

Research article

Running 338 kilometres within five days has no effect on body mass and body fat but reduces skeletal muscle mass – the Isarrun 2006

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Abstract

We investigated the change of body composition in ultra-endurance runners during a multi-stage ultra-endurance run, the Isarrun 2006 in Bavaria, Germany, where athletes had to run 338 km within 5 days. Body mass, skin fold thicknesses and circumferences of extremities were measured in 21 well-experienced extreme endurance male runners (mean \pm SD, 41.5 \pm 6.9 years, 72.6 \pm 6.4 kg, 178 \pm 5 cm, BMI 23.0 \pm 2.0 kg·m⁻²), who finished mainly within the first half of the ranking, in order to calculate skeletal muscle mass and body fat mass to prove changes after the race. Body mass and calculated fat mass did not change significantly ($p > 0.05$), but, calculated skeletal muscle mass decreased significantly ($p < 0.05$) by 0.63 \pm 0.79 kg by the end of the race. The most apparent decline ($p < 0.01$) of the calculated skeletal muscle mass was during the first stage, and no changes were observed during the last 4 stages. We conclude, that a multi-stage ultra-endurance run over 338 km within 5 days leads to no changes of body mass or body fat mass, but a statistically significant decrease of skeletal muscle mass of 0.63 \pm 0.79 kg by the end of the race in well-trained and well-experienced ultra-endurance runners. The change of skeletal muscle mass has to be evaluated in further studies at ultra-endurance races with suitable methods to detect changes in hydration status and water metabolism.

Key words: Body composition, anthropometry, ultra-running, stage race, fat mass, ultra-endurance.

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) and endurance exercise leads to a reduction of adipose subcutaneous tissue as shown in laboratory (Boschmann et al., 2002) and field studies (Helge et al., 2003; Höchli et al., 1995; Raschka et al., 1991; Raschka and Plath, 1992).

Ultra-endurance races are a good opportunity to study the decrease of adipose subcutaneous tissue in long lasting endurance performances. But there seems to be a difference between performances with defined breaks - for example during the night - and non-stop performances without defined breaks. In long lasting endurance performances with breaks such as multi-stage events, body mass may be stable (Cox et al., 2003; Dressendorfer and Wade, 1991; Nagel et al., 1989; Väänänen and Vihko, 2005) or even increase (Raschka and Plath, 1992) and body fat will be reduced (Cox et al., 2003; Raschka et al., 1991; Raschka and Plath, 1992) whereas skeletal muscle

mass seems to be spared (Cox et al., 2003; Dressendorfer and Wade, 1991; Reynolds et al., 1999). In contrast, in ultra-endurance performances for hours or even days or weeks without a break, a decrease of body mass (Bircher et al., 2006; Helge et al., 2003; Knechtle et al., 2005; Lehmann et al., 1995) has been demonstrated, where body fat as well as skeletal muscle mass seems to decrease (Bircher et al., 2006; Knechtle et al., 2005; Knechtle and Bircher, 2005).

Due to the fact, that up to now, the decrease of skeletal muscle mass in ultra-endurance performances has been demonstrated only in case reports (Bircher et al., 2006; Knechtle et al., 2005; Knechtle and Bircher, 2005) or small series (Helge et al., 2003), we wanted to investigate in this present study in a greater sample of ultra-endurance athletes, whether ultra-endurance runners would suffer only a degradation of adipose subcutaneous tissue or whether they would experience an additional loss of skeletal muscle mass. In addition, we intended to quantify the loss of body fat mass and the loss of skeletal muscle mass.

Method

Subjects

All participants of the Isarrun 2006 were contacted through a separate newsletter by the organiser 3 months before the race and asked to participate in the study. Sixty athletes (8 women, 52 men) intended to start. Fifty male and 7 female runners entered the race, 49 runners (6 women, 43 men) finished. Twenty-two white male Caucasian runners entered the study. They all gave their informed written consent. From our subjects, 21 runners (values are given in mean \pm SD; age 41.5 \pm 6.9 years, weight 72.6 \pm 6.4 kg, height 178 \pm 5 cm, BMI 23.0 \pm 2.0 kg·m⁻²) finished, mainly within the first half of the final ranking. One runner dropped out of the study group due to orthopaedic problems. The successful finishers trained for 11.6 \pm 6.0 hours per week and had an average experience of 7 \pm 11 (2 to 50) finished races of 24 hours and longer prior the start of the actual race.

The race

The 3rd Isarrun in Bavaria (Germany) took place from 15th May to 19th May 2006 over a distance of 338 km. Five stages (Table 1) had to be performed within 5 consecutive days. The limited field of 60 runners had to run from the delta of the Isar in Bavaria, Germany, as far as the source of the Isar in Austria. Athletes had their accommodation

Table 1. The stages of the Isarrun 2006 with length and weather of each stage.

| Stage | From – To | Distance (km) | Ascent (m) | Descent (m) | General weather conditions |
|-------|---------------------------|---------------|------------|-------------|----------------------------|
| 1 | Plattling – Dingolfing | 62 | 280 | 230 | Sunshine, dry, 22° Celsius |
| 2 | Dingolfing – Freising | 75 | 240 | 145 | Clouds, rain, 21° Celsius |
| 3 | Freising – Wolfratshausen | 73 | 220 | 90 | Sunshine, dry, 22° Celsius |
| 4 | Wolfratshausen – Fall | 61 | 785 | 570 | Moderate, 22° Celsius |
| 5 | Fall – Scharnitz | 67 | 740 | 580 | Moderate, 19° Celsius |
| Total | | 338 | 2 265 | 1 615 | |

in little hotel-restaurants in the towns for each stage of the run. Every morning at 07:00 a.m., the runners started the next stage together. No runner was allowed help from their personal support crew for the duration of each stage, and they had to run at least at a speed of 9 min·km⁻¹, otherwise they would be taken out of the race.

Measurements and calculations

The evening before the start and after arriving at the finish line every evening, body mass, circumferences of upper arm, thigh and calf were measured. Body mass was measured with a commercial scale (Beurer BF 15, Beurer GmbH, Ulm, Germany) to the nearest 0.1 kg pre and post race while athletes were wearing the same clothes. Skin fold thicknesses and circumferences of the extremities were measured on the right side of the body, according to Lee et al. (2000). Circumference of the upper arm and calf were measured at the largest circumference of the limb; at the thigh 15 cm above the upper pole of the patella. All circumference measurements were recorded to the nearest 1 mm.

Skin fold thicknesses of chest, midaxillary (vertical), triceps, subscapular, abdominal (vertical), suprailiac (at anterior axillary), thigh and calf were measured with a skin fold calliper (GPM-Hautfaltenmessgerät, Siber & Hegner, Zurich, Switzerland) to the nearest 0.2 mm. Every measurement was taken 3 times by the same person and then the mean value was used for calculation. Skeletal muscle mass (SM) was calculated using the following formula: $SM = Ht \times (0.00744 \times CAG^2 + 0.00088 \times CTG^2) + 0.00441 \times CCG^2 + 2.4 \times sex - 0.048 \times age + race + 7.8$, where Ht = height, CAG = skin fold-corrected upper arm girth, CTG = skin fold-corrected thigh girth, CCG = skin fold 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 skin fold thickness of chest, midaxillary, triceps, subscapular, abdomen, suprailiac and thigh mean (Ball et al., 2004). Fat mass was calculated with %BF from body mass.

Statistical analysis

Statistical analysis was performed with the R software package (R Development Core Team 2005). One sample Wilcoxon signed rank test were used to test for significant changes of body mass, skeletal muscle mass and fat mass during the complete Isarrun, during the first stage and during the last 4 stages. Bonferroni correction was used to

compensate for multiple testing effects (3 pairwise tests of 3 parameters). For all statistical tests significance was set at the 0.05 level.

Results

Figure 1 shows the mean body mass, calculated body fat mass and calculated skeletal muscle mass before the Isarrun and after each of the 5 stages. Skin fold thicknesses and limb circumferences are shown in Figure 2 and Figure 3. The day before the race started, body mass of the competitors ranged between 59.6 kg and 85.5 kg and did not change significantly ($p > 0.05$) during the Isarrun. Calculated fat mass ranged between 6.6 kg and 21.2 kg before the start. Even if there was a slight decrease of fat mass ($p > 0.05$) during the first stage, no significant decrease is indicated during the complete Isarrun ($p > 0.05$). Skeletal muscle mass before the Isarrun started ranged from 34.3 kg to 46.1 kg and decreased significantly by the end of the Isarrun ($p < 0.05$) by 0.62 ± 0.79 kg (Figure 1). Decline of skeletal muscle mass was most apparent during the first stage of the Isarrun ($p < 0.001$) but did not change significantly ($p > 0.05$) during the following 4 stages.

Discussion

The main finding of our investigation is that a multi-day ultra-endurance run leads to a statistically significant decrease of skeletal muscle mass, whereas body mass and body fat mass remain stable. This is in contrast to the results of former ultra-endurance races and ultra-endurance performances with breaks where body mass remained stable (Dressendorfer and Wade, 1991; Nagel et al., 1989; Väänänen and Vihko, 2005), body fat was reduced (Cox et al., 2003; Raschka et al., 1991; Raschka and Plath, 1992) and skeletal muscle was spared (Cox et al., 2003; Dressendorfer and Wade, 1991; Reynolds et al., 1999).

Decrease of body mass during endurance performance

Non-stop ultra-endurance races over hours and days, or even weeks, lead generally to a decrease of body mass (Bircher et al., 2006; Helge et al., 2003; Knechtle et al., 2005; Lehmann et al., 1995; Raschka, 1995; Volk et al., 2001). The decrease of body mass in these ultra-endurance athletes lies between 1.75 kg in a multi-day run over 1,000 km, 2 kg in an ultra-cycling 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 (Gastmann et al., 1998; Lehmann et al., 1995) to 5 kg in the Race across America (Knechtle et al., 2005).

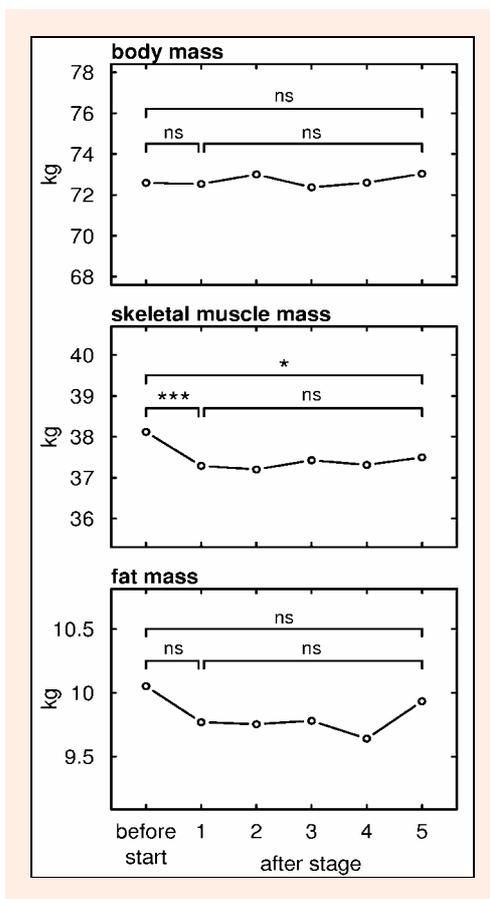


Figure 1. Body mass, calculated skeletal muscle mass and calculated fat mass during the Isarrun 2006.

No standard deviations are included because they would exceed the displayed range. In order to keep multiple testing effects small only the most important time points were used for statistical analysis. The pairwise comparisons are indicated in the figures by bars. * and *** indicate $p < 0.05$ and < 0.001 . “ns” indicates no statistically significant difference.

In contrast to these results, our athletes in this actual multi-stage ultra-endurance run showed no decrease of body mass, but interestingly, a significant decrease of skeletal muscle mass (Figure 1). In general, adipose subcutaneous tissue is the main energy source for long lasting endurance performances (Frykman et al., 2003; Raschka and Plath, 1992) and skeletal muscle mass seems to be spared (Reynolds et al., 1999). In very long lasting performances, body fat mass (Helge et al., 2003; Höchli et al., 1995; Knechtle and Bircher, 2005) as well as lean body mass (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 or studies with only a few subjects – skeletal muscle mass decreases in ultra-endurance performances (Bircher et al., 2006; Frykman et al., 2003; Helge et al., 2003).

Decrease of fat mass in ultra-endurance performance

In several studies, body fat decreases during ultra-endurance performance. In the study of Helge et al.

(2003), where 4 male subjects crossed the Greenland icecap on cross-country skis, body mass decreased from 79.2 ± 3.9 kg to 73.6 ± 3.4 kg, the percentage of body fat decreased from $22.4 \pm 1.4\%$ to $18.2 \pm 1.1\%$ and the lean body mass decreased 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 $78 \pm 7\%$ was fat and the remainder lean body mass. In a run over 1,000 km within 20 days, all skin fold thicknesses and the fat mass showed a falling tendency; only the thigh skin fold initially grew, and then came down from the 4th day onwards (Raschka and Plath, 1992), and Höchli et al. (1995) could show at the Paris-Dakar Foot-Race over 8,000 km (600 km per runner within 30 days) a decrease of 10% body fat in their runners. Cox et al. (2003) demonstrated in a 1,049-mile sled dog race, that fat-free mass was maintained with a concomitant decrease of body fat. In our subjects, body fat mass showed no decrease, but skeletal muscle mass decreased statistically significantly by 0.62 ± 0.79 kg (Figure 1).

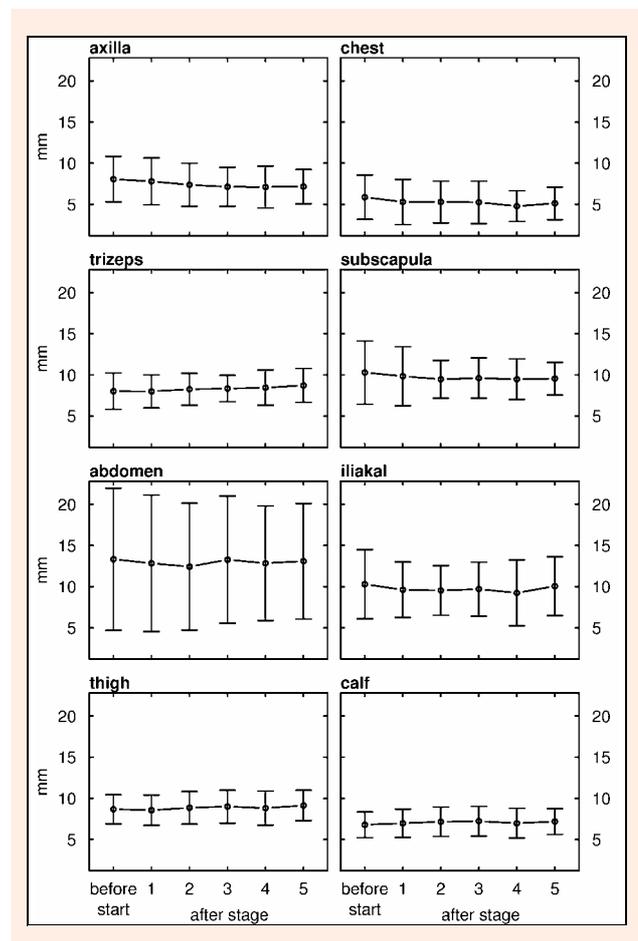


Figure 2. Skinfold thicknesses during the Isarrun 2006.

Decrease of skeletal muscle mass in ultra-endurance performance

Skeletal muscle mass seems to decrease in ultra-endurance races without breaks, as it has been shown in a few case reports (Bircher et al., 2006; Knechtle et al., 2005; Knechtle and Bircher, 2005) or a small series (Helge et al., 2003) of ultra-endurance athletes. In contrast, in other ultra-endurance performances, skeletal

muscle mass remained stable (Cox et al., 2003; Frykman et al., 2003; Reynolds et al., 1999). In a run 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. As a result of the decreased muscle mass, all muscle circumferences were reduced with the exception of the thigh (Raschka et al., 1991).

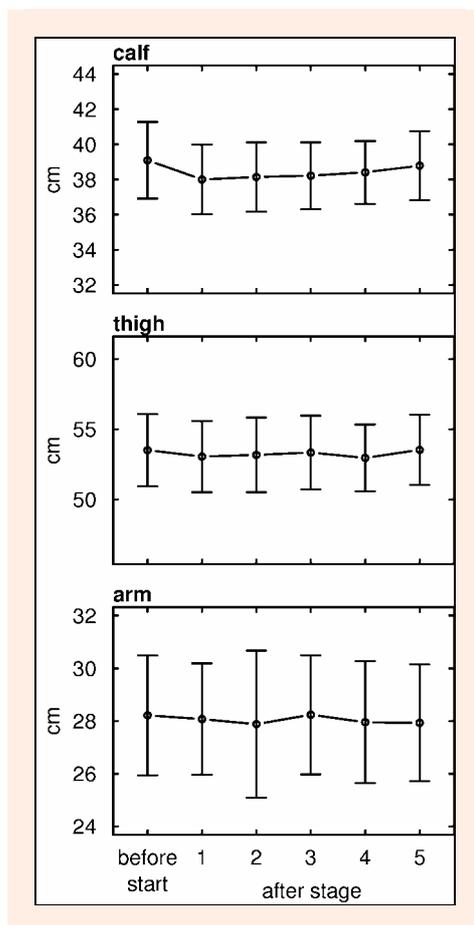


Figure 3. Means and standard deviations of the limb circumferences during the Isarrun 2006.

Does dehydration lead to a loss of skeletal muscle mass in ultra-endurance performance?

One problem in our study is the fact that we measured the athletes every day 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 body mass after the race might also be of importance.

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 is mainly due to dehydration. Endurance performance leads to dehydration, which results in a weight loss (Walsh et al., 1994). It is stated, though, that the weight loss in an Ironman triathlon derives most likely from sources other than fluid losses (Speedy et al., 2001).

Many indices of hydration levels are known, such as body weight, plasma osmolality, urine osmolality and urine specific gravity (Kavouras, 2002). During dehydration, we would generally expect an increase of haematocrit (Whiting et al., 1984). In contrast, ultra-endurance performance leads to a hypervolemia with haemodilution and a decrease of haematocrit (Astrand and Saltin, 1964; Davidson et al., 1987; Lindemann et al., 1978; Refsum et al., 1973; Wu et al., 2004). In a Triple Iron triathlon over 11.6 km swimming, 540 km cycling and 126.6 km running, especially, haematocrit decreased from $48 \pm 4\%$ to $45 \pm 3\%$ (Volk and Neumann, 2001), $47.6 \pm 3.0\%$ to $43.1 \pm 3.4\%$ (Volk et al., 2001) and 48% to 45% (Volk et al., 1998) from pre race to post race. 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., 1987).

But the question still remains, whether dehydration really occurs during an ultra-endurance performance. There are studies at Ironman triathlons and Triple Iron triathlons showing that athletes suffer a loss of body mass without dehydration. Laursen et al. (2006) could demonstrate in their field-study with 10 Ironman triathletes, that the statistically significant decrease of 2.3 ± 1.2 kg ($-3.0 \pm 1.5\%$) body mass during the race was not related to urine specific gravity. Volk et al. (2001) examined, in the Triple Iron Germany 1999 in Lensahn, with bioimpedance analysis the hydration status in ultra-endurance triathletes. They compared their results of bioimpedance analysis with standard laboratory testing (haematocrit, serum osmolality and serum concentration of sodium). During the cycling part over 540 km, haematocrit increased from $45.6 \pm 3.6\%$ to $47.6 \pm 3.0\%$, 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 the cycling under hot conditions caused a steepening and lengthening of the vectors in the bioimpedance analysis. In contrast, after the following running part of 126 km in the heat, haematocrit decreased from $47.6 \pm 3.0\%$ to $46.4 \pm 2.7\%$ (-2.5%), plasma volume increased by 18.5% and in the bioimpedance analysis, the vectors showed a shortening and downwards slope to the baseline.

After the race, only body mass showed a statistically significant decrease of 2 kg. Haematocrit, sodium and osmolality showed no statistically significant changes. They suggest an involuntary dehydration during the cycling because the athlete is lonely during the night; but during the run, the support crew has more possibilities of feeding the athletes, therefore, they could not prove dehydration during a Triple Iron triathlon.

Change of anabolic hormones during ultra-endurance performance and effect on skeletal muscle mass?

The decrease of skeletal muscle might also be related to a change of the anabolic hormones testosterone and growth hormone during ultra-endurance performance. Interestingly, the effect on these 2 anabolic hormones seems to be different during ultra-endurance. An ultra-endurance performance reduces the concentration of testosterone (Bircher et al., 2006; Dressendorfer and Wade, 1991; Fournier et al., 1997; Gastmann et al., 1998) but increases

the concentration of growth hormone (Gastmann et al., 1998; Scavo et al., 1991). Probably the duration of an ultra-endurance performance is of importance for an effect on these anabolic hormones. After a run over 1,000 km, growth hormone showed no changes (Pestell et al., 1989). But during an ultra-endurance run over 1,000 km within 20 days, testosterone increased after the first day from 0.33 µg/dl from pre race to 0.36 µg/dl, but started to decrease after day 3 (Raschka et al., 1991). From this data, we might presume that the decrease of testosterone might have an effect on the skeletal muscle mass. But with the results of Raschka et al. (1991) - where their athletes had to run 50 km per day for 20 consecutive days - the decrease of skeletal muscle mass after the first stage of 62 km (Table 1) in our study seems not to be related to a change of testosterone.

Determination of body fat and skeletal muscle mass by anthropometric measurements

It has to be pointed out that skeletal muscle mass and body fat mass in this current investigation are not determined directly in living humans as it can be done for body mass, skin fold thicknesses and limb perimeters. Various formulas exist in order to calculate skeletal muscle mass and body fat mass by anthropometric measurements. Determination of limb circumferences and skin fold thicknesses is a very common method of estimating skeletal muscle mass (Housh et al., 1995; Kuriyan et al., 2004; Lee et al., 2000) and body fat mass (Eisenmann and Malina 2002; Hildreth et al., 1997; Housh et al., 1996).

Even if simple anthropometric measurements may determine body composition much more easily than other methods, the precision of this method seems to be sufficient in order to determine body fat mass correctly. However, calculation of body composition from anthropometric measurements is an estimation rather than a direct measurement and the question remains under which conditions this method is valid and useful. Simple anthropometric measurements appear to be sufficient in order to determine body fat mass, while skin fold thickness measurements give a good prediction of body fat (Chang et al., 1998; Housh et al., 1996; Lean et al., 1996) and subcutaneous adipose tissue can be estimated from simple anthropometric measurements (Bonora et al., 1995). These simple anthropometric measurements seem to be sufficient in order to determine, correctly, fat free mass.

Under field conditions like this race, complex investigations by means of large laboratory equipment are rather impossible. Body density estimation from skin fold measurements has the advantage of simplicity, low cost and reasonable validity, with predictions to within 3% to 4% for 70% of the population (Brodie, 1988). For all methods to determine body composition it has to be considered that physical exercise and its effects on the body might influence the values of the measuring resulting in systematic errors of measurement. If only pre-post measurements are performed, a possible systematic error cannot be detected. In contrast, a multi-day competition including several similar stages seems to be optimal to validate the methods of body composition determination and to estimate the effect of physical exercise on the method used.

In the current study, calculated skeletal muscle mass decreased highly significantly ($p < 0.001$) during the first stage but no significant ($p > 0.05$) changes of skeletal muscle mass were observed during the following 4 stages. For %BF there seemed to be a similar effect as there was a trend of reduction during the first stage but no changes during the following 4 stages were observed. We assume that the apparent loss of muscle mass during the first stage is caused by an effect of physical exercise on the used method of body composition determination rather than “real” muscle mass degradation. Like dehydration, it takes some time for the athletes to compensate for the physical race effects. According to the latter, body composition determination immediately after the finish seems not to be advantageous because the race effects are most expressed.

However, regeneration of the athletes also starts immediately after the finish and it is hard to distinguish between apparent and “real” muscle mass loss. In our current investigation, body composition was determined at the end of each stage every day in the same manner and it seems to be plausible that the “race effect” on the used method is almost similar during the last 4 days of the Isarrun. No more muscle mass degradation was observed during the 4 following stages. This observation indicates clearly that under the given conditions the resting period between the stages is sufficient to prevent muscle mass degradation.

Conclusion

A multi-stage extreme endurance run over 338 km within 5 days leads to no changes of body mass and body fat mass, but a statistically significant decrease of skeletal muscle mass. To prove that dehydration does not lead to a loss of skeletal muscle mass in ultra-endurance performance, further studies with anthropometric measurements and markers of hydration status (haematological indices like haemoglobin and haematocrit, urinary indices like urine osmolality and urine specific gravity or bioelectrical impedance analysis) should be performed.

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Key points

- Ultra-runners at the Isarrun 2006 suffered no loss of body mass.
- Skeletal muscle mass decreased highly significantly during the first stage but no significant changes of skeletal muscle mass were observed during the following 4 stages of the Isarrun 2006.
- Body fat mass remained stable during the Isarrun 2006.

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