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The Effect of Different Triathlon on Weight, Sodium and Hematological Changes

Park, Chan Ho and Kim, Tae Un[1]*

Research Institute of Sport Science, Pusan National University, Busan, 609-736, Korea
[1]*Department of Physical Education, Pusan National University, Busan, 609-736, Korea*

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This study examined how differing triathlon durations effect weight, serum sodium concentration, and hematological levels, and investigated relationships between these variables and finishing time as well as between body weight changes and serum sodium following Ironman distance triathlons (IDT) and Olympic distance triathlons (ODT). All eight athletes successfully completed ODT and IDT. We found that the mean body weight decreased following both IDT and ODT and that serum sodium was significantly ($p<0.05$) increased immediately after IDT. RBC, Hb, Hct, and MCH were significantly ($p<0.05$) increased immediately after IDT. Hct was significantly ($p<0.05$) decreased immediately after ODT. MCHC was significantly ($p<0.01$) increased immediately after ODT. In IDT, the percentage of change in body weight correlated to the percentage of change in serum sodium concentrations ($r=0.75$, $p=0.05$). In conclusion, our study showed that serum sodium concentraion increased in IDT and maintained in ODT, despite significant body weight loss during the races. The percentage of change in body weight was related to serum sodium concentration but unrelated to performance in the triathlon. The changes of RBC, Hb, and Hct values from two different length triathlons were depending on race distance.

Key words : Triathlon, hyponatremia, sodium, hemoglobin, dehydration

Introduction

A triathlon is an endurance sport-event consisting of swimming, cycling and running over various distances. Ironman distance triathlons (IDT) involving 3.8 km swim, 180 km cycle, and 42.2 km run (total 226 km) and Olympic distance triathlons (ODT) involving 1.5 km swim, 40 km bike, and 10 km run (total 51.5 km) have recently become popular in Korea. However, triathlon competitors participating in these events may experience a wide variety of medical problems during training and competition, including dehydration, hyponatremia, hemolysis [10], and immunological changes [24]. Previous research has shown that dehydration levels of 2-8% of total body mass that occur during endurance activity may impair the function of the thermoregulatory and cardiovascular systems [28]. Other studies have proposed that symptomatic hyponatremia is frequently becoming a medical issue resulting from fluid overload, which conflicts with the more general belief that dehydration is a more common cause of serious medical problems that occur during prolonged exercise [12,20]. This phenomenon has been reported in hyponatremic subjects during South Africa [36], New Zealand [33], Hawaiian [13] Ironman triathlon race, and Zurich marathon race [18]. It was reported recently that plasma volume and serum sodium were maintained in male Ironman triathletes, despite significant body weight loss during the race [11].

The stability of hematological parameters is crucial for sportsmen in order to maintain optimal performance. These changes during exercise may occur due to the intensity and type of training, competitions, trauma and related interruptions of physical activities [1]. Exercise has been shown to increase the rate of red-blood-cell (RBC) destruction, otherwise known as exercise-induced hemolysis [37]. Hemolysis is implicated as a mechanism of iron loss, since the destruction of a RBC's membrane allows the hemoglobin (Hb) and associated iron held within the cell to be released into the surrounding plasma, which may then cause oxidative tissue damage [26]. Particularly, distance running has been associated with significant destruction of RBC [39]. However, studies of athletes involved in swimming [29] and rowing [6] in which foot impact does not occur have also found evidence of exercise-induced hemolysis. Therefore, it might be inferred from previous studies that sports anemia may be a common risk for athletes participating in ultra-endurance sports. However, Long et al. [16] has reported that there were no significant changes during a short tri-

*Corresponding author
Tel : +82-51-510-2717, Fax : +82-51-515-1991
E-mail : tukim@pusan.ac.kr

athlon race involving 1 km swim, 30 km cycle, and 10 km run in any of the hematological variables measured, except for platelet count.

Ultraendurance exercise is classified as prolonged exercise longer than 4 h in duration and most commonly involves running, skiing, cycling or triathlon. A critical component of successful participation in ultraendurance events is the availability of both adequate substrate stores and the maintenance of hydration balance [25].

Accordingly, the purpose of the present study was twofold. In the first instance, we examined the effects of different triathlon duration on weight changes, serum sodium concentration, and hematological changes in recreational triathletes following IDT and ODT. The secondary purpose was to investigate relationships between these variables and finishing times as well as between weight changes and serum sodium concentration.

Materials and Methods

The subjects consisted of eight male triathletes (age: 37±6 yr; height: 175±4 cm; weight: 70±6 kg; career: 2.2±0.8 yr). The athletes had been training and participating in triathlons for 2.2±2.9 yr. All athletes in the present study competed in the 2006 Tongyung Triathlon involving a continuous 1.5 km swim, 40 km bike, and 10 km run. Following an eleven-week period, they competed in the Jeju Ironman triathlon involving a continuous 3.8 km swim, 180 km bike, and 42.2 km run. In total, there were four data-collection sessions which took place both 3 hours before the start and immediately post race for both triathlons. Data collection during all testing session consisted of body weight measurement and venous blood collection. All the participants in the trial were weighed 1 hour before the race, and then immediately after completing the race. All weights were measured on a hard level surface with calibrated HE-5 scales (CAS, Korea).

Ten milliliters of venous blood were obtained from an ante-cubital vein. The biochemical parameter assessed was serum sodium. Hematological parameters measured included red blood cell (RBC), hemoglobin (Hb), hematocrit (Hct), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and platelet count. Post-race plasma sodium concentrations in the subjects were carried out the day after the race with Hitachi 747 analyzers (Boehringer Mannheim, Germany) using standard methods and the manufacture's reagents on plasma that had been collected and stored at 4°C after centrifugation within 1 hour of collection. Hematological parameters were performed the following day with CellDyn 3700 (Abbott, USA) on EDTA-anticoagulated samples that had been stored at 4°C. Plasma volume changes (%⊿PV) were calculated using the formula derived from the equations of Dill and Costill [5]. %⊿PV were calculated as follows: $\%\triangle PV=\{(Hb1/Hb2)\times(100\text{-}Hct2)/(100\text{-}Hct1)\text{-}1\}\times100$. Hb1 and Hct1 are Hb and Hct before the race. Hb2 and Hct2 are Hb and Hct after the race.

Statistical analysis

All data was expressed as the mean ± SD. We analyzed the data using the sign test for paired comparisons. Correlations between weight changes and serum sodium concetrations and between variables and finishing time were calculated using Perarson's correlation coefficient. Differences were considered statistically significant at p value less than 0.05.

Results

Table 1 represents the results of body weight changes, serum sodium concentration, and the percentage of change (%⊿) in plasma volume(PV) following IDT and ODT. All eight athletes successfully completed ODT and IDT. Average race duration for ODT was 164 min 1s ± 14 min 7s (range: 142.2-205.4), and for IDT 817 min 1s ± 139 min 7s (range: 599,38-958.30). Body weight showed significant decreases immediately after both ODT (70.55±7.53 vs 68.58±7.53 kg) and IDT (69.52±6.75 vs 66.15±6.99 kg). Serum sodium concentration was significantly ($p<0.05$) increased immediately after IDT (135.87±1.12 vs 138.87±1.80 mmol/l) whereas serum sodium concentration following ODT was unchanged (137.85±1.46 vs 138.14±1.77 mmol/l). PV changes following IDT and ODT were -1.79% vs 0.06%, respectively. In IDT, the percentage of change in body weight was correlated to the percentage of change in serum sodium concentrations (r=0.75, p=0.05), but in ODT, the percentage of change in body weight was unrelated to the percentage of change in serum sodium concentration (r=0.65). We found no significant correlation between the degree of weight loss and athletes' finishing times in IDT (r=0.263, p=0.529) and ODT (r=-0.225, p=0.628).

Table 2 represents the results of hematological variables following IDT and ODT. Hb was significantly ($p<0.05$) in-

Table 1. Changes of body weight changes, serum sodium concentration, and the percentage of change in plasma volume following IDT and ODT

Variables	Group	Pre	Post	Change and p value
weight	IDT	69.52±6.75	66.15±6.99	Decrease (p<0.001)
(kg)	ODT	70.55±7.53	68.58±7.53	Decrease (p<0.001)
sodium	IDT	135.87±1.12	138.87±1.80*	Increase (p<0.05)
(mmol/l)	ODT	137.85±1.46	138.14±1.77	NS
plasma volume	IDT	0	-1.79±2.77	
(% ⊿)	ODT	0	0.06±0.59	
race time	IDT	0	817.1±139.7	
(min)	ODT	0	164.1±14.7	

Values are means±*SD*.
IDT: Ironman Distance Triathlon, ODT: Olympic Distance Triathlon

Table 2. Changes in hematological variables following IDT and ODT

Variables	Group	Pre	Post	Change and p value
Hct	IDT	44.41±.92	46.50±3.22	Increase (p<0.05)
(g/dl)	ODT	49.42±1.10	47.92±1.61	Decrease (p<0.05)
Hb	IDT	14.11±1.04	14.87±1.18	Increase (p<0.05)
(g/dl)	ODT	14.65±0.65	14.62±0.88	NS
RBC	IDT	4.66±0.32	4.85±0.38	Increase (p<0.05)
(10^3/Ul)	ODT	4.74±0.22	4.74±0.25	NS
platelet count	IDT	231.75±62.79	283.62±91.49	Increase (p<0.01)
(10^3/Ul)	ODT	266.14±49.79	342.00±39.56	Increase (p<0.001)
MCV	IDT	95.35±1.29	95.78±2.14	NS
(fL)	ODT	104.28±2.98	101.18±2.88	Decrease (p<0.01)
MCH	IDT	30.27±0.68	30.61±0.63	Increase (p<0.05)
(pg)	ODT	30.91±0.66	30.84±0.65	NS
MCHC	IDT	31.73±0.71	31.97±0.71	NS
(%)	ODT	29.62±0.82	30.51±0.93	Increase (p<0.01)

Values are means±*SD*.
IDT: Ironman Distance Triathlon ODT: Olympic Distance Triathlon
Hct: hematocrit, Hb: hemoglobin, RBC: red blood cell, MCV: mean corpuscular volume, MCH: mean corpuscular hemoglobin, MCHC: mean corpuscular hemoglobin concentration

creased immediately after IDT (14.11±1.04 vs 14.87±1.18 g/dl) whereas Hb following ODT was unchanged (14.65±0.65 vs 14.62±0.88 g/dl). Hct was significantly (p<0.05) increased immediately after IDT (44.41±2.92 vs 46.50±3.22 g/dl) whereas Hct was significantly (p<0.05) decreased immediately after ODT (49.42±1.10 vs 47.92±1.61 g/dl). We found no significant correlation between pre-race Hct level and athletes' finishing times in IDT (r=0.264, p=0.529) and ODT (r=0.659, p=0.108). RBC was significantly (p<0.05) increased immediately after IDT (4.66±0.32 vs 4.85±0.38 g/dl) whereas RBC following ODT was unchanged (4.74±0.22 vs 4.74±0.25 g/dl). We found no significant correlation between pre-race RBC level and athletes' finishing times in IDT (r=0.330, p=0.425) and ODT (r=0.681, p=0.092). Platelet counts were significantly (p<0.01) increased immediately after IDT (231.75±62.79 vs 283.62±91.49 10^6/UI) and ODT (266.14±49.79 vs 342.00±39.56 10^6/UI). MCV was significantly (p<0.01) decreased immediately after ODT (104.28±2.98 vs 101.18±2.88 fL) whereas MCV following IDT was unchanged (95.35±1.29 vs 95.78±2.14 fL). MCH was significantly (p<0.05) increased immediately after IDT (30.27±0.68 vs 30.61±0.63 pg) whereas Hb following ODT was unchanged (30.91±0.66 vs 30.84±0.65 pg). MCHC was significantly (p<0.01) increased immediately after ODT (29.62±0.82 vs 30.51±0.93%) whereas MCV following IDT was unchanged (95.35±1.29 vs 95.78±2.14 fL).

Discussion

Triathlon has emerged as a popular sport with a world wide variety of participants. Triathlon competitions are performed over markedly different distances such as Sprint, Olympic, Half-Ironman, and Ironman distance. Of particularly, long duration are the Ironman distance triathlons involving 3.8 km swim, 180 km cycle, and 42.2 km marathon run, which last for 9 to 17 hours. A variety of researchers have documented the occurrence of hyponatremia during Ironman distance triathlons [13,33,36]. At serum sodium concentrations between 126 and 130 mmol/l, disorientation may occur. Sodium concentrations <126 mmol/l may result in seizures, coma and death [20]. Significant sodium and fluid loss through sweat occurs with prolonged exercise, leading to a decrease in extracellular fluid volume (ECFV) and plasma volume [2,14]. In the present study, we found that the mean body weight was lost following both IDT and ODT [3.37 kg (range 2.38-4.37 kg) vs 1.97 kg (range 1.52-2.42 kg), respectively] and that serum sodium concentration was significantly ($p<0.05$) increased immediately after IDT. We also found that there was a significant correlation ($r=0.75$, $p=0.05$) between sodium levels and weight changes during IDT. But these changes were not detected immediately after ODT. Similar weight losses have been reported following other ultradistance events, including other ultradistance triathlons [23,31,32], ultradistance running races [22], and ultradistance multisport events [27,35]. It was found from the result of this study that the greater the weight loss, the higher the serum sodium concentration. This is compatible with the finding of an inverse relationship between post-race plasma sodium concentration and body weight changes during ultradistance endurance events [30,23]. However, Speedy et al. [34] also reported that hyponatremic subjects lost significantly less weight during Ironman triathlons than did controls (-0.5% vs -3.9% change in body weight). Chorley et al. [4] reported that a loss of less than 0.75 kg increased the risk of becoming hyponatremic 7-fold compared to those who lost more than 0.75 kg in non-elite marathon runners during a marathon. Therefore, it might be inferred from the result of this study that if triathlon competitors overhydrate to maintain bodyweight, it would increase the probability of exercise-associated hyponatremia in triathlons.

It is known that significant sodium and fluid loss through sweat occurs with prolonged exercise, leading to a decrease in extracellular fluid volume (ECFV) and plasma volume [2,14], and that in prolonged exercise, fluid loss by perspiration is also a factor acting on the plasma volume [17]. In this study, percent changes (%$\triangle$) in plasma volume (PV) were decrease by 1.79% during IDT and increased by 0.06% during ODT. Fallon et al. [7] reported a mean decrease in plasma volume of 7.3% after a 100 km running race. In contrast, there have been several other reports of increased plasma volume (10.8% and 7.6%, respectively) during ultradistance exercise [9,32]. In a recent study, significant body weight loss occurred (4.9±1.7%), while both plasma volume (1.0±11.2%) and serum sodium (0.6±2.4%) increased from pre-race to post-race in Ironman triathlons [11]. We observed a similar trend in our study. Therefore, we wish to remark that the single best predictor of post-exercise serum sodium is the change in body weight during exercise. Avoidance of overhydration is the most important intervention necessary to prevent the development of symptomatic exercise-associated hyponatremia [21,20].

The main function of erythrocytes is to transport the oxygen carrier, hemoglobin. For the most part, Hb and Hct are associated with sports anemia. Naturally, sports anemia is also expressed by low hemoglobin level in total blood [3]. In the present study, RBC and Hb values were significantly ($p<0.05$) increased immediately after IDT, but these responses did not occur immediately after ODT. It was found from the result of this study that the increase in erythrocyte volume is in accordance with increases in the total amount of hemoglobin and that the Hb values after IDT and ODT were in a normal range (14.8 g vs 14.6 g, respectively). Hct value was significantly ($p<0.05$) increased immediately after IDT. A similar finding by Nagao et al. [19] was also reported for subjects performing ultratriathlons. To the contrary, Hct value significantly ($p<0.05$) decreased immediately after ODT. A similar result was reported after an ultratriathlon by Lehmann et al. [15]. But Hct values after IDT and ODT were in a normal range (46.5 g/dl vs 47.9 g/dl, respectively). We also found that there was no significant correlation between pre-race Hct level and athletes' finishing times in IDT ($r=0.264$, $p=0.529$) and ODT ($r=0.659$, $p=0.108$). From the results of the present study, platelet counts were significantly ($p<0.01$) increased immediately after IDT and ODT. This considerable change of platelet counts is known to increase during physical exercise, similar to leucocytes, because of an inflammatory-like reaction, in both short-term and endurance performances [8], but the recovery and normalization of their count is generally rapid [1]. A previous study has shown that there were no significant changes during a short triathlon race involving 1 km swim, 30 km cycle, and 10 km run in any of the hematological variables measured, except for platelet count [16]. In this study, the changes of RBC, Hb, and Hct values from two different length triathlons were dependent on the race distance.

In conclusion, our study showed that serum sodium concentraion was increased in IDT and maintained in ODT, despite significant weight loss during the races. And RBC and Hb values were increased in IDT, but maintained in ODT. Hct value was increased in IDT, but decreased in ODT. Platelet count was increased in IDT and ODT. The percentage of change in body weight was related to serum sodium concentrations but unrelated to performance in the triathlon. We hope that additional studies on triathlon will be encouraged by our data.

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초록 : 다른 거리의 철인 3종 경기 시 체중, 나트륨 및 혈액 성분에 미치는 영향

박찬호 · 김태운[1]*
(부산대학교 체육과학연구소, [1]부산대학교 체육교육과)

철인 3종 경기에 참가하는 선수들은 탈수, 저나트륨혈증, 용혈현상 및 면역반응과 같은 의학적인 문제에 직면할 수 있다. 본 연구는 철인 3종 경기 시 체중의 변화, 나트륨농도 및 혈액성분의 변화를 조사하기 위하여 서로 다른 Olympic Distance Triathlon (ODT)과 Ironman Distance Triathlon (IDT)에 참가한 선수들에게 체중과 나트륨 농도 및 혈액 성분이 어떠한 영향을 미치는가를 연구하였다. 체중은 ODT와 IDT 모두 유의하게 감소하였고, 나트륨 농도는 IDT에서만 증가하였다. RBC, Hb, Hct 및 MCH는 IDT에서 증가하였고, Hct는 ODT에서 감소하였다. IDT에서는 체중의 변화율과 나트륨 농도 간의 유의한 상관관계가 있었으며, 체중 감소에 따른 나트륨농도의 증가현상이 나타났다. RBC, Hb 및 Hct의 변화는 거리에 따라 영향을 받는 것으로 조사되었다. 이러한 결과들을 종합해 볼 때 철인 3종 경기와 같은 장시간 지속되는 운동 시 체중 변화가 나트륨 농도에 영향을 미치는 것으로 파악되었으며, 경기 거리에 따른 혈액 성분의 변화에 차이는 있었지만 이러한 변화는 모두 정상범위인 것으로 나타났다.