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An Ultratriathlon Leads to a Decrease of Body Fat and Skeletal Muscle Mass—The Triple Iron Triathlon Austria 2006

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AN ULTRATRIATHLON LEADS TO A DECREASE OF BODY FAT AND SKELETAL MUSCLE MASS—THE TRIPLE IRON TRIATHLON AUSTRIA 2006

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We investigated the effects on body composition in triathletes at the Triple Iron Triathlon Austria in 2006, where athletes had to perform 11.6 km swimming, 540 km cycling, and 126.6 km running within 58 h. In 16 male triathletes, body mass (BM), skinfold thicknesses, and circumferences of extremities were measured before and after the competition in order to calculate body mass index (BMI), percent body fat (%BF), fat mass (FM), and skeletal muscle mass (SM). Body mass, BMI, %BF, FM, and SM decreased statistically significantly ($p < 0.01$). The loss of BM is associated neither with the decrease of %BF ($p > 0.05$, $r^2 = 0.00$) nor with

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the decrease of SM ($p > 0.05$, $r^2 = 0.06$). There is no association between total race time and the loss of BM ($r^2 = 0.06$), %BF ($r^2 = 0.10$), and SM ($r^2 = 0.11$). No significant correlation ($p > 0.05$, $r^2 = 0.43$) was found between the initial SM and loss of SM.

Keywords: ultraendurance performance, body composition, body mass index, skinfold thickness, anthropometry

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 the laboratory (Boschmann et al. 2002) and in 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—and nonstop performances without defined breaks.

In long lasting endurance performance with breaks, BM may be stable (Dressendorfer and Wade 1991; Knechtle et al. 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).

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. Due to the fact that, until now, the decrease of SM in ultraendurance performance has been demonstrated only in case reports (Bircher et al. 2006; Knechtle et al. 2005; Knechtle and Bircher 2005) and in a few field studies (Helge et al. 2003; Knechtle and Kohler 2007), we intended in this present study to assess a greater sample of ultraendurance athletes. Investigations were performed at an ultratriathlon race over the Triple Iron Triathlon distance to see whether ultraendurance athletes would suffer only a degradation of adipose subcutaneous tissue or whether they would experience an additional loss of SM. In addition, we intended to quantify the loss of body FM and the loss of SM.

SUBJECTS AND METHODS

Subjects

All participants of the Triple Iron Triathlon 2006 in Moosburg, Kärnten, Austria, were contacted by a separate newsletter from the organizer 3 months before the race and asked to participate in the study. Thirty athletes (3 women and 27 men) intended to start. All athletes entered the race; 23 athletes (3 women and 20 men) finished successfully within the time limit. Twenty-two male white Caucasian triathletes entered the study. They all gave their informed written consent. From our subjects, 16 participants (age 36.2 ± 8.5 years, BM 76.4 ± 9.2 kg, body height 1.78 ± 0.07 cm, BMI 23.8 ± 2.0 kg/m^2) arrived successfully at the finish line. They trained 17 ± 5 hours per week in preparation for the race and could show an average experience of 7 ± 8 (one to more than 30) ultraendurance races of 24 hours or longer prior to the current race.

The Race

From June 15 to June 17, 2006, the First Triple Iron Triathlon Moosburg in Kärnten, Austria, which required 11.6 km swimming, 540 km cycling, and 126.6 km running, took place. The race was accepted as the official World Championship Triple Iron Triathlon of International Ultra Triathlon Association (IUTA), with the best ultratriathletes in the world competing. Five participants were ranked within the first 10 places of the IUTA World Circuit 2005, and the first three male athletes of the last World Championship Triple Iron Triathlon were defending their medals. On Thursday, June 15, at 07:00 a.m., the race started. Swimming was in a small lake with a water temperature of 23° Celsius, and wetsuits were allowed. Athletes had to swim 21 laps of 542.85 m with electronic lap counting. After passing the transition area, 90 laps of 6 km with an inclination of 25 m per lap had to be cycled in the town of Moosburg. After cycling, athletes started the running circuit of 60 laps of 2.11 km with an inclination of 5 m per lap, again in the town of Moosburg. The cycling and running courses had flat asphalt, were completely free of traffic, and were illuminated during the night. All athletes had their own support crew in order to provide nutrition and other needs. The athletes had to arrive at the finish line after 58 hours. The weather was fine, with blue sky, a temperature of maximum 30° Celsius, and no precipitation.

Measurements and Calculations

The evening before the start of the event and after arriving at the finish line, BM and circumferences of upper arm, thigh, and calf were measured on the right side. Body mass was measured with a commercial scale (Beurer BF 15, Beurer GmbH, Ulm, Germany) pre- and postrace to the nearest 0.1 kg, without change of clothes. Skinfold thicknesses and circumferences of the extremities were measured on the right side of the body to the nearest 0.2 mm, according to Lee et al. (2000).

Circumference of the upper arm and calf were measured at the largest perimeter of the limb, at the thigh 15 cm above the upper pole of the patella. All circumferences were determined to the nearest 0.1 cm. Skinfold thicknesses of chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary line), thigh, and calf were measured with a skinfold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm. Every measurement was taken three times by the same person, and then the mean value was used for calculation. Skeletal muscle mass (SM) was calculated using the following formula: $SM = Ht \times (0.00744\ CAG^2 + 0.00088 \times CTG^2) + 0.00441 \times CCG^2 + 2.4 \times sex - 0.048 \times age + race + 7.8$, where Ht = height, CAG = skinfold-corrected upper arm girth, CTG = skinfold-corrected thigh girth, CCG = skinfold corrected calf girth, sex = 1 for male, race = 0 for White (Lee et al. 2000). Percent of body fat (%BF) was calculated using the following formula: $\%BF = 0.465 + 0.180(\Sigma 7SF) - 0.0002406(\Sigma 7SF)^2 + 0.0661(age)$, where $\Sigma 7SF$ = sum of skinfold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh mean (Ball et al. 2004). Fat mass (FM) was calculated with %BF from BM.

Statistical Analysis

Statistical analysis was performed with the R software package (R Foundation for Statistical Computing, Vienna, Austria, 2005). The one-sample Wilcoxon signed rank test was used to check for significant changes directly measured and calculated values of the parameters before and after the race. Loss of %BF and SM was correlated with the loss of BM using Spearman's rank correlation analysis to identify the reason for loss of BM. Furthermore, loss of BM, %BF, and SM was correlated with the total race time. Nonparametric methods were used, as not all parameters were ideal normal distributed. Bonferroni correction was used to compensate for multiple testing effects (pre/-post-test of 16 parameters and additional 7 times correlation analyses). For all statistical tests, the significance level was set to 0.05.

RESULTS

The average finish time was 45 h 12 min, varying from 34 h 16 min for the defending world champion up to 56 h 10 min for the last finisher. Table 1 shows the mean values (SD) of the directly measured parameters before and after the race. Body mass decreased statistically highly significantly ($p < 0.01$) by 2.4 ± 1.9 kg. Limb circumferences of upper arm and thigh decreased statistically significantly by 8 ± 6 mm ($p < 0.05$) and 25 ± 14 mm ($p < 0.001$), respectively. Calf circumference did not decrease ($p > 0.05$). With the exception of the leg (thigh and calf), all skinfold thicknesses decreased statistically significantly ($p < 0.05$). The largest decrease of skinfold thickness was measured at suprailiacal (3.1 ± 3.1 mm), followed by at the axilla (2.0 ± 2.3 mm), then at the pectoral (1.6 ± 2.2 mm), and at the triceps (1.6 ± 1.7 mm). Skinfold thickness at the chest decreased by 1.5 ± 2.2 mm ($p < 0.01$), at the triceps by 1.5 ± 1.7 mm ($p < 0.05$), at the subscapular region by 0.4 ± 0.4 mm ($p < 0.001$), at the abdomen by 2.4 ± 2.0 mm ($p < 0.001$), and at the suprailiac region by 3.1 ± 3.1 mm ($p < 0.05$). Table 2 shows the mean values (SD) of the calculated parameters before and after the competition. A statistically significant decrease was shown for BMI (0.7 ± 0.6 kg/m^2; $p < 0.001$). Percent body fat (%BF) as well as SM decreased statistically highly significantly ($p < 0.001$) by 1.7 ± 1.1 %BF and by 1.0 ± 0.6 kg, respectively. Calculated FM decreased also statistically highly significantly (–1.7 ± 1.1 kg; $p < 0.001$). Figure 1 shows that the loss of BM is neither associated with the decrease of %BF ($p < 0.05$, $r^2 = 0.00$) nor with the decrease of SM ($p < 0.05$, $r^2 = 0.06$). Figure 2 shows that there is no association between

Table 1. Mean Values and Standard Deviation (SD) of Directly Measured Parameters Before and After the Race

Parameter	Unit	Prerace	Postrace	Change [in %]
Body myass	kg	76.4 (9.2)	74.0 (8.9)$^{\#}$	– 3.1
C upper arm	cm	29.9 (2.3)	29.1 (2.2)	– 2.6
C thigh	cm	53.7 (3.8)	51.2 (3.9)**	– 4.6
C calf	cm	39.1 (3.1)	38.2 (2.7)	– 2.3
SF pectoral	mm	6.6 (3.9)	5.0 (1.9)$^{\#}$	– 24
SF axillar	mm	7.6 (3.7)	5.6 (2.2)$^{\#}$	– 26
SF triceps	mm	8.1 (3.6)	6.5 (2.6)$^{\#}$	– 20
SF subscapular	mm	8.5 (1.9)	8.1 (1.9)$^{\#}$	– 4.7
SF abdominal	mm	13.3 (7.9)	10.9 (6.1)$^{\#}$	– 18
SF suprailiacal	mm	10.4 (4.9)	7.3 (2.8)$^{\#}$	– 30
SF thigh	mm	9.5 (6.5)	8.7 (6.4)	– 8.4
SF calf	mm	7.1 (2.7)	6.6 (3.0)	– 7.0

C = circumference, SF = skinfold. $^{\#}p < 0.05$; $^{*}p < 0.01$; $^{**}p < 0.001$.

Table 2. Mean Values and Standard Deviation (SD) of Calculated Parameters Before and After the Race

Parameter	Unit	Prerace	Postrace	Change [in %]
Body mass index (BMI)	kg/m^2	23.8 (2.0)	23.1 (2.0)**	– 2.9
Skeletal muscle mass (SM)	kg	40.0 (4.6)	39.0 (4.2)*	– 2.5
Fat mass (FM)	kg	10.2 (3.9)	8.6 (2.8)**	– 15
Percent body fat (%BF)	%	13.2 (4.0)	11.5 (3.0)**	– 13

The decrease of body mass index (BMI), percent body fat (%BF), calculated fat mass (FM), and calculated skeletal muscle mass (SM) is statistically significant (* $p < 0.01$; ** $p < 0.001$).

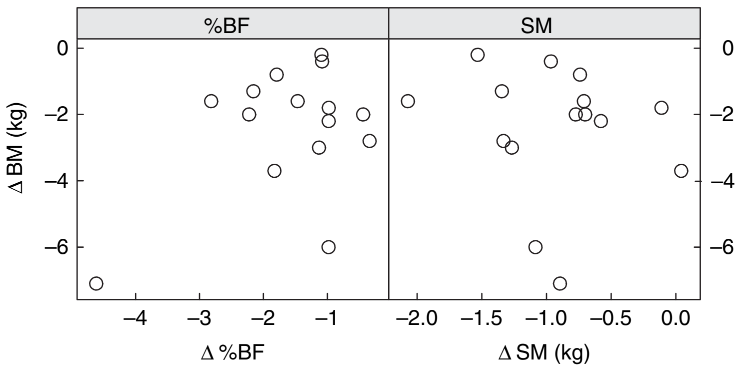

Figure 1. Association of loss of body mass with loss of percent body fat and loss of skeletal muscle mass.
The loss of body mass (BM) during the race is neither associated with the loss of percent body fat (%BF; $p > 0.05$, $r^2 = 0.00$) nor with the loss of skeletal muscle mass (SM; $p > 0.05$, $r^2 = 0.06$).

total race time and the loss of BM ($p > 0.05$, $r^2 = 0.06$), %BF ($p > 0.05$, $r^2 = 0.10$), and SM ($p > 0.05$, $r^2 = 0.11$). A significant correlation ($p < 0.05$, $r^2 = 0.53$) was found between the initial %BF and the loss of %BF during the race (Figure 3), whereas no significant correlation ($p > 0.05$, $r^2 = 0.43$) was found between the initial SM and loss of SM (Figure 4).

DISCUSSION

The main finding of our investigation is that an ultratriathlon with a nonstop performance over 45 h results in a statistically significant

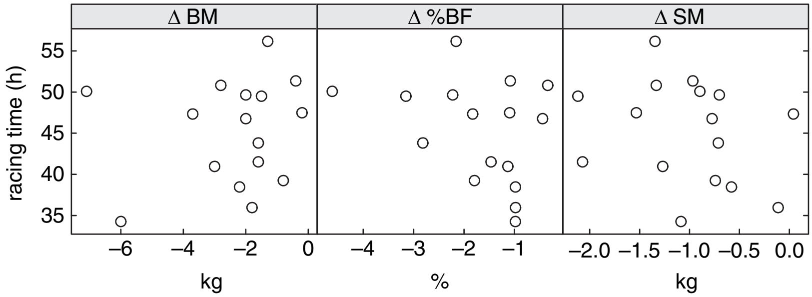

Figure 2. Association of race time with decrease of body mass, percent body fat, and skeletal muscle mass.

Total race time during is not associated with the loss of body mass (BM; $p > 0.05$, $r^2 = 0.06$), percent body fat (%BF; $p > 0.05$, $r^2 = 0.10$), or skeletal muscle mass (SM; $p > 0.05$, $r^2 = 0.11$).

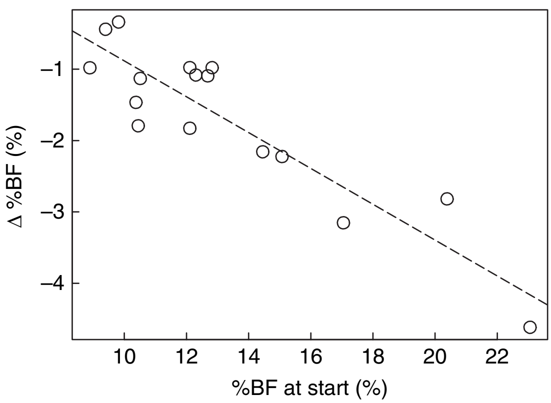

Figure 3. Association of decrease of percent body fat with percent body fat at the start of the race.

The higher percent body fat (%BF) was present at the start of the race. The higher was the loss of %BF during the race ($p < 0.05$, $r^2 = 0.53$).

decrease of BM, %BF, calculated FM and calculated SM in well-trained ultraendurance athletes.

Decrease of Body Mass During Ultraendurance Performance

Nonstop endurance races over hours and days, or even weeks, lead to a decrease of BM (Bircher et al. 2006; Helge et al. 2003; Knechtle et al. 2005; Lehmann et al. 1995; Raschka 1995; Volk et al. 2001) as well as

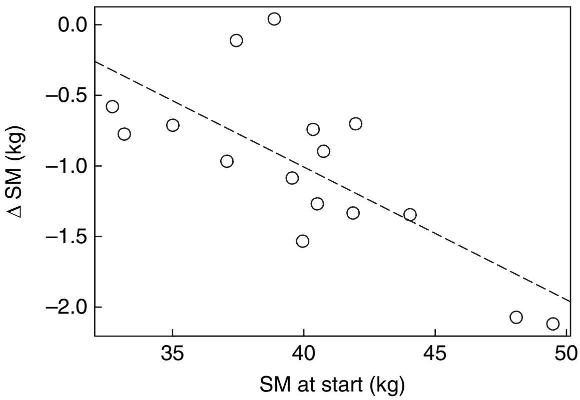

Figure 4. Association of decrease of skeletal muscle mass with skeletal muscle mass at the start of the race.

No significant correlation was found between the initial skeletal muscle mass (SM) and loss of SM during the race ($p > 0.05$, $r^2 = 0.43$).

multiday races with the possibility of breaks during the night (Helge et al. 2003; Knechtle and Bircher 2005; Nagel et al. 1989; Raschka 1995). The decrease of 2.4 kg of BM (Table 1) in this actual investigation lies between 1.75 kg in a multiday run over 1,000 km, 2 kg in an ultracycling race (Bircher et al. 2006), 2 kg in a triple iron triathlon (Volk et al. 2001), 2.5 kg in a 6-day run (Knechtle and Bircher 2005), over 3.3 kg in a double iron triathlon (Lehmann et al. 1995; Gastmann et al. 1998) to 5 kg in the Race Across America (Knechtle et al. 2005). Our athletes in this triple iron triathlon showed an average loss of BM comparable with the decrease of BM in one Ironman triathlon, where BM also decreases significantly during the race (Laursen et al. 2006; Sharwood et al. 2002, 2004). In one Ironman distance, BM declines by 2.3 kg (Laursen et al. 2006) to 2.5 kg (Speedy et al. 2001). A loss of 2.5 kg BM corresponds to a mean percentage loss in BM of 3% (Speedy et al. 1997). This agrees with our findings, where our ultraendurance athletes lost 2.4 kg BM, corresponding to a decrease of 3.1% (Table 1).

In very long lasting performances, FM (Helge et al. 2003; Höchli et al. 1995; Knechtle and Bircher 2005; Knechtle et al. 2007) as well as lean BM (Bircher et al. 2006; Helge et al. 2003; Knechtle et al. 2005; Knechtle and Bircher 2005) can decrease. In some situations—as described in case reports and field studies—SM decreases during ultraendurance performance (Bircher et al. 2006; Frykman et al. 2003; Helge et al. 2003; Knechtle and Kohler 2007). The loss of BM in this ultraendurance race seems to be covered by a loss of BF as well as an additional loss of SM

(Table 1). But the loss of BM is neither associated with the loss of SM nor with the loss of %BF (Figure 1). In general, adipose subcutaneous tissue is the main energy source for long lasting endurance performance (Frykman et al. 2003; Raschka and Plath 1992) and SM seems to be spared (Reynolds et al. 1999). In our investigation, total race time was not influenced by decrease of %BF and decrease of SM (Figure 2). Obviously, neither body fat nor SM contributed as energy supply to race performance. But starting with a higher %BF leads to a higher decrease of %BF during the race (Figure 3).

Decrease of Fat Mass and Skeletal Muscle Mass

In our subjects, the decrease of fat mass was 1.7 kg (–15%) and the decrease of SM was 1.0 kg (–2.5%). The share of FM of this deficit of body mass was higher than that of SM (Table 2). In several studies, FM decreases in ultraendurance performance. In the study of Helge et al. (2003), where four male subjects crossed the Greenland icecap on cross-country skis, BM decreased from 79.2 ± 3.9 kg to 73.6 ± 3.4 kg, %BF from 22.4 ± 1.4% to 18.2 ± 1.1%, and lean BM from 61.3 ± 2.0 kg to 60.3 ± 2.0 kg. On average, their subjects had a mean mass loss of 5.7 ± 0.5 kg, of which 78 ± 7% was fat and the remainder lean BM. In a run over 1,000 km within 20 days, all skinfold thicknesses and the FM showed a falling tendency; only the thigh skinfold initially grew, and then came down from the fourth day onward (Raschka and Plath 1992). Höchli et al. (1995) could show a 10% decrease of body fat in their runners at the Paris-Dakar Foot-Race over 8,000 km (600 km per runner within 30 days).

Muscle mass also decreases in athletes during ultraendurance performance, as it has been shown in case reports (Bircher et al. 2006; Knechtle et al. 2005; Knechtle and Bircher 2005) and field studies (Helge et al. 2003; Knechtle and Kohler 2007). In contrast, in other ultraendurance performances, SM remained stable (Frykman et al. 2003; Reynolds et al. 1999). In a multistage ultrarun over 1,000 km within 20 days, muscle mass initially decreased only from 59.3 kg to 58.9 kg on day 11 and increased at the end of the run to 59.9 kg, which was higher than the muscle mass at the start (Raschka et al. 1991).

Interestingly, the loss of SM in our athletes was not associated with starting mass of SM (Figure 4). We therefore presume that starting an ultraendurance race with a high muscle mass would show no benefit. In contrast, a higher FM (Figure 3) would be of more help from an energetic point of view. Loss of SM probably is related to the running distance. During a multistage triathlon with 10 Ironman triathlons for 10 consecutive days, the athletes lost significant FM during the race (Knechtle et al. 2007), where ultrarunners during a multistage ultrarun over 333 km within

5 days lost significant SM (Knechtle and Kohler 2007). During the 10 Ironman triathlons, athletes had to run a marathon per day (Knechtle et al. 2007), while daily running distance in the ultrarun was more than 60 km per day (Knechtle and Kohler 2007). The limit for a further decrease of SM seems to be between 40 to 50 km of running per day. In the multistage ultrarun from Raschka et al. (1991), daily running performance was 50 km, which resulted in an increase of SM by the end of the race. They concluded that the increase of SM was a training effect of this long-distance run.

Dehydration and Loss of Body Mass in Ultraendurance Performance?

We found no association of loss of BM with loss of %BF and loss of SM (Figure 1). Probably the loss of BM was associated with loss of body water. One problem in our study is the fact that we measured the athletes immediately after arriving at the finish line and could not determine correctly whether they were dehydrated or not. In all methods to determine body composition, it has to be considered that physical exercise and its effects on the body might influence measuring values, resulting in systematic errors of measurement. As it takes some time for the body to compensate for the dehydration, the timing of measuring BM after the race also might be of importance. Höchli et al. (1995) could demonstrate in their runners at the Paris-Dakar Foot-Race over 8,000 km (600 km per runner within 30 days) that 4 days after the race, body fat was close to the conditions before the race.

Like dehydration, it takes some time for the body to compensate for the physical race effects. It must be hypothesized that the weight loss during an Ironman triathlon mainly is due to dehydration. Endurance performance leads to dehydration, which results in a weight loss (Walsh et al. 1994). It is stated, though, that the body weight loss in an Ironman triathlon derives most likely from sources other than fluid losses (Speedy et al. 2001). Decrease of SM must be part of the decrease of BM in an ultraendurance triathlon. It has been shown that athletes in a double iron triathlon undergo an increase of plasma volume, mainly due to a decrease of circulating proteins (Gastmann et al. 1998; Lehmann et al. 1995). Also in a 15-day road race, a significant decrease of serum protein was shown (Dressendorfer and Wade 1991) as well as over the double iron triathlon (Gastmann et al. 1998) and triple iron triathlon distances (Volk and Neumann 1998, 2001). In an ultratriathlon over the double iron triathlon distance, both plasma volume as well as parameters of muscle metabolism increased, although the athletes lost 3.3 kg of BM. The increase of CK (creatin-kinase) was a clear sign of skeletal muscle damage (Gastmann et al. 1998).

During dehydration, we would generally expect an increase of haematocrit. But ultraendurance performance leads to a hypervolemia with haemodilution and a decrease of haematocrit (Åstrand and Saltin 1964; Davidson et al. 1987; Lindemann et al. 1978; Refsum et al. 1973). In triple iron triathlon distance especially, haematocrit decreases from 48 ± 4% to 45 ± 3% (Volk and Neumann 2001), 47.6 ± 3.0% to 43.1 ± 3.4% (Volk et al. 2001), and 48% to 45% (Volk and Neumann 1998) from prerace to postrace. The phenomenon of hypervolemia with haemodilution and decrease of haematocrit is explained by a shift of intracellular water to the extracellular space and an increased fluid intake during performance (Wells et al. 1996).

But the question still remains of whether dehydration really occurs during a triple iron triathlon. Volk et al. (2001) examined, in the Triple Iron Triathlon Germany 1999 in Lensahn, with bioelectrical impedance analysis the hydration status in ultraendurance triathletes. They compared their results of bioelectrical impedance analysis with standard laboratory testing (haematocrit, serum osmolality, and serum concentration of sodium). During the cycling part over 540 km, haematocrit increased from 45.6 ± 3.6% to 47.6 ± 3.0%, concentration of sodium decreased from 142.3 ± 1.0 mmol/l to 140.4 ± 2.3 mmol/l, plasma volume decreased by 5.8%, and cycling under hot conditions caused a steepening and lengthening of the vectors in the bioelectrical impedance analysis. In contrast, after running 126 km in the heat, haematocrit decreased from 47.6 ± 3.0% to 46.4 ± 2.7% (– 2.5%), plasma volume increased by 18.5%, and, in the bioelectrical impedance analysis, the vectors showed a shortening and downward slope to the baseline. After the race, only BM showed a statistically significant decrease of 2 kg. Haematocrit, sodium, and osmolality showed no statistically significant changes. The authors suggested an involuntary dehydration during the cycling because the athlete is alone during the night; during the run, however, the support crew has more possibilities to feed the athletes; therefore, they could not prove dehydration during a triple iron triathlon.

CONCLUSION

In summary, a nonstop ultratriathlon requiring 11.6 km swimming, 540 km cycling, and 126.6 km running within an average finish time of 45 h leads to a statistically significant decrease of BM, SM, and FM. Loss of %BF as well as loss of SM was not associated with loss of BM. Furthermore, no association was observed between race time and loss of body fat or SM. To prove that dehydration does not lead to a loss of BM in ultraendurance performance, further studies with determination of markers of hydration status like hemoglobin, haematocrit, urine osmolality, specific gravity of urine, and total body water by bioelectrical impedance analysis should be performed.

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