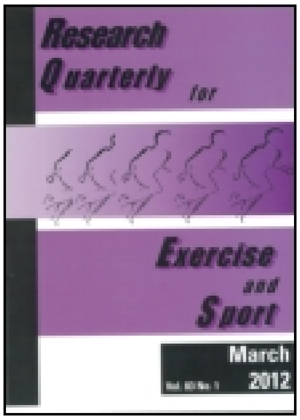

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A Triple Iron Triathlon Leads to a Decrease in Total Body Mass But Not to Dehydration

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A Triple Iron Triathlon Leads to a Decrease in Total Body Mass But Not to Dehydration

Beat Knechtle, Patrizia Knechtle, Thomas Rosemann, and Senn Oliver

A loss in total body mass during an ultraendurance performance is usually attributed to dehydration. We identified the changes in total body mass, fat mass, skeletal muscle mass, and selected markers of hydration status in 31 male nonprofessional ultratriathletes participating in a Triple Iron triathlon involving 11.4 km swimming, 540 km cycling and 126.6 km running. Measurements were taken prior to starting the race and after arrival at the finish line. Total body mass decreased by 1.66 kg (SD = 1.92; -5.3 kg to +1.2 kg; $p < .001$), skeletal muscle mass by 1.00 kg (SD = 0.90; -2.54 kg to +2.07 kg; $p < .001$), and fat mass by 0.58 kg (SD = 0.78; -1.74 kg to +0.87 kg; $p < .001$). The decrease in total body mass was associated with the decrease in skeletal muscle mass ($r = .44$; $p < .05$) and fat mass ($r = .51$; $p < .05$). Total body water and urinary specific gravity did not significantly change. Plasma urea increased significantly ($p < .001$); the decrease in skeletal muscle mass and the increase in plasma urea were associated ($r = .39$; $p < .05$). We conclude that completing a Triple Iron triathlon leads to decreased total body mass due to reduced fat mass and skeletal muscle mass but not to dehydration. The association of decrease in skeletal muscle mass and increased plasma urea suggests a loss in skeletal muscle mass.

Key words: fat mass, skeletal muscle mass, skinfold thickness, ultraendurance

Long-distance triathlons, such as the Ironman (3.8 km swimming, 180 km cycling, and 42.2 km running) are highly popular. From year to year, an increasing number of athletes participate in these races to qualify for the Ironman World Championship (Lepers, 2008). In addition to this type of race, ultratriathletes have also participated in Double (Gastmann et al., 1998; Lehmann, Huonker, & Dimeo, 1995) and Triple Iron triathlons (Knechtle, Duff, Amtmann, & Kohler, 2008; Knechtle, Schwanke, Knechtle, & Kohler, 2008), which cover two and three times the Ironman distances.

Finishing an Ironman triathlon requires enormous effort. Speedy et al. (2001) showed that male finishers lost 2.5 kg of total body mass in an Ironman race, most likely from sources other than fluid loss. The median weight change over the entire race was -2.5 kg (-4 kg to +1.5 kg), which equated to a relative total body mass loss of -3.5% (-6.1% to +2.5%), reaching statistical significance ($p < .0006$). Kimber, Ross, Mason, and Speedy (2002) also found that male Ironman triathletes expended about 10,000 kcal per race and ingested approximately 4,000 kcal, resulting in an energy deficit of 6,000 kcal. Because energy intake provided about 40% of total energy expenditure, endogenous fuel stores were estimated to supply over half the energy expended during the contest. This energy deficit probably cannot be covered by degradation of intramyocellular energy stores, and, consequently, a substantial decrease in total body mass occurs.

Several studies investigating ultraendurance events longer than the Ironman triathlon demonstrated a decrease in total body mass and a corresponding energy deficit (Bircher, Enggist, Jehle, & Knechtle, 2006; Knechtle, Enggist, & Jehle, 2005; Knechtle, Knechtle, Schück, Andonie, & Kohler, 2008; Knechtle, Schwanke et al., 2008). In events such as the Triple Iron triathlon (11.4 km swimming, 540 km cycling, and 126.6 km running), recent studies showed that athletes suffer decreases in total body

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mass consisting of decreases in fat mass (Knechtle, Duff et al., 2008; Knechtle, Schwanke et al.) and skeletal muscle mass (Knechtle, Duff et al.). Because these races are three times the length of one Ironman triathlon, one would expect the energy deficit and decrease in total body mass to be higher compared to a single Ironman triathlon.

Unfortunately, hydration status was not quantified in prior investigations. It was supposed that the decrease in total body mass in marathon (Pastene, Germain, Allevard, Gharib, & Lacour, 1996; Whiting, Maughan, & Miller, 1984) and ultramarathon running (Kao et al., 2008) resulted from dehydration. The aim of the present investigation, therefore, was to quantify a change in hydration status, apart from changes in total body mass, fat mass, and skeletal muscle mass, by determining other parameters of hydration status, such as urinary specific gravity, total body water, plasma sodium, hematocrit, and plasma volume. Thus, we investigated whether an ultraendurance performance longer than a classic marathon or Ironman triathlon distance would lead to a decrease in total body mass apart from dehydration.

Method

Participants

All 53 athletes registered for the 2007 Triple Iron triathlon in Germany were contacted by a separate newsletter 3 months before the race and asked to participate in our investigation. Fifty-three (3 women and 50 men) expressed interest; however, only 45 male athletes entered our investigation (the other 8 decided not to participate without further explanation). All 45 provided informed written consent in accordance with the Institutional Ethics Committee guidelines. No criteria for inclusion/exclusion were used, except that participants had to complete the Triple Iron triathlon within 58 hr. Thirty-one Caucasian nonprofessional ultratriathletes (*M* age = 42.1 years, *SD* = 8.1; *M* total body mass = 77.0 kg, *SD* = 7.0; *M* height =1.78 m, *SD* = 0.06; and *M* body mass index = 24.3 kg/m^2, *SD* = 1.7) finished the race successfully within the time limit. The other 14 athletes dropped out due to medical problems, such as exhaustion and overuse injuries of the lower limbs. Anthropometric parameters (see Table 1), prerace experience, and training parameters (see Table 2) of finishers and nonfinishers are presented in detail.

The Race

The 16th competition of the Triple Iron triathlon was held in Lensahn, Germany, July 27–29, 2007. The weather was dry, with temperatures varying from 11.9°C (July 29 at 00:00) to 20.2°C (July 27 at 2:00 p.m.). Relative humidity varied from 57% (July 27 at 3:00 p.m.) to 96% (July 29 at 3:00 a.m.), with an average of 82–90% during the day. Barometric pressure was at 1,007.0 hPa to 1,009.2 hPa during the day and varied from 1,005.7 hPa (July 29 at 6:00 p.m.) to 1,011.0 hPa (July 27 at 09:00 p.m.).The race started at 07:00 a.m. on July 27. Swimming took place in a heated 50-m outdoor pool with a constant temperature of

Table 1. Comparison of anthropometric variables measured by skinfolds between finishers and nonfinishers

Anthropometry	Finishers (*n* = 31)		Nonfinishers (*n* = 14)	
	M	*SD*	*M*	*SD*
Age (years)	42.1	8.1	37.7	6.7
Body height (m)	1.78	0.06	1.79	0.05
Body mass (kg)	77.0	7.0	77.8	7.9
BMI (kg/m2)	24.3	1.7	24.2	2.1
Percent body fat (%)	15.3	3.2	15.3	3.6
Sum of 7 skinfolds (mm)	81.8	23.0	84.8	27.4
Skeletal muscle mass (kg)	40.5	3.6	41.2	3.8

Note. M = mean; *SD* = standard deviation.

Table 2. Comparison of participants' previous race experience, personal best times, and training variables

Experience and training	Finishers (*n* = 31)		Nonfinishers (*n* = 14)	
	Mdn	IQR	*Mdn*	IQR
No. of Ironman triathlon races	5	2–35	10	1–22
	(*n* = 28)		(*n* = 11)	
Personal best time (min)	670	615–688	698	(600–800)
No. of Triple Iron triathlon races	3	1–6	3	1–4
	(*n* = 18)		(*n* = 7)	
Personal best time (min)	2,728	2,380–3,103	2,331	2,252–2,488*
Training volume per week (hr)	18.0	11.5–25.0	15.5	11.8–21
Swimming (hr)	3.0	1.0–6.0	2.0	1.5–3.0*
Cycling (hr)	10.0	5.0–15.0	9.0	6.0–12.0
Running (hr)	5.8	4.0–7.5	4.0	3.0–6.0
Swimming (km)	8.8	3.0–14.0	6.0	4.0–7.5**
Cycling (km)	250	150–350	250	180–300
Running (km)	55	40–75	40.0	25–65
Swim speed (km/h)	2.7	2.0–3.0	2.5	2.0–2.8
Cycling speed (km/h)	28.0	21.9–30	29.2	24.0–31.8
Running speed (km/h)	10.0	8.6–12.5	9.3	8.3–10.0

Note. Mdn = median; IQR = interquartile range.
**p* = .04.
***p* = .051 by Mann-Whitney.

25°C; wetsuits were allowed. Next, participants cycled 67 laps on a hilly course near the town at 8 km per lap, after which they ran 96 laps on a flat run course in the town at 1.31 km per lap. All athletes had their own support crew to provide nutrition, clothing changes, and equipment. Athletes were free to manage their own nutrition.

Measurements and Calculations

Before starting the race and immediately after reaching the finish line, each participant underwent anthropometric measurements in a room with stable temperature to determine total body mass, skeletal muscle mass, and percentage of body fat. Bioelectrical impedance analysis was used to determine the percentage of total body water. Urine samples were collected to determine urinary specific gravity to quantify hydration status; capillary blood samples were taken at the same time to determine hematocrit, plasma urea, and plasma sodium. Weight was measured to the nearest 0.1 kg using Tanita BC-545 body composition monitor (Tanita Corporation of America, Inc., Arlington Heights, IL). Body height was measured to the nearest 1.0 cm with a stadiometer (Seca, Reinach, Switzerland). Skinfold thicknesses of the chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh, and calf were measured to the nearest 0.2 mm on the right side of the body with a skinfold caliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland). To avoid intertester variability, one trained investigator took all skinfold measurements. An intratester reliability check was conducted prior to this testing on 27 male runners. There was no significant difference between the two trials for the sum of skinfolds ($p > .05$). The intraclass correlation (ICC) was high at $r = .99$. The same investigator was also compared to another trained investigator to determine objectivity. There was no significant difference between testers ($p > .05$). The same investigator repeated all skinfold measurements three times; the mean of these measurements was then used for analysis. According to Becque, Katch, and Moffatt (1986), readings should be taken 4 s after applying the caliper. Percentage of body fat was calculated using the following anthropometric formula for men:

$$\text{Percent body fat} = 0.465 + 0.180(\Sigma 7\text{SF}) - 0.0002406(\Sigma 7\text{SF})^2 + 0.0661(\text{age})$$

where Σ7SF = sum of seven skinfold thicknesses of chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh mean, according to Ball, Altena, and Swan (2004). This formula was used with 160 men ages 18–62 years and cross-validated with dual energy X-ray absorptiometry (DXA). The mean differences between DXA and the calculated percentage of body fat ranged from 3.0% to 3.2%. Significant ($p < .01$) and high ICC ($r > .90$) resulted between the anthropometric prediction equations and DXA. Skeletal muscle mass was calculated using the following anthropometric formula:

$$\text{Skeletal muscle mass} = \text{Ht} \times (0.00744 \times \text{CAG}^2 + 0.00088 \times \text{CTG}^2 + 0.00441 \times \text{CCG}^2) + 2.4 \times \text{sex} - 0.048 \times \text{age} + \text{race} + 7.8$$

where Ht = height, CAG = skinfold-corrected upper arm girth, CTG = skinfold-corrected thigh girth, CCG = skinfold-corrected calf girth, sex = 1 for men and 0 for women, and race = 0 for White, according to Lee et al. (2000). This anthropometric method was evaluated with 189 nonobese individuals and cross-validated with magnetic resonance imagining. Arm circumference was measured to the nearest 0.1 cm in the middle of the upper right arm; thigh circumference was measured on the right thigh where the skinfold thickness was taken, and calf circumference was measured at the maximum circumference of the right calf. Again, the same investigator took all measures to ensure reliability.

The Tanita BC-545 was used to determine the percentage of total body water. This method was evaluated by Jebb, Cole, Doman, Murgatroyd, and Prentice (2000), comparing the Tanita device with dual-energy x-ray absorptiometry methods, total body water using an isotope dilution procedure, body composition using skinfold thicknesses, and tetrapolar bioelectrical impedance analysis. Prior to the race, intratester reliability was conducted with 28 male runners. The ICC was high at $r = .99$. Because total body mass and skeletal muscle mass are determined in absolute values, fat mass was calculated from the percentage of body fat and total body mass; total body water was calculated from the percentage of total body water and total body mass. Capillary blood samples of 80 µl were taken from the ear lobe and immediately analyzed within 2 min using the i-STAT® 1 System (Abbott Laboratories, Abbott Park, IL). This procedure was chosen to detect immediate postrace life threatening disturbances in electrolyte metabolism. Changes in plasma volume were determined from pre- and postrace hematocrit values according to Beaumont (1972). Urinary specific gravity was determined using URYXXON® 300 (Macherey-Nagel, Düren, Germany).

Athletes kept a training diary to record their swimming, cycling, and running training. They reported the distance and duration of training for each discipline until the start of the race. In addition, each athlete indicated the number of Ironman and Triple Iron triathlons completed as well as his personal best time in each race.

Statistical Analysis

Data are presented as means, standard deviations, and median (interquartile range) as appropriate. A Shapiro-Wilk test was used to check for normality distribution. Athletes were categorized into two groups (finisher and nonfinisher). Anthropometric and training variables were compared between groups by unpaired *t* test and Mann-Whitney tests as appropriate. The coefficient of variation (CV% = 100 x *SD*/*M*) was calculated for performance. A nonparametric method was used, as not all parameters were ideally normally distributed. The one-sample Wilcoxon signed rank test was used to check for significant changes in the parameters during the race. Bonferroni correction was used for multiple statistical pre/post comparisons. Pearson correlation analysis was applied to the parameters with statistically significant changes in order to detect associations between parameters. Spearman correlation analysis was applied when the data were nonnormally distributed.

Results

Finishers and nonfinishers showed no differences in their anthropometry (see Table 1). Nonfinishers had a faster personal best time in the Triple Iron triathlon compared to finishers (see Table 2). Finishers reported significantly more training hours and distance in swimming ($p < .05$). There were no differences for volume and intensity in cycling and running between finishers and nonfinishers. The successful athletes finished the race within 47.4:27.5 hr:min (*SD* = 6.8:16.5); 2,874 min (*SD* = 401) respectively (CV = 13.9%). The 14 nonfinishers dropped out during cycling (4 athletes) after 44 laps (*SD* = 4; range: 38–48), respectively, running (10 athletes) after 34 laps (*SD* = 2; range: 1–73), due to exhaustion (cycling) and lower limb injuries (running). No athlete suffered an accident or technical problem that led to dropout during cycling. Total body mass decreased by 1.66 kg (*SD* = 1.92; -5.3 to + 1.2 kg; $p < .001$), skeletal muscle mass decreased by 1.00 kg (*SD* = 0.90; -2.54 to + 2.07 kg; $p < .001$), and fat mass decreased by 0.58 kg (*SD* = 0.78; -1.74 to + 0.87 kg; $p < .001$). Total body water remained stable ($p > .05$; see Table 3). The decrease in total body mass was associated with the decrease in skeletal muscle mass ($r = .44$; $p < .05$), the decrease in fat mass ($r = .51$; $p < .01$) and the nonsignificant change in total body water ($r = .77$; $p < .0001$). The changes in total body mass, fat mass, skeletal muscle mass, and total body water were not related to the total race time ($p > .05$); however, prerace fat mass was associated with total race time ($r = .46$; $p < .01$; see Figure 1). Urinary specific gravity and plasma sodium showed no changes ($p > .05$; see Table 3). Hematocrit decreased significantly ($p < .05$), plasma volume increased significantly by 14.7% (*SD* = 26.1; $p < .01$), and plasma urea increased significantly ($p < .001$). The decrease in skeletal muscle mass and the increase in plasma urea were associated ($r = -.39$; $p < .05$; see Figure 2). The increase in plasma urea was not related to race performance ($r = -.05$; $p > .05$; see Figure 3); however, it significantly correlated to the change in urinary specific gravity ($r = .58$, $p < .001$; see Figure 4).

Discussion

The main finding of this investigation was that a Triple Iron triathlon leads to a decrease in total body mass in the form of skeletal muscle mass and fat mass. The decrease in total body mass was 2.2%, and urinary specific gravity remained stable; therefore, no athlete suffered dehydration, according to Kavouras' definition (2002).

Decrease in Total Body Mass

Athletes in our study lost 1.66 kg (*SD* = 1.92) total body mass (-2.2%), 1.00 kg (*SD* = 0.90) in skeletal muscle mass, and 0.58 kg (*SD* = 0.78) in fat mass. In a study of an

Table 3. Means and standard deviations of solid masses, total body water, hematological and urinary parameters before and after the race (*n* = 31)

Parameter	Prerace		Postrace		Change (absolute)		Change (%)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Body mass (kg)	77.3	7.0	75.6	7.6	- 1.66	1.92**	- 2.2	2.5
Skeletal muscle mass (kg)	40.4	3.6	39.4	3.7	- 1.00	0.90**	- 2.4	2.3
Fat mass (kg)	12.0	3.1	11.4	3.1	-0.58	0.78**	-4.4	6.4
Total body water (L)	50.6	4.5	51.3	6.0	+0.77	3.21	+1.4	6.2
Hematocrit	47.2	5.0	44.3	3.8	-2.9	5.0*	-5.4	9.4
Plasma sodium (mmol/l)	137.9	1.9	137.2	3.4	-0.7	3.2	-0.5	2.3
Plasma urea (mmol/l)	4.2	2.1	9.4	3.1	+5.2	3.3**	+188	172
Urinary specific gravity (g/ml)	1.013	0.007	1.017	0.007	+0.004	0.01	+0.4	0.9

Note. Note. M = mean; *SD* = standard deviation.
*$p < .05$.
**$p < .01$.

Ironman race, Speedy et al. (2001) concluded that a total body mass loss of 2.5 kg (-3.5%) derived from a substantial loss of either skeletal muscle mass or fat mass. In general, in an Ironman triathlon, total body mass decreases significantly (Hew-Butler et al., 2007; Sharwood, Collins, Goedecke, Wilson, & Noakes, 2004; Speedy, Campbell et al., 1997; Speedy, Faris, Hamlin, Gallagher, & Campbell, 1997). Median changes in total body mass up to 2.5 kg during an Ironman race were reported (Laursen et al., 2006; Speedy et al., 2001), in which a 2.5 kg loss of total body mass corresponded to a mean loss of 3.1% to 3.5% total body mass (Speedy, Campbell et al., 1997; Speedy et al., 2001, respectively). Our athletes' loss of total body mass was lower than the results of Speedy et al. (2001). In a study of a Triple Iron triathlon, a significant decrease in total body mass was associated with the decrease in percentage of body fat, which was associated with race intensity (Knechtle, Schwanke et al., 2008). In contrast, in the current investigation the decrease in total body mass, fat mass, and skeletal muscle mass was not associated with race performance. Our athletes finished the race within 47.4:27.5 hr:min (*SD* = 6.8:16.5), corresponding to 2,874 min (*SD* = 401), and lost 1.66 kg (*SD* = 1.92) in body mass. Therefore, they invested more than 15 hr (more than 900 min) per Ironman distance. Laursen et al. (2006) studied 10 male Ironman triathletes who finished the race within

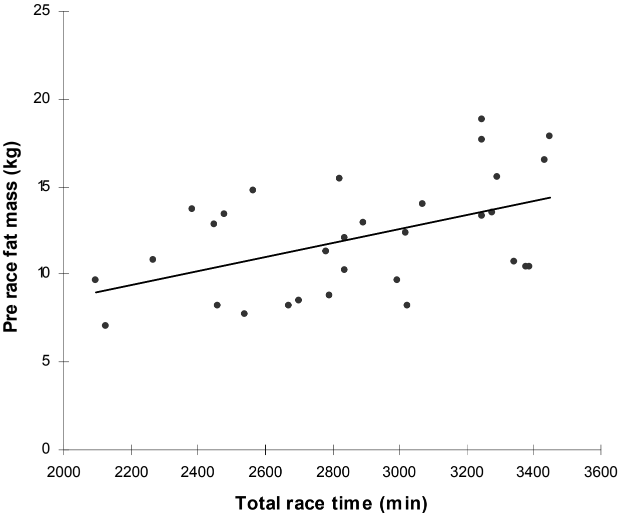

Figure 1. Prerace fat mass was significantly correlated to total race time ($r = .46$; $p < .01$).

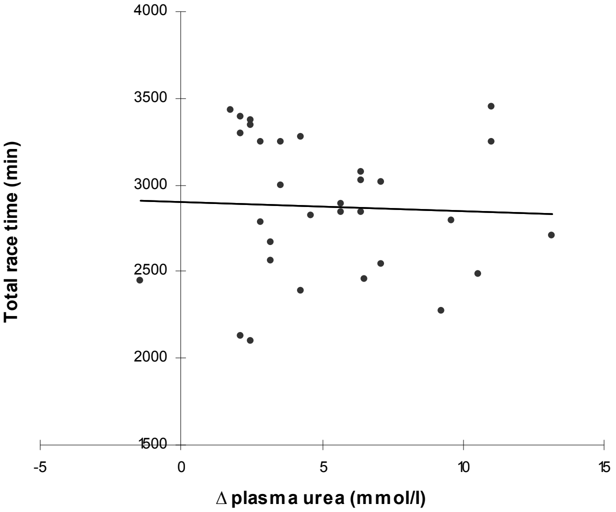

Figure 3. The increase in plasma urea was not associated with total race time ($r = -.05$; $p > .05$) for the 31 athletes.

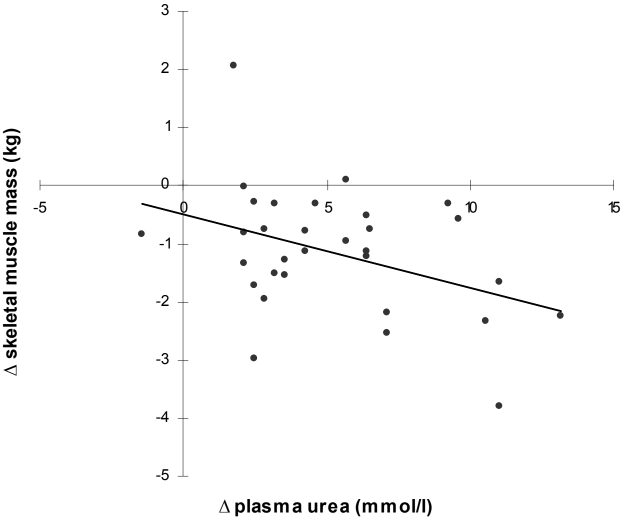

Figure 2. Decrease in skeletal muscle mass was associated with increase in plasma urea ($r = -.39$; $p < .05$) for the 31 athletes.

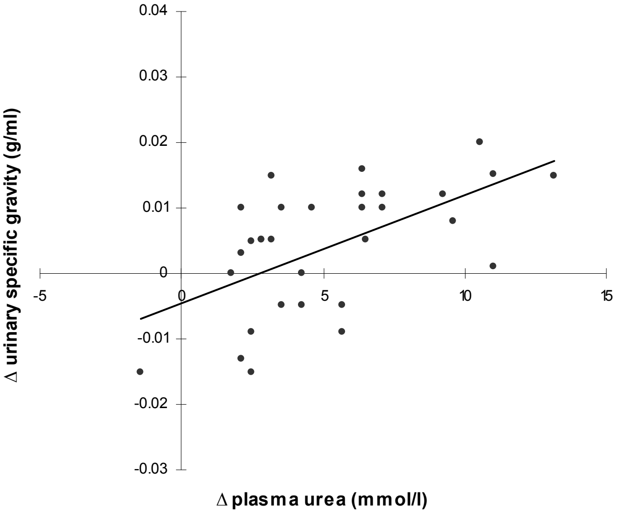

Figure 4. The changes in plasma urea and urinary specific gravity were related ($r = .58$, $p < .001$) in the 31 triathletes.

611 min (*SD* = 49) and lost 2.3 kg (*SD* = 1.2) in total body mass, corresponding to 3.0% (*SD* = 1.5) total body mass. Compared to our athletes, their triathletes were faster per Ironman distance and lost more body mass. However, their athletes had a prerace total body mass of 77.7 kg (*SD* = 5.4) and had identical prerace total body mass compared to our athletes. Presumably, racing intensity was responsible for the decrease in total body mass in the Laursen et al. (2006) study. Sharwood et al. (2002) studied 311 male and 45 female triathletes whose total body mass loss was 3.7 kg (*SD* = 1.6) (-5.2% body weight) and mean race finishing times were 757.1 min (*SD* = 99.8). Although their participants were slower than those in the Laursen et al. (2006) study, the athletes lost more total body mass. However, the study included women and athletes with a total body mass ≥ 100 kg. Including both men and women as participants might explain these differences. In ultrarunners, lean body mass changed in male runners during a > 1,000-km ultrarun in 20 days, but not in female runners (Raschka et al., 1991). In female ultrarunners, fat mass decreased from 10.75 to 9.9 kg (18.6–17.2%) during a >1,000-km run compared to a decrease of 8.8–7.7 kg (11.9–10.6%) in male ultrarunners after 500 km of the race (Raschka & Plath, 1992).

Decrease in Fat Mass and Skeletal Muscle Mass

A decrease in fat mass is expected in an ultraendurance performance of approximately 2 days. It is also well known that fat is the main energy-rich substrate for long-lasting physical exercise endurance (Frykman et al., 2003; Helge et al., 2003; Raschka & Plath, 1992). Endurance performance leads to a reduction of adipose subcutaneous tissue as shown in several studies (Frykman et al., 2003; Helge et al., 2003; Höchli et al., 1995; Raschka & Plath, 1992). In addition, we found a significant reduction in skeletal muscle mass. In general, the decrease in total body mass during an ultraendurance performance is thought to be due solely to a reduced fat mass (Helge et al., 2003; Höchli et al., 1995). However, in a study with ultrarunners in a multistage ultraendurance run, a substantial decrease in skeletal muscle mass by 0.6 kg was found after the first stage of 62 km (Knechtle & Kohler, 2007). In contrast to the present investigation, those ultrarunners showed no change in total body mass. In a multistage ultraendurance triathlon with one Ironman distance per day for 10 consecutive days, there was also a significant decrease in total body mass after the first day (Knechtle, Salas, Andonie, & Kohler, 2008). At that time, fat mass was reduced by 5 kg, whereas skeletal muscle mass was increased by 0.7 kg. The methods of measuring body composition (anthropometric method, bioelectrical impedance analysis) and competitions investigated (swimming, cycling, running, triathlon), especially running length, might have influenced these results. In a multistage ultraendurance run of 62 km (Knechtle & Kohler, 2007), the anthropometric method was used; in the multistage ultraendurance triathlon run of 42 km (Knechtle, Salas et al., 2008), bioelectrical impedance analysis was applied.

We presume our triathletes experienced a substantial loss of myofibrillar protein, because plasma urea increased after the race and was associated with the decrease in skeletal muscle mass (see Figure 2). Urea can be an indicator of skeletal muscle catabolism. Fallon, Sivyer, Sivyer, and Dare (1999) found an increase of urea and creatine kinase during a 1,600-km ultramarathon. Performance duration may also influence the increase in urea. Janssen, Degenaar, Menheere, Habets, and Geurten (1989) and Reid and King (2007) described an increase in urea after a marathon and an ultramarathon. In a 525-km cycling race, urea rose significantly by 97% (Neumayr et al., 2005) and 54% (Neumayr et al., 2003) in a 230-km ultracycling marathon.

A postexercise increase in urea may also be attributed to an enhanced protein catabolism during performance. After a Double Iron triathlon, urea was significantly increased (Gastmann et al., 1998). However, in our ultratriathletes, the increase in plasma urea was not associated with race performance (see Figure 3), but it was significantly correlated to the change in urinary specific gravity (see Figure 4). This association might be due to renal function impairment, as Gastmann et al. (1998) found an increase in plasma volume and serum urea as well as a decrease of hemoglobin and hematocrit in a Double Iron triathlon. These changes could not be explained by hemoconcentration but were related to supressed renal function with diminished renal blood flow, decreased glomerular filtration rate, increased hyperaldosteronemia-related renal sodium-re-uptake, and proteolysis during prolonged exercise.

Dehydration in Ultraendurance Performance?

During the past 20 years, many indexes have been developed to assess human hydration levels accurately, including changes in total body mass, hematological and urine parameters, bioelectrical impedance, skinfold thickness, heart rate, and blood pressure (Kavouras, 2002; Shireffs, 2003). Although there is no “gold standard” for assessing hydration status, it appears that changes in total body mass, along with urine osmolality, specific gravity of urine, conductivity, and color of urine are among the most widely used of these indexes (Kavouras, 2002). It is assumed that a decrease in total body mass corresponds to dehydration during marathon (Pastene et al., 1996; Whiting et al., 1984) and ultramarathon running (Kao et al., 2008). The current evidence and opinions tend to favor urine indexes as the most promising markers available (Shireffs, 2003). Hematological measurements, such as plasma osmolality, plasma sodium, or hematocrit, are not as sensitive in detecting mild hypohydration as selected urinary parameters are (Armstrong et al., 1994; Armstrong et al., 1998). Our athletes lost total body mass (see Table 3), hematocrit was significantly reduced, and plasma sodium and urinary specific gravity did not change. According to Kavouras (2002), a decrease of 2.2% total body mass and a urinary specific gravity of 1.017 indicate minimal dehydration. In contrast to Ironman triathletes, our athletes competed at a slower pace (average 15:55 hr:min per Ironman distance for the Triple Iron triathlon) than in a single Ironman and were, therefore, able to eat and drink more during the race. In particular, our athletes may have been relatively overhydrated, as evidenced by the apparently nonsignificant increase in total body water and the fact that capillary blood [Na] and hematocrit were lower postrace than prerace. Presumably, the rather slow race pace led to a fluid overload due to excessive fluid intake during prolonged exercise (Noakes, 2002). Fluid intake was not determined during the race, which is a limitation of this study. Furthermore, there is concern that bioelectrical impedance analysis might not provide valid estimates of total body water when rapid hydration changes occur that typically involve concomitant changes in electrolyte content. Organizational barriers associated with this kind of field study and costs hampered the use of an isotope dilution method to assess total body water. The coefficient of variation of the total body water estimation pre- and postrace was 8.8% and 11.8%, respectively, which is near the reported range for bioelectrical impedance analysis under stable conditions (O'Brien, Young, & Sawka, 2002). This method may not provide valid estimates of total body water when hydration is in acute disequilibrium (O'Brien et al., 2002). To determine body water with bioelectrical impedance analysis, plasma osmolality and electrolyte concentrations should remain stable (Berneis & Keller, 2000; Pialoux et al., 2004). Because urinary specific gravity and plasma sodium were unchanged during the race, we assumed the athletes' hydration status was equilibrated.

Practical Implications

From these findings, we deduce two practical implications for the ultraendurance athlete aiming to perform a Triple Iron triathlon. Because athletes' skeletal muscle mass significantly decreased, we suggest incorporating strength training into the general training program to maintain or increase skeletal muscle mass (Häkkinen, Mero, & Kauhanen, 1989). Prerace fat mass was related to total race time ($r = .46$, $p < .01$). However, the average weekly training volume was not correlated to prerace fat mass ($r = -.12$, $p > .05$). We assume that training did not affect fat mass, which might be genetically determined or influenced by diet. Obviously, low body fat enhances race performance in an ultraendurance event, although fat mass is significantly reduced during the race. An increase of fat mass prerace, for example, might not be beneficial for successful race outcome.

Conclusions

A Triple Iron triathlon leads to decreased total body mass, consisting of reduced fat mass and skeletal muscle mass. The association of decreased skeletal muscle mass and increased plasma urea suggests damage to skeletal muscle. Athletes in our study experienced no dehydration, as their total body mass decreased by 2.2% and urinary specific gravity remained stable. In effect, these triathletes were overhydrated postrace, rather than dehydrated. Therefore, the effective loss in total body mass must be rated higher than the postrace decrease. In future studies of ultraendurance races, the fluid intake during performance should also be determined to detect a fluid overload. Furthermore, body composition should be measured several days after the competition, when athletes' reach their prerace total body water condition.

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