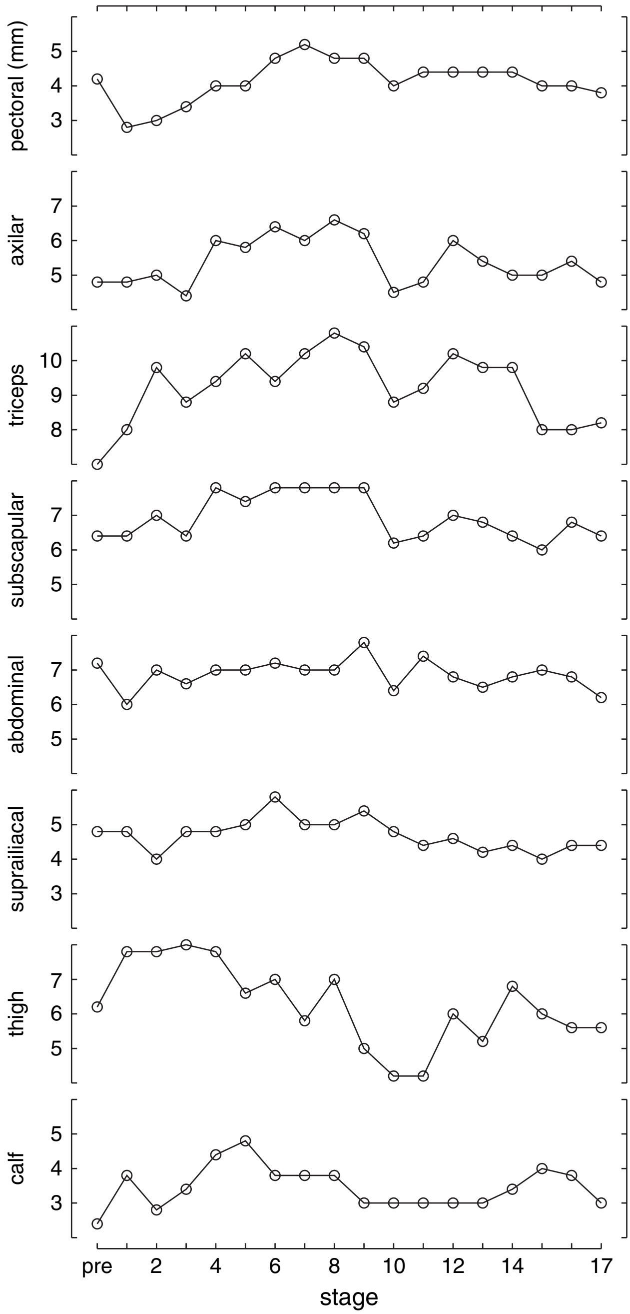

Figure 2. Skinfold thicknesses determined with calipermetry.

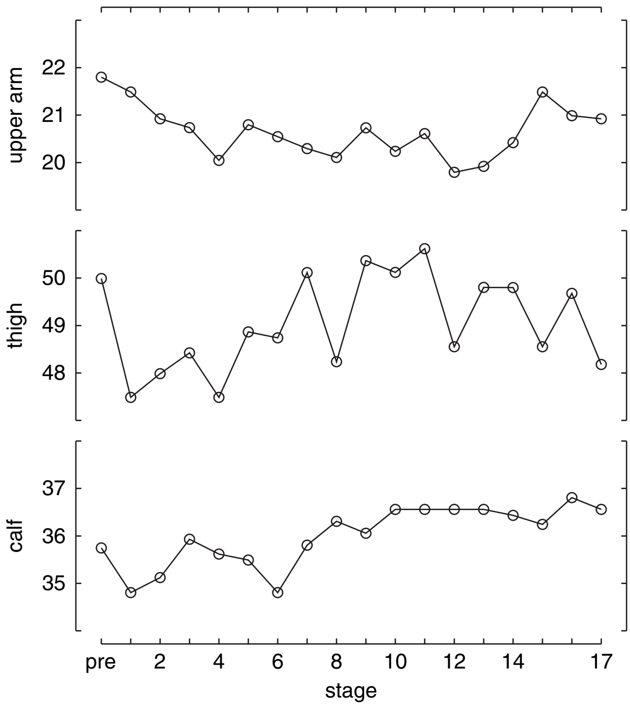

Figure 3. Skinfold corrected circumferences of limbs.

recent years (Sparling et al. 1998). This has been shown in several studies. Daniels and Daniels (1992) demonstrated that men are more economical than women in middle-and long-distance running on the track. Padilla et al. (1992) compared the relative contributions of functional capacities in male and female middle-distance runners. Although female runners had a lower BM, their energy cost of running was identical to men. Coast et al. (2004) could show in a study comparing world best running performances at distances from 100 to 200 km that speeds were different for men and women with an average difference of 12.4% in favour of the men. On longer distances, differences were greater, but this is probably as a result of the small number of women participating in longer distance events. In distances from 100 m to 10,000 m, sex differences in running performance have not changed in the last years; the remaining sex gaps in performance appear to have a biological origin (Cheuvront et al. 2005). Comparing the gender differences in world best times from 1980 to 1996, for 1,500 m and marathon, a difference of 11% between men and women were found (Sparling et al. 1998). For distances up to the marathon

Table 2. Visceral Fat Mass, Bone Mass Determined with Bioelectrical Impedance Analysis (BIA) and the Urinary Specific Gravity During the Race

Stage	Visceral fat mass (kg)	Bone mass (kg)	Urinary specific gravity
Prerace	1	2.2	1.025
1	1	2.3	1.020
2	1	2.3	1.025
3	1	2.3	1.025
4	1	2.3	1.025
5	1	2.3	1.030
6	1	2.4	1.030
7	1	2.4	1.020
8	1	2.4	1.025
9	1	2.4	1.025
10	1	2.4	1.020
11	1	2.4	1.025
12	1	2.4	1.020
13	1	2.4	1.020
14	1	2.4	1.025
15	1	2.4	1.020
16	1	2.4	1.020
17	1	2.4	1.010

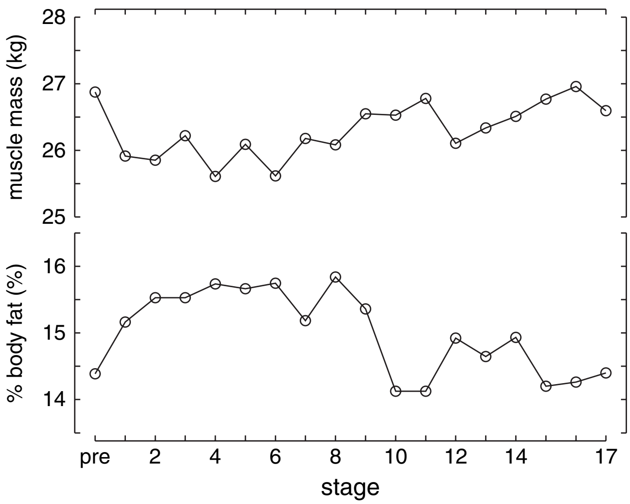

Figure 4. Body composition determined with anthropometry.

distance, men seem to be more economical than women. Helgerud et al. (1990) compared six male and female runners and their performance over the marathon distance with a practically identical race time. Men with a mean time of 199.4 min and women with a mean time of 201.8 min had approximately the same VO_2max, and the anaerobic threshold was reached at an exercise intensity of about 83% of VO_2max. The females' running economy, however, was poorer; that is, their oxygen uptake during running at a standard submaximal speed was higher and the females' training programme over the last 2 months prior to running the actual marathon composed of almost twice as many kilometres of running per week compared with the males. For longer distances, women seem to be more economical than men.

Bam et al. (1997) compared male and female ultrarunners over racing distances from 5 km to 90 km running. Men were running faster over 5 km to 42 km, but not in a 90 km race. The stages of the *Deutschlandlauf* are about 70 km on average (Table 1), so probably our female runner shows this greater fatigue resistance. According to Bam et al. (1997), the observation that the male runners outperformed the female runners at distances below a marathon may have been due to the greater capacity of the women to oxidize fat than men (Tarnopolsky et al. 1990). Although not all studies have shown more fat oxidation in women than in men during prolonged exercise at given percentages of maximum work rate (Powers et al. 1980), an increased rate of fat oxidation would enhance endurance by sparing muscle glycogen (Bosch et al. 1993). The greater endurance of female compared with male runners also might result from their generally smaller sizes and lighter body masses. It is a common observation that elite male distance runners are smaller than elite male middle-distance runners (Coetzer et al. 1993). Our female runner was 48.8 kg, 158 cm with a BMI 19.5 kg/m^2. Compared with successful male finishers of the *Deutschlandlauf* in 2006 (Knechtle et al. 2007), our female runner was the same age (45 years compared with 46.2 ± 9.6 years for the male), but was smaller (1.58 m compared with 1.79 ± 0.06 m), lighter (48.8 kg compared with 71.8 ± 5.2 kg), and had a lower BMI (19.5 kg/m^2 compared with 22.5 ± 1.9 kg/m^2). The relatively high age of 45 years has no negative influence on race performance. According to Leyk et al. (2007) age seems to have no negative effect on marathon times. In trained subjects, significant age-related losses in endurance performances over a marathon distance did not occur until the age of 50 years. Alternatively, the muscles of women may have a fatigue resistance, which is unrelated to any metabolic differences, superior to those of men. When subjected to repeated maximal isometric contractions for even short periods of time, the muscles of women fatigue less rapidly than those of men (Misner et al. 1990). Another explanation could be the motivation of the female runner. After her second place in the *Deutschlandlauf* in 2006 she was probably especially motivated to win the race in 2007.

Why Does Body Mass Increase?

During the race we found, astonishingly, an increase of BM (Figure 1). The BM of our female runner initially decreased from 48.8 kg prerace to 48.3 kg at stage 6, but then it increased up to 50.3 kg at stage 16. After the race, she had gained 1 kg more of BM. In general, a decrease of BM is observed during ultrarunning (Rehrer et al. 1992; Skenderi et al. 2006). The increase of BM appears to be a result of the increase of % TBW. The %TBW increased continuously (Figure 1) for 12 stages and USG (Table 2)—as a sign for dehydration and renal impairment—was increased throughout the race. The retention of % TBW could be the result of different mechanisms: protein catabolism with hypoproteinemic oedema, increased protein synthesis with increased plasma volume, increase of plasma volume due to sodium retention based on an increased aldosterone and impairment of the antidiuretic hormone and dehydration, and impaired renal function due to skeletal muscle damage.

Protein Catabolism with Hypoproteinemic Oedema?

Protein catabolism and the consequent fluid shifts might occur in an ultraendurance performance. Lehmann et al. (1995) postulated an exercise-related intra-extra-cellular water shift after a Double Iron triathlon. They found a decrease in intracellular water and an extracellular fluid increase and stated the decrease in cellular hydration state as a protein-catabolic signal. The SM determined with anthropometry showed no change (Figure 4), but LMB determined with BIA increased in parallel with % TBW (Figure 1). Parameters to detect skeletal muscle damage were not performed, and we cannot therefore judge correctly a decrease of SM and protein catabolism.

Increased Protein Synthesis and Increase of Plasma Volume?

A further explanation for the retention of % TBW could be an increase in circulating proteins inducing an increase in plasma oncotic pressure. An increase of plasma protein—especially albumin—might explain an increase in plasma volume. Maughan et al. (1985) found after a marathon an increase of total protein and albumin as well as Mischler et al. (2003) after a multistage ultraendurance trial. Mischler et al. (2003) detected an increased albumin synthesis after day 4 of exercise by 15%, whereas protein concentration was decreased by 8% after the same day. The increase of albumin cannot be explained properly by Mischler et al. (2003). In contrast, Wu et al. (2004) reported in a 24-hour run that two days after the race there was a significant decrease of total protein, and Fellmann et al. (1989) found a reduced concentration of plasma protein after a 24-hour run with a continuous drop in the days after the race. In several other ultraendurance performances, either amino acids (Lehmann et al. 1995) or total protein (Neumayr et al. 2005) were reduced after physical exercise.

Change of Plasma Volume Due to Hormonal Changes?

A further possible explanation for the increase of % TBW could be an increase of plasma volume due to sodium retention as a consequence of increased activity of aldosterone. Transient expansion of plasma volume commonly is reported after endurance events (Fellmann 1992; Fellmann et al. 1999; Maughan et al. 1985; Milledge et al. 1982). Probably plasma volume seems to behave differently after longer distances. Immediately after a 24-hour run, plasma volume initially was reduced, but it started to increase after the race with a peak on day 2 (Fellmann et al. 1989). Prolonged exercise causes increased loss of TBW by sweating and respiration. The resulting activation of the renin-angiotensin-aldosterone system (RAAS) leads to a retention of sodium, causing retention of water within the circulation. After intense exercise, the antidiuretic hormone and aldosterone are increased (Freund et al. 1987; Melin et al. 1980), and both hormones increase with increasing intensity (Freund et al. 1991). After an ultraendurance performance like a 24-hour run, aldosterone is increased significantly (Fellmann et al. 1989). Increased aldosterone production during intense exercise helps the body to maintain sodium by increasing its reabsorption from the filtered tubular fluid (Poortmans 1984).

After an ultraendurance performance like a 24-hour run, not only aldosterone, but also the antidiuretic hormone is increased (Fellmann et al. 1989). Physical exercise leads to an elevated plasma antidiuretic hormone concentration, probably due to an increase in plasma osmolality and a decrease in plasma volume (Schrier et al. 1970). Fluctuations in plasma osmolality and blood volume are described as triggering mechanisms for the rise in the antidiuretic hormone (Ramsay 1989). Changes in urine flow are dependent on the plasma antidiuretic hormone levels, which are increased by intense exercise (Poortmans 1984). The antidiuretic hormone is involved in the conservation of body water by facilitating the reabsorption of solute-free water (Fellmann 1992).Water balance is regulated by the adjustment of the antidiuretic hormone, which reduces water excretion, and by the feeling of thirst, which induces water intake (Ramsay 1989). The activation of the RAAS and of the antidiuretic hormone system leads to an enhanced retention of sodium and free water, consequently resulting in an increase of plasma volume (Neumayr et al. 2005). Fellmann et al. (1999) conclude that the sodium retention in an ultraendurance race is the major factor in the increase of plasma volume. Fellmann et al. (1989) published in 1989 results from a 24-hour run where they measured changes in plasma volume and various controlling hormones of fluid and electrolyte metabolism. They found an increase in plasma volume leading to a hypervolemia, with the consequence of an increase of aldosterone and antidiuretic hormone. The reaction of the hormones was interpreted to favour a relative fluid consumption. Five consecutive days of hill walking led in the study of Milledge et al. (1982) to a retention of sodium leading to an expansion of the extracellular space. The retention of sodium led to a positive water balance with a shift of fluid from the intracellular to the extracellular space. In addition, they found a significant correlation between sodium retention and the increase of leg volume, which suggests that oedema may be the result of prolonged exercise of this type due to sodium retention.

Dehydration and Impaired Renal Function Due to Skeletal Muscle Damage in Running

We presume that the increase of % TBW also could be a result of the impairment of the kidney due to the rhabdomyolyis occurring in ultraendurance performances (Kim et al. 2007). Rhabodmyolysis during ultraendurance running has been demonstrated (Skenderi et al. 2006; Uberoi et al. 1991), and an association between skeletal muscle damage and impaired renal function has been postulated. Strenuous exercise including running leads to the damage of the skeletal muscle cells (Koller et al. 1998). Especially marathon running has been demonstrated to alter renal function exacerbated by thermal stress under hot and humid conditions (Gault et al. 1992; Neviackas and Bauer 1981).

It is known from marathon running that the eccentric loads of long-term running may cause acute renal failure through dehydration, hemolysis, and rhabdomyolysis (Irving et al. 1990; MacSearraigh et al. 1979). In case of severe muscle damage, creatine kinase and myoglobin from the skeletal muscle cells will be released into the blood, and myoglobinuria (Uberoi et al. 1991) can result. Under certain circumstances such as dehydration and heat stress (Neviackas and Bauer 1981), myoglobin can precipitate in the kidneys and thereby result in acute renal failure (Uberoi et al. 1991).

During a prolonged endurance performance, extensive fluid losses through sweat and respiration may lead to dehydration and hypovolemia accompanied by an exercise-induced impairment of renal blood flow and renal function (Suzuki et al. 1996). Severe cases were considered to be the result of renal hypoperfusion aggravated by hemolysis and rhabodmyolysis as a result of a considerable amount of sports-specific, eccentric loads of running (Ounpuu 1990). The pathophysiology of acute renal failure, however, is multifactorial and is the combined result of rhabdomyolysis, dehydration, hypotension, nonsteroidal anti-inflammatory drugs, and hyperuricemia (Uberoi et al. 1991). The duration of an ultraendurance performance might be of importance in developing such disturbances. Already a 100 km run can reduce renal clearance of creatinine (Décombaz et al. 1979), and a 90 km run can lead to a transient oliguria (Irving et al. 1990). Acute renal failure in an ultraendurance run, however, is in general very rare (MacSearraigh et al. 1979). MacSearraigh et al. (1979) found 10 cases within 9 years at the Comrades Marathon with more than 2,000 participants every year. There is one study of an ultraendurance race presuming that an increase of plasma volume is due to impaired renal function. Gastmann et al. (1998) found in a double iron triathlon an increase in plasma volume and serum urea as well as a decrease of hemoglobin and hematocrit. These changes could not be explained by hemoconcentration but were related to a suppressed renal function with diminished renal blood flow, decreased glomerular filtration rate, and increased hyperaldosteronemia-related renal sodium-reuptake as well as to proteolysis during prolonged exercise.

Determination of Body Parts with Anthropometry and BIA

We determined % BF with both of these methods, but only BIA showed a detectable decrease of % BF (Figure 1), whereas % BF with the anthropometric method showed no obvious change (Figure 4) during the race. In general, the anthropometric method with determination of skinfold thickness and calculation of % BF is a recognised method (Durnin and Womersley 1974). Determination of limb girths and skinfold thicknesses is a common method of estimation of SM (Doupe et al. 1997; Lee et al. 2000) as well as % BF (Lean et al. 1996; Van der Ploeg et al. 2003). Skinfold thickness measurements give a good prediction of % BF (Lean et al. 1996; Tucker et al. 1998), and subcutaneous adipose tissue can be estimated from simple anthropometric measurements (Bonora et al. 1995). In women, the circumference equations including the most labile sites of female fat deposition (waist and hips instead of upper arm or thigh) have proved to be the most reliable (Friedl et al. 2001). When comparing BIA, DEXA (dual energy X-ray absorptiometry), and skinfold method, the skinfold method gives the most reliable results and requires only a limited instrumentation. Moreover, this examination can be performed correctly and easily in all circumstances (Claessens et al. 2000). One problem of the anthropometric method is that different investigators measure different skinfolds thicknesses (Fuller et al. 1991). In this case study, the anthropometric measurements as well as the BIA were determined throughout the whole race by the same investigator.

And as we already have mentioned, the anthropometric method cannot detect changes of visceral fat mass in contrast to BIA (Table 2). BIA has been proposed as a valid method to determine body composition (Janssen et al. 2000; Macfarlane 2007), and BIA devices are reliable and can be recommended as valid field measures of fat mass and % BF (Macfarlane 2007) and SM (Janssen et al. 2000). Nevertheless, measurement reliability is higher for skinfold than for BIA (Gualdi-Russo et al. 1997). Skinfold measurements appear to be a superior alternative for rapid and accurate body composition assessment of athletes compared with BIA (Hortobágyi et al. 1992). Saunders et al. (1998) stated that BIA was not a valid technique in athletes, especially when one wants to determine the body composition effects of training and detraining. Even small fluid changes may be incorrectly interpreted as changes in an athlete's BF content (Saunders et al. 1998). BIA appears not to be an appropriate measurement tool for tracking body composition changes in endurance and resistance training individuals (Broeder et al. 1997). Interestingly, the BIA seems to have limits. As Figure 1 shows, values below 5% of the % BF cannot be detected.

Association in Change of Body Mass with Lean Body Mass and Percent Total Body Water

We found that the change of BM seems to be associated with the change of LBM and % TBW, not with the change of % BF (Figure 1). These results were determined by BIA, which induces a small current through the body, providing resistance and reactance values from body tissues. This current measures % TBW, which is indicative of the fat-free mass (Hoffer et al. 1969). We presume that the shift of water was into the LBM, not into fat mass. Therefore, not only % BF, but also visceral fat mass, showed no increase in BIA. This might explain why BIA found a decrease of % BF (Figure 1), whereas the anthropometric method did not (Figure 4). It seems that visceral fat mass of less than 1 kg cannot be detected by BIA. Additionally, the glycogen stores have to be taken into account. We did not determine these stores, as this is almost impossible for the whole body in living individuals. It is likely, however, that our athlete started the race with full glycogen stores. Furthermore, it seems to be likely that the glycogen stores decreased during the starting stages and never recovered completely during the night. The reduction of the glycogen stores would result in a loss of SM and BM. The total amount of glycogen can reach several hundred grams, and each gram of glycogen binds 2.7 g of water. A loss of 400 g glycogen alone—which might be the case for our athlete—would result in a loss of 1.5 kg of mass, whereas 1.1 kg would be water. Without a formation of oedema, the released water should leave the body; otherwise, it has to be added to the oedema. Therefore, the size of the oedema might be greater than assumed from the net body water measure.

Of What Importance Was Stage 11?

Our results show that after stage 11 the increase of mentioned parameters turned into a decrease, as well a decrease of the other parameters turned into an increase for the rest of the race.

Stage 11 covered a distance of 86 km (Table 1), and the athlete's lowest speed was at this stage. At the beginning of the race, stages 2 to 4 were 80 km long and more, but flat. Then stage 8 and 11 were 80 km and longer, partially reaching an altitude of more than 1,000 m. After stage 11, stages became shorter and athletes had more time for recovery. This might also have had an effect on % BF and the decrease of % TBW (Figure 1). In the 1,000 km run described by Raschka and Plath (1992), fat mass decreased in the male runners by 8.8 kg (-11.9%) after 500 km and at the end of the run by 7.7 kg (–10.6%). A statistically significant decrease of fat mass occurred after day 11.

CONCLUSIONS

A female ultraendurance runner winning a run over 1,200 km within 17 days, ahead of all the men, showed an increase of BM and an increase of TBW as well as LBM when determined by BIA. The calculation of SM and % BF with the anthropometric method showed no obvious change. A real change showing an increase or decrease of solid body masses such as fat mass and SM can be determined only when body water has returned to preexercise levels after a performance. The results of this description should be compared with male runners in order to determine whether these changes are unique to one female ultrarunner or can be generalised. Future studies should be undertaken to see whether skeletal muscle damage can be objectively quantified and which mechanism really leads to the storage of body water.

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