ABSTRACT

Purpose. The aim of this study was to investigate the effects of training and triathlon competition on anthropometry, plasmatic free fatty acids (FFA) and hydration status.

Methods. Twelve male triathletes were submitted to a 12-week training program to compete in the “32° Pirassununga Half Ironman”. Anthropometric measurements such as skinfold thickness and bioelectrical impedance (BIA) as well as urine and blood samples were collected at three intervals: at the beginning of the training program (M-1), before (M-2) and after competition (M-3). FFA were analyzed using a NEFA-C kit. Urine pH and density was determined using reagent tapes and a manual refractometer. Data were analyzed using one-way ANOVA and the Tukey-Kramer post-test (p < 0.05).

Results. No differences were found for body mass (M-1 = 71.83, M-2 = 74.22, M-3 = 72.15 kg), percent body fat using skinfolds (M-1 = 10.98, M-2 = 10.92, M-3 = 10.40%), urine density (M-1 = 1.02, M-2 = 1.01, M-3 = 1.02) and urine pH (M-1 = 6.00, M-2 = 5.92, M-3 = 5.35). For BIA and FFA, differences were found after competition (BIA: M-1 = 13.54, M-2 = 13.91, M-3 = 9.45%; FFA: M-1 = 0.16, M-2 = 0.15, M-3 = 1.69 mEq/L).

Conclusions. These results illustrate the effects of training and competition on body composition and FFA mobilization. Additionally, after five hours of effort, no evidence of dehydration was found after the race.

Key words: body composition, endurance training, hydration and triathlon

Introduction

The triathlon is a sport that consists of swimming, cycling and running performed sequentially one after the other. Since its emergence in the late 70s, the distances of the different parts of triathlon were changed. Currently, the International Triathlon Union (ITU) recognizes official events as those with distances ranging from 0.75, 20 and 5 km for swimming, cycling and running in the short triathlon, to 3.8, 180 and 42 km for the Ironman competition, respectively.

According to Hausswirth et al. [1], triathlon training and competition can result in changes in the hydration status of athletes in the sense that dehydration may be dangerous when the athlete loses more than 7% of body weight during training and competition [1, 2]. Changes in body mass may also be due to liquid release from skeletal muscles and the liver during strenuous effort due to glycogen oxidation [2–5]. Therefore, changes in body mass are a result of modifications in body composition induced by the training program and the hydration status during the training program and competition [2].

In a study done by Sharwood et al. [6], 872 athletes participating in the 2000 and 2001 South Africa Ironman showed significant reductions in body mass after the competition and this effect was attributed to liquid release, as well to the consumption of energetic substrates during the race. Sharwood et al. [7] also found reductions in body mass in seventeen triathletes after an Ironman, however, the objective of the research was to correlate body mass with performance indicators and blood sodium concentration in each segment of the competition. They concluded that weight loss correlates with blood sodium concentration, which apparently is a good indicator of dehydration after long-term efforts.

Knechtle et al. [8], studying athletes participating in the Deca Ironman World Championship (38 km swimming, 1800 km cycling and 420 km running divided across ten consecutive days), found reductions in body mass with maintenance of fat free mass and reduction of fat mass. Similar results were found in the Hew-Butler et al. [9] study with 181 athletes during the 2000 South Africa Ironman. In another study, Knechtle and Kohler [10] studied 17 athletes who were competing in the 2006 Triple Iron ultra-triathlon in Germany (11.6 km swimming, 540 km cycling and 126.6 km running), no differences in body fat were found at the end of the competition. The same author, while studying the same group of athletes, detected...
reductions in body fat by skinfold thickness when this variable was correlated with race intensity [11]. Knechtle et al. [12], in a case study performed during the Deca Ironman World Championship, detected reductions in percent body fat by skinfold thickness in an athlete that completed the competition in the third place. In this case, fat consumption was attributed to the distance and elapsed time during the competition (128 h 22 min 42 s), as well the energetic cost estimated for this competition (89112 Kcal).

In the study by Knechtle et al. [8], bioelectrical impedance analysis (BIA) was also used to estimate the percent body fat of eight athletes after a Deca Ironman competition, where it was possible to identify reductions in percent body fat after the race. In a similar study by Knechtle and Kohler [10], reductions in percent body fat by using BIA were found after an ultratriathlon. According to Farber et al. [13] and Gerth et al. [14], intense endurance exercise causes the mobilization of fat from storages in the liver, skeletal muscle and subcutaneous tissue to provide for the energy used during the effort, consequently, reducing the water content within the cell.

Knoepfli et al. [15] studied the blood free fatty acids (FFA) concentration during a 25 km running test. The results revealed a significant increase of FFA from the beginning of the test, suggesting the participation of this substrate in order to make up for the energetic cost of this activity. In the case of the Hausswirth et al. [1] study, nine athletes were evaluated in three different exercise situations to estimate the energy cost of running. The first trial was a simulated triathlon with a similar distance to official Olympic events, the second was a 2 h 15 min run and the third a 45 min race at an average intensity used in the run segment of triathlon competitions. Although in all of the conditions the plasma FFA concentrations increased significantly, in the second exercise trial it was found to be higher, probably due to the time spent performing the activity and the amount of performed cyclic movements.

Long distance sports such as the triathlon commonly cause reductions in total kidney blood flow and this effect seems to be related to exercise intensity [16]. The major factor associated with this exercise effect is catecholamine release, causing a constriction of blood vessels and a reduction in the glomerular filtration ratio, and in the case of exercise-induced dehydration, the glomerular filtration ratio may also be further reduced [16].

Currently, few studies have devoted to understanding body composition changes (body mass and percent body fat and hydration) in triathlon athletes in pre-race training programs and after a long-distance competition. In this sense, the main purpose of this study was to verify the effects of a twelve week training program in body composition, FFA mobilization and hydration status in an attempt to understand the acute changes in body composition and hydration after long term efforts.

At the beginning of this study, we hypothesize that during the training program, changes would occur in body composition, reflected by body mass and percent body fat without changes in hydration status of athletes. Immediately after competition, it was expected to find modifications of all variables of body composition, as well as the increased availability of plasmatic free fatty acids and the incidence of dehydration, which would be indicated by changes in both the urinary density and urinary pH.

**Material and methods**

Twelve male triathletes volunteered to participate in the study. They signed an informed consent waiver and were submitted to the experimental protocol according to the design of the study. The anthropometric characteristics are provided in Table 1. They were submitted to a 12-week training program composed of 20% of interval training and 80% of continuous training. They were evaluated at the beginning of the training season (M-1), before the competition (M-2) and 30 min after the “Pirassununga Half Ironman” (1.8 km swimming, 90 km cycling and 21 km running) (M-3). The procedures and techniques proposed in this study were approved by the ethics committee of the School of Physical Education and Sport of the University of Sao Paulo.

| Table 1. The anthropometric characteristics of the triathletes |
|---------------------------------------------------------------|
| **N** | 12 |
| **Age** | 32.6 ± 5.1 years |
| **Sex** | male |
| **Training Experience** | 6.5 ± 4.9 years |
| **Race Time** | 5 h 07 min ± 38 min |

Body mass was determined using a digital balance (PL200, Filizola, Brazil). Skinfold thickness was obtained using a skinfold caliper (HSB-BI, Baty International, UK) and the Jackson and Pollock [17] equation was used to estimate percent body fat. Finally, bioelectrical impedance analysis (BIA) was performed by using a tetrapolar body analyzer (BF-900, Maltron International, UK).

Urine and blood samples were also collected at the beginning of the training season, before the competition and 30 min after the Half Ironman. Blood samples were obtained by antecubital vein puncture into 10 mL tubes containing EDTA. After collection, the samples were stored in ice and transported to the laboratory for further analysis. Urine was collected into universal
The FFA concentration was determined by using a Nefa C kit (Wako Chemicals, Germany). The assay consists of a colorimetric enzymatic reaction, producing a violet compound that was quantified by spectrophotometry in a SpectraMAX Plus (Molecular Devices, EUA) at 550 nm against a calibrator.

The results obtained were analyzed with the GraphPad Prism (Graphpad Software, USA) statistic software package. Data were submitted to the Shapiro-Wilk normality test and ANOVA for repetitive measurements followed by the Tukey-Kramer test, where differences were considered significant at \( p < 0.05 \).

**Results**

The results found for each variable studied in M-1, M-2 and M-3, and the \( p \)-values for the statistical comparisons are shown in Table 2.

For the first measurement (M-1), body mass was found to be 71.83 ± 7.42 kg, at M-2 to be 75.52 ± 5.99 kg and at M-3 to be 72.15 ± 5.58 kg. Percent body fat, estimated by using the skinfold thickness method was 10.98 ± 7% at M-1, 10.62 ± 7% at M-2 and 10.40 ± 6.63% at M-3. When using BIA, percent body fat was 13.54 ± 1.17% at M-1, 11.54 ± 1.39% at M-2 and 9.45 ± 2.73% at M-3. Differences were found for this indicator when M-3 was compared to the other collected samples. The results are presented in Figure 1.

Blood samples collection revealed free fatty acids concentration (FFA) to be 0.16 ± 0.11 mEq/L at M-1, 0.15 ± 0.08 mEq/L at M-2, and 1.69 ± 0.61 mEq/L at M-3. Differences were found when the result obtained at M-3 was compared to the other measurements. The results are presented in Figure 2.

Urine samples collected showed no modifications in the hydration indicators such as urine density and pH during the training program and after the Half Ironman. Urine density was 1.02 ± 0.005 g/ml at M-1, 1.01 ± 0.01 g/ml in M-2 and 1.02 ± 0.008 g/ml at M-3. Urine pH was 6.00 ± 0.53 at M-1, 5.92 ± 0.83 at M-2 and 5.35 ± 0.41 at M-3. The results are presented in Figure 3.

**Table 2.** Results obtained for each variable studied during the experimental protocol. Data are expressed in mean ± standard deviation and * indicates statistical difference when compared to the other collection times

|                     | M-1          | M-2          | M-3          | \( p \)   |
|---------------------|--------------|--------------|--------------|-----------|
| Body Mass (Kg)      | 71.83 ± 7.42 | 75.52 ± 5.99 | 72.15 ± 5.58 | 0.5410    |
| Percent body fat (skinfold thickness) | 10.98 ± 7.00 | 10.62 ± 7.00 | 10.40 ± 6.63 | 0.9972    |
| Percent body fat (BIA) | 13.54 ± 1.17 | 11.54 ± 1.39 | 9.45 ± 2.73* | 0.0001    |
| AGL (mEq/L)         | 0.16 ± 0.11  | 0.15 ± 0.08  | 1.69 ± 0.61* | 0.0001    |
| Urine Density (g/ml)| 1.02 ± 0.005 | 1.01 ± 0.01  | 1.02 ± 0.008 | 0.4591    |
| Urine pH            | 6.00 ± 0.53  | 5.92 ± 0.83  | 5.35 ± 0.41  | 0.0571    |
Discussion

The main findings of this study was the change in percent body fat measured using BIA, where the skin fold thickness method was not sensitive enough to detect the change after competition. Another important finding was the maintenance of hydration indicators through urine analysis, contrary to the expectation that a long-term triathlon race would induce significant liquid release due to the performed effort.

Body mass changes generally are the result of a training program and hydration status in endurance athletes [2]. According to Laursen et al. [2], Sawka and Coyle [3], body mass changes also occur due to liquid release by the liver and skeletal muscles during glycogen oxidation to provide for the expenditure of energy. Our results revealed no reductions in body mass during the training program and after the Half Ironman competition, which was different to the results reported in literature [1, 2, 5, 9, 18, 19], where longer events such as an Ironman, a Triple Iron ultra-triathlon and a Deca Ironman were studied. Therefore, it is possible to argue that the results found in the cited studies are the result of the energetic demand imposed by long-distance competitions, as well external variables such as hydration strategies, humidity, atmospheric pressure, temperature and nutrient supplementation during the competition. In this study, the maintenance of body mass was attributed to the distance of the event, as well as to the liquid and substrates consumption during the Half Ironman. In this sense, it is possible to deduce that body mass is not a reliable indicator to be used alone to study body composition and hydration status of athletes.

The finding that skinfold thickness did not reveal differences is very similar to the results found in the literature [10]. These data indicate that muscle glycogen and triacylglycerols are important substrates to supply energy when compared to subcutaneous sources of fat [2]. In another study of Knechtle et al. [11], changes in percent body fat percentage by skinfold thickness were found when this variable was associated with the intensity of the event, as well the intramuscular liquid loss promoted by the degradation of the energy sources. Another case was found in a case study of Knechtle et al. [12] performed in the Deca Ironman World Championship, when reduction in percent body fat, measured by skinfold thickness, was detected in an athlete that finished third in the competition. Once more, the subcutaneous fat consumption was attributed to the distance and the time of the competition (128 h 22 min 42 s), as well the energy cost estimated for the competition (89112 Kcal).

From the data observed in the studies cited above, it is possible to argue that in the present study, the maintenance of percent body fat measured by using skinfold thickness occurred due to the time and energy elapsed during the Half Ironman. However, in the percent body fat measured using BIA, we observed reductions in percent body fat at M-3. These data are very similar to those found by Knechtle et al. [8], were BIA was also used to assess percent body fat before and after a Deca Ironman. In this case, the differences are explained by the increased training volume (M-2) and fatty acids mobilization from the muscles and liver storages, caused by the training and the Half Ironman (M-3). This assumption explains why the skinfold
thickens was not sensitive enough to detect the modifications in body composition, since this method is based on the estimative of body fat in subcutaneous deposits.

Similarly to the other studies reported in literature [1, 15, 18, 20], the results found in the present study revealed a significant increase of FFA after the race. Here it is possible to argue about the participation of substrate fatty acids during the energetic expenditure imposed by aerobic effort. In the Hausswirth et al. [1] study, nine volunteers were evaluated in three different situations to estimate the energetic cost of running. Despite the experiments, plasma FFA concentration was significantly increased and probably caused by the time spent during the effort and amount of cyclic movements performed during the experiments. In the present study, a significant increase of plasma FFA concentration was found after the effort, probably induced by endocrine factors such as a release in catecholamine and cortisol (data not shown).

We expected to find evidences of dehydration after the Half Ironman by using urine density as a marker of hydration status. According to Clerico et al. [16], renal blood flow is reduced during physical effort and this effect is related to the intensity of the exercise. Apparently, this effect reflects sympathetic nervous system activity and catecholamine release, inducing a reduction in kidney blood flow and in the glomerular filtration ratio. In the case of dehydration due to long-term physical effort, the glomerular filtration ratio can be further reduced. In this study, urine density and urine pH showed similar responses during both the training season and competition. When these results are taken together, they confirm the hydration status of the athletes during the testing conditions. The present results confirm the results of previous studies when the athletes did not demonstrate evidence of dehydration [5].

In the present study, no evidence of dehydration, as measured by using both urine density and urine pH, was found. These results can confirm the data obtained by using BIA after the competition and collaborate with the findings of Pastene et al. [5], where even with the weight loss after an endurance effort, the hydration status did not change, probably due to the athletes using an appropriate hydration strategy during the race. From the present results obtained after the competition, we can observe that the 112.9 km effort of a Half Ironman promoted reduction in body fat of the athletes without signs of dehydration (Fig. 1 and 3).

**Conclusion**

This study illustrates the important effects of a training program through the reduction of percent body fat, measured by using BIA, and in the increase of plasma free fatty acids availability caused by the Half Ironman. Another important contribution is that approximately five hours of effort did not affect the hydration status of the athletes when this indicator was assessed by measuring both urine pH and urine density. Despite the changes found in body composition, it is important to note that body mass did not significantly change during the entire experimental protocol. Some practical implications of this study are that, from the results obtained in this study, we would like to suggest a revision of the interchanging uses of measuring body composition methods. The previous recommendations for using BIA do not guarantee measurement accuracy, since the decrease in total body water, not representing dehydration, need to be revised. Finally the obtained results in this study suggest that FFA mobilization is specific and not generalised.

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