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Body Composition, Energy, and Fluid Turnover in a Five-Day Multistage Ultratriathlon: A Case Study

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A multistage ultraendurance triathlon over five times the Ironman distance within five consecutive days leads in one ultraendurance triathlete to minimal changes in body mass (BM; −0.3 kg), fat mass (FM; −1.9 kg), skeletal muscle mass (SM; no change), and total body water (TBW; +1.5 l). This might be explained by the continuously slower race times throughout the race every day and the positive energy balance (8,095 kcal), although he suffered an average energy deficit of −1,848 kcal per Ironman distance. The increase of TBW might be explained by the increase of plasma volume (PV) in the first 3 days. The increase of PV and TBW could be a result of an increase of sodium, which was increased after every stage. We presume that this could be the result of an increased activity of aldosterone.

KEYWORDS *ultra-endurance, skin-fold thickness, anthropometry, percent body fat*

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INTRODUCTION

It is well known that fat is the main energy-rich substrate for long-lasting endurance performance (Frykman et al. 2003; Helge et al. 2003; Raschka and Plath 1992; Reynolds et al. 1999). Endurance exercise leads to a reduction of adipose subcutaneous tissue in laboratory (Boschmann et al. 2002) and field studies (Helge et al. 2003; Höchli et al. 1995; Knechtle et al. 2007; Raschka et al. 1991; Raschka and Plath 1992). Ultraendurance races are a good opportunity to study the decrease of adipose subcutaneous tissue in long-lasting endurance performance. There seems to be a difference between performances with defined breaks—for example, during the night in multistage races—and nonstop performances without defined breaks. In long-lasting endurance performances with breaks, body mass (BM) may remain stable (Dressendorfer and Wade 1991; Knechtle et al. 2007; Knechtle and Kohler 2007; Nagel et al. 1989; Väänänen and Vihko 2005) or even increase (Raschka and Plath 1992) and BF will be reduced (Knechtle et al. 2007; Raschka et al. 1991; Raschka and Plath 1992), whereas SM seems to be spared (Dressendorfer and Wade 1991; Knechtle et al. 2007; Reynolds et al. 1999). In contrast, in ultraendurance performances for hours or even days or weeks without a break, a decrease of BM (Bircher et al. 2006; Helge et al. 2003; Knechtle et al. 2005; Lehmann et al. 1995) has been demonstrated, where BF as well as SM seems to decrease (Bircher et al. 2006; Knechtle et al. 2005; Knechtle and Bircher 2005). Up until now, the change of BM has been investigated only pre- and postrace, but not during recovery in multistage ultraendurance races. In the study of Kimber et al., (2002) male Ironman triathletes expended, during one Ironman race, 10,036 ± 931 kcal and ingested 3,940 ± 868 kcal, so an energy deficit of −5,973 ± 1,274 kcal resulted. This deficit must be covered by degradation of body-own energy stores. In the "World Challenge Quintuple Iron Triathlon" 2007 in Mexico, the athletes had to perform one Ironman distance per day for 5 consecutive days. The aim of the present investigation was to study the change of body composition, fluid metabolism, and selected laboratory and urinary parameters before and after the stages of a multistage ultraendurance triathlon in one athlete in order to describe recovery phase from ultraendurance performance. We would presume that a continuous energy deficit will occur thus leading to a continuous degradation of BM with decrease of FM and SM.

SUBJECT AND METHODS

Subject

Our subject was a well-experienced, nonprofessional ultraendurance triathlete (43 years, 79.5 kg BM, 178 cm body height, BMI 25.1 kg/m^2). He had 11 years experience in ultraendurance events and had taken part in more than

50 ultratriathlons in the past 11 years. His average training volume per week ranged from 30 up to a maximum of 50 h, with a total volume of 1,600 h per year.

Prerace Laboratory Testing

A maximal exercise test was performed prerace on a stationary cycle ergometer (Corival Cycle Ergometer, MedGraphics, St. Paul, Minnesota, USA) to assess maximum oxygen uptake (VO_2max). The exercise protocol started at 100 Watt and was increased by 30 Watt every 3 min until exhaustion. During the step test, oxygen uptake (VO_2) and carbon dioxide release (VCO_2) were measured continuously (CPX Ultima, MedGraphics, St. Paul, Minnesota, USA). Our athlete completed 370 Watt (4.93 Watt $\cdot$ kg^{-1}) and reached a VO_2max of 59.0 ml $\cdot$ min^{-1} $\cdot$ kg^{-1}. A portable heart rate (HR) monitor POLAR® S625X (POLAR Electro Oy, Kempele, Finland) was programmed with gender, age, body mass, and the subject's VO_2max in order to determine energy expenditure (EE) during exercise (Hilloskorpi et al. 2003). Due to the fact that measurement of EE during physical exercise with the POLAR® S625X starts at 90 beats per minute (bpm), we measured the resting metabolic rate (RMR) using indirect calorimetry in order to determine total EE over 24 hours, with the EE during the recovery phase in addition to EE under load. The athlete was sitting on the cycle ergometer, at rest, while VO_2 and VCO_2 were continuously measured. VO_2 and VCO_2 were used for 5 min to calculate the oxidation rates of carbohydrate and fat. To determine RMR with the respiratory gases, the oxidation rates of fat and carbohydrate were calculated using the stochiometric equations of Frayn (1983). Energy expenditure (EE) from fat and carbohydrate oxidation was converted into kcal $\cdot$ min^{-1} by multiplying the oxidation rate of fat by 9.1 and the oxidation rate of carbohydrate by 4.2 using the Atwater general conversion factor (1909). Resting metabolic rate (RMR) was 2.04 kcal $\cdot$ min^{-1} (8.54 kJ), resulting in a total daily estimated EE of 2,937 kcal at rest.

Collection of Data During the Race

The World Challenge Quintuple Iron Triathlon 2007 took place in the city of Monterrey in the Province of Nuevo León in the North of Mexico. Monterrey, the capital of Nuevo León, lies at 540 m above sea level and has more than one million inhabitants. Temperature in Monterrey varies from 16°C to 28°C in November. The race started on November 10, 2007, and went on until November 15, 2007. The weather was mostly fine, with sun and maximal temperatures of 30°C. Nine athletes (six male, three female) from all over the world were supposed to enter the race. At the end, one female and one male athlete finally arrived at the start line. They had to perform, every day for 5 continuous days, an Ironman distance of 3.8 km swimming, 180 km cycling, and 42.195 km running. Every morning at 09:00 a.m., the swimming started in the 50 m nonheated outdoor pool, in the park of Sociedad Cuauhtemoc & Famosa in Monterrey, 3 km distant from the cycling and running tracks. The temperature of the water in the Olympic pool was between 17°C and 21°C. Laps of 100 m were counted by personal lap counters. After having completed the swimming part, athletes cycled to the Parque Niños Héroes, where they had to complete the cycling and running. The Parque Niños Héroes is a park closed to traffic, completely illuminated, and has an asphalt cycling track, which is 95% flat and has a hill on the remaining 5% of the distance. On the cycling section, athletes had to perform 92 laps of 1.915 km each. After changing to the run, athletes had to run first a short lap of 703 m and then 22 laps of 1.886 km. An altitude of 2,450 m had to be climbed in each Ironman distance. Athletes had the possibility of being helped by their own support crew. Drafting during cycling was prohibited. Laps in the park were counted electronically. During the whole race, accommodation was offered in the Sport Village of the park, where athletes had a room with a toilet and shower. For nutrition, the organizer offered a restaurant operating 24 hours a day, with an abundant buffet. The athlete prepared all his food before the race and took prepacked food with him. Nutrition consisted mainly of commercial food with a detailed description of its content upon the packing (WINFORCE, Menzingen, Zug, Switzerland). Analysis of the energy content of noncommercial food was determined before the race. All food that the organizer supplied to the athlete during the race was continuously recorded. The food was weighed with an electronic balance (SOEHNLE mara, Soehnle, Murrhadt, Germany), and energy content was determined according to a food table (Kirchhoff 2002). The water used for drinks was measured separately using a graduated jug. Heart rate (HR) was continuously monitored with the POLAR® S625X and EE recorded. The POLAR® S625X was programmed and used according to the manufacturer's instructions. Bioelectrical impedance analysis (BIA) was performed before and immediately after every Ironman distance as well as every 24 hours after arriving at the last Ironman distance until initial BM was regained. At the same times, all anthropometric data as well as laboratory parameters were determined by the same investigator as follows: BM was measured with the BIA balance Tanita BC-545 (Tanita Corporation of America Inc., Arlington Heights, IL, USA) to the nearest 0.1 kg. The circumferences of the extremities and the skin-fold thicknesses were determined in the same way on each occasion. The circumferences of the extremities were measured only on the right side, following Lee et al. (2000). All measurements were repeated three times to the nearest 0.1 cm, and the average value was recorded. The thicknesses of the skin-folds were measured likewise only on the right side, following Lee et al. (2000), using a skin-fold calliper (GPM skin-fold calliper, Siber & Hegner AG, Zurich, Switzerland). Measurement points were in the middle axillar line, the chest (at the edge of the musculus pectoralis major, on the medium height of the armpit), the flank (central axillar line, rib bow-crista iliaca), belly (right of the navel), the triceps (middle of acromion-olecranon), the scapula (below the head of the scapula), the calf (on the back of the knee) and finally the thigh (20 cm above the patella). All measurements were repeated three times to the nearest 0.2 mm and the average value recorded. Skeletal muscle mass (SM) was calculated according to Lee et al. (2000). Percent body fat (% BF) was calculated according to Ball et al. (2004). Absolute fat mass (FM) in kg was calculated with % BF from BM with the results of the BIA. Percent total body waters (% TBW) and % BF were measured with the BIA balance Tanita BC-545. Impedance measurements were performed with the subject standing in an upright position, barefoot in swimwear, on foot-electrodes on the platform of the instrument, with the legs and thighs not touching, and the arms not touching the torso. The athlete stood on the 4 foot-electrodes: 2 oval-shaped electrodes and two heel-shaped electrodes, and gripped the 2 palm-and-thumb electrodes in order to yield 2 thumb electrodes and 2 palm electrodes. He did this without shoes or excess clothing. The skin and the electrodes were precleaned and dried. Total body water (TBW) was calculated with % TBW from BIA. Urinary specific gravity (USG) was determined with the Combur$^{\underline{10}}$ 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. Capillary blood samples of 80 μl were taken from the ear lobe and immediately analysed with i-STAT® 1 System (Abbott Laboratories. Abbott Park, IL, USA). Sodium is measured by ion-selective electrode potentiometry. Hematocrit is determined conductometrically. The measured conductivity, after correction for electrolyte concentration, is inversely related to the haematocrit. Urea is hydrolysed to ammonium ions in a reaction catalysed by the enzyme urease. The ammonium ions are measured potentiometrically by an ion-selective electrode. In the calculation of results for urea, concentration is related to potential through the Nernst Equation. Changes in plasma volume (PV) were determined from the pre- and postrace haematocrit values according to Beaumont (1972).

RESULTS

Race Performance

The athlete finished the race in 69:29:01 h:min:s as the only finisher. He performed his fastest Ironman distance on day 1 (12:25:31 h:min:s) and the slowest on day 4 (15:08:39 h:min:s). The split times for swimming, cycling, and running for every Ironman distance are represented in Figure 1.

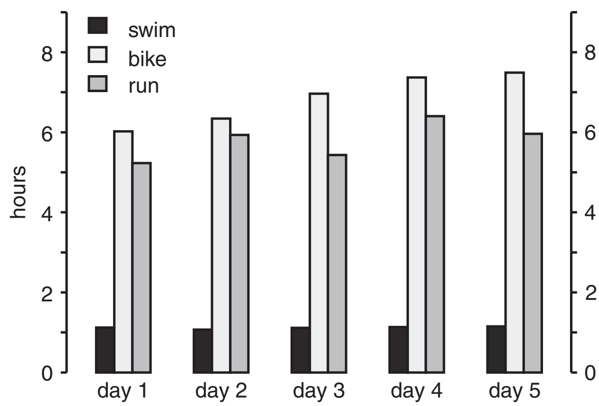

FIGURE 1 Split times for swimming, cycling, and running (excluding transition times) for the 5 Ironman distance triathlons.

Energy Expenditure, Energy Intake, and Energy Balance During the Race

The athlete expended during the whole race—collecting data from the POLAR® S625X and including RMR during the night—a total energy of 36,780 kcal, with an average daily EE of 4,270 ± 1,150 kcal during one Ironman distance (Figure 2). In the whole race, he had a plus in energy of 8,095 kcal.

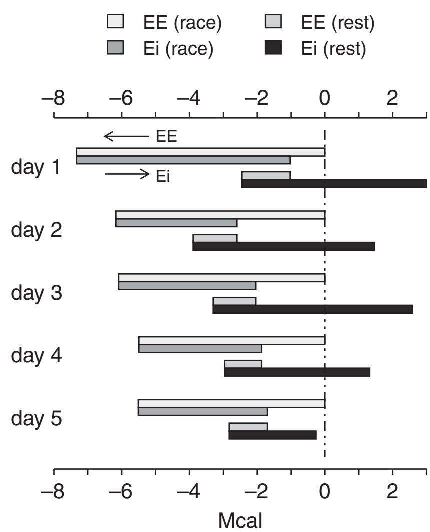

FIGURE 2 Energy balance per day during racing and resting times. Energy expenditure (EE) exceeds energy intake (Ei) during the racing times. Food intake during the resting times, however, compensates the energy deficit during the first four contest days. Only on the fifth day, daily energy balance is negative.

Body Mass and Body Composition

The athlete started with a BM of 79.5 kg and 11.9 kg fat mass (BIA), respectively, 13.4 % BF (anthropometric method). At the end of the race, BM was at 79.2 kg, fat mass (BIA) at 10.0 kg, and % BF unchanged at 13.4% with the anthropometric method (Figure 3).

Fluid and Water Metabolism

During the race, the athlete drank 7.6 ± 0.9 l of fluids and excreted 2.2 ± 0.8 l of urine per Ironman distance. On the whole, he drank 56.1 l of fluids and

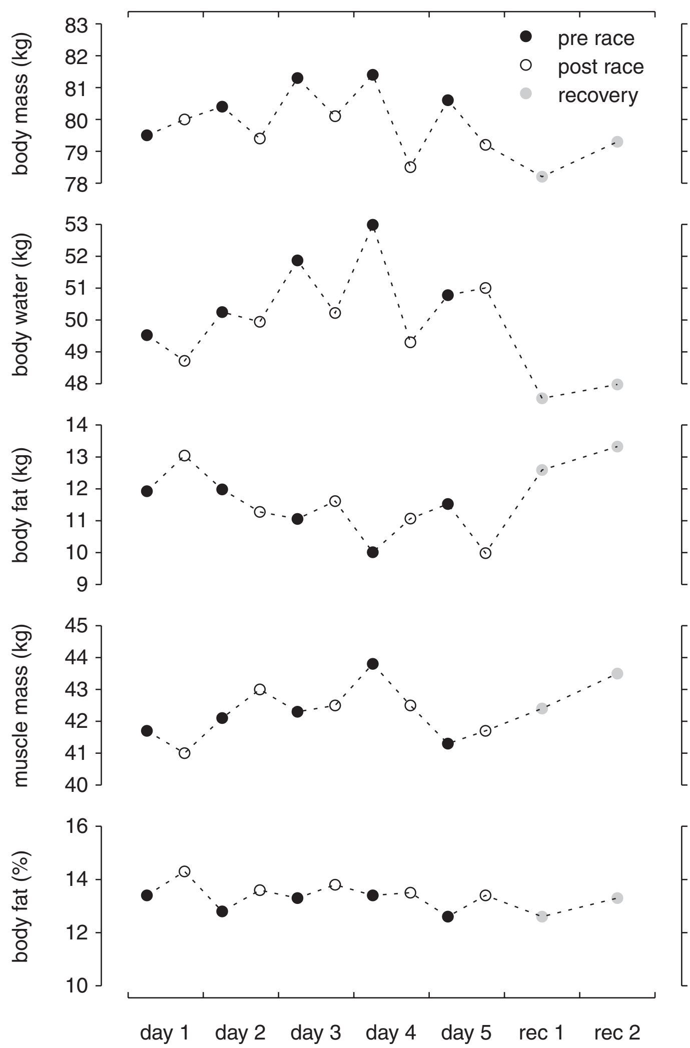

FIGURE 3 Body mass and body composition, determined by bioelectrical impedance analysis (body water, body fat) and anthropometric method (muscle mass, % body fat).

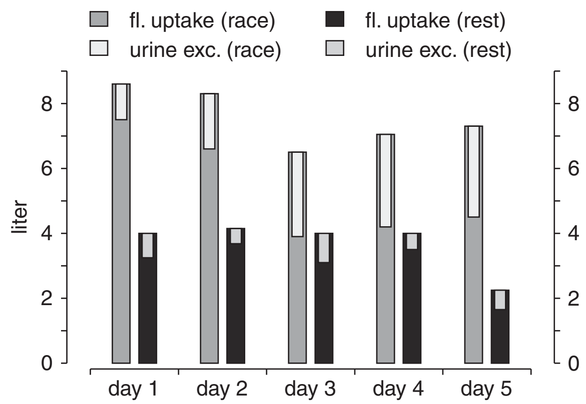

FIGURE 4 Fluid uptake and urine excretion during racing and resting times.

excreted 14.3 of urine during the 5 race days (Figure 4). Total body water (TBW) increased from 49.5 l prerace to a maximum of 53.0 l before stage 4 (Figure 3). Before and during the race, USG was between 1.020 and 1.025, and dropped to 1.010 48 hours after the race (Figure 5). After an Ironman distance, plasma sodium was always higher than prerace and PV was increased in the first 3 days but decreased in the last 2 days (Figure 5).

DISCUSSION

The main findings of this case study are the facts that the athlete suffered during these continuous five Ironman distance triathlons on average an energy deficit of −1,848 ± 568 kcal per race day but had a plus of energy in the recovery phases of 3,467 ± 1,245 kcal on average with a total plus of energy of 8,095 kcal in the whole race and a stable BM of 79.2 kg immediately postrace compared with 79.5 kg prerace. One day after arriving at the finish line, BM dropped by 1 kg, but 2 days after the finish, 79.3 kg were again reached. Fat mass (FM) dropped in the BIA by 1.9 kg from pre- to postrace compared with a stable % BF in the anthropometric method. The two methods presumably detect body fat in a different manner in the tissue. In the BIA, TBW increased by 1.5 l from pre- to postrace and decreased immediately after the race from 51.0 l to 47.6 l.

Performance and Energy Balance

As described in a case study in the World Challenge Deca Iron Triathlon in 2006 where the athletes had to perform in a multistage ultraendurance triathlon one Ironman distance per day for 10 consecutive days, the weakest performance occurred in day 4 (Knechtle et al. 2008). After day 1, the performance

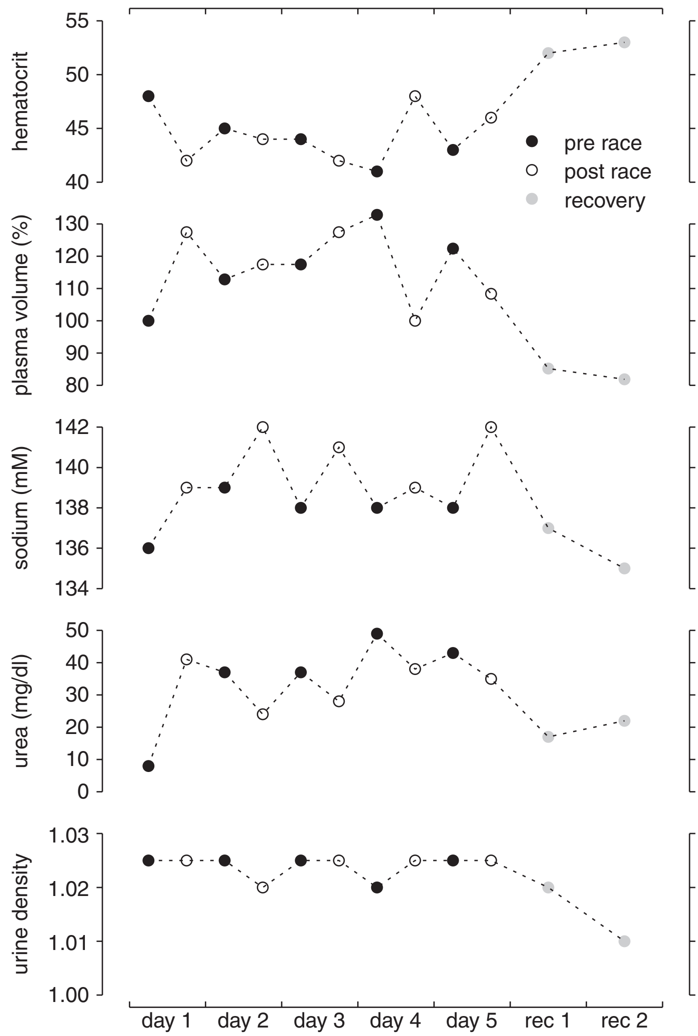

FIGURE 5 Haematological parameters and urinary specific gravity.

deteriorated on the bike whilst running performance remained rather constant (Figure 1). We presume that after the first day with an energy deficit of −1,030 kcal (Figure 2), a part of the intramyocellular energy stores was depleted and the increase of urea nitrogen (Figure 5) from 8 mg/dl to 41 mg/dl showed a damage of SM. The increasing deterioration of performance—although a positive energy balance during the recovery phase was obvious—must be the result of the daily energy deficit of −1,900 kcal (Figure 2) and the constant increased value of urea (Figure 5) as sign of constant skeletal muscle damage. The energy intake during the rest (Figure 2) was obviously inefficient to refill the partly depleted intramyocellular energy stores, probably due to a damage of the fibres, although the athlete had a surplus of energy every day.

Change of Body Composition

In general, ultraendurance performance leads to a decrease of BM as described in several case (Bircher et al. 2006; Knechtle et al. 2005) and field studies (Helge et al. 2003; Lehmann et al. 1995). Our athlete had immediately after the race a decrease of BM by 0.3 kg (Figure 3). Interestingly, FM determined with BIA decreased by 1.9 kg, whereas % BF determined with the anthropometric method remained stable.

Skeletal muscle mass (SM) determined with an anthropometric method was stable immediately after the race and was increased in the following 2 days, whereas TBW was decreased. We presume that the BIA and anthropometric method detect changes of fluid in the body in a different manner.

Why Does Body Water Increase?

As figure 3 shows, the athlete underwent a continuous increase of TBW until day 4. This could be due to a fluid overload (Figure 4) or a consequence of the increased PV (Figure 5). According to the literature, the increase of TBW could be the result of several different mechanisms: Protein catabolism with hypoproteinemic oedema (Lehmann et al. 1995), increased protein synthesis with increased PV (Mischler et al. 2003), increase of PV due to sodium retention as a result of increased aldosterone (Fellmann et al. 1999), or impaired renal function due to skeletal muscle damage (Uberoi et al. 1991). Regarding the increased sodium after every stage and the increase of PV and TBW, we presume that the increase of TBW is a result of hormonal changes. A possible explanation for the increase of TBW could be an increase of PV due to sodium retention as a consequence of an increased activity of aldosterone. We found an increased concentration of sodium postrace and an increase of PV (Figure 5). Transient expansion of PV is commonly reported after endurance events (Fellmann et al. 1999; Milledge et al. 1982). Prolonged exercise in the heat 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 a retention of water within the circulation. After intense exercise, aldosterone is increased (Freund et al. 1987; Melin et al. 1980), and 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, 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 decreased PV. Fluctuations in plasma osmolality and blood volume are described as triggering mechanisms for the rise in antidiuretic hormones (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 TBW 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 PV (Neumayr et al. 2005). Fellmann et al. (1999) concluded that the sodium retention in an ultraendurance race is the major factor in the increase of PV. They published results from a 24-hour run where they measured changes in PV and various controlling hormones of fluid and electrolyte metabolism (Fellmann et al. 1989). There they found an increase in PV leading to a hypervolemia with the consequent increase of aldosterone and the antidiuretic hormone at the end of the race. The reaction of the hormones was interpreted to favour a relative fluid consumption. In another study, 5 consecutive days of hill walking led to a retention of sodium leading to an expansion of the extracellular space (Milledge et al 1982). 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.

Where Does the Fluid Shift?

Body mass (BM) increased on day 1 by 0.5 kg after the race, but in the subsequent days it always decreased after the stage (Figure 3). A decrease of BM during performance can be the result of dehydration (Kavouras 2002). Our athlete had a continuous USG of 1.020 to 1.025 before and after the stages (Figure 5). Only 2 days after the finish, USG dropped to 1.010. According to Kavouras (2002), a decrease of USG and a decrease of BM are signs of dehydration. Therefore, our athlete underwent severe dehydration or was continuously dehydrated every day, although he had a plus of fluid of 5.3 ± 1.6 l every day, when we compare fluid intake and urinary output (Figure 4). When we consider a possible sweat rate of 0.9 l/h (Rogers et al. 1997; Speedy et al. 2001) during performance, we calculate for the total race time of 69:29:01 h:min:s a total sweat loss of about 62 l, so that a fluid deficit of more than −20 l in the whole race must have occurred. Total body water (TBW) was reduced on day 1 to day 4, and on day 5 increased only slightly (Figure 3). And in the 2 days after the race, TBW dropped below the prerace value. Plasma volume (PV) was increased only on the first 2 days, then was decreased (Figure 5), and a fluid overload due to hyponatremia seems not to be possible due to the always increased sodium concentrations after the daily Ironman distances. With these parameters, we cannot explain the shift of water. With the continuous increased values for urea (Figure 5) during the race, we must postulate a continuous damage of SM. We presume that water shifted in the damaged skeletal muscle, what we presumed years ago in a case study (Knechtle et al. 2003), where BM was increased after a Triple Iron triathlon. DEXA (Dual-Energy X-ray Absorptiometry) revealed an oedema of the skeletal muscle presumably due to an increase of LBM (lean body mass) by 4.4 kg after the race. CK increased in that case from 145 U/l prerace to 3,218 U/l postrace, but muscle biopsy revealed no damage of skeletal muscle in the thigh.

How Reliable are Determinations with BIA and Anthropometric Measurements?

Interestingly, FM determined with BIA decreased by 1.9 kg (Figure 3), whereas % BF and SM remained stable with the anthropometric method. In the measurements in the 2 days after the race, FM was increased in the BIA, but % BF rather decreased with the anthropometric method. In general, the anthropometric method with determination of skin-fold thicknesses and calculation of % BF is a recognized method (Durnin and Ramahan 1967; Durnin and Wormersley 1974). Determination of circumferences of limbs and skin-fold thicknesses is a common method of estimation of SM (Doupe et al. 1997; Lee et al. 2000) as well as FM (Lean et al. 1996; Van der Ploeg et al. 2003). Skin-fold thickness measurements give a good prediction of % BF (Lean et al. 1996; Tucker et al. 1998), and subcutaneous adipose tissue can be estimated from these simple anthropometric measurements (Bonora et al. 1995). When comparing BIA, DEXA (dual energy X-ray absorptiometry), and the skin-fold method, the skin-fold method gives the most reliable results and requires only a limited instrumentarium. 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 skin-folds 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. In addition to the anthropometric method, 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 the skin-fold method than for BIA (Gualdi-Russo et al. 1997). Skin-fold measurements appear to be a superior alternative for rapid and accurate body composition assessements of athletes compared with BIA (Hortobágyi et al. 1992). Saunders et al. (1998) stated that BIA is not a valid technique in athletes, especially when one wants to determine 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).

Determination of Energy Expenditure Using Heart Rate Measurements

In this case report we used the HR method to determine EE (Figure 2). It has been suggested that HR recording with a portable HR monitor during field conditions is as accurate as measuring HR with an ECG (Kingsley et al. 2005). Also HR recording in the field is feasible, reasonably priced, and accurate due to the technology of portable HR monitors (Hiilloskorpi et al. 2003). Compared with indirect calorimetry or the doubly labelled water technique, the HR method shows no difference, even when differences between subjects and within subjects are reported (Li et al. 1993). Nevertheless, measuring EE using continuous HR monitoring has limitations. During field conditions, HR is influenced by emotion, high temperature, high humidity, dehydration, and illness (Davidson et al. 1997). The determination of EE by HR is useful as a group mean, but interpretation of the individual EE requires caution because of great deviations from the reference values (Kashiwazaki 1999; Livingstone et al. 1990). Thus the methodology employing continuous HR monitoring may overestimate EE. Indeed, EE measured using HR has been reported to be 6% higher compared with EE derived using the technique of doubly labelled water (Davidson et al. 1997). Similarly, during measurements in the field, continuous HR monitoring to estimate EE shows a difference compared with the technique of using doubly labelled water (Kashiwazaki 1999). It is possible to estimate EE from HR during submaximal exercise with a great deal of accuracy, after adjusting for age, gender, BM, and fitness (Keytel et al. 2005). The relationship between HR and oxygen uptake seems to be linear during dynamic exercise up to about 85% of the individual maximum HR (Li et al. 1993).

CONCLUSIONS

A multistage ultraendurance triathlon over five times the Ironman distance within 5 consecutive days leads in one ultraendurance triathlete to minimal changes in body mass (–0.3 kg), fat mass (–1.9 kg), skeletal muscle mass (no change), and total body water (+1.5 l). This might be explained with the continuously slower race times throughout the race every day and the positive energy balance (+8,095 kcal), although he suffered an average energy deficit of −1,848 kcal per Ironman distance. The increase of TBW might be explained by the increase of PV in the first 3 days. The increase of PV and TBW could be a result of an increase of sodium, which was increased after every stage. This could be the result of an increased activity of aldosterone. The results of this case study should be checked in future field studies in multistage ultraendurance races.

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