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Pacing Strategy and Change in Body Composition during a Deca Iron Triathlon

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Abstract

We investigated the timeline of performances in the three races of the 'World Challenge Deca Iron Triathlon', held in 2006, 2007 and 2009, where the athletes completed one Ironman triathlon daily on 10 consecutive days. The association of anthropometric characteristics such as body fat estimated using bioelectrical impedance analysis and previous experience in ultra-triathlon with race time was investigated using multiple linear regression analysis. Forty-nine athletes participated in these three races; 23 (47%) participants completed the race within 8,817 (1,322) min. Day 1 was the fastest with 762 (86) min; the slowest was Day 10 with 943 (167) min (P < 0.05). The time per Ironman increased during the race (P < 0.05). Body mass and fat mass decreased whereas lean body mass increased (P < 0.05). Race time was related to both the number of finished Triple Iron triathlons (P = 0.028) and the personal best time in a Triple Iron triathlon (P < 0.0001). We concluded that performance in a Deca Iron triathlon decreased throughout the competition, with the fastest race on Day 1 and the slowest on Day 10. The number of finished Triple Iron triathlons and the personal best time in a Triple Iron triathlon, but not anthropometry, were related to race time. To conclude, athletes need to have a high number of previously completed Triple Iron triathlons, as well as a fast personal best time in a Triple Iron triathlon, in order to finish a Deca Iron triathlon successfully.

Key Words: ultra-endurance, body fat, lean body mass, Ironman

Introduction

Ultra-endurance competitions are defined as events exceeding 6 h in duration (54) and they are of increasing popularity (11-14, 26, 37, 43, 53). To sustain an endurance performance for days or even weeks, extraordinary characteristics in physiology, anthropometry and pre race preparation are required. When the association of these characteristics with race performance was analysed in details, physiologic characteristics such as maximal oxygen uptake (42), anthropometric characteristics such as body mass (17), body mass index (12, 14), percent body fat (11, 20, 22, 28-30), the sum of skin-folds (20, 21), the circumferences of limbs (17, 25), and training variables such as volume (32), intensity (14, 22, 35) and previous experience (22-24, 28, 32-35) were related to race performance. In addition, a decline in endurance performance was related to increasing age in ultra-endurance athletes (22, 38, 39).

Multistage cycling races such as the 'Tour de France' or the 'Vuelta a España', have a long tradition (6, 40, 41, 47, 48). Besides these multistage cycling races, there are multistage ultra-runs (16, 17) and multistage mountain bike races (49, 53). Apart of these multistage races consisting in single-disciplines,

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a new kind of multistage ultra-race was launched in 2006, the 'World Challenge Deca Iron Triathlon' (18, 26, 27) in which athletes have to perform the daily distance of one Ironman triathlon, consisting of 3.8 km of swimming, 180 km cycling and 42.2 km running for 10 consecutive days. Up to now, this kind of event has only taken place in 2006, 2007 and 2009 in Monterrey, Mexico. In the first event, no association between anthropometry and race time was found (18). In that study, variables of previous experience such as personal best time were not considered whereas meanwhile, the personal best time for Triple Iron triathletes was found to be a predictor variable in a Triple Iron triathlon, but not anthropometry or training (23). After three years of race experience, we intended i) to analyse the pacing strategy during a multistage ultra-triathlon event, ii) to determine predictor variables for a successful finish in such a multistage ultra-endurance race and iii) to estimate the changes in body composition throughout such an ultra-endurance race.

Materials and Methods

The Race

The 'World Challenge Deca Iron Triathlon' is a multistage race, where triathletes have to complete the distance of one Ironman triathlon in the compulsory order of a 3.8 km swim, a 180 km cycle ride and lastly a 42.2 km run, on each of 10 consecutive days within a time limit of 24 h per day. Until today the competition took place in the years 2006, 2007 and 2009 in the City of Monterrey in the Province of Nuevo León in northern Mexico, about 230 km south of the United States border. The only difference in those three races was the swimming. In the years 2006 and 2007 the swimming took place in the Park of 'Sociedad Cuauhtemoc & Famosa' in Monterrey, 3 km away from the cycle/run track, in a 50 m outdoor pool with the water temperature of between 17°C and 21°C. In the 2009 event the swimming was in a 25 m indoor pool, with a water temperature of 28°C, at the 'Centro Acuatico Olimpico Universitario' of 'Universidad Autonoma de Nuevo León' in Monterrey, 2 km away from the cycle/run track for all three races, which was located in 'Parque Niños Héroes'. The swimming started every morning at 09:00 A.M. and the laps were counted by personal lap counters for each athlete. After the swimming, the athletes changed in the transition area and then cycled to the park, which was closed to traffic, completely illuminated and had a cycle/run track that was 95% flat, but with one ascent of about 5% per lap. The cycling consisted of 94 laps of 1.915 km each, which were counted electronically using a chip system. Drafting was strictly prohibited and controlled by the race director. After changing for the running course, the athletes had to run a single short lap of 703 m first and then 22 laps of 1.886 km each, these were also counted using the chip system. The athletes had to cover a total ascent of 1,650 m in each Ironman triathlon. The athletes were supported, for nutrition and change of equipment and clothes, by their own crews. There was also a variety of food offered in a 24-h restaurant, and accommodation for the athletes and teams was provided in the 'Sports Village' inside the Park, close to the race site.

Subjects

Forty-nine athletes (45 males and 4 females) took part in those three races. In 2006, 19 athletes started, eight males and one female finished. In 2007, three males finished among a total of 10 starters and in 2009, 11 males finished from 18 starters. All starters gave their informed written consent to the study which was approved by the Ethical Committee of Canton St. Gallen, Switzerland. Table 1 shows the anthropometric characteristics, training and previous experience of all the athletes.

Measurements

Before the start of the race, anthropometric parameters such as body mass and body height were measured by the medical team. During the stages of the race, body mass, fat mass, percent body fat, lean body mass, protein mass, total body water, extra-cellular water and intra-cellular water were determined before the start, as well as at the finish, of each of the ten Ironman triathlons, using direct segmental multi-frequency bioelectrical impedance method (InBody 3.0, Biospace, Seoul, Korea) following Bedogni *et al.* (4). The measurements before a stage were performed after emptying of the urinary bladder, post-race measurements immediately upon arrival at the finish line. The split times and the total race time per Ironman distance were provided by the person in charge of lap counting. In addition, we consulted all the rankings for Triple Iron triathlons, which were collected by an ultra-triathlete, for the last 25 years (19). Triple Iron triathlons, in which nowadays most of the ultra-triathletes compete in order to prepare for a Deca Iron triathlon, take place twice a year with one race in USA (Virginia) and one race in Europe (Germany). We recorded the number of completed Triple Iron triathlons, the personal best time in a Triple Iron triathlon and the race time of the last Triple Iron triathlon before a Deca Iron triathlon, for each participant in the 'World Challenge Deca Iron Triathlon'. The personal best time in a Triple Iron triathlon was defined as the fastest time in a Triple Iron triathlon performed in their career as an ultra-triathlete, independent of general conditions such as race course and weather.

Statistical Analysis

Results are presented as means and standard deviations (SD). Friedman's two-way analysis of variance by ranks was used to determine whether the changes for body mass, fat mass, lean body mass, protein mass, total body water, extra-cellular water, intra-cellular water, split times in swimming, cycling and running and total race time were significant. In case of a significant change during the race, a paired *t*-test was applied to detect the change. The athletes were categorized into two groups (finishers and non-finishers). Body mass, body height, body mass index, fat mass, and the personal best time in a Triple Iron triathlon were compared between these two groups using the Kruskal-Wallis equality-of-populations rank test. The split times of the first and the last completed Ironman triathlon of the non-finishers were compared using paired *t*-test. A multiple linear regression analysis with total race time as the dependent variable was performed to assess predictor variables for total race time. A power calculation was performed. To achieve a power of 80% (two-sided Type I error of 5%) to detect a minimal association between race time and anthropometric variables of 20% (*i.e.* coefficient of determination $R^2 = 0.2$) a sample of 40 participants was required. Associations between significant variables were investigated using correlation analysis. Statistical significance was set at $P < 0.05$ for all tests.

Results

Finishers and Non-Finishers

A total of 49 athletes (44 male and 5 female) entered the three races, 23 (47%) athletes completed the race, 26 (53%) were not able to finish. In 2006, eight male and one female triathletes finished, ten males and two females dropped out. In 2007, three males finished, six males and one female did not finish. In the 2009 event, eleven males finished, six males and one female dropped out. Regarding gender, one female finished the race. No finisher competed in more than one year. The finishers completed the total distance of 38 km swimming, 1,800 km cycling and 422 km running within 8,817 (1,322) min, on average within 881 (132) min per single Ironman distance. The fastest day was Day 1 with 762 (86) min, the slowest day was Day 10 with 943 (192) min. Fig. 1 shows the breakdown of the total time per Ironman including split times for swimming, cycling and running during the ten days. The time per total

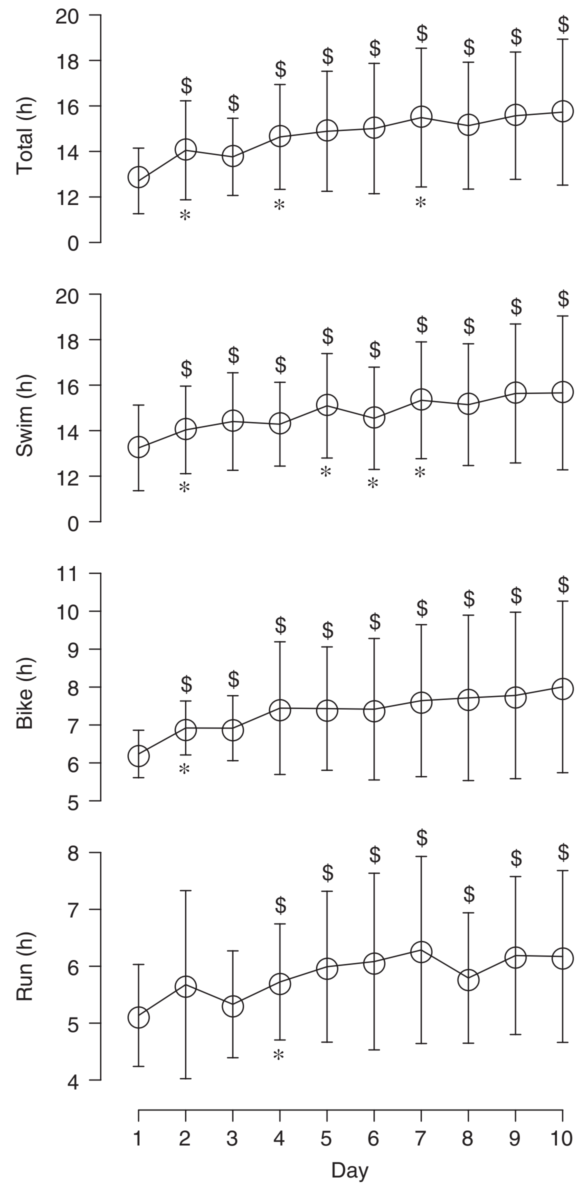

Fig. 1. A breakdown of the total time per Ironman including split times for swimming, cycling and running during the ten days (n = 23). $: $P < 0.05$ versus baseline value. *: $P < 0.05$ versus previous value.

Ironman distance, and all the split times, increased during the race ($P < 0.05$). The time for the total distance per Ironman increased from Day 1 to Day 10 by 24 (21) % ($P < 0.05$). In swimming, the split time increased by 18.5 (19.5) %, from Day 1 with 79 (45) min to 93 (20) min on Day 10 ($P < 0.05$). The split time for cycling increased by 27 (29) % from Day 1 with 374 (37) min to Day 10 with 480 (135) min ($P < 0.05$). For running, the fastest day was Day 1 with 308 (53) min, the slowest was Day 7 with 377 (98) min. The running performance decreased from Day 1 until Day 7 by 23.3 (29.5) % ($P < 0.05$). From Day 7 until Day 10, running performance decreased by 22.5

Table 1. Comparison of age, anthropometry and pre race experience of finishers and non-finishers. Results are presented as mean (SD). *: $P < 0.05$, **: $P < 0.01$

	Finisher (n = 23)	Non-Finisher (n = 26)
Age (years)	42.2 (9.9)	45.3 (11.1)
Body mass (kg)	74.2 (8.6)	74.9 (9.5)
Body height (m)	1.73 (0.06)	1.73 (0.08)
Body mass index (kg/m^2)	24.7 (2.4)	25.0 (3.7)
Percent body fat (%)	16.4 (3.0)	21.6 (10.5)
Number of finished Triple Iron triathlons	5.9 (5.9) (n = 16)	6.1 (5.8) (n = 16)
Personal best time in a Triple Iron triathlon (min)	2,577 (291)* (n = 16)	2,891 (494) (n = 16)
Years between best time in a Triple Iron triathlon and the 'World Challenge Deca Iron Triathlon'	2.3 (3.8)**	6.7 (5.2)
Finish time in the last Triple Iron triathlon before the 'World Challenge Deca Iron Triathlon' (min)	2,731 (299)** (n = 15)	3,173 (413) (n = 15)
Years between the last Triple Iron triathlon and the 'World Challenge Deca Iron Triathlon'	0.4 (1.5)**	2.9 (4.5)

Table 2. Multiple linear regression analysis with race time as the dependent variable (n = 23). β = regression coefficient; SE = standard error of the regression coefficient; Coefficient of determination (R^2) of the model was 81%

	β	SE	*P* value
Body mass	17.7	26.2	0.51
Fat mass	-43.9	101.4	0.67
Number of finished Triple Iron triathlons	87.3	34.6	0.028
Personal best time in a Triple Iron triathlon	4.5	0.7	< 0.0001

(32) % until Day 10 where the split time for running was 370 (90) min ($P < 0.05$). The non-finishers dropped out after 2.1 (1.4) days. They completed their first Ironman within 940 (187) min and their last completed Ironman was 1,005 (103) min. The finishers completed their first Ironman within 762 (84) min, significantly faster than the non-finishers ($P < 0.05$). They finished Day 10 with 943 (192) min which was no faster compared to the last day of the non-finishers ($P > 0.05$).

Predictor Variables for Race Time

There were no statistically significant differences in anthropometry between finishers and non-finishers (see Table 1). The finishers had both a faster personal best time in a Triple Iron triathlon ($P < 0.05$) and also a faster time in the last performed Triple Iron triathlon before the 'World Challenge Deca Iron Triathlon' ($P < 0.05$). Comparing the time between the personal best time in a Triple Iron triathlon and the 'World Challenge Deca Iron Triathlon' we see a larger gap in the group of non-finishers, with 6.7 years, than in the finishers, with 2.3 years ($P < 0.05$). In addition, the last performed Triple Iron triathlon was longer ago in the group of non-finishers, with 2.9 years, than in the finishers, with 0.4 years ($P < 0.05$). In a multiple linear regression analysis the association of body mass, percent body fat, the number of finished Triple Iron triathlons and the personal best time in a Triple Iron triathlon with total race time in the 'World Challenge Deca Iron Triathlon' was investigated for the finishers. The number of finished Triple Iron triathlons and the personal best time in a Triple Iron triathlon were related to race time, but not the variables of anthropometry (see Table 2).

Changes in Body Composition during the Race

Fig. 2 shows the timeline of body mass, fat mass, lean body mass and protein mass throughout the race. Body mass and fat mass decreased during the race ($P < 0.05$). Body mass decreased from 75.8 (8.0) kg to 74.0 (7.6) kg by 1.8 (2.1) kg, equal to a

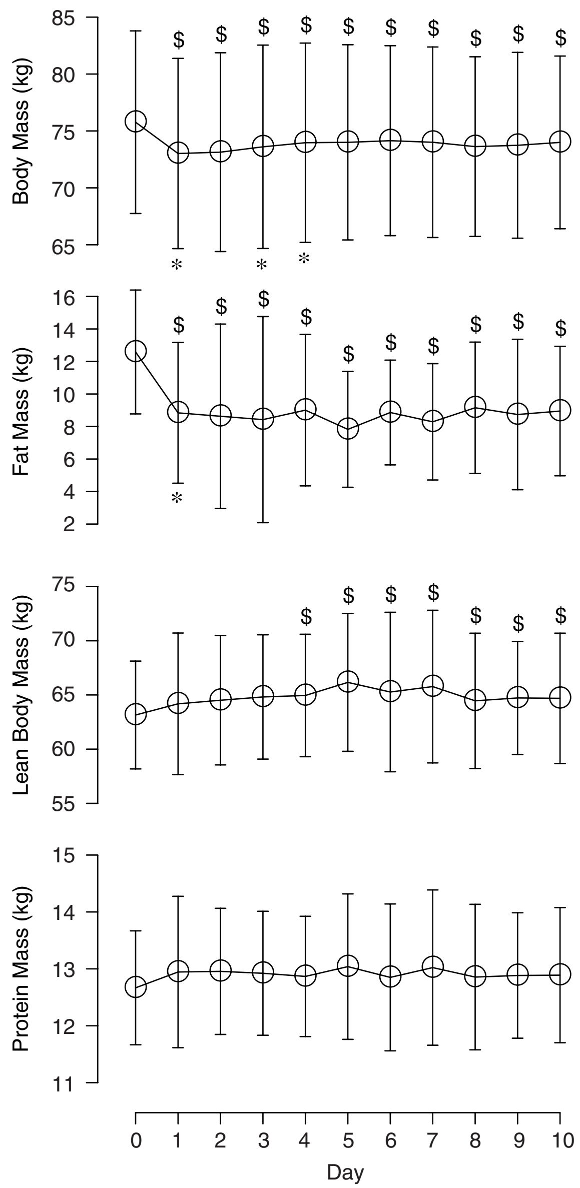

Fig. 2. Timeline of body mass, fat mass, lean body mass and protein mass during the ten days for the 23 athletes. $: $P < 0.05$ versus baseline value. *: $P < 0.05$ versus previous value.

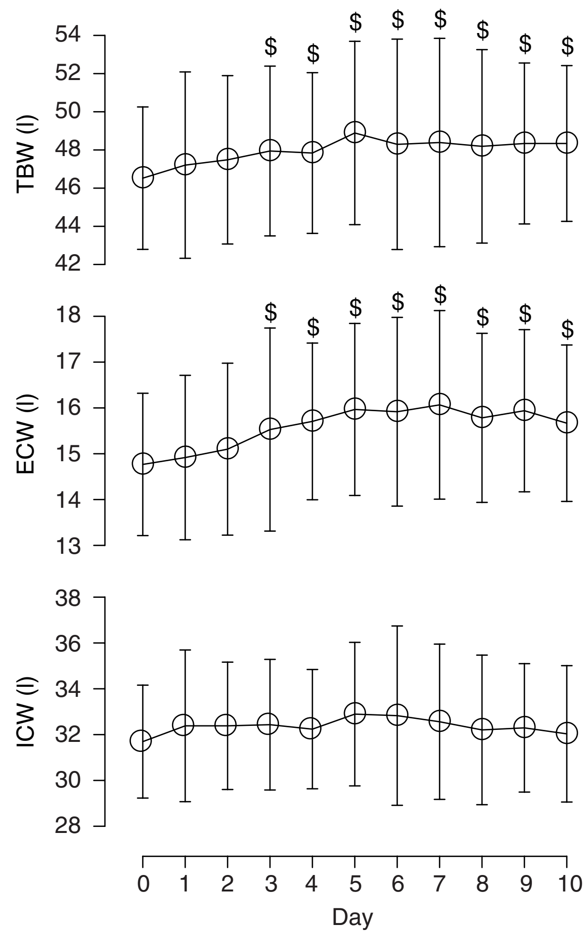

Fig. 3. Time course of total body water (TBW), extracellular water (ECW) and intracellular water (ICW) (n = 23). $: $P < 0.05$ versus baseline value.

decrease of 2.3 (2.9) % ($P < 0.05$). Fat mass decreased by 3.6 (1.6) kg from 12.6 (3.8) kg pre race to 9.0 (4.0) kg after Day 10, a loss of 30.7 (17.3) % ($P < 0.05$). The decrease in body mass was not related to the decrease in fat mass ($r = 0.39$, $P > 0.05$) and the decrease in fat mass was not related to total race time ($r = -0.08$, $P > 0.05$). Lean body mass increased ($P < 0.05$) and protein mass showed no changes ($P > 0.05$). Lean body mass increased from 63.1 (5.0) kg pre race to 64.7 (6.0) kg post race by 1.6 (2.5) kg, equal to an increase of 2.4 (4.0) % ($P < 0.05$). Protein mass showed a non-significant increase of 0.2 (0.5) kg, from 12.7 (1.0) kg pre race to 12.9 (1.2) kg post race, an increase of 1.7 (4.2) kg ($P > 0.05$). Fig. 3 shows the changes in total body water, extracellular water and intracellular water. Total body water increased by 1.8 (1.8) l, equal to 3.9 (4.0) % ($P < 0.05$). Extracellular water increased by 0.9 (1.0) l, corresponding to 6.3 (7.3) % ($P < 0.05$). Intracellular water remained stable ($P > 0.05$). The increase in lean body mass was related to the increase in both total body water ($r = 0.67$, $P < 0.05$) and extracellular water ($r = 0.52$, $P < 0.05$).

Discussion

The main findings in the study were i) a continuous decline in performance after Day 1 ii) a significant association of the number of completed Triple Iron ultra-triathlons and the personal best time in a Triple Iron triathlon with Deca Iron race time and iii) a decrease in both body mass and fat mass as well as an increase in lean body mass, total body water and extracellular water during the race.

Performance and Pacing Strategy

The fastest Ironman was on Day 1, the slowest on Day 10. Expressed in percent of the World record for the Ironman distance of 7:50:27 h:min:sec of Luc van Lierde (Belgium) in 1997 in Roth (Germany), these athletes finished Day 1 within 162% of the World record and performance decreased to 200% of the World record on Day 10. The decrease in performance per Ironman might be explained by the continuous energy deficit as has been described in case reports on ultra-endurance athletes (15, 26). Although we see a continuous decrease in performance, some athletes could keep up their efforts for longer at the same level than others. This has been described in a study of 100-km ultra-marathoners, showing that faster runners had fewer changes in running speed and could keep up their initial speed for a longer time than slower runners (36). Regarding the split performances for swimming and cycling, the slowest split times were found on Day 10. For running, however, the weakest performance was on Day 7. We see an increasing duration of the bike split which might have been due to the heat during the day. During the day, the temperature can increase to more than 30° Celsius in Monterrey (18, 26, 27). So the athletes might have had only little reserves left for the run. Towards the end of the race, motivation presumably increased to successfully finish the race. However, the lower temperatures during the nights in November in Monterrey (18, 26, 27) could have also enhanced running performance.

We have to assume that the decrease in performance was due to the increasing deficit in energy as has been found in ultra-endurance races (15, 18, 43). The energy deficit might control the brain regarding power output and pacing strategy in order to preserve whole body homeostasis and to prevent catastrophic physiological failure (52). The experienced athletes may anticipate the coming problems and therefore slow down to insure that a catastrophic biological failure does not occur (43). Self-selected exercise intensity is regulated within the brain based on a complex algorithm involving peripheral sensory feedback and the anticipated workload remaining (2). The training and previous experience gave the athletes the empirical knowledge to select the optimal pacing strategy with the ability to maintain that pace (3). In general during multi-stage races such as an 8-day mountain bike marathon (53), the 'Tour de France' and the 'Vuelta a España' (6), race intensity is rather high. However, these experienced ultra-triathletes may have modulated the intensity of each stage due to the total race duration (47). Elite cyclists are able to adopt a pacing strategy designed to optimally distribute energy reserves over the duration of a long race (7) and Ironman triathletes have a special strategy during the cycling phase dependent upon the wind (1).

Predictor Variables for Race Time

In the first 'World Challenge Deca Iron Triathlon' in 2006, anthropometry was not related to race time (18), as has been confirmed in this larger sample. In multistage ultra-endurance runners, however, body mass (17) and circumference of upper arm (20, 25) were related to total race time. Furthermore, in male Ironman triathletes competing in a classic Ironman triathlon, percent body fat was related to race time (20, 29). However, in those studies, the variables of personal best times were not taken into consideration. In the present study, variables of pre race experience were included in the analysis, and pre race experience seems to be of importance, since both the number of finished Triple Iron triathlons and the personal best time in a Triple Iron triathlon were related to race time in the 'World Challenge Deca Iron Triathlon', whereas both body mass and fat mass were not. Therefore, the actual findings confirm the negative findings for anthropometry in the first 'World Challenge Deca Iron Triathlon' (18). A recent study of ultra-runners showed that personal best time in a marathon was the single predictor variable for race performance in a 24-h run (33). In a study of 100-km ultra-runners a correlation between both the personal best time in a marathon and training volume with the 100 km race time was described (32). In a study of ultra-triathletes, the personal best time in a Triple Iron triathlon was associated with the race time in a Triple Iron triathlon, but not anthropometry or training (23). Considering these findings, the number of finished Triple Iron triathlons might reflect pre-race training volume and experience, where athletes with a higher training volume might compete faster in a longer ultra-triathlon than athletes with a lower training volume and less experience. However, this might not be valid for endurance sports in general, since another study found no correlation between increasing participation and performance in 161-km ultra-runners (11). That study was performed retrospectively using the race results of over 30 years. One might assume that athletes competing regularly in a 161-km ultra-marathon might be at the top of their personal physical performance, thus further improvement is hardly possible. In these non-finishers, the time between both the personal best time in a Triple Iron triathlon and the last Triple Iron triathlon was longer compared to the finishers, although the number of completed Triple Iron triathlons was no different. Furthermore, the finishers had a faster time in both personal best times in a Triple Iron triathlon and the last completed Triple Iron triathlon. We assume that successful finishers in the 'World Challenge Deca Iron Triathlon' prepared more accurately than non-finishers.

Change in Body Composition during the Race

Body mass and fat mass decreased significantly. A decrease in body mass (9, 15, 26, 31, 46) and fat mass (9, 10, 15, 26, 31, 44, 46) is a common finding in ultra-endurance performances. Lean body mass, however, increased. An increase in lean body mass was also recently described by Rehrer *et al.* (45) in a multistage cycling race. One might assume that the development of edema might be responsible for the increase in lean body mass since body water can increase in ultra-runners (31). We presume that the increase in total body water was responsible for the increase in lean body mass. The increase in both total body water ($r = 0.67$, $P < 0.05$) and extra cellular water ($r = 0.52$, $P < 0.05$) were related to the increase in lean body mass.

Weaknesses, Limitations and Implications for Future Research

We are aware of limitations in this descriptive study, since this race had been held only three times up to now and the number of successful athletes was limited. We assumed that personal circumstances during the race, such as equipment, nutrition and support by the crew, were optimal for each athlete. Also, since most participants came over from Europe, acclimation time to heat and humidity might have affected performance. Recently, it has been shown that temperature can affect performance in ultra-marathoners (51). Temperature can considerably vary between 16°C and 28°C in Monterrey during November; it can drop from one day to another down to 10°C and increase to 36°C and higher. Usually there is no rain and only a little wind (18, 26, 27). We did not evaluate training volume before the races. A recent study of 100-km ultra-runners showed that the correlation between the personal best time in a marathon and race time was higher ($r^2 = 0.334$) than between pre race training volume and race time ($r^2 = 0.224$) (32). It might be of interest for further studies of future 'World Challenge Deca Iron Triathlons' to evaluate the athletes' training diary. Unfortunately, we did not ask for the reasons of the abandonment of the non-finishers. The non-finishers dropped out very soon in the race and the performance of their last day before dropping out of the race was not slower compared to the performance on Day 10 for the finishers. We assume that orthopedic problems were the reason for the give-up. Overuse injuries of the lower limbs are frequent problem in triathletes (5) and a long experience as endurance athlete with graduated training program seems to prevent overuse injuries (8, 50). Five females started the race where one female athlete finished. Due to this low number, we did not include gender in our considerations. In a recent analysis of participation and performance in ultra-triathlons from 1985-2010, participation of females was low at ~10% and ~50% dropped out on the longer distances (26).

Conclusions

To summarize, this study showed that previous ultra-endurance experience, mainly expressed as the personal best time in a Triple Iron triathlon and the number of completed Triple Iron triathlons, seems to be a valuable predictor variable for the successful outcome of a 'World Challenge Deca Iron Triathlon'. Body mass and fat mass decreased during the race while split time per Ironman increased. We assume that these experienced ultra-triathletes developed a strategy to finish the race independent of the decrease in body mass and fat mass due to their previous ultra-endurance experience.

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